# Environmental impacts of aquaculture and coexisting industries

# Miljøkonsekvenser av akvakultur og sameksisterende næringer

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# Miljøkonsekvenser av akvakultur og sameksisterende næringer


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# Preface

This is the final report for the project "Environmental impact of aquaculture and coexisting industries - scope for comprehensive regulation" - "MILJØREG". The project is funded by the Norwegian Fisheries and Aquaculture Industry's research funding. The main goal of the project has been to prepare a broad overview of the knowledge base related to the environmental impact of aquaculture, as well as environmental impact from other industries with activities in the same areas as aquaculture. Requirements for the regulation of aquaculture were compiled and the scope for a more direct and differentiated regulation of the environmental impact from aquaculture was explored, based on the collected knowledge base. The project has been a collaboration between Akvaplan-niva, the Norwegian Institute for Water Research (NIVA) and Nofima, where NIVA has had the main responsibility for chapter 3, Akvaplan-niva for chapter 4 and Nofima for chapters 5 and 6. However, all institutes have contributed to all chapters.

Dette er sluttrapport for prosjektet «Miljøpåvirkning havbruk og sameksisterende industrier- mulighetsrom for helhetlig regulering"- "MILJØREG"» finansiert av Fiskeri og havbruksnæringens forskningsfinansiering. Hovedmålet med prosjektet har vært å utarbeide en bred oversikt over kunnskapsgrunnlaget relatert til miljøpåvirkning av havbruk, samt miljøpåvirkning fra andre næringer med aktiviteter i samme områder som havbruk. Krav til regulering av havbruk ble sammenstilt og mulighetsrommet for en mer direkte og differensiert regulering av miljøpåvirkningen fra havbruk ble utforsket, basert på kunnskapsgrunnlaget. Prosjektet har vært gjennomført som et samarbeid mellom Akvaplan-niva, Norsk Institutt for Vannforskning (NIVA) og Nofima, hvor NIVA har hatt hovedansvar for kapittel 3, Akvaplan-niva for kapittel 4 og Nofima for kapittel 5 og 6. Alle institutt har imidlertid bidratt i alle kapitler.

# Sammendrag og konklusjoner

Et forbedret FoU-basert kunnskapsgrunnlag om miljøpåvirkning fra akvakultur og sameksisterende næringer kan bidra til bedre forvaltning, som igjen vil bidra til økt forutsigbarhet og mer miljømessig bærekraftige næringer. Hovedmålet med prosjektet «Miljøpåvirkning havbruk og sameksisterende industrier- mulighetsrom for helhetlig regulering"- "MILJØREG"» har vært å utarbeide en bred oversikt over det FoU-baserte kunnskapsgrunnlaget knyttet til miljøpåvirkning fra havbruk, samt miljøpåvirkning fra andre næringer med virksomhet innenfor samme områder som havbruk. Krav til regulering av akvakultur ble sammenstilt og mulighetene for en mer direkte og differensiert regulering av miljøbelastningen fra akvakultur ble undersøkt, basert på det kartlagte kunnskapsgrunnlaget. Prosjektteamet har gjennomført en omfattende gjennomgang av publikasjoner fra forskningsbaserte studier (tusenvis av artikler). Dette materialet har så blitt systematisert og oppsummert ved bruk av den såkalte Quick Scoping Rewiev-metoden. Dette har resultert i en bred oversikt, (leksikon), som kan oppdateres jevnlig ettersom grunnlaget allerede er laget i form av de nå definerte/identifiserte søkestrengene for publikasjonssøk. Noen hovedfunn fra prosjektet er:

- Det finnes en god del FoU-basert kunnskap om miljøeffekter av noen spesifikke miljøpåvirkningsfaktorer som organisk belastning på bløtbunn og lusemidler.
- Ulike mengder kunnskap er tilgjengelig for ulike påvirkningsfaktorer. For noen påvirkningsfaktorer er det kunnskap som kan brukes direkte til å forbedre regelverk/håndtering, mens det for andre påvirkningsfaktorer er lite FoU-basert kunnskap (f.eks. organisk belastning på hardbunn/blandingssubstrat, enkelte antigroemidler, støy).
- Det er noen miljøpåvirkninger som ikke dekkes godt nok i gjeldende miljøregelverk.
- Litteraturstudien viste at det er lite kunnskap om kombinerte effekter av ulike næringer, noe som gjør at det er vanskelig å vurdere kumulative miljøpåvirkninger, noe som igjen begrenser muligheten for økosystembasert forvaltning.
- Økosystembasert marin arealplanlegging og vurdering av samlede miljøeffekter er nødvendig for å fremme bærekraftig forvaltning av marine økosystemer, for å fremme god miljøtilstand i havet og for å møte FNs bærekraftsmål 14 (UN SDG 14), Liv under vann. En metode for kumulative konsekvensvurderinger (CIA), basert på en geospatial indeks som beskriver den relative påvirkningen flere menneskelige påvirkninger har på det marine miljøet, er utviklet som et verktøy for marin arealplanlegging. I en casestudie ble det undersøkt hvordan dette verktøyet fungerte i en norsk sammenheng. Studien viste at det var utfordrende å finne gode grunnlagsdata og at rådata, som er nødvendige for å kunne gjøre grundige vurderinger, ofte ikke var tilgjengelig. Dette begrenser muligheten til å gjennomføre kumulative konsekvensutredninger for områder langs norskekysten.
- Det pågår for tiden noen få forskningsprogrammer som fokuserer på kumulative effekter og virkninger i norske havområder, men både litteraturstudien og casestudien viste at det er et stort behov for mer kunnskap og forskning (detaljert beskrivelse av forskningsbehov finnes i avsnitt 4.4).
- Miljøforvaltning av akvakultur kan av noen ses på som en teknisk øvelse, men forvaltning er å veie ulike interesser mot hverandre, noe som innebærer at det er en verdibasert og sosial prosess. Det er derfor grenser for hvor mye miljøforvaltningen av akvakultur bør standardiseres og gjøres til en teknisk øvelse. Det bør være rom for skjønn og lokale tilpasninger.

- Prosjektet har vist at kunnskapsgrunnlaget som brukes i forvaltningen er omfattende, inkludert for vitenskapelig kunnskap. Det pekes allikevel på manglende kunnskap for mange områder og temaer, og det kommer til å være situasjonen også i framtiden. Forvaltningen må derfor ha gode måter å håndtere usikkerheten på.
- For å være troverdig må forvaltningen også vise og på en god måte formidle usikkerheten og de vurderinger som gjøres. At det i en del tilfeller er vanskelig å skjønne hvilke vurderinger som faktisk er gjort svekker ikke bare troverdigheten til beslutningene, men reduserer også mulighetene for kvalitetssikring, læring og mer harmonisert praksis på tvers av forvaltningsorganer.
- Noen typer vurderinger sliter forvaltningen mer med enn andre, og de som utfører faktisk saksbehandling ønsker seg mer støtte og retningslinjer. Det gjelder særlig det å avveie vekst i akvakultur mot miljørisiko/miljøeffekter, og det å vurdere «samlede virkninger».
- Gjennomgangen vår finner flere områder hvor det fortsatt er rom for forbedringer i samspillet mellom forvaltningsregimer og forvaltningsorganer knyttet til miljøforvaltning av akvakultur. Det gjelder akvakultur sektor-forvaltningen og den kommunale kystsoneplanlegging, særlig knyttet til miljøkvalitetskrav, og det gjelder i noe grad kystsoneforvaltningen og vannforvaltningen.
- Prosjektet har identifisert flere stressorer som i større grad bør inkluderes i forvaltningen: partikulært organisk avfall på hardbunn, rømt rensefisk, antibegroingsmidler (kobber), lus (godt dekket, men fortsatt ikke godt nok) og avlusningsmidler
- Det meste av kjent og tilgjengelig kunnskap tas i bruk av forvaltningen, men spesielt for avlusingsmidler og kobber finnes det mer kunnskap som kan tas i bruk
- Det finnes potensial for å utnytte bedre den kunnskap som samles inn av oppdrettsbedriftene
- Egen regulering av nye oppdrettskonsepter, som kan dokumentere at de har mindre miljøpåvirkning enn de tradisjonelle (innaskjærs notbaserte), kan legge til rette for mer vekst uten at det totale miljømessige fotavtrykket blir større.
- Mer treffsikker regulering kan gi rom for vekst uten at miljøpåvirkningen nødvendigvis blir større.

## Summary and conclusions

An improved research-based knowledge base can contribute to improved management, which in turn will contribute both to increased predictability as well as more environmentally sustainable industries. The main goal of the project has been to prepare a broad overview of the research-based knowledge base related to the environmental impact of aquaculture, as well as environmental impact from other industries with activities in the same areas as aquaculture. Requirements for the regulation of aquaculture were compiled and the scope for a more direct and differentiated regulation of the environmental impact from aquaculture was explored, based on the collected knowledge base. A large amount of information (thousands of articles) has been systematized and summarized using the QSR method. This has resulted in a broad overview, (encyclopedia), which can be updated regularly as the foundation is laid in the form of existing search strings. A few key points/findings from the project are provided below:

- Much research-based knowledge is available on environmental effects of certain stressors, e.g. organic enrichment on soft bottom and de-licing agents.
- Different amounts of knowledge available are available for different stressors. For some stressors there is available knowledge which can be used directly to improve regulations/management, for other stressors there is little research based knowledge.
- There are some environmental impacts that are not covered well enough in current environmental regulations.
- There is available knowledge base for some stressors which are suitable for improving regulations.
- The literature-based assessment showed that there is little knowledge available for combined effects of different industries, hence it is difficult to assess cumulative environmental impacts, which in turn limits the possibility of performing ecosystem-based management (EBM).
- EBM marine spatial planning and cumulative effect assessments are key to foster sustainable use of marine ecosystems, to promote ocean conservation and United Nations Sustainable Development Goal 14 (UN SDG 14), Life Below Water. A method for cumulative impact assessments (CIA) based on a geospatial index describing the relative impact of multiple human stressors on the marine environment, has been developed, to assist marine spatial planning. The case study was exploring using this approach in Norwegian context (the feasibility a practical application of EBM in selected areas along the Norwegian coastline). The assessment showed that input data was challenging and raw data, essential for thorough analysis, was often not available. Therefore, development of CIA models for the Norwegian coastline or more localised focus areas with the currently available database is limited or implementation is not feasible.
- There are currently a few ongoing research programs on cumulative effects and impacts in Norway already, but both the literature based, and the case study assessment showed that more knowledge and research is urgently needed (detailed description on research needs can be found in section 4.4).
- Environmental management of aquaculture can be seen by some as a technical exercise, but management is weighing different interests against each other, which implies that it is a value-based and social process. There are therefore limits to how much the environmental management of aquaculture should be standardized and made into a technical exercise. There should be room for subjective assessment and local adaptations.

- The project has shown that the knowledge base used in administration is extensive, including scientific knowledge. It is nevertheless pointed to a lack of knowledge for many areas and topics, and this will also be the situation in the future. The environmental authorities must therefore have good ways of handling the uncertainty.
- To be credible, the authorities must also show and convey the uncertainty and the assessments that are made. The fact that it in some cases it is difficult to understand which assessments have actually been made, not only weakens the credibility of the decisions, but also reduces the possibilities for quality assurance, learning and more harmonized practice across administrative bodies.
- Some types of assessment are very challenging, and those who carry out actual case management want more support and guidelines. This applies in particular to balancing growth in aquaculture against environmental risk/environmental effects, and to assessing "overall effects".
- Our review finds several areas where there is still room for improvement in the interaction between management regimes and administrative bodies linked to the environmental management of aquaculture. This applies to aquaculture sector management and municipal coastal zone planning, particularly linked to environmental quality requirements, and to some extent to coastal zone management and water management.
- The project has identified several stressors that should be included in the management to a greater extent: particulate organic waste on hard/mixed bottoms, escaped cleaning fish, anti-fouling agents (copper), lice (well covered, but still not good enough) and de-licing agents.
- Most of the known and available knowledge is used by the authorities, but especially for de-licing agents and copper there is more knowledge that should be used.
- Knowledge and data gathered by the aquaculture industry can be utilized better.
- Own regulation of new farming concepts, that can document lower environmental impact than the traditional ones (inshore, net-based), can facilitate growth without an increase in environmental impact.
- More accurate regulation can provide room for growth without major environmental impacts.

# 1 Introduction

In recent decades, the Norwegian aquaculture industry has been through a phase of rapid expansion, with good profitability, great value creation and increasing importance for communities along the entire coast. Possibilities for a doubling of value creation towards 2050 are pointed out by politicians, however, growing concerns related to both fish welfare and environmental impacts have resulted in regulations that have slowed down production growth. Growth in the industry is mainly regulated through the traffic light system, which per today is based on one environmental indicator, namely the salmon lice. Entire production areas are basically regulated as one, and local conditions are taken into account to a lesser extent. Growth is also limited by access to locations prioritized for aquaculture, and by willingness to set aside land based on social acceptance.

Sustainable growth in salmon farming requires solutions that provide control over environmental challenges as well as fish health challenges, which in turn contribute to greater acceptance of the industry's area needs. Growth in the aquaculture industry is managed through the allocation of permits to given companies, in given production areas (POs). However, production on the location can only take place once a company has received clearance for a certain production volume. Today, expansion of production volume is limited by certain environmental impact indicators, such as salmon lice and organic load. Parts of the environmental management of the aquaculture industry take place through regulations that to a limited degree take into account variation in condition and vulnerability in the areas where the sites are located.

The term green shift has been established as a central political goal on the Norwegian agenda (Haarstad and Rusten, 2018, MCE Parliamentary White Paper 2017). Both the industry and management aim environmentally sustainable growth, following a holistic and ecosystem-based management (St.meld. nr. 12 (2001-2002) Rent og rikt hav, Blått hav, grønn fremtid rapport (Solberg government), Meld St 29 (2020-2021), Sjømat Norge – Sjømat 2030). Ecosystem-based management is in demand by several bodies, such as e.g. UN (https://www.oceandecade.org/decade-news/). Comprehensive ecosystem-based management requires an understanding of the ecosystem's function and structure and overall effects of different types of human influence on the ecosystems. In Norway, there are currently various regimes that are based on holistic and ecosystem-based management, e.g. "vannregion-forvaltning gjennom vannforskriften" (water region management through the water regulations) (https://lovdata.no/dokument/SF/forskrift/2006-12-15-1446), comprehensive management plans, coastal zone planning, and wild salmon management.

There is ongoing work related to both technological and biological innovations to solve challenges in the aquaculture industry, such as land use, fish welfare, feed resources and impact on the external environment, e.g. wild fish, benthic animals and vulnerable habitat types. It is further assumed that appropriate regulatory mechanisms will be able to help reduce the total environmental footprint of production. This is because new environmental technology and improved knowledge can contribute to measures being better adapted to the current challenge and seen in relation to other sources of environmental impact.

New concepts for aquaculture have different forms of environmental footprint than conventional aquaculture. Closed or semi-closed facilities can in principle be located closer to each other, and in shallower locations with low water currents compared to open cages. In addition to new concepts, new ecosystems will also be used as a result of increased diversification within aquaculture and with culturing of new species. The rapid development of Norwegian aquaculture production therefore entails a spatial expansion from the traditional cage locations to operations in a diverse ecosystem; on land, in fjords and at sea. This entails a need for new types of requirements and environmental regulations, and also new knowledge concerning environmental impact. Some of the current ways of regulating environmental impact from aquaculture are not relevant for some types of new solutions.

The aquaculture industry is not the only stakeholder in Norway's coastal and marine areas. Other industries, such as mining, oil and gas operations (offshore), maritime industry, fisheries, tourism and renewable energy (offshore wind, liquid solar, hydropower) can potentially overlap with the aquaculture industry in terms of need for areas and resources. These industries can also have an influence on each other so that they can be mutually exclusive within an area. According to the water regulations (vannforskriften), which cover rivers, lakes, coastal waters and groundwater in Norway, sector-wide regional water management plans must be prepared for each water region. This means that the management must consider the overall impact of all types of human activity, but in practice the various environmental impacts are mainly addressed individually. The environmental management aims to become more holistic, considering the environmental impact from both aquaculture and other industries to a greater extent. The industries' impact on the environment should be assessed, but it is also important to assess how the industries indirectly affect each other. Also, the overall environmental impact in different ecosystems with different carrying capacities should be assessed, as well as the socio-economic costs of environmental regulation of the various industries.

In the current project, we have compiled and evaluated the knowledge base related to environmental impact from the aquaculture industry. The impact of other industries on aquaculture, through their environmental impacts, was also addressed. An overview of requirements and practices related to environmental regulation of the aquaculture industry, and socio-economic conditions is summarized. Finally, it was analyzed to what extent the existing knowledge base can provide a fundament for a more comprehensive ecosystem-based regulation. The review has revealed both opportunities and knowledge gaps within the existing knowledge base for further exploring a new management regime in Norway based on a more holistic approach.

# 2 Methodological approach

This project is not an extensive compilation of all possible environmental impacts from and on aquaculture and their possible interaction, as this is outside the project's time and financial framework. We have chosen a selection of stressors/classes of stressors which knowledge acquisition is focused on:

- **Organic waste – particulate matter**
- **Dissolved nutrients**
- **Environmental contaminants**
- **Escapes**
- **Disease & parasites**
- **Noise**
- **Light**
- **Artificial structure**

An overview sketch developed by the Norwegian Environmental Agency (NEV)[1] was used to identify the main stressors associated with finfish aquaculture, but some additional stressors were added by the review team (see chapter 3.1.3). A full comprehensive review or risk assessment of each stressor has not been carried out directly in this project. However, we have provided a broad overview of literature available for the various stressors from aquaculture and other industries, and this knowledge is presented and summarized in an objective manner using a quick scoping review method (described in chapter 3 and 4). This systematization of the knowledge base formed the foundation for compiling environmental requirements and regulations for the various stressors. The knowledge base was also assessed for suitability for use to explore and develop new types of requirements and regulations, based on a more holistic approach. The knowledge base of environmental impacts from aquaculture and other industries will serve as input to environmental regulation assessment (*chapter 5*) and finally all results are integrated to explore possibilities for holistic local ecosystem-based management (chapter 6).

The report is divided into different chapters reflecting these themes, where both method, results and discussion are presented for each of the topics:

*Chapter 3:* Compilation of the knowledge base related to environmental impact of the aquaculture industry. The compilation was performed by using a "Quick Scoping review" approach (QSR). Through the compilation, we addressed the most important environmental impacts.

*Chapter 4*: Compilation of the knowledge base on environmental impacts from other industries and activities that operate in the same ecosystems as aquaculture. A case study aiming using the knowledge base is also presented in chapter 4, for one geographical area.

*Chapter 5*: Reviews the regulation of environmental impact from the aquaculture industry, including the knowledge base that is used today and how trade-offs are made.

*Chapter 6*: Analyzed the possible opportunities in the knowledge base for a more differentiated and locally adapted aquaculture management, as well as a more holistic and

[1] https://www.miljodirektoratet.no/ansvarsomrader/vann-hav-og-kyst/Akvakultur-fiskeoppdrett/

economically efficient management of environmental impact from both the aquaculture industry and other industries.

The literature-based assessments and case study (Chapter 3 and 4) is written in English language as the compilation were searching for both Norwegian and international literature (often in English) and may be interesting for a wider international audience. In these chapters we have chosen to include the references directly after each section, as these are the direct result of the work. The environmental regulation assessments (Chapter 4 and 5) are written in Norwegian language as they are investigating Norwegian laws and regulations, and due that fact that national expressions for regulations with specific terms, names, etc., which sometimes is difficult to translate into English. Furthermore, it may have more relevance for the Norwegian context, and it is therefore more practical that this part is in Norwegian as the readers are primarily expected to be Norwegian. References included in these sections are given at the end of the report.

# PART 1: The literature-based assessments and case study (*Chapter 3* and *4*).

Chapter 3 Environmental impacts from aquaculture industries.

Chapter 4 Cumulative environmental impacts from coastal industries and risk posed to aquaculture*.*

# 3 Environmental impacts from aquaculture industries

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## Executive summary

The objective of this study was to compile a knowledge base related to environmental impacts arising from aquaculture, with a main emphasis on Atlantic Salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus mykiss*) farming. Stressors are the drivers of environmental impact and the stressors addressed were; particulate organic waste, dissolved nutrients, diseases & parasites, environmental contaminants (pharmaceuticals & other substances), escapes, light, noise and artificial structure. Our primary research question was; What is the impact of stressor X on the marine environment? The secondary research questions were; What is the spatial and temporal scale of the impact? Which species, habitats and/or ecosystem components are affected? Which indicators, monitoring and assessment tools are used to measure and assess the impacts? Do the identified indicators, monitoring and assessment tools reflect the impact's spatial and temporal scale?

The compilation of literature was performed by using a "Quick Scoping review" approach (QSR). A QSR is a type of systematic review (SR), which is less comprehensive than a full SR, but where the main features, such as a detailed and comprehensive plan and search strategy derived a priori, clearly stated research questions, a transparent and reproducible method and a systematic summary of the evidence, are included. Stressors described above formed the starting point for the QSR, and a separate search was carried out for each stressor. Published scientific literature was extracted from the online databases "Web of Science, Scopus, WorldCat Dissertations and Theses and ORIA. Some work of relevance is not published in peer-reviewed journals (grey literature), but can instead be found in reports and reviews from different institutes and governmental organisations. Therefore, websites of relevant organisations and respective databases were also included in the search.

For each stressor the characteristics of the evidence base was described, and the main knowledge gaps identified. There were clear differences in the volume of the evidence base between stressors, where some stressors have received far more research focus than others. Where over 230 papers were addressing impacts of escapes, 40 were addressing impacts of dissolved nutrients, and about 20 papers were addressing the impacts of each of the stressors noise, light and artificial structure. Also, within a single stressor the research focus could be skewed, e.g towards impacts on a specific ecosystem component, of a specific type of compound. The first can be exemplified by the stressor particulate organic waste. Here the impacts on softbottom habitats have been extensively studied and are well understood, while our understanding of impacts on hardbottom habitats and associated epifauna is limited. The latter can be illustrated by the stressor environmental contaminants where delousing agents accounted for almost 50 % of the articles. The importance of temporal and spatial scale for the assessment of impact were evident for several of the stressors, where the “value” of the evidence e.g for management purposes is depending on appropriate scale.  Since the main focus of this literature review where on salmon and rainbow trout farming, the outputs naturally reflect the research focus in the main producer countries for these species, which again reflects the environmental impacts of concern in the management and the public in these countries.

The output of this literature review formed the basis for the wider discussion on the feasibility of achieving a more ecosystem-based management approach of aquaculture in Norway (Chapter 5 and 6).

## Sammendrag

Målet med denne studien var å sammenstille kunnskapsgrunnlaget knyttet til miljøpåvirkning fra akvakultur, med hovedvekt på oppdrett av atlantisk laks (*Salmo salar*) og regnbueørret (*Oncorhynchus mykiss*). Stressorer er driverne for miljøpåvirkning og stressorene som ble adressert i denne studien var; partikulært organisk materiale, oppløste næringsstoffer, sykdommer og parasitter, legemidler og andre fremmedstoffer, rømming, lys, støy og kunstige strukturer. Det primære forskningsspørsmålet var; Hva er virkningen av stressor X på det marine miljøet? De sekundære forskningsspørsmålene var; Hva er skalaen til påvirkningen i tid og rom? Hvilke arter, habitater og/eller økosystemkomponenter påvirkes? Hvilke indikatorer, overvåkings- og vurderingsverktøy brukes for å måle og vurdere konsekvensene? Gjenspeiler disse indikatorene, overvåkings- og vurderingsverktøyene virkningens romlige og tidsmessige skala?

Vi brukte en systematisk tilnærming til gjennomgangen av eksisterende forskning, hvor en såkalt rask evidens vurdering, "Quick Scoping review" (QSR) ble gjennomført. En QSR er en type systematisk kunnskapsoversikt (SR) som er mindre omfattende enn en full SR, men som inneholder hovedtrekkene fra en SR, slik som en detaljert og omfattende plan og søkestrategi utledet a priori, klart uttalte forskningsspørsmål, en transparent og reproduserbar metode og en systematisk oppsummering av resultatene. Stressorerne som beskrevet over dannet utgangspunktet for QSR'en, og det ble utført separate søk for hver stressor. Vitenskapelig litteratur ble hentet ut fra databasene "Web of Science, Scopus, WorldCat Dissertations and Theses and ORIA. Noe relevante arbeider er ikke publisert i fagfellevurderte tidsskrifter (grå litteratur), men kan i stedet finnes i rapporter og sammendrag fra ulike institutter og statlige organisasjoner Derfor ble nettsidene til relevante organisasjoner og respektive databaser inkludert i søket.

For hver stressor ble evidensgrunnlaget beskrevet og de viktigste kunnskapshullene identifisert. Det var klare forskjeller i volumet på evidensgrunnlaget mellom stressorer, hvor noen stressorer har fått langt mer forskningsfokus enn andre. Det ble f.eks. funnet over 230 artikler som omhandlet effekter av rømming, 40 som omhandlet effekter av oppløste næringsstoffer, og rundt 20 artikler om effektene av hver av stressorene støy, lys og kunstige strukturer. Også innenfor en enkelt stressor kunne forskningsfokuset være skjevt, for eksempel ved at hovedvekten av litteraturen fokuserte på effekter på en spesifikk økosystemkomponent eller art, av på en spesifikk gruppe av fremmedstoffer. Den første kan eksemplifiseres ved stressoren partikulært organisk materiale. Her er påvirkningene på bløtbunnshabitater blitt grundig studert og er godt forstått, mens vår forståelse av påvirkning på hardbunnshabitater og tilhørende epifauna er begrenset. Sistnevnte kan illustreres ved stressoren legemidler og andre fremmedstoffer hvor studier av effekter av avlusningsmidler utgjorde nesten 50 % av artiklene. Betydningen av tidsmessig og romlig skala for påvirkning var tydelig i litteraturen for flere av stressfaktorene. Dette betyr at «verdien» av kunnskapsgrunnlaget f.eks. til forvaltningsformål er avhengig om man har dekket riktig tidsmessige og romlig skala.

Siden hovedfokuset i denne litteraturgjennomgangen var på oppdrett av laks og regnbueørret, reflekterer resultatene naturligvis forskningsfokuset i de viktigste produsentlandene for disse artene, noe som igjen reflekterer hvilken type miljøpåvirkning som har vakt størst bekymring i forvaltningen og allmennheten i disse landene. Resultatet av

denne litteraturgjennomgangen dannet grunnlaget for den bredere diskusjonen om muligheten for å oppnå en mer økosystembasert forvaltningstilnærming for akvakultur i Norge (kapittel 5 og 6).

## 3.1 Background, scope and objectives

### 3.1.1 Background

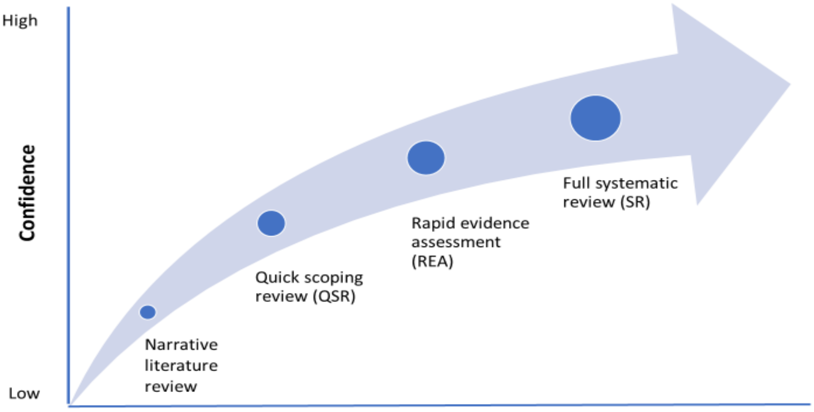
Ecosystem-based management of aquaculture requires knowledge of individual and cumulative effects on the environment and sensitive and scale-relevant indicators that ensure that permanent losses of vulnerable individual species/habitats or ecosystem functions are avoided. Environmental research in general varies in methodological quality, degree of bias, and relevance to policy. Using this heterogeneous, and sometimes polarized, research to inform environmental policies can be a challenging task (Boyd, 2013). Also, for management and regulation of aquaculture there are several urgent problems for which we need a reliable source of evidence on which to base actions. These actions might be controversial and/or expensive and it is vital that they are informed by the best available evidence.

Therefore, an accurate, concise and objective synthesis of available knowledge is one of the most valuable contributions the research community can offer decision-makers, and evidence reviews have become more and more in demand in many important areas of society. In this work package, we will compile a knowledge base for different types of environmental impacts from aquaculture using a «Quick Scoping Review» (QSR) approach. A QSR is a type of systematic review (SR), which is less comprehensive than a full SR, but where the main features such a detailed and comprehensive plan and search strategy derived a priori, clearly stated research questions, a transparent and reproducible method and a systematic summary of the evidence. The output of this literature review will form a basis for a wider discussion on the feasibility of achieving a more ecosystem-based management approach of aquaculture in Norway (Chapter 4, 5 and 6). Furthermore, the evidence base derived from this QSR can form a starting point for a more comprehensive synthesis at a later stage.

### 3.1.2 Scope

An Evidence Review (ER) allows to search, review and synthesise evidence related to a specific question. The spectrum of ER approaches ranges from Literature Reviews to Systematic Reviews and can be differentiated based on detail and rigor applied. The Quick Scoping Review (QSR) lies in the middle of this spectrum. It is based on a systematic and transparent search approach, which minimises bias within the body of evidence. It, however, does not conduct a critical assessment of the quality of evidence, which overall reduces time and costs of ER production (Figure 3.1).

**A**




**B**

| Attributes | Literature Review | QSR | REA | SR |
|---|---|---|---|---|
| Time duration* | 1-2 weeks | 3-5 months | 5-8 months | 10-18 months |
| Used to | Inform on a specific topic | Identify evidence available on a topic and summarise | Identify evidence available on a topic, summarise and provide a critical assessment of the evidence | Comprehensive review and assessment of evidence available on a topic |
| Search published data | ✓ | ✓✓ | ✓✓ | ✓✓✓ |
| Search additional sources of information | | ✓ | ✓✓ | ✓✓✓ |
| Systematic map of evidence | | ✓ | ✓ | ✓✓✓ |
| Informed conclusion upon completion | Maybe | ✓ | ✓✓ | ✓✓✓ |
| Critical assessment of evidence | | | ✓ | ✓✓✓ |
| Input from external experts | Maybe | Maybe | ✓ | ✓✓✓ |

*Figure 3.1. A. Schematic description of the hierarchy among Evidence reviews. B. Description of attributes of different types of ER. Modified from Collins et al. 2015.*

A QSR thus provides a rapid and cost-efficient method to answer a specific question by compilation and assessment of relevant evidence. Based on the available time and budget given for this review, QSR was identified to be the most suited ER approach. The step-by-step guide by Colins et al. (2015) on how to conduct a QSR is providing the framework for the here presented review.

> A Quick Scoping Review (QSR) provides "*an informed conclusion on the volume and characteristics of an evidence base and synthesis of what that evidence indicates in relation to a question.*". It does not conduct a critical appraisal of that evidence (Colins et al. 2015).

The scope of this review is very broad as it aims to provide a general summary of the environmental impacts arising from aquaculture production, an overview of associated assessment and monitoring methods and identify knowledge gaps. The output of this report will form the basis for a wider discussion on the feasibility of the implementation of an ecosystem-based management approach.

### 3.1.3 Objectives

The main objective of the review is to gain an insight into the environmental impacts arising from aquaculture production. At the start of the project a workshop was held with the complete review team, which is composed of experts with backgrounds in ecology, environmental impact assessment and/or aquaculture. This workshop was used to refine the broad main objective into a more targeted and manageable QSR framework. It was decided to focus the QSR on finfish production. Due to the dominant position in Norwegian aquaculture the main emphasis was on Atlantic Salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus Mykiss*). We also included Atlantic cod (*Gadus morhua*), since this is a revitalised, “new” species which has seen a boost in production over the past years (Fiskeridirektoratet, 2021). Here the focus is on production in open net-pens only. Seaweed farming (macroalgae) is still in its infancy in Europe but have received much attention recently and shows high potential for commercialisation on a larger scale and several initiatives are driving its progress in Norway (Fiskeridirektoratet, 2021; Araújo et al. 2021). Accordingly, macroalgae was considered a relevant new farmed species to be included in this review. However, for summarising the potential environmental impacts from macroalgae, a literature review approach was taken (see Figure 3.1).

Stressors are the drivers of environmental impact and are thus naturally forming the starting point for the QSR. An overview sketch developed by the Norwegian Environmental Agency (NEV)[2] was used to identify the main stressors associated with finfish aquaculture; feed & faeces (particulate organic waste), dissolved nutrients, diseases & parasites, environmental contaminants (pharmaceuticals & other substances) and escapes. In addition, the review team identified the following stressors as relevant: light, noise and artificial structure (Figure 3.2).

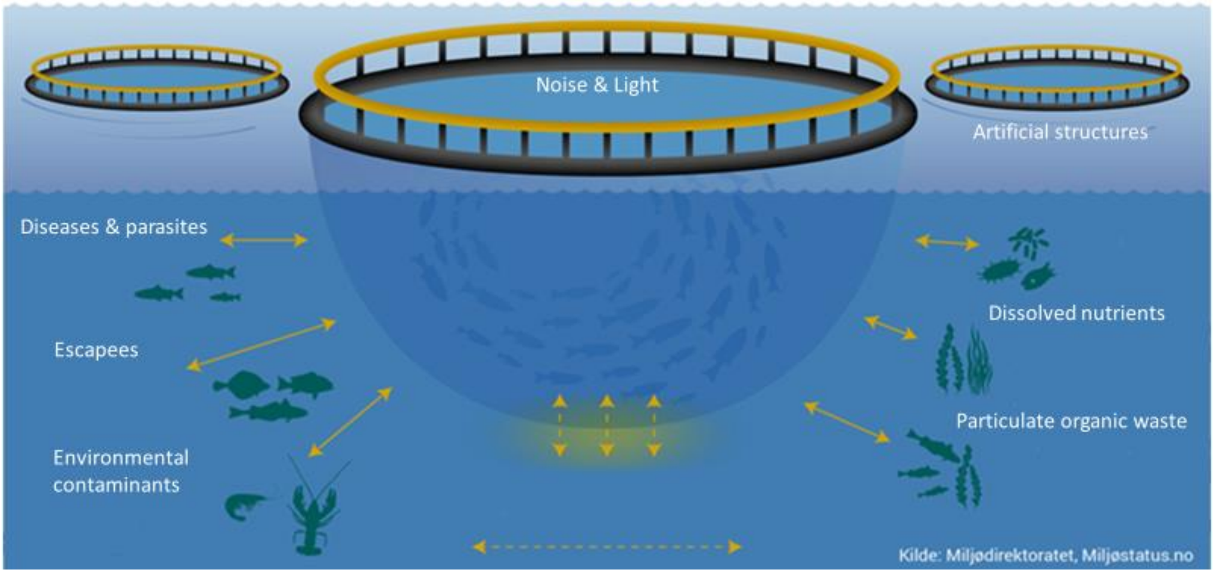



*Figure 3.2. Identified stressors from finfish aquaculture. Modified from Norwegian Environmental Agency.*

[2] https://www.miljodirektoratet.no/ansvarsomrader/vann-hav-og-kyst/Akvakultur-fiskeoppdrett/

Following the protocol steps outlined in Colins et al. (2015) and applying the Population, Intervention/exposure, Comparator, Outcome (PICO) approach the review team developed overarching primary and secondary questions for the QSR (Table 3.1).

***Primary question:***

What is the impact of stressor X on the marine environment?

*Table 3.1. PICO elements of the primary question.*

| *PICO element* | *PICO element within this QSR* |
|---|---|
| **Population** | Aquaculture |
| **Intervention / Exposure** | Stressor X from aquaculture activity |
| **Comparator** | Absence of stressor X from aquaculture activity |
| **Outcome** | Impact (positive/negative, direct/indirect) on marine environment (species / habitats and ecosystems) |

***Secondary questions:***

What is the spatial and temporal scale of the impact?
Which species, habitats and/or ecosystem components are affected?
Which indicators, monitoring and assessment tools are used to measure and assess the impacts?
Do the identified indicators, monitoring and assessment tools reflect the impact's spatial and temporal scale?

Answering the primary and secondary questions for each stressor following the detailed approach outlined in the stressor specific QSR protocols represents the main objective of this review.

<u>Macroalgae</u>

The main objective of the macroalgae search was to gain an insight into the possible environmental impacts from macroalgae cultivation, which have been less investigated than that of finfish production. The initial search focused on national and international knowledge compilations and review literature on environmental impacts of macroalgae, in order to identify the most likely stressors. The secondary search focused on finding research papers with original research data directed specifically at macroalgae cultivation, primarily from Norway or Europe, secondarily from other parts of the world when considered relevant for the industry in Norway. The search aimed at answering the same primary and secondary questions as mentioned above for finfish aquaculture.

### 3.1.4 References

Araújo, R., Vázquez Calderón, F., Sánchez López, J., Azevedo, I.C., Bruhn, A., Fluch, S., Garcia Tasende, M., Ghaderiardakani, F., Ilmjärv, T., Laurans, M., Mac Monagail, M., Mangini, S., Peteiro, C., Rebours, C., Stefansson, T., Ullmann, J., 2021. Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. Frontiers in Marine Science 7 (1247). doi:10.3389/fmars.2020.626389

Boyd, I. (2013). A standard for policy-relevant science. *Nature*, *501*(7466), 159-160.

Colins, A.M., Coughlin, D., Miller, J., Kirk, S., 2015. The production of Quick Scoping Reviews and Rapid Evidence Assessments. A How to Guide.

Fiskeridirektoratet, 2021. Nøkkeltall fra norsk havbruksnæring 2021. ISSN/ISSB: 1893-6946.

## 3.2 Methods

Following the definition of the overall objective for the QSR (Section 3.1.3), the review team was divided into stressor specific focus groups (Figure 3.2) based on their background and expertise. A QSR was then developed for each stressor by the respective focus group. Librarians from the University of Oslo Library of Medicine and Science supported the review team with their technical knowledge and advice. They created the outline of the first QSR (stressor: organic waste – particulate matter) together with selected members of the review team and provided feedback on challenges related to the development of the remaining QSRs. Experience and insights gained from the set-up of the first QSR were shared with the wider review team and supported the development of the QSRs for the remaining stressors. This chapter provides a generalised overview of the different stages of the QSR.

### 3.2.1 Search strategy

The framework of the search was defined through discussion with the complete review team during a workshop at the beginning of the project.

Published scientific literature was selected to be extracted from the online databases "Web of Science" (www.webofscience.com/), Scopus (www.scopus.com), WorldCat Dissertations and Theses (www.worldcat.org) and ORIA (https://oria.no ). Web of Science and Scopus are publisher-independent global citation databases of scientific peer-reviewed journals, whilst WorldCatDissertations and ORIA are used to access theses and dissertations in English and Norwegian respectively. ORIA only allowed for a simplified search input, which was not stressor specific. Accordingly, the same output was used for each stressor.

Some work of relevance has not been published in peer-reviewed journals, but instead can be found in reports and reviews from different institutes and governmental organisations (grey literature). Therefore, websites of relevant organisations and respective databases were included in the search. Examples are given in

Table 3.2, but suitability and relevance varied with stressor.

*Table 3.2. Examples of sources for grey literature.*

| Organisation & website | Country |
|---|---|
| Norwegian Environment Agency (https://www.environmentagency.no/) | Norway |
| Scottish Environment Protection Agency (SEPA) (https://www.sepa.org.uk/) | UK |
| Institute of Marine Research (https://www.hi.no/hi/en) | Norway |
| Environment Canada (https://www.canada.ca/en/services/environment.html) | Canada |
| Fisheries and Oceans Canda (DFO) (https://www.dfo-mpo.gc.ca/) | Canada |
| Internal project results | Norway |
| Databases (Vannmiljø, the Norwegian Seafood Database, Barents Watch, the Norwegian Institute of Public Health) | Norway |
| Monitoring programs (e.g. MILKYST, ØKOKYST etc.) | Norway |

Literature published during the time period 2010 to 2022 (may vary depending on stressor) and written in English and Norwegian was included. Geographical restrictions were not set as search keywords were thought to naturally select for relevant ranges.

Applying the PICO approach (Collins et al. 2015), each focus group collated relevant keywords for their search. The focus was thereby on defining the population, intervention and outcome, whilst the comparator was not seen relevant to this review and thus was not considered. For the stressor specific QSRs the focus of the selected PICO elements was as follows:

*Population*: Aquaculture and focus species
*Intervention:* Stressor
*Outcome:* Receiver

Allowing for a most unbiased approach, the "Outcome" element was intentionally kept broad with a focus on the receiver whilst refraining from adding a potential impact.

The selected keywords were discussed within the focus group and, where needed, adjusted and/or expanded upon. The final selection was then used to build the search profile for the respective stressor. Here different variations of the initial keywords (for example: "open cage" or netpen* or "net pen") were used to build search strings for the relevant PICO elements. Combined these search strings created the search profile. Keywords and search strings were linked with Boolean operators (simple words like AND, OR, NOT or AND NOT used as conjunctions to combine or exclude keywords in a search). The searches targeted title, abstract and keyword for relevant matches. An example of initial keywords and final input into the search profile are given in Table 3.3. The full search profiles for all stressors can be found in Appendix A (chapter 8). The search functionality varies between the search engines of different databases. Whilst the searches drew upon the same keywords, the combination and phrasing had to be adapted to the requirements of the respective search engine causing a slightly different outline of the search profiles. The search results for each database were exported and compiled into one Endnote library file. Duplicates were initially removed using Endnote's internal algorithm for duplicate detection. Subsequently each file was quality checked and, if required, remaining duplicates removed manually. The final endnote file, containing outputs from all search databases, provided input for the screening of literature.

*Table 3.3. Example of initial keywords and finalised search profile for the selected PICO elements and the stressor "Feed & faeces (particulate organic waste)".*

| PICO element | Keywords | Search profile |
|---|---|---|
| *Population* | Aquaculture, Atlantic salmon, cod, open cage, netpen | TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) |
| *Intervention* | Faeces, feed, organic waste, carbon | TS=(faec* OR feces OR fecal OR feaces OR feacal OR excrement* OR excret* OR carbon OR ((feed* OR food*) NEAR/4 spill*) OR "uneaten feed*" OR "uneaten food*" OR ((organic or particulate) NEAR/3 (waste* OR material* OR matter*)) OR ((waste* OR excess*) NEAR/4 (feed OR food*))) |
| *Outcome* | Impact, effect, indicator, threshold, ecology, ecosystem, diversity, abundance, reproduction, enrichment, coast, fjord, marine, fish, pelagic, plankton, benthos, seabed, substrate | TS=(impact* OR effect* OR indicat* OR biolog* OR divers* OR biodiverse* OR abundan* OR pollut* OR enrich* OR ecolog* OR trophic OR chemi* OR eutrophicat* OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR benth* OR epibent* OR infauna* OR epifauna* OR ecosystem* OR "eco system*" OR substrate* OR pelagic OR water OR composition* OR reprodu* OR dispers* OR sediment* OR lethal OR "sub lethal" OR threshold* OR phytoplankton* OR zooplankton* OR plankton*) |

### 3.2.2 Screening

The screening of search results ("evidence") was undertaken in the freeware Rayyan, which provides an easy, accessible platform for collaborative systematic literature reviews (https://www.rayyan.ai/). A two phased screening approach was applied. The first phase screening scanned title and abstract of the identified evidence and evaluated their relevance towards the primary and secondary questions as well as the predefined inclusion/exclusion criteria (section 3.2.1). The literature was marked in accordance as "Included", "Excluded" or "Maybe". The first phase screening was conducted by two members of the respective stressor focus group, which independently assessed the literature on hand. This approach reduces bias and ensures that relevant evidence is extracted. To guarantee independence a blind filter was applied during the screening process so that neither of the two reviewers could see the other's assessment. The blind filter was turned off following the completion of the screening by both reviewers, allowing for a comparison of screening results. Conflicting classifications of evidence, i.e. mismatch of "Included", "Excluded" or "Maybe" between the two screening outputs, as well as evidence labelled by both reviewers with "Maybe" were individually discussed and following a joint agreement reassigned. "Included" literature was used for evidence extraction (section 3.2.3), where it also underwent the second phase screening. Here one member of the stressor team re-assessed the identified literature based on the complete text and excluded evidence if seen to be not relevant to the topic.

### 3.2.3 Evidence extraction

Information relevant to the QSR's primary and secondary questions was extracted from the studies that passed the screening. An indicative guide for the evidence extraction is shown in the following:

**Base info:** Title, author, year and geographic location

**Type of study:** In-situ, field experiment, lab, review etc.

- if *in-situ* extract data on the physical environment, i.e. setting of the study (if available): depth, season, exposure, spatial scale etc.
- if lab-experiments extract key information on experimental set up, for example exposure time.

**Receiver:** Which species/habitat/ecosystem component is affected?

**Impact:** What is the impact?
Is it a direct or indirect impact?
How is the impact measured?
Stressor & response concentrations (if available).
What is the spatial & temporal scale of the impact?

**Monitoring:** Does standardized, regulated monitoring exist or only suggestions from research?
What are the monitoring methods / modelling tools?
What are the indicators used for monitoring?
Do threshold levels exist and what are they?
Are the identified indicators, thresholds, monitoring methods & modelling tools suitable to the spatial and temporal scale of the impact?

**Knowledge gaps:** Does the study highlight knowledge gaps?

## 3.3 Results – salmon & cod

### 3.3.1 Organic waste – particulate matter

#### 3.3.1.1 Background

Aquaculture production in open net-pens releases organic material in form of unconsumed feed, fish faeces and bio-fouling break-offs from the cage and mooring structures to the surrounding waters. The amount of released particulate organic waste in form of feed and faeces is thereby proportional to the production volume and thus varies throughout the production cycle. Feed composition and consequently utilisation as well as feeding strategies have significantly improved over the past years, thus reducing the amount of feed waste. Fish faeces is the dominant contributor of particulate organic waste release from fin-fish farming.

Depending on local environmental conditions (current flow, wave exposure, depth, seabed type) and particle characteristics (size, density, weight) particulate organic waste disperses, settles on the seabed and, in some cases, accumulates over time. Besides localised smothering of sessile organisms, the decomposition process of the bio-deposits can significantly alter benthic communities below and adjacent to a farm production site (Figure 3.3). Benthic environments close to the farm experience changes in the structure and function of infauna communities and degradation of sediment biogeochemical processes once enrichment thresholds are exceeded (Brooks & Mahnken, 2003; Kutti et al. 2007; Hargrave et al. 2008; Bannister et al. 2014). Very high organic loadings can result in anoxic and azoic conditions (Valdemarsen et al. 2012), whereas less intense levels of bio-deposition stimulate secondary production and alters the composition of the benthic communities (Kutti et al. 2007; Kutti, 2008).

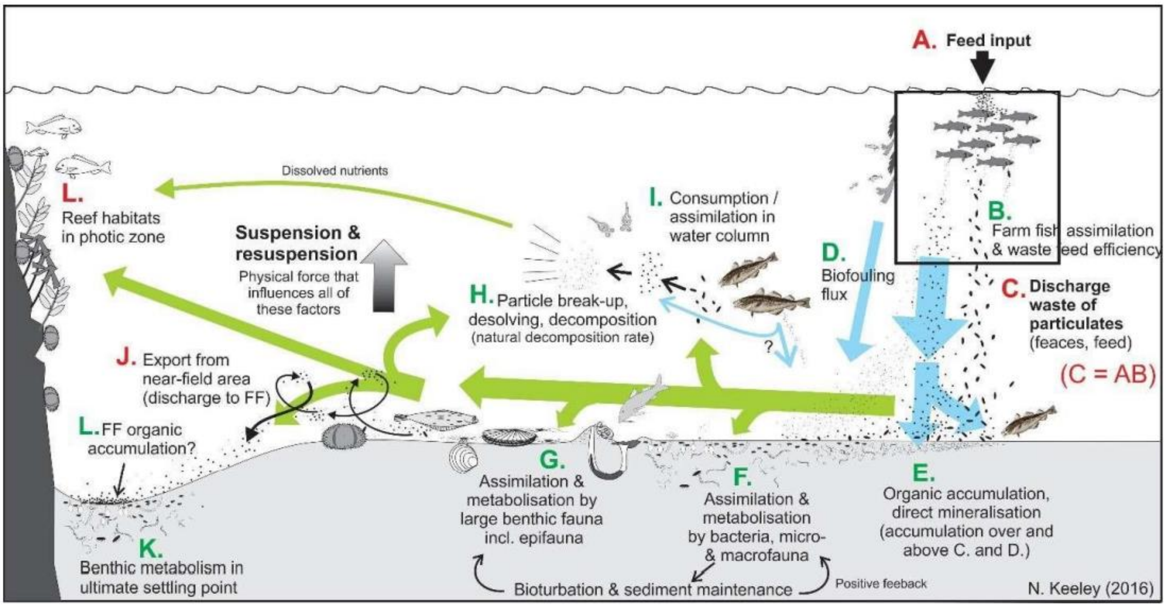



*Figure 3.3: Conceptional figure showing the pathways of particulate organic waste released under fin-fish production (Keeley, 2020).*

**Key findings**

- Field studies are most commonly used to assess impacts of particulate organic waste.
- The benthic environment is main receiver of particulate organic waste.
- Impacts on softbottom habitats have been extensively studied and are well understood. The majority of studies uses changes in infauna composition and function and sediment chemistry, i.e. a combination of biotic and abiotic indices, to assess enrichment status.
- Our understanding of impacts on hardbottom habitats and associated epifauna is limited.
- The spatial and temporal extent of the impact is site-specific as it depends on production parameters (biomass, feed output etc.) and status (active, fallowing) as well as the physical characteristics of the farm location, i.e. local hydrodynamics, wave exposure, substrate type and depth.
- Aquaculture production in dispersive sites might increase the likelihood of overlapping farm footprints and thus regional ecological effects.
- Wave activity has shown to be an important, but yet not well understood, driver for seabed processes in exposed locations.
- Monitoring of impacts of particulate organic waste on soft bottom habitats is regulated in Norway through the Norwegian Standard NS9410:2016. The monitoring approach is divided into B (qualitative, near-field) and C (quantitative, far-field) survey. Biotic and abiotic indices applied reflect those commonly used in the literature.
- Standardised monitoring approaches for mixed and hard substrates and associated (sensitive) species and habitats do not exist. Knowledge on sensitivity levels of associated fauna to organic waste and exploration and development of novel, suitable indicators of ecological effects is urgently needed.
- Microbial eDNA provides a sensitive proxy for enrichment status, which can be universally applied to soft- and hard-substrates. It, however, still has to be validated for a broader range of environmental conditions and sampling tools suitable for standardized monitoring have to be tested and developed.
- Dispersion models are a useful management tool as they provide an indication of magnitude and spatial extent of the farm footprint. Solving challenges around resuspension processes, implementing wave activity and a module representative for benthic biogeochemical processes will enhance and further improve this tool.

#### 3.3.1.2 Method – deviation

The base outline of the QSR for this stressor was set up with support of a librarian from the University of Oslo, who subsequently also conducted the QSR and extracted the final output. Throughout the QSR development process the researcher team provided feedback on QSR results, based on which the QSR was refined. This QSR also included the "Zoological Records" database, which was not considered for the remaining stressors. Following the final extraction of literature and first in-depth assessment of the database, it became evident that the phrase "Salmonella" is the source of many publications irrelevant to this QSR. Respective publications were removed prior to the literature screening. The initial QSR was conducted with the focus on Atlantic salmon (*Salmon salar)* and rainbow trout (*Oncorhynchus mykiss*), whilst it was in a later project phase decided to add Atlantic cod (*Gadus morhua*) as an aquaculture focus species. To evaluate the impact of these changes, concept 1 (population) was expanded with keywords for Atlantic cod and comparison runs between initial and expanded concepts were conducted in Web of Science. The difference in publication records was n=18, all of which were not relevant to the QSR topic. Based on this result and the expected similarity of output and impact between the selected farmed species, the initial QSR results were seen to be sufficiently representative and the QSR was not repeated. A summary of the publication selection process is given in Figure 3.4.

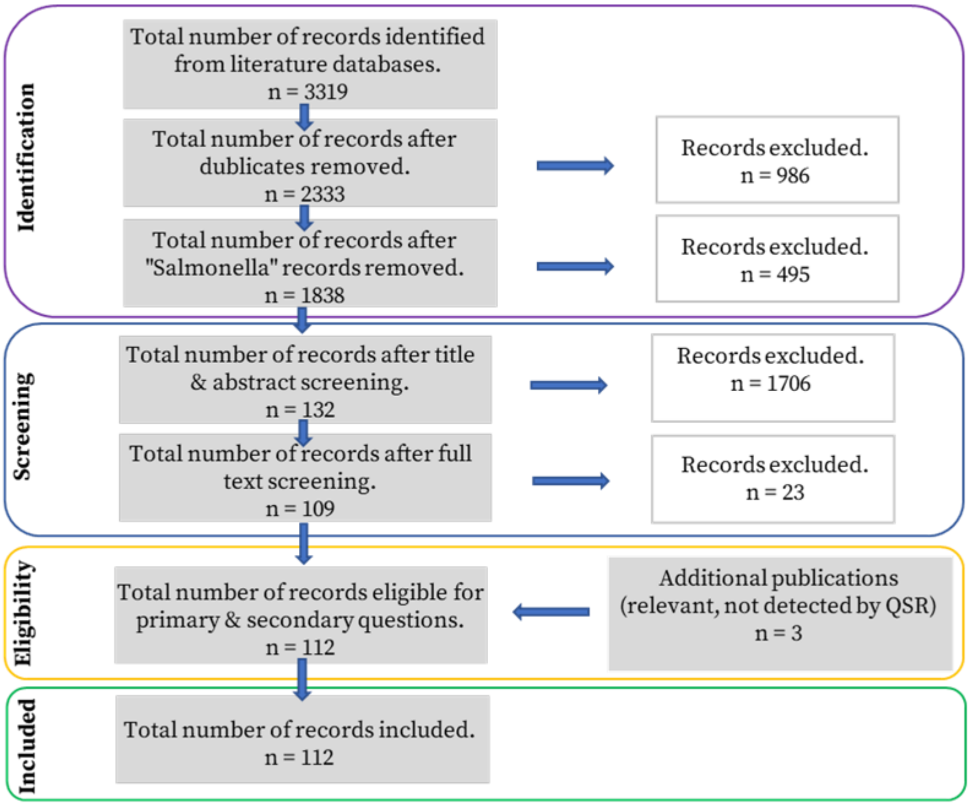



*Figure 3.4: PRISMA flowchart visualising the different steps of the selection process of the QSR for organic waste.*

### 3.3.1.3 Search results

The QSR identified initially a total of 3310 records, which was reduced to 1838 records following the removal of duplicates and publications related to the keyword "Salmonella" (see section 3.3.1.2). Screening of title, abstract and subsequently full text identified 109 publications to be relevant to the primary question: "What is the impact of particular organic waste from aquaculture production on the environment?". Three relevant publications were added post-screening, which increased the number of total records included to 112. The distribution of publication dates is relatively even throughout the selected timeframe (2010 – 2021, full years), with an average number of nine papers being published per year (Figure 3.5). The continuity of published work reflects the relevance of the topic in the context of environmental management. Most studies is conducted in Norway (n=39), followed closely by Canada (n=29). Chile accounts for 11 studies, whilst seven studies have been undertaken in New Zealand and Scotland (UK) respectively (Figure 3.5). These countries represent the main producers of Atlantic salmon.

Studies presented in the literature were predominantly field studies (n= 53) followed by combined approaches of field and laboratory studies (n=8) as well as field and hydrodynamic/dispersion model studies (n=6) (Figure 3.6). The focus of the field studies is on investigations of impact at and/or in the close vicinity of operating aquaculture production sites in varied environmental conditions and production stages. Combined approaches of laboratory and field experiments are used to a) substitute *in-situ* field data with measurements (benthic flux) collected under controlled laboratory conditions from sediment cores originating from related farm sites and b) evaluate the suitability of tracers of organic waste (stable isotopes or fatty acids), by coupling controlled feeding/exposure experiments with *in-situ* measurements of the selected tracers. In cases where field studies were coupled with hydrodynamic and/or dispersion modelling, it was either a) to validate model outputs, i.e. use of in-situ data to assess model quality; b) to substitute limited field surveys (restricted extent, duration) with modelling data or c) to refine parameters essential to the model set up (for example particle size & resuspension parameters).

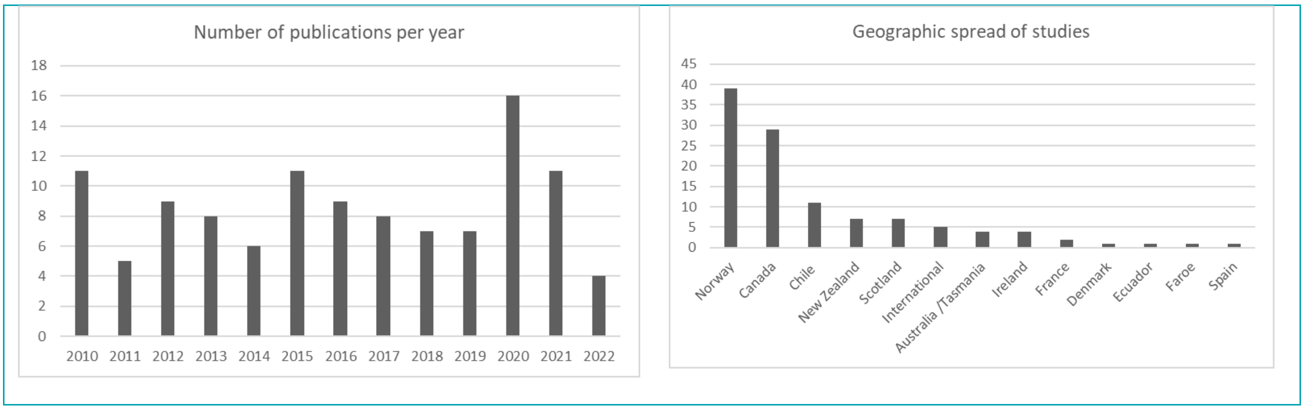



*Figure 3.5: Left: Overview on number of scientific articles published per year. Right: distribution of published literature per country.*

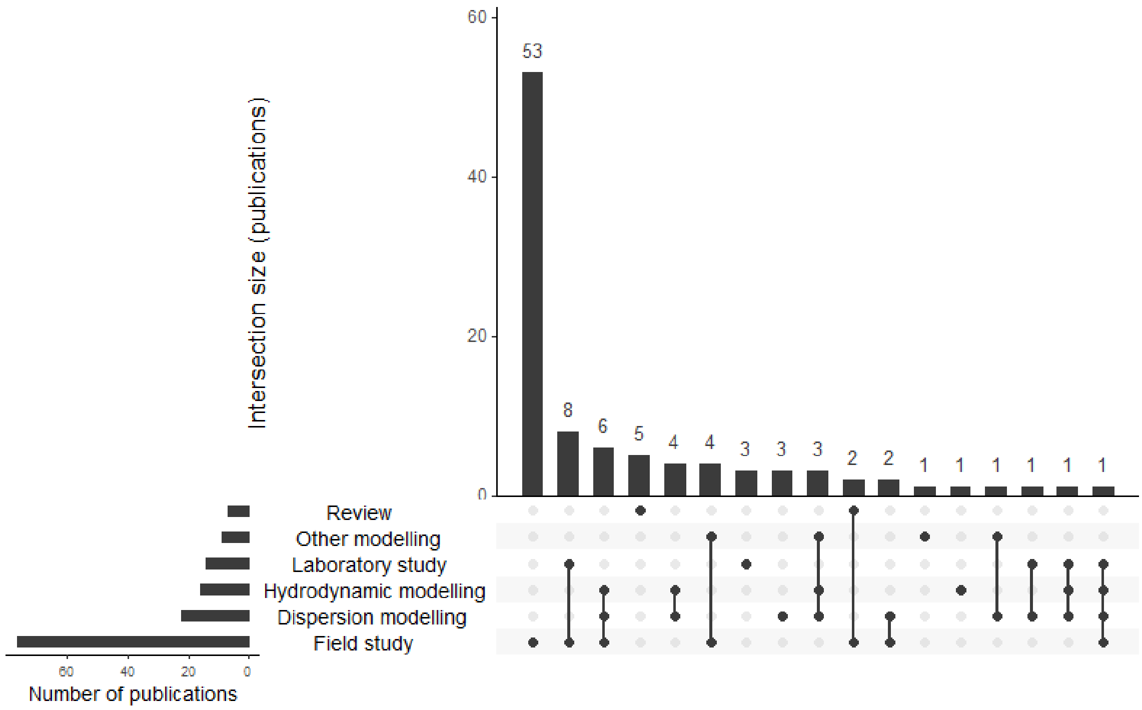



*Figure 3.6: Overview on number of publications per study category (field, lab, hydrodynamic modelling, dispersion modelling, other modelling, review) and intersections between different categories.*

### 3.3.1.4 Receiver & impact

Particulate organic matter released from open net-pens sinks through the water column and settles on the seabed. The main receiver is therefore the benthic environment, which is also reflected in the QSR output with a clear dominance of studies targeting benthos (Figure 3.7). Studies investigating impacts on benthic habitats represent 88% of the literature, whilst studies with a combined focus on benthic and pelagic components comprise 8% and studies with a sole pelagic focus 4% of the selected literature (Figure 3.8). Most benthic studies (n=21) assess changes in infauna community composition combined with responses in sediment biogeochemical processes. This is followed closely by studies on epifauna (n=19), microbial communities (n=6), studies with a sole focus on sediment chemistry (n=6) and approaches combining these benthic components (n=12). Wild fish is the most prominent pelagic receiver (n=8), followed by water chemistry (n=3) and plankton (phyto=3, bacterio=2, zoo=1). The remaining literature represents varied multi-receiver approaches (Figure 3.8).


*Figure 3.7: Proportional representation receiver (species/habitat/ecosystem component) that was impacted by particulate organic waste. Size of segment correspond to the total number of papers that describe impact on the given receiver.*

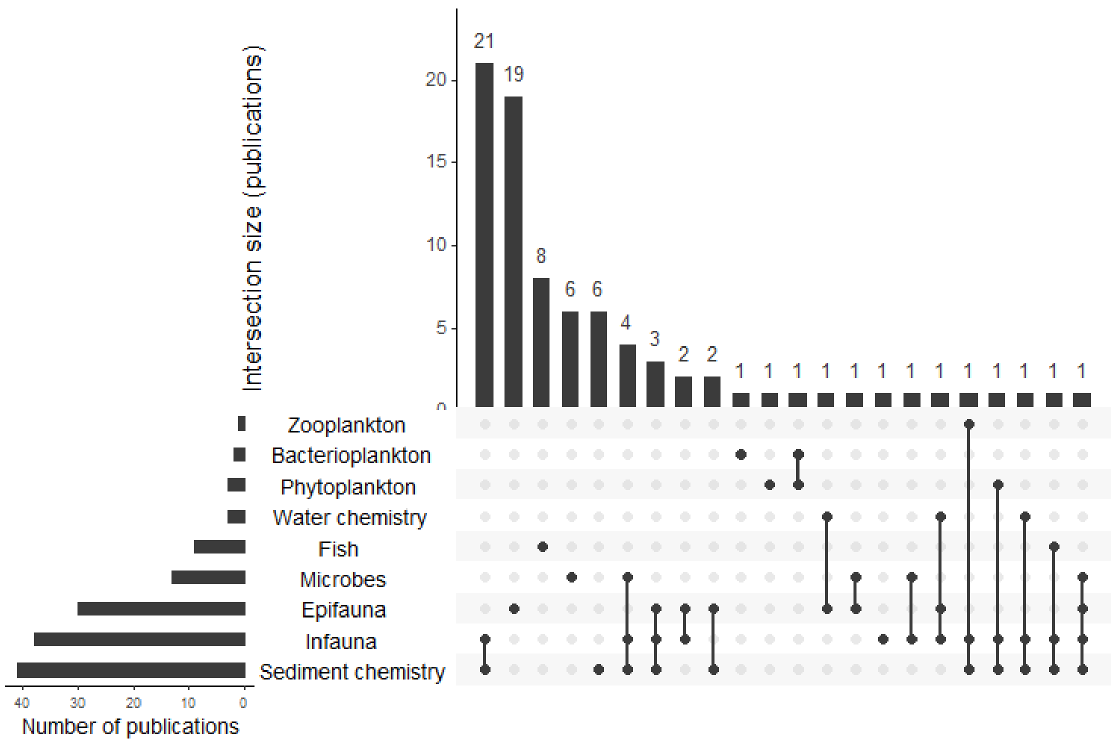



*Figure 3.8: Overview on number of publications per receiver and combinations of receivers.*

Changes in **infauna** and **sediment geochemistry** are a common indicator to assess enrichment status of **softbottom habitats,** which is reflected in the dominance of respective studies within the QSR (Figure 3.8). The process of organic enrichment for softbottom habitats has been extensively studied for several decades and is well documented (Pearson and Rosenberg, 1978; Gray et al. 2002; Diaz et al. 2004; Hargrave et al. 2008; Keeley et al. 2012) (Figure 3.9).

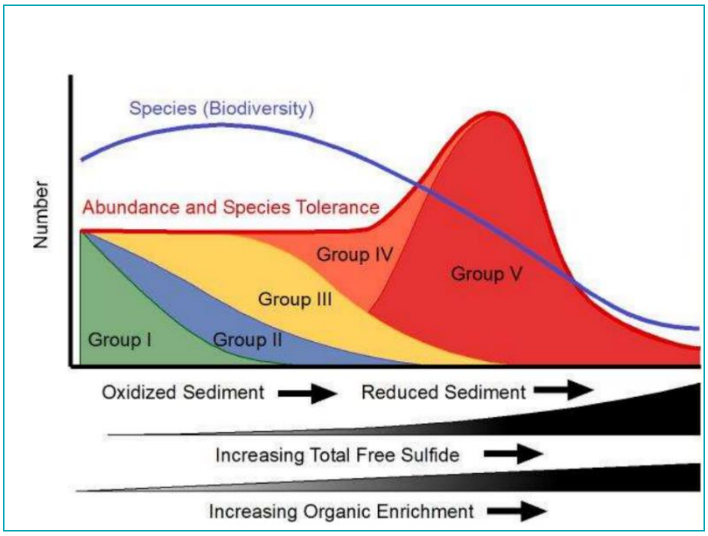



*Figure 3.9: Generalised schematic overview on relations between organic enrichment, sediment chemistry and macrofaunal communities (ASC, 2020).*

Increased supply of solid organic waste to the seafloor stimulates aerobic decomposition processes, leads to an initial increase of macrofaunal biodiversity and results in higher oxygen demands. If oxygen demand, however, exceeds natural resupply then conditions within the sediments will turn hypoxic or anoxic. At this stage microbial communities take over the decomposition of organic waste using anaerobic respiration processes, including sulfate reduction and methanogenesis which further increase oxygen demands. The changes in sediment geochemistry affect macrofaunal community structure and function as tolerance towards hypoxic and sulfidic conditions varies between species. Abundance of tolerant, opportunistic species initially increases under moderate enrichment conditions. If oxygen is further depleted and free sulfides ($S^{-2}$) accumulate, a general decline in abundance, biodiversity and biomass becomes evident. A complete collapse of macrofaunal communities is often reached when sediment conditions and adjacent water layers turn complete anoxic and toxic gasses (hydrogen sulfide and methane) are freely released.

Studies including **epifauna** as receiver (n= 30) are divided into two focus areas: a) impact assessment & method development and b) exploration of suitable tracer of organic waste to higher trophic levels. About half of the publications (n=14) investigate changes in epifaunal communities following the exposure to particulate organic waste or aim to develop suitable survey methods. Mobile benthic epifauna are predominantly predatorial, whilst sessile epibenthic organisms are filter-feeders and thus highly susceptible to anthropogenic sedimentation events. They settle on hard substrate and dominate mixed and hardbottom habitats. The latter are often found in physical dynamic waters, which in recent years have been increasingly utilized by the aquaculture industry as they provide favorable conditions for the development of larger sized fish farms. The study of impacts on epifaunal communities associated to **mixed and hardbottom habitats** is thus a relatively new research area and our understanding is limited. Visual surveys show a significant decline in density of sessile epibenthic species with higher sedimentation pressure, whilst mobile species can increase in abundance (Sutherland, 2018; Keeley et al. 2020; Dunlop et al. 2021). Analysis of biomarkers (microbiome, fatty acids) on sessile epibenthic species indicated a stress response in target fauna exposed to higher sedimentation. Responses were, however, varied between target species (Laroche et al. 2022). Total loss of epifauna (barren stations), formation of opportunistic polychaete complexes (OPC) and bacterial mats (*Beggiatoa* spp.), the presence of the lugworm *Arenicola marina* and aggregations of polychaete tubes have been detected in the close vicinity of the cages under different production stages (Hansen et al. 2011; Eikje, 2013; Hamoutene et al. 2015; Salvo et al. 2017; Pezzola, 2021).

Vulnerable Marine Ecosystems (VMEs), such as coral reefs, coral & sponge gardens, maerl beds etc., are formed by epibenthic species and are thus relevant to this category. VMEs are ecologically highly valuable (biodiversity hotspot, carbon cycling) and characterised by slow growth rates, late maturity and low or unpredictable reproductivity, making them very susceptible to degradation by anthropogenic activities. Over the past 4 years an increase in visual mapping surveys has revealed an overlap of coastal aquaculture production with vulnerable marine ecosystems. Studies conducted in this context report negative effects on ecophysiology of the respective species and thus high sensitivity towards particulate organic waste (Sanz-Lazaro et al. 2011; Husa et al. 2016; Legrand et al. 2021; Kutti et al. 2022).

The remaining studies (n=16) document the use of stable isotopes ($\delta^{15}N$, $\delta^{13}C$) and fatty acids as tracers for organic waste in higher trophic levels. Target species include sessile species such as bivalves (blue mussels, scallops, limpets) and sponges and mobile species including a range of crustacean (crabs, lobster & shrimp) and various echinoderms (urchin, seastar). These studies show that particulate organic waste from aquaculture production is utilized also by higher trophic species, which might provide some with a competitive advantage and thus lead to further ecosystem effects. The latter is yet poorly understood (Grefsund et al. 2022).

The fourth receiver group is **microbes** (n=13). Here, most of the studies explore changes in microbial community composition/diversity and/or function/trait along organic enrichment gradients using environmental DNA (eDNA) metabarcoding. Findings show that in particular bacterial community responses under increased organic loading are similar to those of macrofaunal bioindicators. Bacteria are thus thought to be a sensitive proxy for enrichment status, which can be universally applied to soft- and hard-substrates (Dowle et al. 2015; Verhoeven et al. 2018; Keeley et al. 2021).

**Wild fish** were the most prominent pelagic receiver (n=9). The release of particulate organic waste can be an attractive feed substitute for wild fish (cod, saithe, haddock, halibut), which consequently change their natural behavior and aggregate around active fish farms. Farm feed as supplement food has been shown to elevated body and liver condition and cause changes in skin & muscle color, pH, fatty acid composition and sensory parameters. Potentially nutritional deficiencies are also thought to cause reduced reproductivity, but these effects are yet poorly understood. Behavioral changes might affect migratory patterns. Here studies present, however, conflicting results with some showing attraction to farms and longer residence times, whilst others suggest avoidance of aquaculture production areas (Callier et al. 2018).

Biotic and abiotic indicators are used as **assessment tools** for impacts of particulate organic waste. Overall, a total of 58 biotic and 23 abiotic indices were extracted from the QSR literature. The most prominent (n=>5) are shown in Figure 3.10 (biotic) and Figure 3.11 (abiotic). The **biotic indices** cover the key receivers (except of wild fish) and range from the simplest measure of community composition (abundance, species richness & number of taxa) to more advanced statistical indices describing biodiversity (Shannon Wiener (H')), sensitivity (AMBI, M-AMBI) and evenness/uniformity (Pielou (J)). eDNA outputs for microbial communities are assessed with similar criteria. Visual approaches have been tested for mixed and hardbottom habitats with an emphasis on presence/absence of species and percentage cover of potential enrichment indicators such as bacterial mats and opportunistic polychaete complexes. Their performance is, however, challenged by the sparse and patchy nature of the target species. Visual parameters are also typically indicative of severe, localised impacts, but unable to discern a broad range of effects, including moderate effects and the outer extent of influence. The unidirectional characteristics of the approach, i.e. presence means effect whilst absence does not necessarily mean no effect, adds to the limitations of these indicators. More reliable indicators capable of detecting moderate effect stages are thus urgently needed. The most prominent **abiotic indices** are representative for the pressure load (TOC, TOM), the assimilation capacity (grain size) and the sediment biogeochemical processes associated to organic enrichment (redox, total nitrogen, sulfide, pH). In general, combinations of biotic and abiotic indices are commonly used to assess impact status. All of these indicators have their advantages and limitations, and performance might be varied depending on environmental / pressure setting. Accordingly, expert judgement is still required to select and appropriately weight indicator variables (Keeley et al. 2012).

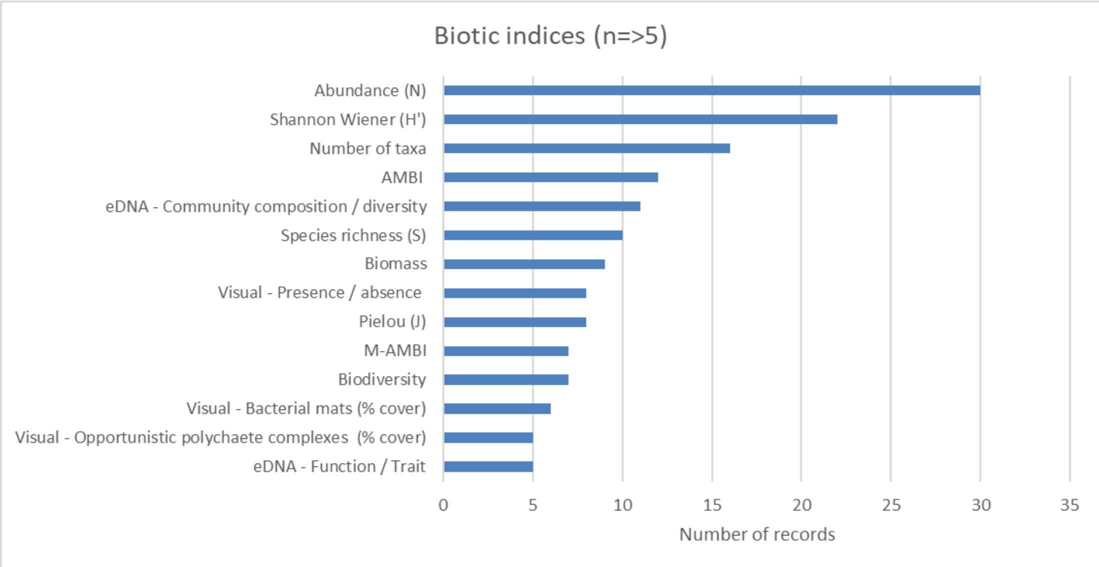



*Figure 3.10 . Overview of most prominent biotic indices (n=>5) as extracted for all studies.*

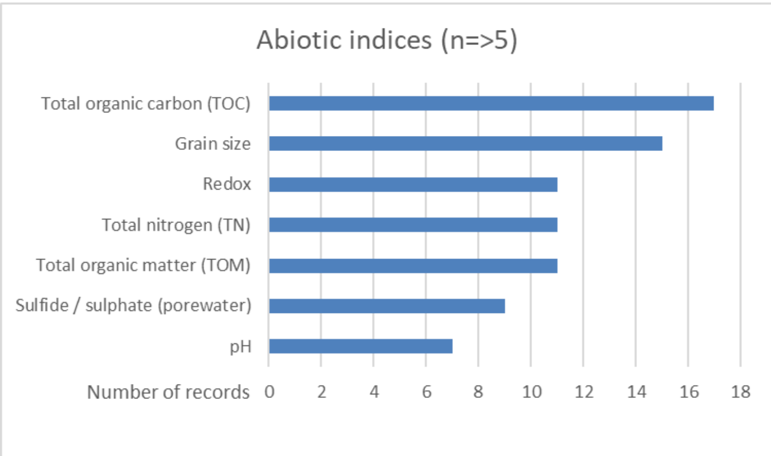



*Figure 3.11. Overview of most prominent abiotic indices (n=>5) as extracted for all studies.*

The **spatial and temporal extent** of the impact is largely dependent on production parameters (biomass, feed output etc) and status (active, fallowing) as well as the physical characteristics of the farm location, i.e. local hydrodynamics, wave exposure, substrate type and depth. The latter are main drivers for the dispersion of particulate organic waste, but also steer oxygen supply and thus affect assimilation capacity (Keeley et al, 2013).

The QSR literature shows that studies interpret and thus represent these components in different ways, making it challenging to systematically assess and compare their output. A site characterised in one study as "shallow, exposed and dispersive", would be classified as "deep with average current flow" in another study. Here, standardised definitions and threshold values would be beneficial, i.e. what range of current flow, wave exposure and depth is suitable to classify a site "exposed" or "sheltered" and "dispersive" or "non-dispersive". Information on production was also given in various forms, with some studies just mentioning that the site was stocked or not in production, whilst other provided detailed production data but in different measures (example: biomass (t) vs. number of fish) and timeframes (snapshot vs. production cycle). The survey design of the extracted field studies is in addition variable. Spatial approaches differ between assessments of changes along a distance gradient and comparisons of farm vs reference location. Phrases such as "near-field", "far-field", "localised" and "regional" are often used to describe the sampling set up and impact distances. Distance measures associated to these categories are, however, highly variable and related to site characteristics. It is therefore challenging to extract a generalised measure of spatial extent as these are highly site specific. A comparison of sampling distances used in the field provide a simplified insight into expected effect distance (Figure 3.12). The majority of studies with the focus on softbottom habitats (infauna) limit their sample range to areas <250 m from the farm, whilst reference sites are placed as close as 500 m from the farm location (Figure 3.12 a & b). This scale is in agreement with the anticipated primary influence area (initial settlement of particles) of a traditional non-dispersive site, where most severe impacts are expected just below the cages with a notable change in infauna composition and sediment chemistry out to ca. 300 m. Contrarily the footprint of high dispersive sites have been shown to be more diffuse, but spatially larger with effects detected out to 600-1000 m. There is thus an increased scope for broad-scale, cumulative effects in production areas characterised by strong current flow and/or significant wave exposure. Our knowledge on these effects is to date, however, limited (Valdemarsen et al. 2012, Keeley et al. 2013, 2019 & 2020, Cranford et al. 2022). The spatial scale applied in studies on mixed and hardbottom habitats (epifauna) is somewhat extended compared to softbottom studies and covers at farm level distances out to 1000 m and beyond, whilst reference sites are placed as far as >5000 m from the farm (Figure 3.12 c & d). Mixed and hard substrates can be associated with more exposed sites, which consequently will lead to a larger area that is impacted. In addition, many of the epibenthic studies focused on tracer elements in mobile species, which naturally have a wider range and thus require a spatially more extensive sampling regime. Overall, however, our knowledge on the scale of effects on epibenthos and mixed/hardbottom habitats is limited as suitable monitoring methods are lacking.

On a temporal scale studies provide snapshots of enrichment status (one sample event) or compare results of multiple sampling events, which differ between systematically targeting a range of production stages, opportunistic sampling unconnected to production or following seasonal changes. Also here it is evident that enrichment status and recovery is directly related to site-specific production practises and assimilation capacity, which is driven by the physical characteristics of the farm location. Site recovery, for example, has been shown to vary between a few months and several years (Keeley et al. 2014, Verhoeven et al. 2018, Cranford et al. 2022).

Dispersion models based on local hydrodynamics are useful tools to assess the spatial footprint of a farm site. Although these models have not fully resolved particle resuspension yet and often lack a compartment that considers biogeochemistry processes, they provide a site-specific trend indication of waste dispersal. They are valuable to management, which is also reflected in the number of studies developing or applying dispersion models (Figure 3.6).

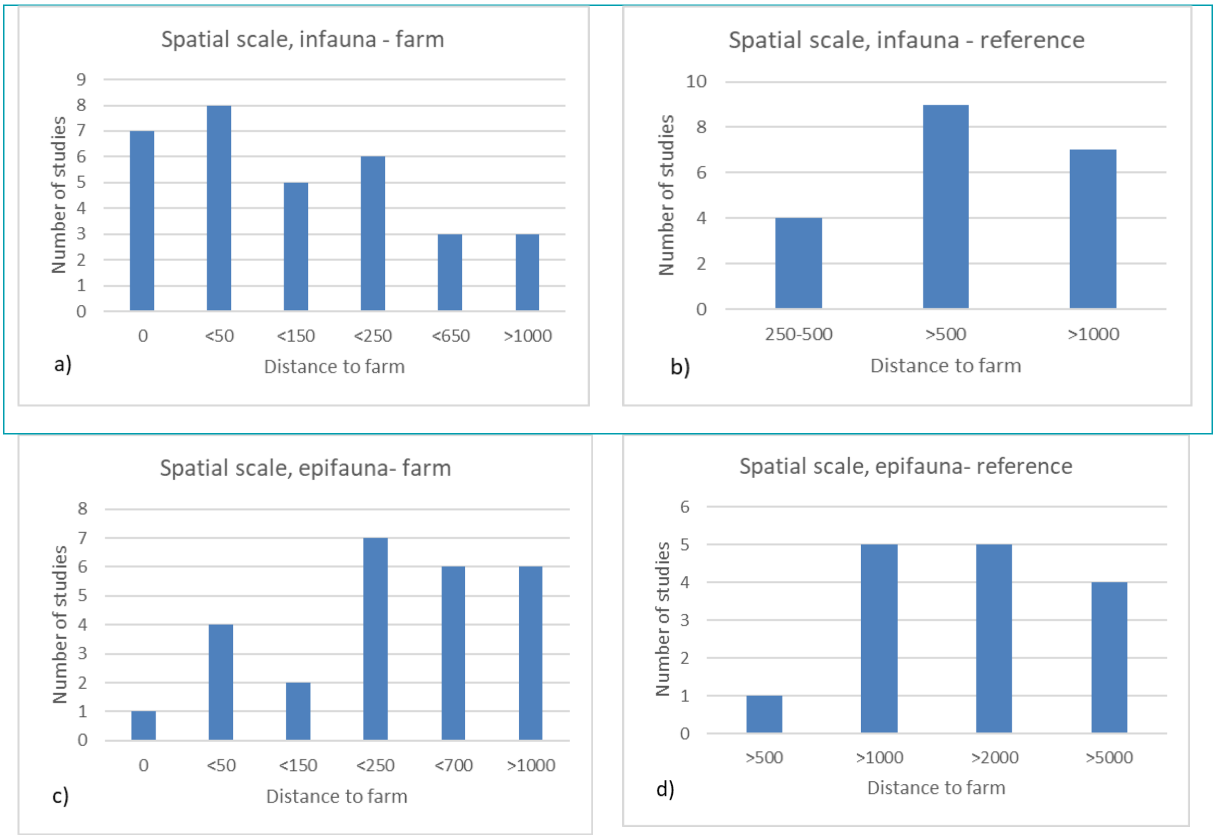



*Figure 3.12. Overview on spatial scales applied in field studies with the main focus on infauna (a, b) and epifauna (c, d). Figure shows the sampling extent at the farm site (infauna = a; epifauna=c) and reference (infauna = b; epifauna = d). For ease of access distances were categorised.*

#### 3.3.1.5 Monitoring

Monitoring efforts in Norway are solely focusing on direct impacts on the benthic environment. Potential higher trophic level effects (direct or indirect) are not addressed by current monitoring programs.

Monitoring of impacts of particulate organic waste on **soft bottom habitats** is regulated in Norway through the Norwegian Standard NS9410:2016 (Hansen et al. 2001, Norwegian Standard, 2016). The monitoring approach is divided into B and C survey, which assess near- and far-field of the impact zone respectively. The standard provides in addition guidance to a baseline survey, which has to be conducted at potential, new farming locations. It combines B and C survey approaches and is used as baseline for further assessments under production. B and C surveys are conducted in regular intervals with a key focus on max production, but sampling frequency increases with deteriorating environmental condition. The **B survey** covers the area under and in the closest vicinity of the cages and is based on the qualitative assessment of sediment chemistry (pH and redox) and sensory parameters (outgassing, odour, colour, consistency etc.). The presence and/or absence of macrofauna is noted, but only serves as a supportive criterion. The performance of sediment chemistry and sensory parameters against predefined thresholds categorises the farming locations into different environmental conditions (1. low-, 2. medium-, 3. high-organic loading, and 4. organic overloading). Environmental condition 4 represents thereby an unacceptable state when production cannot continue before the farming location has recovered. As an impact is inevitable in this area, low impact does not reflect pristine conditions, but that the farm is managed within acceptable conditions in regard to its local impact. The **C survey** covers the "far-field" of the impact zone, which outer extent is related to the maximum allowed biomass at site and varies between 300 to 500 m. It is based on a more extensive, quantitative assessment of sediment chemistry and macrofauna. Biotic indicators used to describe changes in macrofauna community structure and function reflect those commonly referred to in the literature (Figure 3.10). The application of nEQR (normalised ecological quality ratio) considers the different diversity and sensitivity indices and is used to describe the environmental status per station. Abiotic indicators used in the C survey represent exactly those identified to be most applied in the literature (Figure 3.11). Only free sulfides are currently not part of the standard monitoring in Norway. Biological data are the main driver for the assignment of environmental condition, whilst abiotic data provide support information for the assessment. Threshold levels for environmental condition are given by the Norwegian classification guidelines 02:2018 (Direktoratgruppen, 2018), which are based on the same principles as the European Water Framework Directive but adapted to Norwegian coastal waters. B and C surveys are accepted monitoring methods for softbottom habitats and supply sufficient information for localised management.

An increasing number of Norwegian aquaculture companies also aim to certify their products using the **Aquaculture Stewardship Council (ASC) standard** (salmon). Monitoring of the benthic environment (soft bottom) forms a key part of the certification process as farmers must show that they are actively minimizing their impact on the surrounding natural environment. To date ASC surveys in Norway monitor broadly impacts within the same spatial extent as the C survey, but use a denser station network. The ASC divides the impact zone into the Allowable Zone of Effects (AZE), which is representative for the area where highest impact is expected, and the area beyond AZE. The AZE is expected to be modelled (dispersion models) and subsequently validated by *in-situ* sampling. For impact assessment a subset of key biotic (Abundance, Shannon Wiener, AMBI, Benthic Quality Index (BQI), Infaunal Trophic Index (ITI)) and abiotic indices (Redox, sulphide) are used, but other indices can be supplemented if seen appropriate. Threshold levels for AZE and outer AZE are overall more conservative than those given by guidelines 02:2018 (ASC, 2022).

Standardised monitoring methods for **mixed and hardbottom habitats** and associated fauna do not exist in Norway. In 2019 alternative guidelines for the monitoring of mixed and hardbottom habitats were released (Hansen et al. 2019). Substituting the B survey sampling at sites where >80% of sampling stations are classified as "hardbottom", this visual approach suggests collecting quantitative data (percentage coverage) on epifauna, feed/faeces, organic material, bacterial mats, opportunistic polychaete complexes and offgassing. It therefore builds upon the monitoring scheme implemented in Canada (DFO, 2018), but lacks threshold values and thus evaluation criteria. The same challenges apply to sensitive species and habitats often associated with hard substrates. Whilst suggestions for methods of mapping of sensitive species at aquaculture sites have been released (Kutti & Husa, 2021; Husa & Kutti, 2022), tools for impact assessment and monitoring methods are lacking.

#### 3.3.1.6 Knowledge gaps

There is an extensive knowledge base on enrichment effects from particulate organic waste on softbottom habitats and monitoring tools have been developed over decades. The QSR, however, highlights shortcomings in our understanding of enrichment processes at dispersive sites typically found in so called "offshore" environments. The diffuse, large impact area (up to 1.5 km) of farms in these environments increases the possibility of overlapping footprints and thus potential regional effects. To date these have not been explored and measurable ecological impacts might be subtle and challenging to detect with current methods. Studies undertaken in these environments also highlighted the effect of wave action on seabed processes, something that is yet not considered and certainly not well understood.

There is also an urgent need for the development of suitable monitoring methods for mixed and hardbottom substrates as well as associated (sensitive) species and habitats. This will firstly require a better understanding of the sensitivity levels of associated fauna to organic waste, followed by the exploration of new indicators of ecological effects. Microbial eDNA has been shown to be a promising tool and should be further explored and validated. Biomarkers indicative of physiological stress are thought to be useful for defining sub-lethal threshold values required for management. Although a limited range are explored under an ongoing FHF project (901785), there is still need and scope for further development and validation of novel indicators.

Studies on mobile epifauna also indicate impacts on higher trophic levels, which might contribute to changes in the wider ecosystem. The latter is yet not well understood and should further be explored.

Dispersion models have been established as useful management tools as they allow to predict the magnitude and spatial extent of waste deposition. There are, however, still several challenges, one of which is the implementation of resuspension processes. Here more knowledge on particles break-up cycle and behaviour under varied environmental conditions is required. Seabed complexity (including biotic coverage) and roughness should also be considered by the model. Most dispersion models are solely based on hydrodynamics as driving force. As mentioned above, wave activity should be implemented as another driving factor in future model set ups. Adding on a module which resolves biogeochemical processes would also add valuable information and improve predictions.

#### 3.3.1.7 Conclusions

The QSR showed that impacts of particulate organic waste received continuous attention over the years, with scientific contributions being mainly submitted from key producing countries of Atlantic Salmon. Field studies and the collection of *in-situ* data are the most commonly applied ways of gathering knowledge on related environmental impacts. Wild fish was thereby the most studied pelagic receiver. Numbers of publications on the pelagic were, however, neglectable compared to those focusing on the benthic environment, which is clearly the key receiver of organic waste. The benthic environment comprises biotic components (infauna, epifauna and microbes) as well as sediment chemistry. The process of organic enrichment for softbottom habitats has been extensively studied for several decades and is well documented and understood. Spatial and temporal extent of associated impact is largely dependent on production parameters (biomass, feed output etc.) and status (active, fallowing) as well as the physical characteristics of the farm location, i.e. local hydrodynamics, wave exposure, substrate type and depth. Tracers such as fatty acids and stable isotopes are used to delineate the spatial extent of waste dispersion in the field, whilst dispersion models have been shown to be a cost-efficient tool to predict magnitude and extent of farm-specific footprints. A large suite of biotic and abiotic indices has been developed to affectively assess changes in benthic infauna community composition and function in relation to the different stages of oxygen depletion (hypoxic/anoxic) of substrates under increased enrichment conditions. The latter are successfully incorporated into national (NS9410:2016) and international (ASC) monitoring programs. The increased use of exposed, dispersive ("offshore") sites for large-scale farming (MTB >5000 t), however, might lead to overlapping footprints and consequently regional effects, potentially requiring a re-evaluation of monitoring scales and methods. Also, our understanding of impacts on mixed- and hard substrate and associated (sensitive) species and habitats is poor. There is an urgent need for increased knowledge on sensitivity of epifauna towards organic waste and the development of suitable monitoring indicators and sampling methods.

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### 3.3.2 Dissolved nutrients

#### 3.3.2.1 Background

Individual fish release dissolved inorganic nutrients through excretion mainly in the form of ammonium ($NH_4$) and phosphate ($PO_4$). The amount of dissolved inorganic nutrients increases proportional to fish production, but the exact amount released from the Norwegian aquaculture industry is uncertain as numbers differ substantially between different calculation approaches (Grefsrud et al. 2023). Aquaculture is however considered the most important anthropogenic source of dissolved nutrients from Rogaland to Finnmark (Sample 2023).

Dissolved inorganic nutrients from aquaculture do not significantly differ from those from other sources, hence the potential effects on estuarine and coastal ecosystems are expected to be of the same type for all emissions. There can be direct effects on primary producers such as changes in phytoplankton and macroalgae biomass or community, or indirect effects e.g. on benthic biomass and communities, on zooplankton, and on fish. Responses to increased nutrients load depend on system-specific attributes leading to significant differences among estuarine-coastal systems in their sensitivity to nutrient enrichment. The most visible and well described effects of high load of dissolved nutrients appear in a late stage of a continuum towards eutrophication ( Figure 3.13). One challenge for management is to be able to detect the subtle changes associated with the early stage of this continuum.

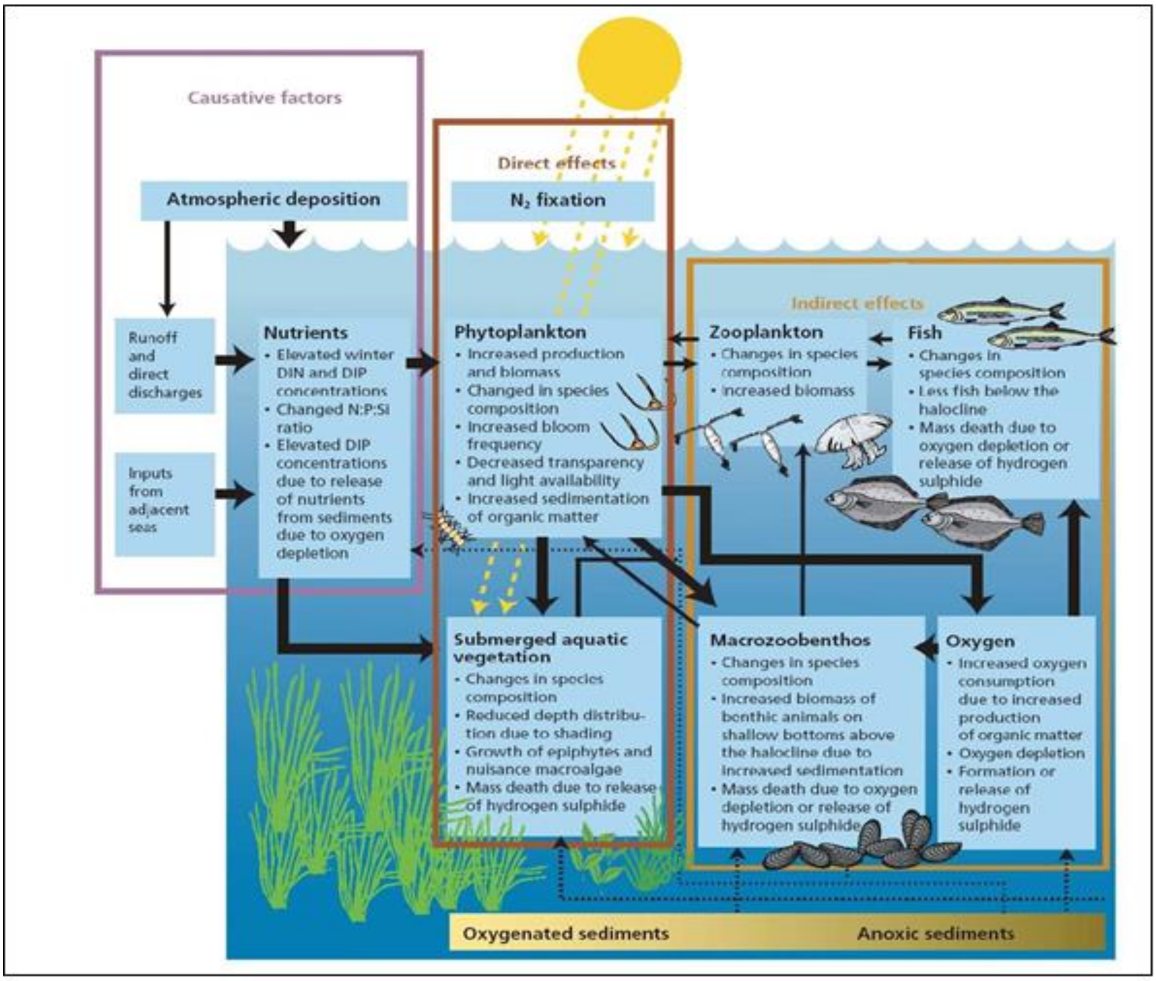


*Figure 3.13. Conceptual model of eutrophication (Andersen et al. 2010). The arrows indicate the interaction between different ecosystem compartments. Nutrient enrichment results in changes in the structure and function of marine ecosystems, as indicated with bold lines. Dashed lines indicate the release of hydrogen sulfide ($H_2S$) and phosphorus, which both occur under conditions of oxygen depletion. Abbreviations: N = nitrogen; P = phosphorus; Si = silicon; DIN = dissolved inorganic nitrogen; DIP = dissolved inorganic phosphorus.*

**Key findings**

- Field studies are most commonly used to assess impacts of dissolved nutrients, followed by combined approach of field studies and modelling.
- The was a slight overweight of studies addressing benthic environment, but receivers from benthic and pelagic (water column) environments were almost equally represented.
- The most commonly reported receivers were water quality, phytoplankton and macrophytes. Many studies assessed more than one receiver, most commonly water quality together with phytoplankton.
- There were few studies addressing impacts on higher trophic levels such as zooplankton and fish.
- Reported impacts on macrophytes included increased growth of epiphytes on macroalgae, enhanced growth/cover of opportunistic species, reduced lower growth limit of kelp and reduced cover of seagrasses.
- Reported pelagic impacts included increased nutrients concentrations and enhanced phytoplankton biomass.
- The spatial extent of the impacts is site-specific and are in most "gradient" studies limited to 500 m from the farm. The spatial extent depends on several factors where hydrodynamic conditions and water-exchange mechanisms are particularly important.
- Metrics/indicators most frequently applied in the literature reviewed are common eutrophication metrics/indicators and are implemented in Norwegian monitoring programs. However, the programs do not aim to capture the unwanted effects of nutrients inputs of aquaculture and the spatial and temporal coverage are currently not fit for this purpose.
- Modelling (biogeochemical/hydrodynamic/dispersal) are useful tools particularly for the assessment of far-field/regional impacts.

#### 3.3.2.2 Search results

The QSR identified initially a total of 2015 records, which were reduced to 1315 records following the removal of duplicates, records that dated older than 2010 (despite selected timeframe 2010-2021, full years), and publications related to the keyword *"Salmonella"* (see section 3.3.1.2)(Figure 3.14). Screening of title, abstract and subsequently full text identified 28 publications to be relevant to the primary question: "What is the impact of dissolved nutrients from aquaculture production on the environment?" In addition, 13 relevant publications were added post screening. Six of these were grey literature in Norwegian. The remaining were papers that were **a)** not picked up the search (n=3), **b)** published outside the selected timeframe (n=2), **c)** covering a receiver where the initial search returned no results (n=2)(see section about receiver)(Figure 3.14).

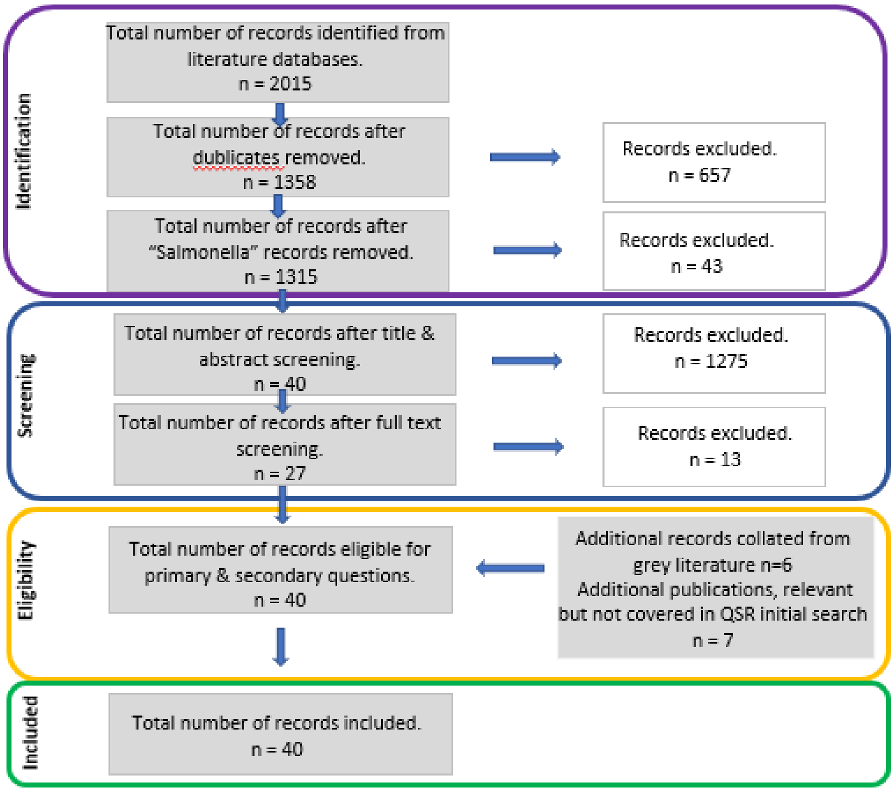


*Figure 3.14. PRISMA flowchart visualising the different steps of the selection process of the QSR for dissolved nutrients.*

Between 1 and 5 papers were published each year throughout the selected timeframe (2010 – 2021, full years), with no pronounced temporal trend (Figure 3.15). There were studies from all major salmon and trout producing countries. Most studies were conducted in Norway (n=15), Canada (n=5), Chile (n=5) and Australia/Tasmania (n=4). There were fewer studies undertaken in other salmonid producing countries such as Scotland (UK) (n=1) and New Zealand (n=0) (Figure 3.15).

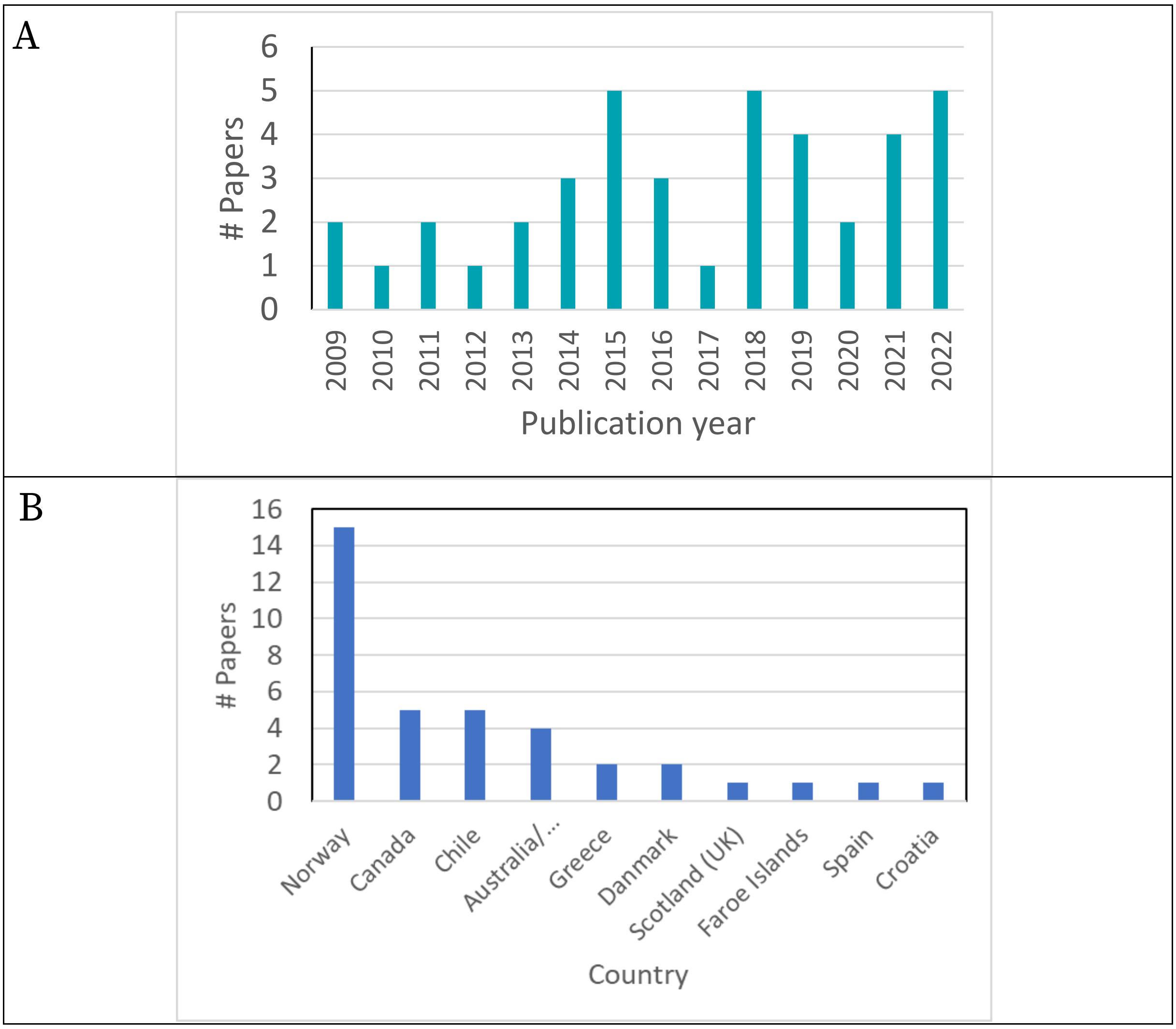


*Figure 3.15. A. Overview on number of scientific articles published per year. B. Distribution of published literature per country.*

Studies presented in the literature were predominantly field studies (n=20) followed by combined approaches, combining field and modelling (biogeochemical/hydrodynamic/dispersion modelling) (n = 7). There were also some (n=4) literature reviews and experiments either alone (n = 2) or combined with field studies or modelling (n = 5) (Figure 3.16). Among the field studies and experiments the majority (<60%) were carried out i fjord/bay/estuary while a smaller proportion (16 %) were from exposed/open coast environments. Around 20% of studies covered both.

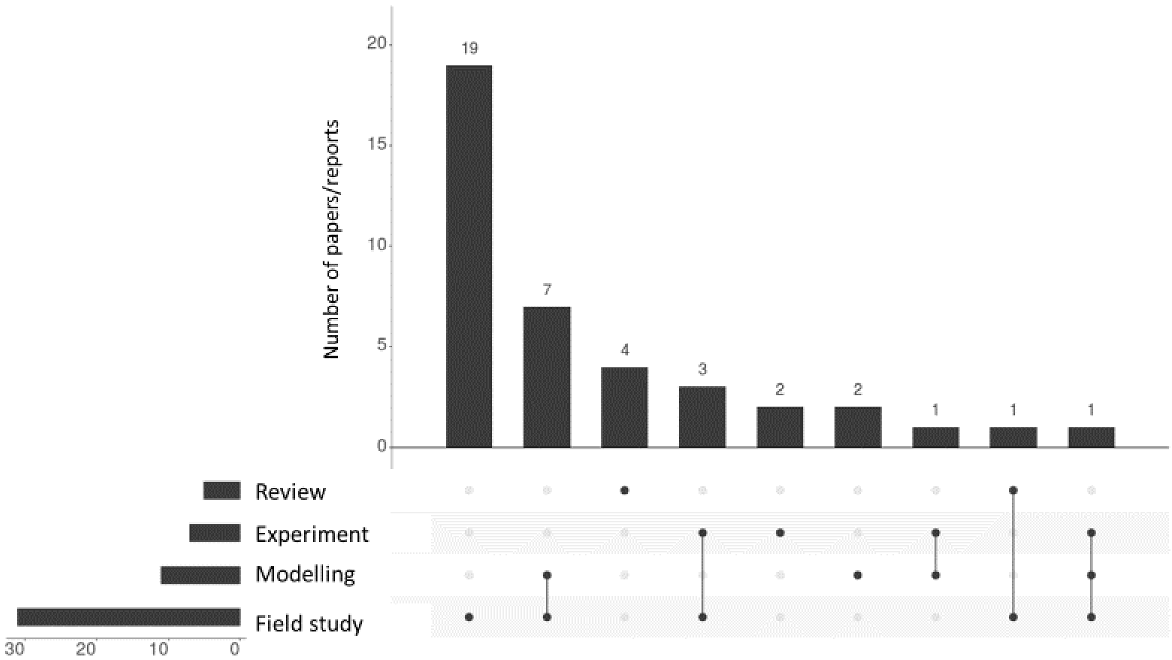


*Figure 3.16. Overview on number of publications per study category (field, lab, hydrodynamic/dispersion modelling, and review) and intersections between different categories.*

The spatial scale of each paper/report was extracted. Scale reflects the distance from the farm where potential impacts were measured. Setting meaningful scale categories fit for this review was however a challenge. Terms like “farm scale, “near field”, “local”, “regional scale”, “far field” regularly appear in studies addressing impacts from aquaculture, but there is no clear standardized definition for these terms and the actual distance from farm differs. This do make sense since most study designs take into consideration existing knowledge about the hydrodynamic conditions in the study area and define “local” or “far field” accordingly. This is also seen in the very varying distance-from-farm of the reference stations in different studies. In this review we ended up using somewhat random scale categories; <150 m, 150-1000 m and >1000 m, where studies with a focus on >1000 m scale category are in the following referred to as regional.

The majority of studies were sampling more than one scale category (n=22), often with a “gradient” design with one or more several within a 500 m distance from the cages and a references station >1000 m away. Although the station furthest from the farm in many cases were >1000 m away, less than 20 % of the studies can be defined to be on regional scale, meaning that the design aimed to address potential effects on larger areas such one fjord, entire bay and coastal section (Figure 3.17).

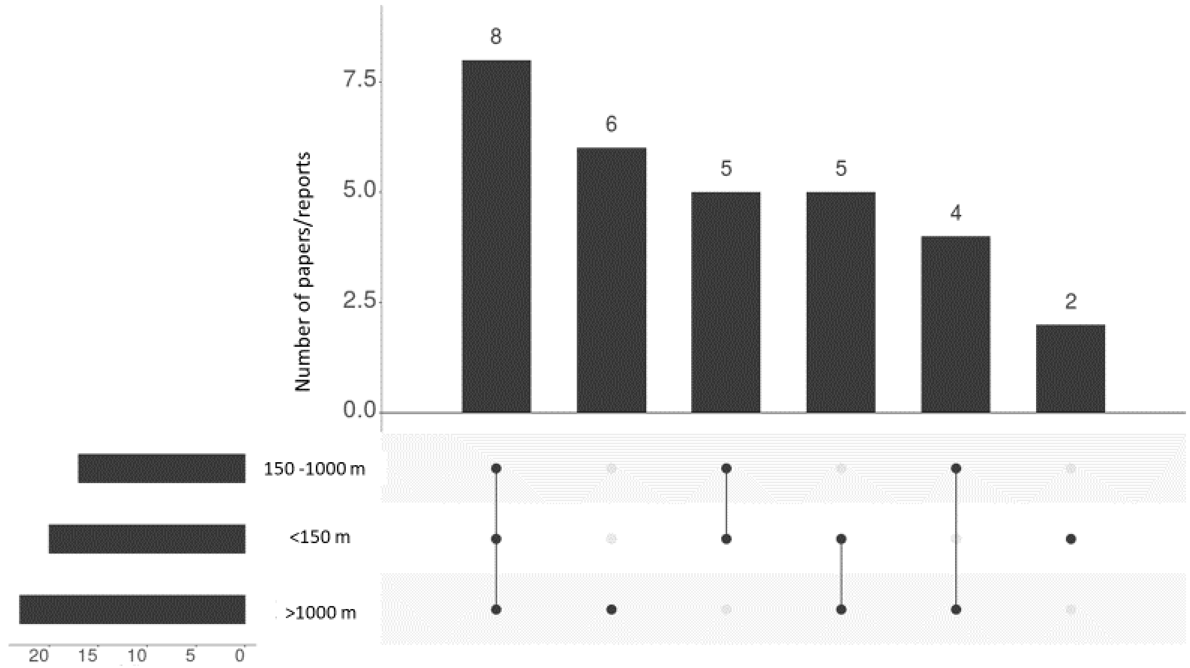


*Figure 3.17. Overview on number of publications per scale category (< 150 m, 150-1000 m and > 1000 m) and intersections between different categories.*

#### 3.3.2.3 Receiver & impact

See also section 3.2.3

Negative effects of dissolved nutrients in general- or the process towards eutrophication consist of several "steps": 1) Increased inputs of nutrients leads to increased concentrations and/or increased amounts of these substances in the water. 2) Increased concentrations of nutrients (or increased amounts and turnover) lead to increased uptake and stimulated growth in algae and higher plants. Different response to the stimulation among species can lead to changes in the species composition. 3) Increased algae growth provides increased food access to grazers among zooplankton and benthic animals with possible changes in species composition, or in the structure and function of pelagic and benthic food webs. 4) Increased production in the water column results in an increased amount of organic material which can lead to sedimentation and reduced oxygen concentration and, in the worst case, to an oxygen-free environment in the deeper water layers and in bottom sediments.

The outputs from the QSR were organized according to receiver, where receiver means species/habitat/ecosystem component that was affected. The receivers were based on points 1-3 above; water quality (nutrients and oxygen concentrations), microbiota, phytoplankton, zooplankton, fish, macrophytes and benthic fauna.

If we consider the focus of the studies, there were more studies investigating impact on benthic habitats (48%) compared to water column (35%), with a significant proportion (16 %) of studies addressing both. If we consider receiver *per se* there was a slight overweight of studies including water column receiver (56%), where water quality and phytoplankton constituted 52 and 41 % respectively. There was a striking lack of studies describing impacts on higher trophic levels such as zooplankton and fish. For studies with benthic species and ecosystem as receiver, 66% described impacts on macrophytes, 33% on benthic fauna and 1

% om microbiota (Figure 3.18). For the studies on macrophytes, almost 60% had focus on one or a few species, where several had an integrated multitrophic aquaculture (IMTA) angle. The most studied species were those considered relevant for IMTA in our waters such as *Saccharina latissima*.

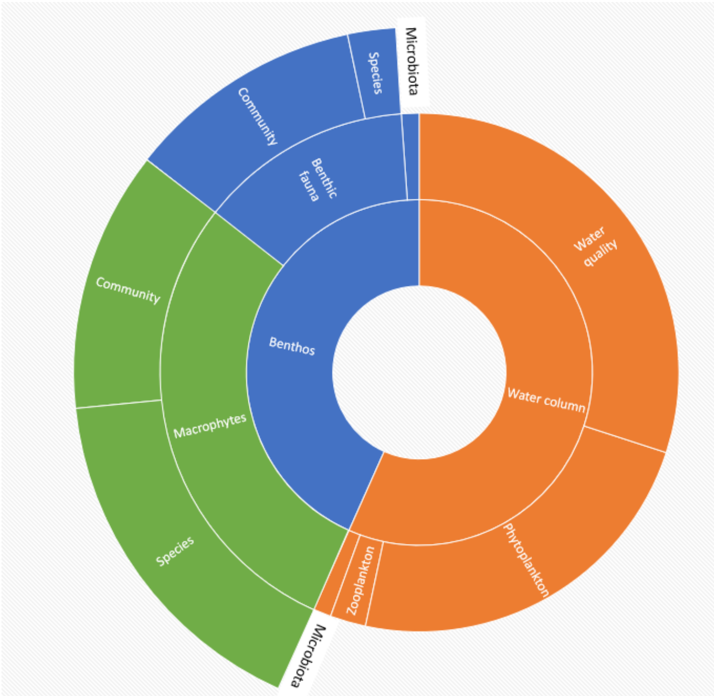


*Figure 3.18. Proportional representation of impacts organized by receiver (species/habitat/ecosystem component) that were impacted. Size of segment correspond to the total number of papers that describe impact on the given receiver.*

Most studies assess impact on more than one receiver, where the most frequent combination was water quality and phytoplankton (n=7), followed closely by studies targeting both benthic communities, water quality and phytoplankton (n=5). Of the single receiver approaches the most frequent were studies on single species of macrophytes (n=6) and water quality (n=5) (Figure 3.19).

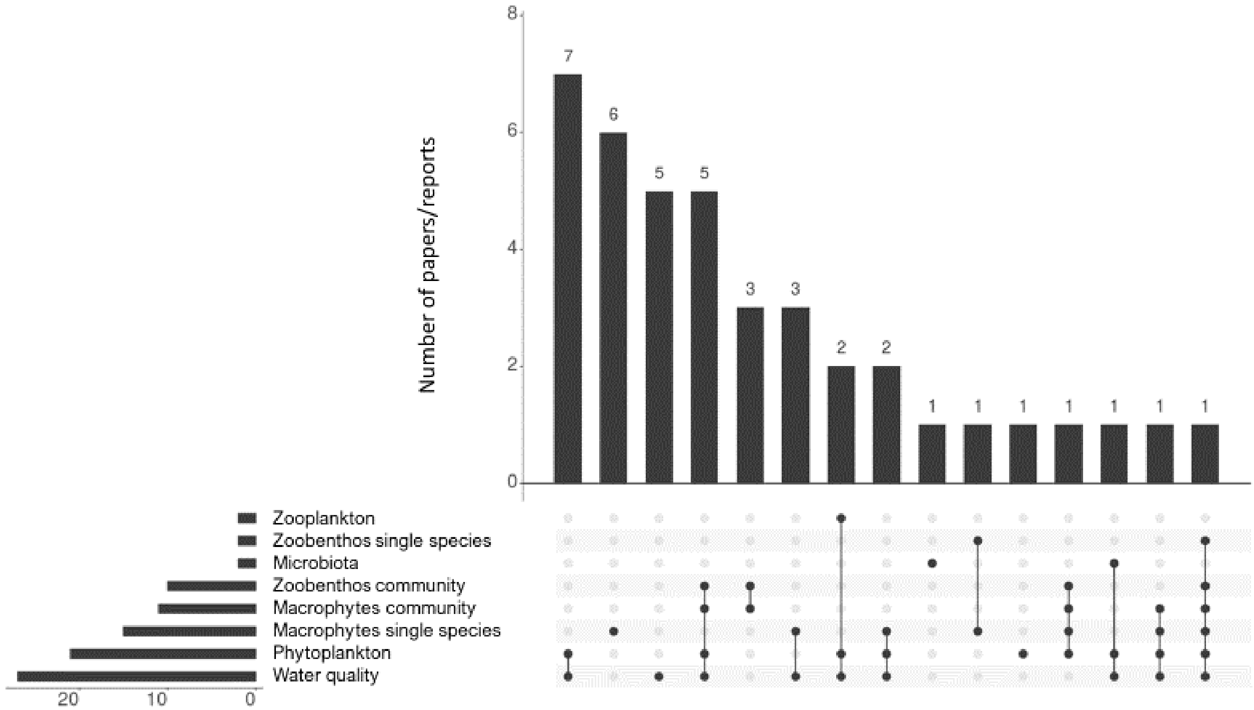


*Figure 3.19. Overview on number of publications per receiver and combinations of receivers.*

The studies included in this QSR were very different regarding temporal (spans from 1 sampling to monthly sampling over almost 10 years) and spatial scale (see above), size of the farm(s), water depth, exposure (see above), hydrography, trophic status of receiving waters etc. This (natural) lack of standardization makes it challenging to assess and compare their outputs, as also pointed out in previous reviews (Sarà 2007, Price et al. 2015).

Direct effects on **Water quality** include e.g. changes in nutrient concentrations, nutrient ratios and levels of dissolved oxygen. The impact of aquaculture on **water quality** was recently reviewed by Price et al. (2015). Their review covered the period from 2000-2014, hence partly overlapping the timespan of our QSR. Nutrient enrichment in terms of elevated concentrations of dissolved phosphorus and nitrogen was rarely observed beyond 100 m from the farms in the literature reviewed by Price et al. (2015). This is to a large extent supported by our QSR. Some studies did not detect enhanced concentrations of nutrients at all (Tsagaraki et al. 2013, Howarth et al. 2019), while others observed enhanced concentrations at the farm, but rapidly decreasing with distance and often not detectable beyond 300 m from the farm (Norði et al. 2011, Morata et al. 2015, Jansen et al. 2018). One study measured elevated concentrations up to 700 m distance from the farm, but there was not a very clear gradient from the farm and the results had high spatial (both vertical and horizontal) and temporal variability (Elizondo-Patrone et al. 2015).

Since many estuarine and coastal waters are considered nutrient limited (most often N limited) a general assumption is that any fertilization will stimulate the growth, biomass accumulation, and primary production of the phytoplankton community. However, cause–effect relationships are not straightforward as coastal ecosystems respond to nutrient loading in various ways, with inherent physical and biological attributes that operate in concert to set the sensitivity of individual ecosystems to nutrient enrichment (Cloern et al. 2001).

The QSR showed variable results regarding impacts of dissolved nutrients from aquaculture on **phytoplankton**. Of the "gradient" studies (sampling at farm site and outwards), some did not observe any clear response in the phytoplankton (Norði et al. 2011, Morata et al. 2015) while others showed evidence of a clear phytoplankton response (Pitta et al. 2009, Skejić et al. 2011, Tsagaraki et al. 2013). In their field experiment using dialysis bags, Pitta et al. (2009) showed that phytoplankton growth in the bags was stimulated in the close vicinity (< 100 m) of the farm, rapidly decreasing with distance. Tsagaraki et al. (2013) did not observe significant response in phytoplankton biomass but a significant shift in phytoplankton community composition measurable 500 m downstream from the farm. Skejić et al. (2011) compared samples taken inside a farm with a reference station. The phytoplankton biomass was significantly higher inside the farm, but the phytoplankton biomass was very low at both stations.

The studies addressing effects on **phytoplankton** on a regional scale (>1000 m) had a different approach than the "gradient" studies. Most of the regional scale studies addressed potential impacts of dissolved nutrients from aquaculture by an assessment of the ecological status in the study area, where the classification of ecological status in the water column was based on phytoplankton biomass (chl a), macroalgae communities and soft bottom fauna (Husa et al. 2014, Brkljacic et al. 2016, Bye-Ingebrigtsen et al. 2019, Brkljacic et al. 2022, Økland et al. 2022). These were all carried out in Norwegian waters and did to a large extent follow established protocols and thresholds given in national guidelines developed for implementation of the WFD[3] (Veileder 02:2018). The study of Husa et al. (2014) were in the Hardangerfjord, one of the most intensively farmed areas for salmon in the world. Nutrients and chl-*a* values were within national thresholds defined as high water quality, and the authors concluded that parameters studied in the fjord showed little evidence of a regional impact from aquaculture. The of studies of Brkljacic et al. (2016), Brkljacic et al. (2022), Økland et al. (2022) and Bye-Ingebrigtsen et al. (2019) were carried out in the county Nordland, Rogaland and (former) Hordaland respectively, all with relatively good temporal resolution. In Nordland five out of six fjord basins achieved "good" ecological status based on the biological quality element phytoplankton (chl a), while one fjord basin was classified as "moderate". However, the time series of chl measurements indicate that the concentrations in all fjords have increased in recent years (Brkljacic et al. 2022). Also, the studies from Rogaland and Hordaland obtained "good" to "very good" ecological status based on phytoplankton (chl a) in most of the investigated fjords (Bye-Ingebrigtsen et al. 2019, Økland et al. 2022). Residence time of the water is often suggested as an explanation (Price et al. 2015) for differences of response to nutrient loading in phytoplankton, where blooms are not likely to occur when flushing times are less than the phytoplankton doubling or turnover time (Cloern 1996, Ferreira et al. 2005). The Hardangerfjord, where the above-mentioned study of Husa et al. (2014) took place, has a monthly renewal of the upper fjord water (Asplin et al. 2014). Modelling the distribution of nutrients in the fjord using these water exchange rates, indicated that even with a ten time increase in fish production, the mean chl a concentrations only increases by about 4%, and are still well below the reference values (Skogen et al. 2009).

The initial QSR search did not return any studies addressing effect of dissolved nutrients on **zooplankton,** and two studies know to the authors were therefore included (see section 3.3.2.2). Tsagaraki et al. (2013) showed community-level responses to fish farming in two different sites in the Mediterranean. Changes manifested themselves in terms of size for some groups and abundance for others, and the most pronounced response was observed at intermediate distance (here 100 m from the farm). The second study showed how microzooplankton effectively transfers nutrients up the food web in fish farming areas in the oligotrophic eastern Mediterranean (Pitta et al. 2009), explaining the lack of response in

[3] Water Framework Directive.

phytoplankton seen in studies in this area. The lack of studies addressing effects of dissolved nutrient from aquaculture on zooplankton are in accordance with a general picture where zooplankton-based indices have historically lagged other bio indicators used to detect ecosystem changes (Ndah et al. 2022). However, zooplankton has a crucial role in the pelagic food web providing transfer of energy from primary consumers (phytoplankton) to higher trophic levels (e.g. fish), and in recent years the systematic development, coordination and use of zooplankton indicators have increased largely due to the requirements of the EU Marine Strategy Framework Directive (MSFD) to include zooplankton to the descriptors of Good Ecological Status (GES)(Gorokhova et al. 2016, McQuatters-Gollop et al. 2019, Labuce et al. 2020).

There were no studies addressing the effects of dissolved nutrients from aquaculture on **wild fish** in this QSR. Other impacts of aquaculture on wild fish are addressed under other stressors. Earlier studies from the eastern Mediterranean have shown an overall increase of fish abundances after the establishment of fish-farms (Machias et al. 2004) and significant increase (by a factor of four) in total biomass and abundance to zones with fish farms in comparison to respective reference areas (Machias et al. 2005). In the same area Machias et al. (2006) also studied landings in local fisheries and their results suggested that increased fish-farming activity in enclosed, oligotrophic areas could imply an increase in fisheries landings. Possible processes that could explain the increased landings were increased primary production due to release of nutrients and/or the rapid transfer of released nutrients up the food web, but direct consumption of feed pellets by the fish species aggregating beneath the cages was also an option (Machias et al. 2006 and references therein).

A well-documented consequence of excessive nutrients for **macroalgae** in general is the massive growth of certain types of productive, fast growing macroalgae (Krause-Jensen et al. 2008, Teichberg et al. 2008) at the expense of habitat-forming perennial species (Worm and Sommer, 2000, Gorgula and Connell, 2004). These fast-growing algae are often referred to as “opportunistic”, “nuisance”, “turf” or “lurv” in Norwegian, and has received much attention in Norway recently (e.g. Moy and Christie 2012, Christie et al. 2019, Rinde et al. 2021). A few of the QRS studies were addressing possible impacts on **macroalgae communities**. The comprehensive study of Oh et al. (2015) showed detectable impacts 100 - 500 m from farms, where macroalgae assemblages near farms were overgrown with epiphytes. The study of Haugland et al. (2021) carried out in mid-Norway, also demonstrated a response on epiphyte communities up to 520 m from the farms. The most pronounced effect was observed in the bryozoan epiphyte community on *Laminaria hyperborea* stipe, where biomass was significantly higher near the farms compared to refence. Although less pronounced, the biomass of macroalgal ephiphytes also increased near the farms, including opportunistic *Ectocarpus* spp., resulting in a less heterogeneous macroalgae community.

The five regional (> 1000 m) studies described under the section treating phytoplankton (Husa et al. 2014, Brkljacic et al. 2016, Bye-Ingebrigtsen et al. 2019, Brkljacic et al. 2022, Økland et al. 2022) also assessed the ecological status of the macroalgae communities. Except one station in the innermost part, the macroalga community in the Hardangerfjord had high ecological status (Husa et al. 2014). Similar results were reported in the Hordaland and Nordland county studies where all stations showed either "good" or "high" ecological status of the macroalgae community in the littoral zone (Brkljacic et al. 2016, Bye-Ingebrigtsen et al. 2019, Brkljacic et al. 2022). However, in Rogaland several stations showed signs of eutrophication with increased cover of opportunistic species with corresponding decrease in kelp cover (both *Laminaria latissima* and *L. hyperborea*). The lower growth limit of kelp was also reduced at some stations (Økland et al. 2022). The authors point out that the reason for reduction in the lower growth limit and cover for kelp and increase in filamentous opportunists is complex, when both climate change and nutrients release are important.

Among the QSR studies addressing impact on **specific species of macroalgae,** most show an effect spatially limited to the close vicinity of the cages. In a "gradient" study using bioassays with three species of macroalgae, Streicher et al. (2021) showed a species-specific response where the green annual species *Ulva* had enhanced growth at farm and at intermediate distance (300 m), while the two perennial species *Palmaria palmata* and *Fucus vesiculosus* had a less clear response. Although not designed to capture negative effects of dissolved nutrients, some evidence can indirectly be derived from IMTA studies because they focus on the size of the area where macroalgae can benefit from increased nutrients from fish farms. One can therefore assume that outside the area of enhanced growth direct negative effects are less likely to occur. Several IMTA angled studies showed a clear response in terms of enhanced macroalgae (*Laminaria latissima* and *Palmaria palmata*) growth at farm sites compared to control sites (Sanderson et al. 2012, Wang et al. 2014, Marinho et al. 2015, Fossberg et al. 2018). In some cases, there was lack of stations between farm and control, thus the spatial extent of enhanced growth remained unknown (Wang et al. 2014, Sanderson et al. 2012). In Fossberg et al. (2018) a clear gradient of decreasing growth rates with increasing distance from the farm was observed, suggesting the main influence of the farm to be in the first 200 m from the farm. The meta-analysis of Kerrigan et al. (2018) extracted data from 8 different IMTA studies (including Sanderson et al. 2012 and Wang et al. 2014) and concluded that the areas with enhanced growth were limited to the close vicinity of the net pens.

Howarth et al. (2022) reviewed the impacts of aquaculture on **eelgrass** (*Zostera marina*) in temperate waters, and only found one study. This study was carried out in Nova Scotia in eastern Canada, and the results were inconclusive (Cullain et al. 2018). The review of Howarth et al. (2022) showed that much of the knowledge available on impact on seagrasses stems from the Mediterranean. These studies showed a clear negative impact and reported decreases in seagrass cover with increasing proximity to farms for distances up to 300 m (Howarth et al. 2022 and references therein). The authors did however question the transferability of the Mediterranean results to temperate regions, due to differences in environmental conditions, different species with different depth range and different type of farm sites (shallow, sheltered on top of seagrass beds), and that studies from temperate waters are warranted.

#### 3.3.2.4 Monitoring

See also section 3.2.3

Most eutrophication monitoring approaches are based on a combination of physico-chemical and biological indicators (Ferreira et al. 2011). This is also the case for Norwegian monitoring programs that aims to capture the unwanted effects of inputs of nutrient and organic material. The most extensive program is the ØKOKYST ("Ecosystem Monitoring in Coastal Water) ran by the Norwegian Environmental Agency. This program was established in 2013 as part of the implementation of the Water Framework Directive (WFD) in Norway. The program includes sampling of biological communities (macroalgae, soft bottom fauna and phytoplankton) and supporting elements (nutrients, oxygen, Secchi-depth, TSM, temperature and salinity). Hence, the indicators used to describe changes in macroalgal communities, phytoplankton biomass communities and water quality in ØKOKYST largely reflect those commonly referred to in the literature reviewed in this QSR (Table 3.4). Very few studies address impacts on higher trophic levels in the pelagic zone, such as zooplankton and fish (see Section 3.3.2.3). Recently zooplankton were included in a limited number of stations in ØKOKYST, but fish are not included in eutrophication monitoring in Norway. The

Norwegian Food Safety Authority (NFSA) runs a monitoring program of algae toxins in mussels and issue dietetic advice to the public. The aim of the program is, on a weekly basis, to advice public on the risk associated with consumption of wild mussels. Quantitative methods are not used, but semiquantitative information about phytoplankton abundance and species composition is collected. Currently the ØKOKYST stations are mostly located in unaffected areas (over a certain distance from known point sources), and the monitoring network has a limited spatial and temporal distribution. The stations in NFSA are chosen to cover areas with mussel farming or areas where the public harvest mussels. There are therefore no operational monitoring programs that are designed to capture possible impact of dissolved nutrient from aquaculture in particular.

*Table 3.4. Table shows how metrics/indicators applied in the literature reviewed are covered in Norwegian monitoring programs.*

| **Impacts of dissolved nutrients can be observed as:** | **Metric/indicator** | **# studies in the QSR where this metric/indicator was included** | **Included in Norwegian national monitoring for eutrophication?** |
|---|---|---|---|
| **Elevated nutrients concentrations** | Concentration | 11 | Yes |
| **Changes in nutrients ratio** | Concentration | 0 | Yes |
| **Phytoplankton** | | | |
| Increased primary production | mg C $m^{-2}day^{-1}$ | 2 | No |
| Increased biomass | Chl a/carbon | 7 | Yes |
| Changed community structure/species composition | Abundance | 2 | Yes |
| Changed bloom frequency/seasonal timing | Abundance | 0 | Yes*** |
| **Macroalgae and sea grasses** | | | |
| Changed biomass/growth | | 9 | No |
| Reduced depth distribution | MSMDI* or similar | 1 | Yes |
| Changes in species composition | RSL/RSLA** or similar | 4 | Yes |
| **Higher trophic levels pelagic** | | | |
| Changes in biomass ZP | Abundance | 1 | No |
| Changes in community structure/species composition ZP | Abundance | 1 | No |
| Changes in biomass in fish | Abundance | 0 | No |
| Changes in community structure/species composition in fish | Abundance | 0 | No |

*Multispecies depth index. Depth distribution of 3 to 9 disturbance sensitive species. ** Species richness, proportion red algae, proportion of green algae, proportion opportunistic species, ratio of perennial forms to annual/ephemeral forms. Abundance of opportunistic species. *** Can be calculated from abundance data in long time series

### 3.3.2.5 Knowledge gaps

See section 3.2.3

There are knowledge gaps on potential effects on higher trophic levels, and how these might be addressed and monitored. Most studies addressing far-field and regional effects in the QSR were grey literature suggesting limited knowledge on far-field and regional processes, especially over longer time scales in intensively farmed areas. There is very little knowledge on potential effects on eelgrass in temperate regions. This is an important habitat that has been declining throughout much of its range over the last century.

### 3.3.2.6 Conclusions

The QSR showed that impacts of dissolved nutrients have received a low, but continuous attention within the selected timeframe, with scientific contributions from major salmonid producing countries. There were no studies on cod *(Gadus morhua).* Empirical field studies were the most common way of building knowledge about the impacts, but also studies combining modelling (biogeochemical/hydrodynamic/dispersal modelling) and field studies were quite frequent. Receivers from both benthic and pelagic environments were addressed in the literature reviewed, but potential impacts on higher trophic levels are less studied. Impacts were reported in all receivers. However, where impacts were observed, the spatial extent was mostly limited to 500 m from farms. One important finding is that the impacts of dissolved inorganic nutrients from aquaculture are site-specific and depending on several factors where hydrodynamic conditions and water-exchange mechanisms are particularly important. Furthermore, trophic status in receiving waters as well as other sources of nutrient loading are important for the susceptibility to impacts of dissolved nutrients from aquaculture. Both are important for future farm siting and design of monitoring programs.

Most of the metrics/indicators frequently applied in the literature reviewed are common eutrophication metrics/indicators and are implemented in Norwegian monitoring programs such as the ØKOKYST program ran by the Norwegian Environment Agency. However, this program does not aim to capture the unwanted effects of nutrients inputs of aquaculture and the spatial and temporal coverage are currently not fit for this purpose.

### 3.3.2.7 References

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### 3.3.3 Environmental contaminants

#### 3.3.3.1 Background

Environmental contaminants are chemicals, metals or plastic debris that accidentally or deliberately enter the environment, often, but not always, as a result of human activities. Some of these contaminants may have been manufactured for industrial use and because they are very persistent, their degradation time in the environment is long. If released to the environment, these contaminants may cause impacts on ecosystems or enter the food chain and pose risk for human health.

A variety of environmental contaminants released by the aquaculture industry have been detected in the QSR search. The search resulted in 2449 hits where 353 articles were found relevant after first screening. After further screening of full text 256 articles were found relevant and included in the review (Figure 3.20). Almost 50% of the articles (164) concerned de-licing agents (Figure 3.21). A high number (N=66) of articles dealt with different substances in aquaculture feed, both residues of substances from plant- based feed (such as for example pesticides and polybrominated diphenyl ethers (PBDEs)) and additions to feed. Most of the articles from the QSR for contaminants were related to salmon farming, but 10 cod related publications were found. However, these dealt with impact on cod from salmon farming or impact on wild cod from various pollutants. Therefore, these publications were irrelevant and not included in the QSR. One report by IMR (Bjørn et al. 2021), states that many environmental effects of cod farming are parallel to the effects of salmon farming, for example interactions between farmed and wild populations. Therefore, when it comes to contaminants, there might be effects of feed ingredients on wild populations. Spreading and transfer of parasites and diseases are challenges also in cod farming, and therefore pesticides can be used, with associated effects on non-target species. However, there is limited knowledge about environmental impacts from cod farming (Bjørn et al. 2021), and a risk assessment as the one from IMR on salmon farming is planned for cod farming (Bjørn et al. 2021).

Knowledge of aquaculture–environment interactions is essential for the development of a sustainable aquaculture industry and for efficient marine spatial planning. As described in previous chapters many impact studies have focused on interactions with sessile organisms or those with low mobility, particularly infauna. This is useful as these organisms integrate effects over time and are thus commonly used as indicators of farm environmental performance (Callier et al. 2017). However, analyses of benthic organisms are not so useful for monitoring e.g. impact if delousing agents, as some of the de-losing compounds spread in the water-column (bath treatments) and the targeted species most sensitive toward the compounds (crustaceans such as shrimps) are not part of the infauna samples collected and analysed for community changes. More mobile wild fauna also interacts with aquaculture operations, but the interactions are more complex, and often the cause-effects in the environment are very difficult to establish, due to many confounding factors. *In situ* observations after a release of delousing agents is challenging for many reasons. First, it is difficult to assess exactly where the plume of chemicals is transported. Further, after a delousing event, mobile species such as e.g. deep water shrimp (*Pandalus borealis*) may be exposed at one site, however, as death do not occur immediately, the shrimp may swim away and die in another location, or be eaten by a predator. Effects are thus very challenging to document *in situ*, and monitoring techniques to assess mortality directly in the field are not developed. Also, if dead organisms are observed, it is difficult to assess cause of death. It has for instance been demonstrated that crustaceans can die from different delousing agents at very low concentrations (see 3.3.3.2). However, today's analysing methods are not good enough to detect very low levels of the chemicals used as bath treatments in tissue. In one experimental study, deltamethrin caused mortality in shrimps, however, deltamethrin concentration in the shrimp tissue could not be detected (Bamber et al. 2021).

Hence for chemicals released to the environment, there recommended techniques to assess possible impacts, are based on sensitivity of different species (mainly documented through laboratory studies) and predicted environmental concentrations (from hydrodynamic modelling). If the predicted environmental concentrations exceed sensitivity thresholds there is a risk for negative impacts. If the method reveal risk for negative environmental effects, risk reducing measures should be taken, according to international guidelines (European Commission (EC) 2003), US-EPA Guidance on Risk Assessment). Many of the studies collected and described in this section are based on these principles.

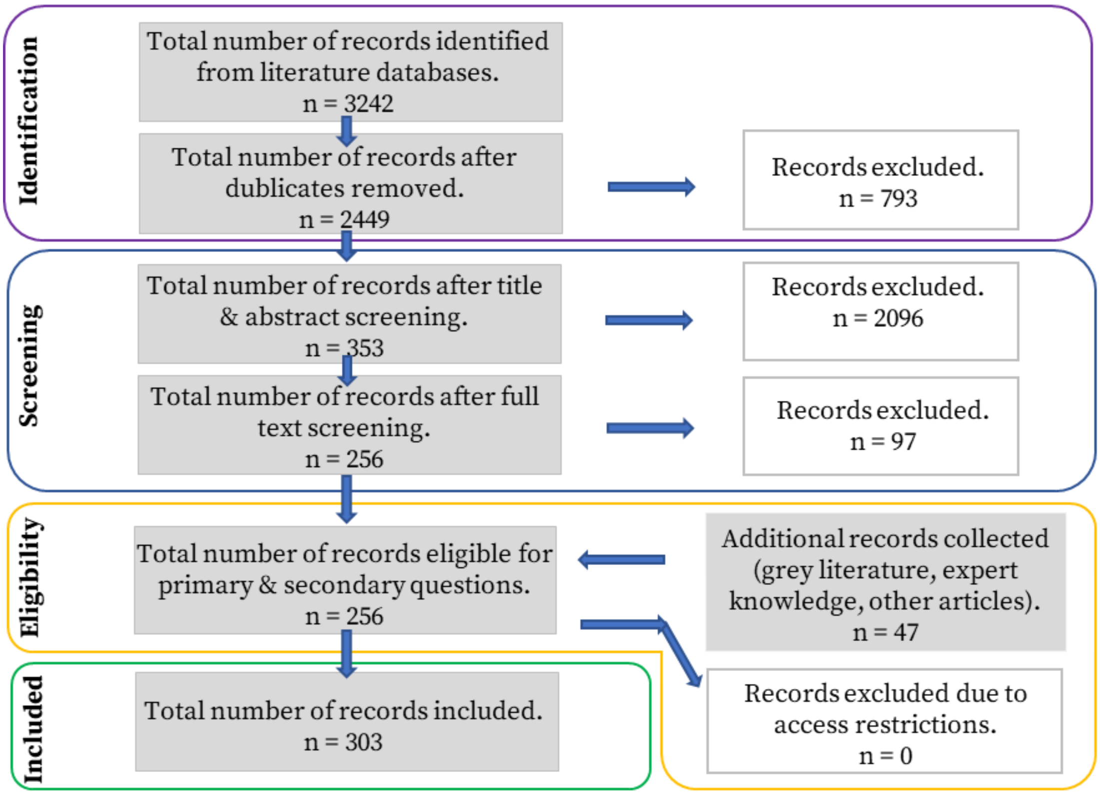


*Figure 3.20. PRISMA flowchart visualising the different steps of the selection process of the QSR for contaminants.*

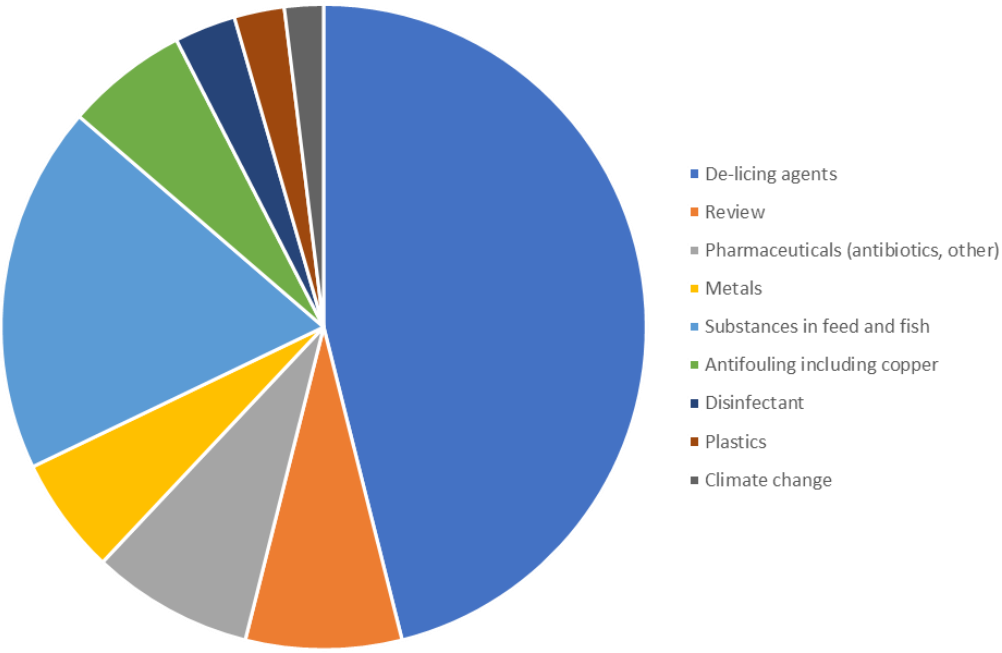


*Figure 3.21. The amount (times mentioned of all relevant articles) of a variety of environmental contaminants released by the aquaculture industry in the current QSR search.*

The contaminants were grouped in 7 groups: 1) Pesticides, including delousing agents, biocides and disinfectants. 2) Plastics (macro plastics, microplastics, nano plastics). 3) Antifoulants and metals. 4) Pharmaceuticals (antibiotics and other). 5) Oil/Oil containing. 6) Nanoparticles. 7) Other organic substances. The QSR search results are presented individually for each contaminant group. For some of the groups, QSR results (publications) raised questions or topics about other possible impacts (that were not described thoroughly in this literature), here additional searches for more information had to be performed (e.g., new types of antifoulant biocides), but these publications were kept separate from QSR results. Some contaminant groups (e.g., plastics, nanoparticles), where not much published literature was found, additional subjective searches (also including grey literature) were made to collect additional information. Furthermore, some literature that were from other salmon producing countries raised concern on certain contaminants, therefore searches for additional information to investigate relevance to Norwegian aquaculture conditions (e.g., use and practises of these contaminants) were made. These searches were also kept separate from the QSR searches.

#### 3.3.3.2 Pesticides including delousing agents, biocides, and disinfectants.

Marine pests can have a serious effect on aquaculture businesses. Pathogens and parasites represent a 'chronic risk' for the sector. They may damage infrastructure, prey on your stock, spread diseases or affect human health. Aquatic pest management is required by environmental and food authorities and is important to keep aquaculture industries safe. Therefore, the aquaculture industry uses several pesticides to mitigate pests. A pesticide is any substance used to kill, repel, or control certain forms of plant or animal life that are considered to be pests.

Delousing agents are pesticides used to combat sea-lice in aquaculture. Farmed fish can be treated directly in the cage (bath treatment), or using a well-boat (bath treatment), or the delousing agents can be administered through the fish feed (in-feed). The fish are treated with single chemicals and/or combinations of chemicals, in prescribed or higher dose (off label). Azametiphos, hydrogen peroxide, cyper- and deltamethrin are bath treatments added directly to the fish cage. After bath treatment, the treatment water with the chemical is released to the surrounding marine environment. Imidacloprid is the active ingredient in a new bath treatment, Ectosan® Vet, Ectosan Vet with a CleanTreat combination was granted marketing authorisation in Norway in 2021. CleanTreat is used to filter water containing Ectosan Vet, in order to reduce emissions to the environment.

Medicated feed includes the flubenzurones (diflubenzuron, teflubenzuron), and emamectin benzoate (EMB). Residual feed that contains the chemicals sinks to the bottom and spreads in the environment, and so does the fish's feces with residues of these delousing agents. Organisms in the marine environment can be exposed to the delousing agents when they spread in the environment.

Antimicrobial biocides and their effectiveness against aquatic pathogens are of growing interest for the aquaculture sector. Due to environmental concerns the use of copper, that has been the most effective antifouling agent, is declining. The aquaculture industry is therefore now testing substances that can replace copper, such as different types of biocides. Antifouling biocides are described in section 3.3.3.4 Antifoulants and metals.

The use of disinfectants is an important hygiene measure to combat fish diseases (pathogens). It is used to eliminate infectious agents but may be responsible for negative effects on fish and water quality. Different chemicals are used as disinfectants. Formalin (aqueous solution of formaldehyde stabilized with methanol) is one of the most used disinfectants in aquaculture. Other disinfectants used are potent oxidative chemotherapeutic peracetic acid (PAA), peracetic acid-based disinfectant product (Aquastart (R), formic acid (HCOOH), Natriumhydroksyd, chlorine, formaldehyde and potassium permanganate (PP).

**Key findings:**

- There is good availability of data for delousing agents, both ecotoxicological and risk metrics, oceanographic modelling and risk methods that can be useful for regulating purposes. There are also some available techniques which can be used for future monitoring of environmental concentrations.
- Field measurements and oceanographic modelling show that both the pelagic and benthic environment and species living there can potentially be affected by both bath and in-feed delousing agents.
- Documented impacts of infeed delousing agents' from farming sites are mostly local, i.e. takes place in a limited geographical area. However, since there may be multiple farms present in a region, which may have treatments during the same time, impacts could be regional. Furthermore, their persistence in the sediment may also result in harmful concentrations remaining for a longer time period in the environment.
- For bath delousing treatments, toxic concentrations could reach several kilometres away from a treated salmon farm and remain in the environment long enough to cause severe impacts on nontarget organisms and therefore impact may be regional.
- Furthermore, the farm sites may be used over many years, therefore the impact could be long-lasting. Considering the numbers of farms along the Norwegian coast performing delousing over several years, the total affected area can be large.
- The use of delousing agents is reported to the Norwegian Food Safety Authority, however some of this information (vet reg) is not public. No acceptance criteria in far field and near field zone exist today, but there are literature availability and methods which can be used in regulations for indicating allowable thresholds in near- and far field zones.
- Delousing agents are not considered in the "traffic light system" which is the method developed by Institute of Marine Research (IMR) to decide if a farm should be allowed to increase their production. Sealice is the parameter determining the development potential. An indirect effect of this could be that farmers using more delousing agents would be allowed to grow due to less sea lice. This underlines the importance of including the delousing agents into standard monitoring and regulation procedures.
- There is limited information on the discharge of disinfectants and antimicrobials to the marine recipient. Given the limited amount of information, is seems like there is not enough data to assess possible environmental impact.

## QSR results

**Delousing agents** accounted for almost 50 % of the articles about environmental contaminants. A total of 164 articles from the QSR search, 10 reports from grey literature (Figure 3.20), and 5 added publications were included in the assessment. There is information on e.g. levels of delousing agents measured in the environment, risk assessment reports and sensitivity data for different species which are not publicly available.

The public available studies were evenly distributed throughout the years and conducted in numerous countries; however, most studies were conducted in the largest salmon producing countries, most in Norway followed by Canada, Chile and Scotland (Figure 3.22). All the studies fit within one or more of the following categories: laboratory studies, oceanographic modelling studies/modelling studies, field studies or environmental risk assessment (Figure 3.23). There is very good data availability for both chemicals used as bath treatments and in-feed treatments. The effects on non-target organisms have recently been summarized and are available in various reviews and reports (e.g., Sæther et al. 2016, Urbina et al. 2019, Martins et al. 2023). Studies cover a range of test species and different life-stages, varying laboratory conditions and a range of endpoints covering both acute effects (mortality) and different sub-lethal effects such as behavior, mobility, growth, and reproduction as well as a range of different biomarkers. Field data are less numerous compared to laboratory data. However, field studies have been conducted at various locations in different parts of Norway and concentrations of delousing agents have been documented both in water, sediments, and organisms (Langford et al. 2014, Samuelsen et al. 2015, Arnberg et al. 2023). Sediments and waters samples have in addition been analysed by research institutes in Norway, however, not all information is publicly available. Substances mentioned in the QSR literature: copper sulphate, photochemically active biocides, lufenuron, biosurfactant (SPH6), formalin, calcium oxide (CaO), hydrogen peroxide, cypermethrin, deltamethrin, azamethiphos, diflubenzuron, emamectin benzoate, teflubenzuron, ivermectin. The two most studied pesticides are emamectin benzoat and deltamethrin (Figure 3.24).

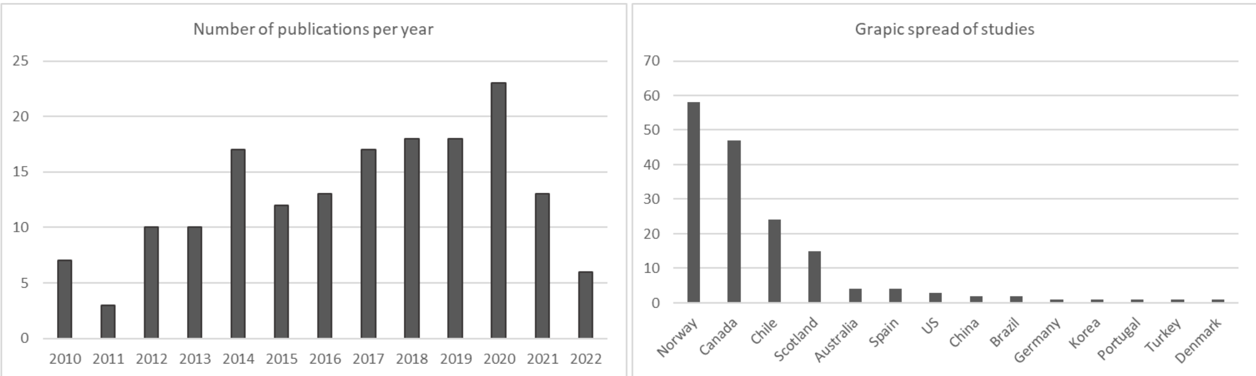


*Figure 3.22. Left: Overview on number of scientific articles published per year from the QSR. Right: distribution of published literature per country (if no mention of country in article, affiliation country of lead author was chosen).*

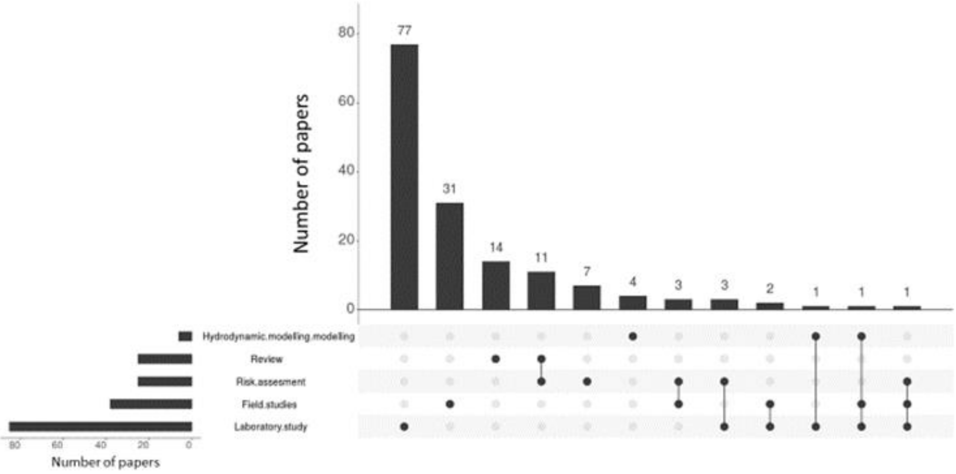


*Figure 3.23. Overview on number of publications per study category (field, lab, hydrodynamic modelling, risk assessment, review) and intersections between different categories.*

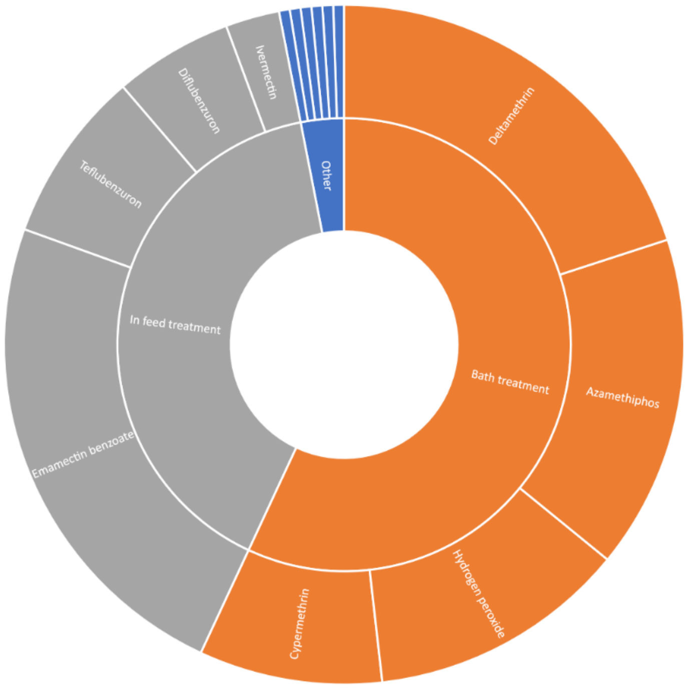


*Figure 3.24. Number of delousing papers distributed in the following active substance categories.*

The QSR result showed several articles on **antimicrobial biocides.** Substances mentioned in the literature were: Bronopol and Detarox. There was, however, only 1 article that considered environmental effects. Bronopol is listed in Felleskatalogen, the veterinary catalogue in Norway (Medisin - Veterinærkatalogen (felleskatalogen.no)), while Detraox is not, indicating that only Bronopol is used in Norway.

A total of 11 articles were found in the QSR search for **disinfectants**. Most of the studies were effects studies. However, among those, the majority investigated effects on farmed fish itself. Impacts on fish health must be determined before it is used either as a routine disinfectant or chemotherapeutant. Hence most of the available studies are on salmon, and only 2 studies were related to possible environmental impacts. Substances mentioned in the literature were: peracetic acid, formalin, potassium permanganate.

**Receiver and impact**

**Delousing agents.** Methods have recently been adapted to measure concentration of delousing agents in the field, using passive sampling technique and sediment traps (Arnberg et al. 2023). The reported concentration varies greatly, from not detectable to concentrations beyond thresholds for effect, depending on numerous factors. For example, concentrations measured in the field after a bath treatment using deltamethrin in water was higher than the concentration known to be lethal to deep-water shrimps (Arnberg et al. 2023). Also, feed treatments have been measured in sediments. Field investigations have shown that the levels of flubenzurons in the sediment are highest near the facility (above environmental quality standards, indicating that these compounds may pose a risk to benthic marine species), and residual concentrations have been found at a distance of 2 km (Parsons et al. 2021). Emamectin benzoate (EB) has also been found in sediments in concentrations above far field Scottish environmental quality standards (EQS) (see appendix 9.1.9 operational standards for aquaculture). EB has furthermore been detected in sub-surface water samples after delousing (e.g., Langford et al. 2014, Refseth et al. in prep). EB and flubenzurons have a long half-life and may remain in the sediment for a long period of time after release (e.g., Benskin et al. 2016).

Imidacloprid is the active substance in the new bath treatment Ectosan® Vet, used together with the CleanTreat system. 3252 kilo of the active substance imidacloprid was sold in 2021, and 5900 kg in 2022 (FHI, 2021). Imidacloprid has been used over many years on land to protect plants against insect damage, but today it is clear that it has negative effects on both aquatic and terrestrial fauna. In the European Environment Agency's report 2016, it was concluded that imidacloprid should be withdrawn from the market given the evidence of harm and scale of the risk. Therefore, imidacloprid is now banned from use on land. In Norway, imidacloprid is only allowed to be used in marine waters along with a cleaning system installed on a well boat. The system removes medicines from treatment water before returning purified water into the sea. There was a spill from a well boat in Northern Norway in 2021, resulting in 110. 000 litres Ecosan Vet entering the sea. Given the documented risk of environmental damage of imidacloprid, possible risk related to the usage if imidacloprid in the aquaculture industry should be monitored. There are no routine measurements of imidacloprid or break-down products in either water or sediment today.

Lately, oceanographic modelling has been adapted to model the spreading and breakdown of delousing agents. To obtain a good picture of dispersion in Norwegian coastal areas, characterised by complex topography including narrow straights and sounds, high-resolution ocean modelling is required. Therefore, for example the open-source circulation model FVCOM (Finite Volume Community Ocean Model) has been used for the determination of predicted environmental concentrations (PEC) of delousing agents (e.g., Refseth et al. 2016, 2018, 2019, Arnberg et al. 2023). To simulate the dispersion of the discharge, as well as the fish faeces containing the medication, FVCOM is coupled to a tracer model within the Framework for Aquatic Biogeochemical Models (FABM) (providing physical/chemical properties of delousing agents, from literature studies) (see Figure 3.25). Results (PEC) vary depending on local conditions such as ocean current, depth, type of chemical etc. However, generally, results show that the delousing agents from bath treatments can spread several kilometres away (e.g., Refseth et al. 2019, Arnberg et al. 2023). One study showed spreading up to 32 kilometres away from source (deltamethrin) (Parsons et al. 2020).

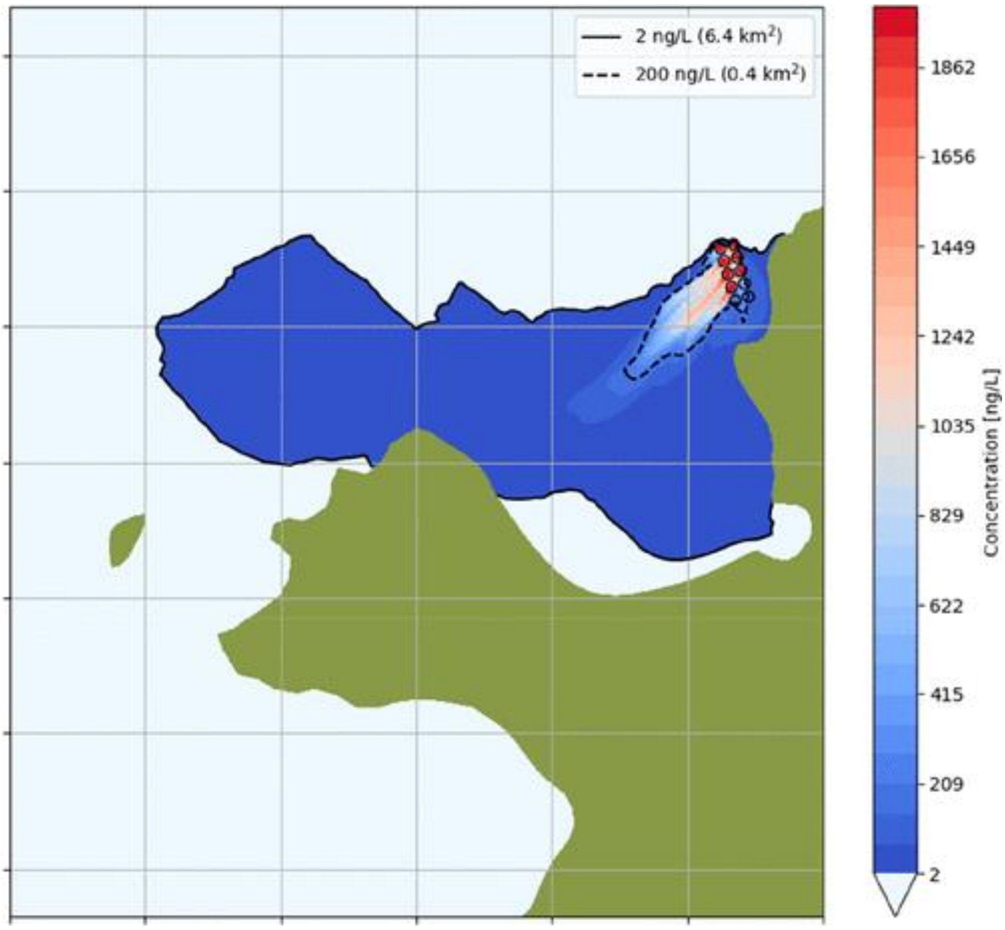


*Figure 3.25. FVCOM model results showing the spreading of deltamethrin during a simulated delousing operation of seven cages. The colours indicate the maximum concentration within the water column during the entire simulation period (7 days). Contours of 2 ng $L^{-1}$ (black solid line) and 200 ng $L^{-1}$ (black dashed line) are plotted separately. 2 ng $L^{-1}$, was the lethal concentration for the shrimp (Pandalus borealis) derived in laboratory experiments. Gridlines (grey) are spaced 1 km apart to indicate distance. (Source: Arnberg et al. 2023).*

Field measurements and oceanographic modelling show that both the pelagic and benthic environment and the species living there can be affected by both bath and in-feed delousing agents.

There is a huge variation in sensitivity towards different delousing agents for different species, life stages and endpoint studied. However, generally, when comparing treatment concentrations of the different delousing agents to concentrations shown to impact different nontarget species, it is clear that toxic effect on non-target species (both acute and sub-lethal) is documented at concentrations much lower than the treatments concentrations used in fish cages and released to the surrounding environment (e.g., Martins et al. 2023). The most studied non-target species in effect studies of delousing agents are the crustaceans, which often are shown to be the most sensitive species (Sæther et al. 2016). This is not surprising given the fact the delousing agents are meant to be lethal to sea-lice, which is a crustacean. Fish is generally more robust and tolerate higher concentrations of delousing agents than other organisms (Martins et al. 2023). Data from laboratory studies are used to generate risk assessment metrics/threshold values for effects, often with an assessment factor ('safety factor') added to the value.

Several studies of effects of different delousing agents have been conducted on relevant Norwegian commercial and ecological important species (Arnberg et al. 2023, Bechmann et al. 2017, 2018, 2019, 2020, Cresci et al. 2018, Escobar-Lux 2019, 2020, Fang, 2018, 2020, Frantzen et al. 2020, Hansen et al. 2017, Parsons et al. 2020, 2021). Several studies show that deltamethrin has a high toxicity. For example, for the deep-water shrimp (*Pandalus borealis*), mortality occur even at highly diluted deltamethrin treatment concentrations. One study revealed 100 percent mortality of the deepwater shrimp after exposure to 330 times diluted treatment concentration for two hours (Frantzen et al. 2020). The study also revealed more severe effects of deltamethrin compared to the bath-treatments hydrogen peroxide and azamethiphos. A recent published study combining different scientific disciplines addressed the effects of deltamethrin (Arnberg et al. 2023). Acute (mortality) and sub-lethal effects on northern shrimp (*Pandalus borealis*) were studied in laboratory experiments, and passive water sampling combined with sediment analyses revealed concentrations in the environment (field studies). Finally, dispersal modelling was performed to predict environmental concentrations. Ecotoxicological analyses showed mortality in shrimp after 1 hour exposure to 1000-fold dilution of treatment dose, revealing a high sensitivity to deltamethrin. Ecotoxicological values were compared with measured and modelled concentrations and the results showed that concentrations higher than those causing mortality could be expected up to 4-5 km from point of release, in an area of 6.4 $km^2$. Lethal concentrations for shrimp remained for up to 35 h in the environment. The study demonstrates that deltamethrin poses a considerable risk for negative effects on the ecologically and commercially important deep-water shrimp (Arnberg et al. 2023). Deltamethrin was used 31 times in Norway in 2022, and 29 of 31 treatments were done in Vestfjorden/East-Finmark.

Data from laboratory studies are often used to define threshold for effects for use in risk assessment (see appendix 9.1.9. operational standards for aquaculture). Different thresholds are available for different species (e.g., LC50 (concentration killing 50 % of test species)), and for whole communities (PNEC (predicted no effect concentration, the species' tolerance can be expressed as the concentration of a substance that produces no measurable effect)). In several recent reports these threshold values are compared to the PEC from oceanographic modelling. If PEC are exceeding threshold values for effects, there is a risk for negative effects, and further investigations/risk reducing measures should be initiated to ensure protection of habitats. PEC/PNEC ratio is a well-known and commonly used method for risk assessment. Several environmental risk studies on agents used in Norwegian fjords have shown a risk for negative environmental effects. The studies are reporting how far harmful concentration can reach (spatial scale), and some studies are also estimating how long harmful concentration stay in the environment (temporal scale) (Refseth et al. 2016, 2018, 2019). In some of these studies, there is a lot of information available on the sensitivity of species from different functional groups, and the PNEC data are derived from SSD-curves (species sensitivity distribution) generated for whole communities, with a low level of uncertainty and hence a low assessment factor. An SSD curve including Norwegian species have been used to develop SSD for biological communities for hydrogen peroxide (Refseth et al. 2019) (Figure 3.26).

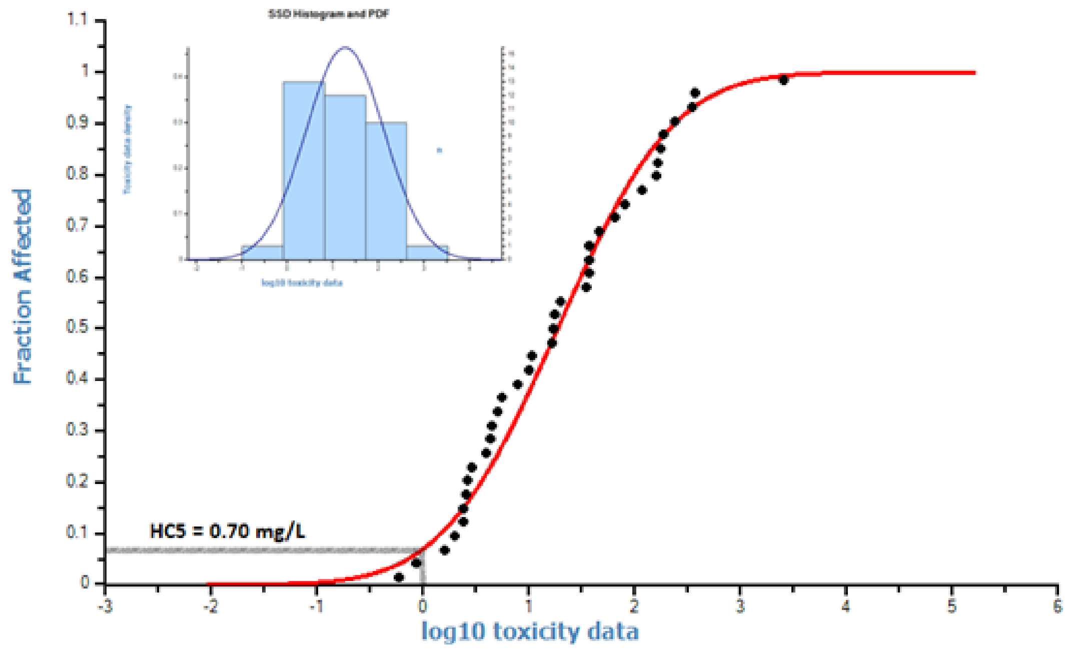


*Figure 3.26. Species sensitivity distribution (SSD) of hydrogen peroxide based on acute toxicity data, E(L)$C_{50}$s, derived from 34 species representing seven different phyla (Refseth et al. 2019).*

In Refseth et al. (2019) the PNEC level derived from the SSD curve was compared to PEC levels from oceanographic modelling, and the study showed that there is environmental risk associated with release of hydrogen peroxide. The risk was reduced, but not eliminated when a well-boat was used. There is another on-going study on risk reducing measures (breaking down hydrogen peroxide before it is released to the marine environment from well boat) (Carlsson, 2021).

Field investigations may be used to calibrate/verify PEC data form models. However, field investigation provides fewer data, and the uncertainties are higher the greater the distance from cage is (lower chance to hit the plume/spot where chemicals are transported/deposited). A good approach is therefore to measure concentrations close to cages and perform oceanographic modelling to assess spreading of delousing further out from cage.

**Antimicrobial biocides:** In Norway the antifungal Bronopol is used as a protection for fungal infection on fish skin in freshwater salmonid production systems. In 2021 490 kg of the active substance was sold in Norway (FHI, 2021). As far as the authors know there is no information on if/how this is discharged to the marine environment. Only one study described environmental effects (Magara et al. 2021). In this study the acute and sublethal toxicity of two commercially available antimicrobial biocides Bronopol (organic compound that is used as an antimicrobial) and Detarox AP (a peracetic acid-based antimicrobial) for a freshwater bivalve were determined. Biomarkers were also studies after exposure. Although the LC50 was higher for Bronopol (2440 mg/L) than for Detarox AP (126mg/L), fluctuations in oxidative stress biomarkers levels indicated that both biocides exerted a slight oxidative pressure on the freshwater bivalve. Theoretical environmental risk assessment suggested a relatively low risk with Detarox AP and greater eco sustainability compared to Bronopol. However, the relevance of this study for Norwegian aquaculture and the marine environment is limited. Although it was an aquatic species that was studied, it is a freshwater species, and the risk for non-target species in marine environments should be based on marine species. Hence, these data are of limited value for risk assessment in the marine environmental and hence for regulatory purposes.

**Disinfectants:** As far as the authors are aware there is very little information about the use and discharge of disinfectants. Requirements for disinfection use in aquaculture can be found in several regulations and include e.g., disinfection of equipment, transport units, facilities, and water. However, there appears to be no regulations regarding the discharge of disinfectants and little information about possible environmental effects. Most studies have investigated the effect on farmed animals (fish). The results of the studies varied; some concluded that the disinfectants are safe to use and that minor effects were seen on the caged fish (Hushangi et al. 2018). Another study showed altered salmon physiology at both the systemic and mucosal levels after PAA exposure (Lazado et al. 2020). Ecotoxicological metrics have been developed to provide guidance for developing safe PAA treatment protocols for Atlantic salmon eggs, fry, and/or fingerlings. Toxicity of PAA for different fish species have also been tested, for the purpose of finding important information on the safe application of PAA for the aquaculture industry. A study shows that salmon were able to mount a robust adaptive response to different PAA doses and exposure times, and a combined exposure to stress and PAA (Lazado et al. 2021). The main consequences of formalin exposure to fish were shown to be damage in gills and alterations in mucous cells (Leal et al. 2018). Formalin also interacts with some treatments adopted in aquaculture establishments (for example biological filter). Few studies address potential environmental effects of disinfectants. One study concluded that formaldehyde (effluent) should be diluted with water or that specific treatments should be conducted to decrease concentration before its discharge into the environment. There is available information on decay rate for one disinfectant, PAA, which reveals that PAA degrades rapidly in sea water (half-lives on the order of minutes to hours). However, two active ingredients in PAA degraded much more slowly (hydrogen peroxide and acetic acid). The authors concluded that PAA is far more environmentally advantageous to use than existing chemical treatments, especially targeting ectoparasitic infections in fish (Pedersen and Lazado 2020). One study examined the effects of PAA on catfish and revealed that exposure to PAA significantly disturbed the external microbiomes and increased catfish mortality following the exposure (Straus et al. 2018). In Norway the disinfectant formaldehyde (Aquacen®) has long been used on freshwater fish with surface infections caused by parasites, bacteria, and fungi. In 2021, 47282kg of the active substance was sold in Norway (FHI, 2021). As far as the authors know there is no information on if/how this is discharged to the marine environment. Given the limited amount of information, it seems likely that there is not enough data to assess possible environmental effects due to discharge of disinfectants in the aquaculture industry. Some data, e.g., LC50 values (concentration lethal to 50 percent of test animals) for fish exist, but no prediction of environmental concentrations (either modelled or measures in Norwegian fjords).

### Monitoring

Data on the usage of delousing agents are reported to the authorities (Norwegian Food Safety Authority). BarentsWatch is a tool for displaying the usage, based on the reported numbers. The use of delousing agents is reported to the Norwegian Food Safety Authority in two ways.

1. Weekly from the breeder to the Norwegian Food Safety Authority in accordance with the requirements of the Salmon Lice Regulations § 10, Regulations on combating salmon lice in aquaculture facilities - Legal data. These data are shown on BarentsWatch

2. Continuously from suppliers and requisitioners of pharmaceuticals for animals to the Norwegian Food Safety Authority in line with the regulation on the reporting of information

on used pharmaceuticals for animals § 3, prescriptions reported in VetReg. There is limited access to the numbers in VetReg. The numbers in the database (Vetreg) are not displayed in BarentsWatch.

In the years 2012–2022, the use of agents against salmon lice has varied greatly. The widespread use of delousing agents in the period 2010–2015 was mainly caused by the increasing occurrence of resistance in salmon lice. Consumption was reduced in the years 2016–2018, but use of some of the medicines has again increased in recent years. The reduced use in recent years compared to the peak years 2010-2015 is because the sea lice is also removed with other methods such as the use of cleaning fish, warm water, freshwater and mechanical removal. Medical-free control methods now account for the largest proportion of treatments against lice. However, there are great fish health challenges related to these methods, resulting in the continued use of significant amounts of delousing agents. History has shown that use can vary widely over a period of a few years.

Comparing the usage of the different delousing agents from year 2021 to 2022, the usage of deltamethrin, emamektin benzoate and teflubenzurones has decreased, while azametiphos, diflubenzurones and imidacloprid has increased (FHI, 2022).

Before a delousing event a risk assessment of environmental effects is performed, however, this is done by fish health veterinarians, and not by specialist environmental researchers. The literature study reveals that there are available data, both ecotoxicological and risk metrics, available monitoring techniques, oceanographic models and risk methods that can be useful for regulating purposes, also on a local scale. The approach described above (risk metrics and FVCOM) have been used for all the delousing agents, except for the flubenzurones. However, the same methodology can be used for these compounds as well, as the physical/chemical data that is needed already exist in the literature and can easily be implemented in famb framework within FVCOM. Concentrations of delousing agents are not monitored regularly (e.g., in standard B-surveys), however, the industry are sometimes asked by regulatory agencies, such as Statsforvalter, to provide concentration data. However, these data are usually confidential. Levels of delousing agents in sediments are required in ASC-surveys (Aquaculture Stewardship Council), and the industry itself also sometimes take initiative to analyse sediment for delousing agents. Methods for sampling and analytical methods are available for monitoring purposes for all the in-feed delousing agents. In a recent study, EMB concentrations in sediment were compared to modelled concentrations, and generally, there were a good match between modelled and measured EMB concentrations (Refseth et al. in prep). Analysing chemicals in water column are more challenging. However, passive sampling methodology to analyse delousing agents in water has been developed for deltamethrin, azamethiphos, and EMB using the co-solvent method. As additional experiments, partitioning coefficients were also established for cypermethrin, diflubenzuron and teflubenzuron (Arnberg 2023, Refseth et al in prep). As previously mentioned, analysing chemicals used as bath treatments are challenging in animal tissue. For possible future monitoring purposes, chemical concentrations in sediment are possible to measure, and some chemicals can be measured in water, using passive sampling technology.

Regulation of nature-based industries is often based on a defined tolerance/threshold limits for relevant influences. The tolerance limits for acceptable impact can be defined on the basis PEC/PNEC. Experiences shows that it is need for an active knowledge-based public regulation that sets clear boundaries and conditions for aquaculture production. Today, the only regulation of delousing agents is no dumping of bath treatments closer than 500 m away from shrimp fields, and no use of flubenzurones closer than 1000 m to shrimp fields. Recent studies discussed in these sections reveal that delousing agents can spread further out than 500 and 1000 meters. No accepted regulatory Norwegian threshold levels in near or far field zones have been developed, except for flubenzorones (Direktoratgruppen, 2016, revised 2020). However, although this limit exists, it is unclear how it is used by regulators. For other delousing agents, international thresholds levels in zones similar to the Norwegian "near and far field zones" can be found, both for water and in sediments for emamektin benzoate (see appendix 9.1.9 operational standards for aquaculture). Literature availability and methods indicate that allowable thresholds in near and far field zones can be defined for delousing agents in Norway. The aquaculture industry is not obliged to monitor concentration of delousing agents in the areas around the farms in traditional B-surveys.

### Knowledge gaps

For a more precise risk assessment of delousing agents in local areas, more information on ecology (local populations present) may be needed, if more local, precise threshold values should be used rather than e.g., threshold values for communities defined in SEPA (see appendix 9.1.9 operational standards for aquaculture). Multistressor studies on delousing agents and other stressors are limited, hence there is a challenge to address combined effects.

Given the limited amount of information, is seems like there is not enough data to assess possible environmental effects due to discharge of disinfectants and antimicrobials in the aquaculture industry. Some data, e.g., LC50 values (concentration lethal to 50 percent of test animals) for fish exist, but no predictions or measurements of environmental concentrations were found in the literature review.

### Conclusions

The literature study reveals that there is good availability of data, both ecotoxicological and risk metrics, available monitoring techniques, oceanographic modelling and risk methods that can be useful for regulating purposes, also on a local scale for delousing agents. Field measurements and oceanographic modelling show that both the pelagic and benthic environment and species living there can be affected by both bath and in-feed delousing agents. It is documented that toxic effect on non-target species (both acute and sub-lethal) may occur at concentrations lower than the treatments concentrations used in fish cage and released to the surrounding environment. The impact of delousing agents from farming is mostly local for infeed treatments, however since there may be multiple farms that perform treatments during the same time, impacts could be regional for in feed treatments. The persistence of the in-feed chemicals in the sediment may result in potential harmful concentrations remaining for a longer time period in the environment. For bath treatments, toxic concentrations can reach several kilometres away from a treated salmon farm and remain in the environment long enough to cause severe impacts on nontarget organisms, therefore the impact may be regional. The size of the impacted areas may vary and will depend on chemical as well as on the specific geographical and weather conditions occurring at the time of treatment. Furthermore, the sites may be used over many years, therefore the impact could be long-lasting. Considering the numbers of farms along the Norwegian coast performing delousing over several years, the total affected area can be large. When the environmental status of an area is given a score in the routine monitoring the concentration of delousing agents is not considered. Considering the goal of "sustainable growth" the environmental effects of delousing agents should be controlled and monitored, as there is a documented risk related to the use of these chemicals in the aquaculture industry today.

Literature availability and methods indicate that allowable thresholds in near- and far field zones can be defined for delousing agents in Norway.

Delousing agents are not considered in the "traffic light system" which is the method developed by Institute of Marine Research (IMR) to decide if a farm should be allowed to increase their production of salmon or not. An indirect effect of this could be that farmers using more delousing agents would be allowed to grow due to less sea lice. This underlines the importance of including the delousing agents into standard monitoring and regulation procedures.

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**QSR** (delousing).


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#### 3.3.3.3 Plastics (macro, micro & nano)

Plastics represent a two-fold challenge in aquaculture; on one hand production represents a source of environmental release and on the other hand fish in aquaculture can be affected by plastics in the environment. Plastic waste from the aquaculture production can consist of macro plastics (larger plastic units > 5 mm, such as whole or parts of cages, wrasse hides, rope, buoys, strips etc.) and micro/nano plastic (small plastic particles < 5 mm). Compared to sea-based fish aquaculture, the use of plastics in kelp and blue mussel aquaculture is at a smaller scale. Both blue mussel and kelp aquaculture uses ropes placed in the marine environment and boat trafficking for maintenance, supervision and harvesting. Plastics debris can be transformed into smaller pieces by photodegradation and other biological, physical, and/or chemical processes often called secondary micro plastics. Based on size, pieces can further be classified into nano plastics (NP < 100 nm) and micro plastics (MP, 100 nm – 5 mm). Micro- and nano- plastics can also directly be released from for example wear in feed hoses or chipped ropework, and wear of nanotech plastic-based anti-biofouling agents and paints. Grey water emission from household activities (run off from dishwashers, washing machines and sinks) are furthermore released directly into the marine environment from the platforms and might also contain microplastic due to the direct and unfiltered release to the marine environment. Microplastics is more difficult to see and quantify than macro plastics and the amount of the smallest components of plastic leaked into the environment can potentially be large because this fraction of plastic is more easily overlooked. Microplastics are contaminants of emerging concern as they are ingested by marine biota.

**Key findings:**

- Plastic waste from the aquaculture production can consist of macro plastics (larger plastic units > 5mm, such as whole or parts of cages, wrasse hides, rope, buoys, strips etc.) and micro/nano plastic (small plastic particles < 5 mm, from for example wear in feed hoses or chipped ropework, and wear of nanotech plastic-based anti-biofouling agents and paints).
- Plastics debris (macro plastics) can be transformed into smaller pieces by photodegradation and other biological, physical, and/or chemical processes often called secondary micro plastics.
- Studies have confirmed the presence of macro plastics and micro plastic in the environment originating from aquaculture. Microplastics occurs in higher concentrations in sediments close to the fish pens compared to the reference area, and in seawater samples taken close to the site.
- There have been efforts to quantify plastics loss from aquaculture (for example from feeding tubes), but the available data is not sufficient to provide a solid estimate of the all the release of macro/microplastics.
- There are studies that show that macro plastics and micro plastics may adversely affect organisms in the marine environment, depending on size and type of plastics and type of organism.
- There are also studies that suggest that micro plastics from aquaculture may be vectors of contaminants in the marine environment.
- Microplastics have been found in gills of farmed fish and this shows that MPs are concentrated enough in the aquatic environment near the net pens to increase the risk of exposure in farmed salmon. It is not known what significance it has.
- The risk of microplastics ingestion for humans is thought to be reduced by the removal of the gastrointestinal tract (GI-tract) in seafood consumed.
- There is a concern about the nano plastics ingestion, as nanoparticles can translocate across the gut epithelium resulting in systemic exposure, and a very wide distribution in all organs is likely. Although nano plastics may pose significant concerns, the data needed to perform a full food safety risk assessment of nano plastics in seafood are lacking.
- There are knowledge gaps related to aquaculture and plastics. There is also a need to consider if traditional environmental risk assessment approaches can be applied to assess micro plastic contamination impacts on aquaculture operations.

**QSR results**

A total of 8 articles were included from the QSR search. One concerned macro plastic and 7 concerned micro plastics. Most studies came from Chile, Norway, and Canada. Research on plastic pollution has been fast paced in recent years and much relevant literature concerning aquaculture and plastics in Norway were found in grey literature (n = 7) and were included in addition to one review and one paper published before 2010. The QSR literature described different topics concerning plastics in aquaculture: 1) how macro/micro plastics are released by aquaculture, 2) how plastic can act as vectors for pollution, 3) field investigations of micro plastics near fish farms and 4) effects from micro plastics on farmed animals (salmon) and wild fish. The grey literature described microplastics occurrence near aquaculture sites, effects on fish and possible contribution of plastics by the aquaculture industry.

### Receiver and impact

Lost gear, broken and fragmented equipment, and release of MP debris because of intense use have been suggested as sources of both macro and microplastic emissions from aquaculture at both the global and local level. In context of ocean plastic pollution, the aquaculture industry has been reported by several studies as a potential significant contributor (Hinojosa et al. 2009, SALT, 2019). However, one study concluded that it is unlikely that Norwegian aquaculture facilities are a source of extensive marine litter (Hognes and Skaar, 2017). Macro plastics can be found in the five different compartments of the marine environment: coastlines, water surface, the water column (pelagic), the seafloor (benthic), and in biota. The dispersal macro plastics are influences by wind, surface currents and geostrophic circulation (Law et al. 2010) and it can be distributed over long distances, even on a global scale. It is difficult to estimate the percentage of marine litter that originates from maritime sources, also from aquaculture. One study by Abihssira-García et al. (2020) tried to quantify the loss of micro plastic from 1000 Norwegian salmon farms per year (Table 3.5).

Studies and reports have identified the material flow in an aquaculture facility and several potential sources for micro plastics. The loss of plastic from feeding tubes (along with fish feed) has been identified as a source of micro plastics. One study has also identified plastic polymers from sediment samples, in higher concentrations in sediments close to the fish pens compared to the reference area (Gomerio et al. 2019). Furthermore, seawater samples taken close to aquaculture site indicated potential emission MPs from aquaculture activities (Gomerio et al. 2019). Micro plastics were also identified in the gills of farmed fish, indicating a source related to the fish farm. Fish meal contaminated by MP may also constitute a potential threat to aquaculture animals and surroundings (Wang et al. 2022).

The dispersal from secondary sources of micro /nano plastics are the same as for macro plastics and distribution can therefore be global. However, aquaculture release of some MP may be more locally distributed, since it is released close to the pens, by for example wear and tear in feed hoses. The polymer type of micro plastics will likely influence how far they disperse from their sources (Lusher et al. 2021). At smaller scales, turbulent flows, from tides or waves, high-energy oceanographic events, like sea storms can influence the distribution. MP/NP plastics are found in the surface, water column and particles which have a greater density than seawater and those which are biofouled will readily sink to the seafloor and are therefore also present in sediments. In general, sediments show higher concentrations of MP than water samples (Lusher et al. 2018).

The Institute of Marine Research (IMR, Hansen et al. 2022) assessed environmental risk of plastics. They concluded that macro plastic is larger than phytoplankton and zooplankton and has no impact on them, but that macro plastics can act as a substrate for organisms, including alien species, to settle and thus have an indirect impact. Fish are generally considered to be less vulnerable to macro plastic. Benthic communities have no to medium vulnerability to macro plastics depending on particle size. However, seabirds have shown medium to high vulnerability, as large amounts of plastic have been found in the stomachs of some bird species. It has been observed that seabirds can mistake waste for food, and it is estimated that 95% of fulmars have plastic in their stomachs. Also, mammals are considered vulnerable to macro plastics as it can clog their digestive system, they can get entangled, and lose their lives by ghost fishing of lost fishing gear. Lusher et al. (2018) found litter in 8.5 % of 274 stranded whales in the Irish Sea, but such figures have great geographical variation and there are no corresponding figures for Norway. An overview of direct impacts of marine litter (macro plastics, microplastics and nano plastics) are given in Figure 3.27.

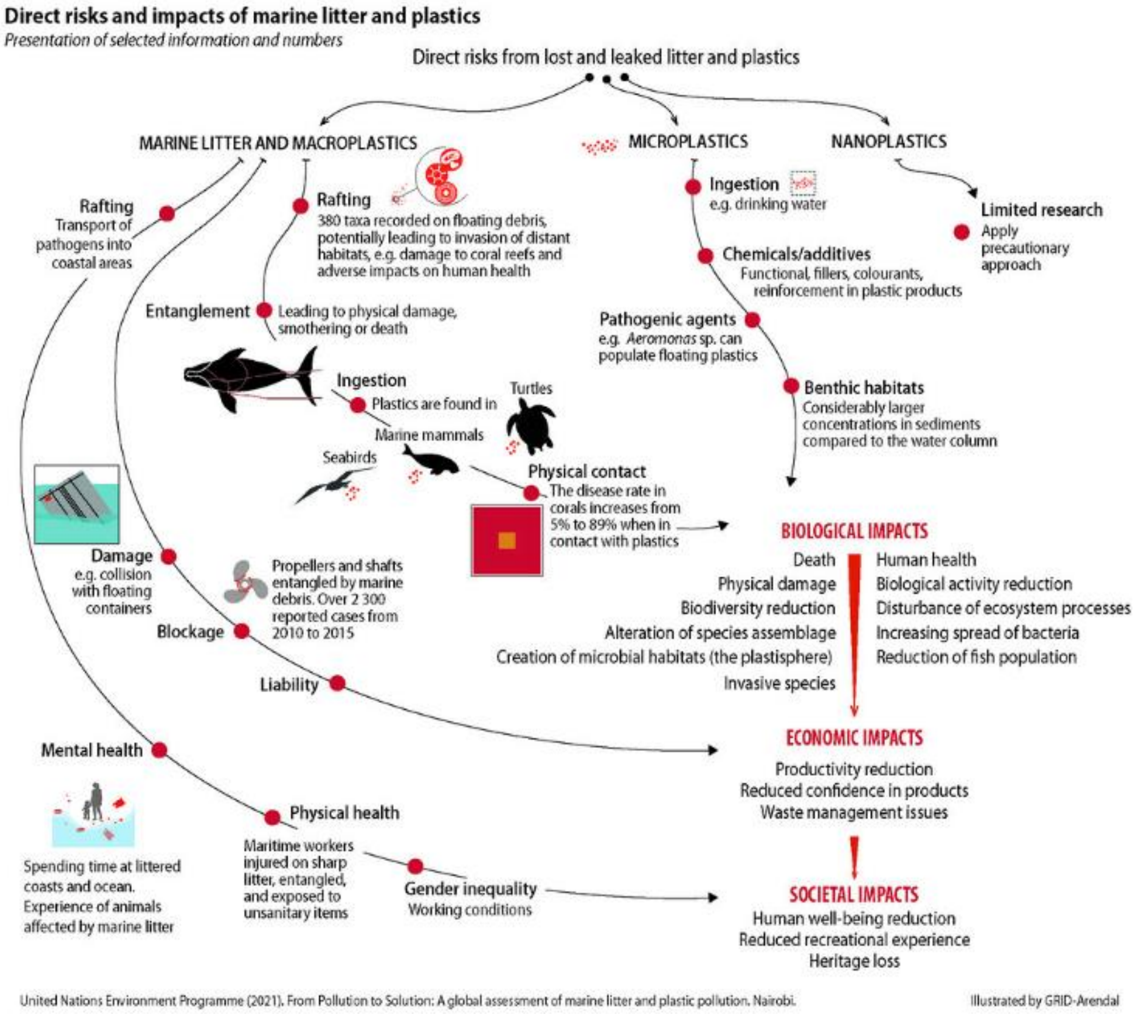


*Figure 3.27. Direct risks and impacts of marine litter and plastics (source Grid Arendal (https://www.grida.no/resources/15021).*

High doses of micro plastic have been showed to affect phytoplankton both at individual and population level. High concentrations can affect growth, development, reproduction, and life cycle of zooplankton (Hansen et al. 2022). However, there are few observations of such high doses from the field. One study also suggested that anthropogenic activities (including aquaculture) can have an effect on bacterial communities on microplastics (Aguila-Torres et al. 2022).

It has been uncertain if particles of micro plastics and nano plastics can penetrate over the gills, skin and intestines, so that they enter fish. In one recent study the researchers found microplastics of several types in both liver and muscle tissue, in both wild and farmed fish (Gomiero et al. 2020). It is not known what significance it has, and no sign of ultrastructural alterations such as swelling, necrosis or cell infiltration was observed in farmed salmon samples in the study. Another study concluded that immune cells of Atlantic salmon can phagocytose micro plastics, and the impact is dependent on the micro plastic type (Abihssira-Garcia et al. 2020). The study also showed that micro plastics are concentrated enough in the aquatic environment near the net pens to increase the risk of exposure in farmed salmon.

Requirements for food safety may also be applied to micro and nano plastics in food and the environment. According to FAO (Lusher et al. 2017), the risk of micro plastic ingestion for humans is reduced by the removal of the gastrointestinal tract (GI-tract) in most species of seafood consumed. However, there is a concern about the nano plastics, as they can be transported across the gut epithelium resulting in systemic exposure, and a very wide distribution in all organs is likely. Although nano plastics may pose significant concerns, data needed to perform a safety risk assessment of nano plastics in seafood are lacking (Lusher et al. 2017).

Vulnerability of benthic communities to micro plastics have been classified as low to medium, depending on the amount, time of exposure and size of the micro plastic particles (Hansen et al. 2022).

Three studies in the QSR described that micro plastics could act as vectors of contaminants in the marine environment. Micro plastics occurring near fish farms can sorb aquafeed-associated contaminants (Abihssira-Garcia et al. 2022). The study of polystyrene micro plastics and chlorpyrifos insecticide, found that polystyrene micro plastics cause toxicity and increase the adverse effects of chlorpyrifos on the muscle of fish. This investigation provided evidence toward low nutritional value of farmed or wild fish muscle that grows in areas with high concentrations of micro plastics and pesticides (Hanachi et al. 2021). The last study showed that micro plastics that enter the digestive tracts in mammals increased pollution levels of e.g., phthalates, which are linked to hormonal disorders (Hansen et al. 2022 and the references therein).

*Table 3.5. Calculation of use, degradation, and possible amount of plastic per year from 1000 salmon farm facilities in Norway. Number based on Abihssira-García et al. (2020).*

| **Material** | **Plastic** | **Use ton** | **Loss** | **Loss ton/Y** | | |
|---|---|---|---|---|---|---|
| **Nets** | PE/nylon | 35,571 | PE (0.45% mass loss/month) Nylon (1.02% mass loss/month) | 3137 | | Welden and Cowie 2017 |
| **Ropes** | PP | 17,201 | 0.39% mass loss/month | 805 | | Welden and Cowie 2017 |
| **Feed pipes** | HDPE | 4440 | 0.25 g/m/day | 225 | | Gomiero et al. 2020 |
| **Floater/ walkways** | HDPE | 108,405 | 0.5%/Y | 5.4 | | Booth et al. 2017 |
| **SUM** | | 191,799 | | 4172.4 | | Abihssira-García et al 2020 |

## Monitoring

Routine, long-term monitoring programs for micro plastic were not implemented in Norway until recently, and several pilot studies have investigated how to include micro plastic into ongoing monitoring programs. Now a new monitoring program which has a goal to increase knowledge about the extent of microplastic pollution in Norway has been implemented recently in 2021 (Mikronor https://www.niva.no/tjenester/overvakningsprogrammer/mikronor). The monitor program will measure levels and types of microplastics in Norwegian water bodies (in coastal areas, rivers and lakes). The first phase of this monitoring program lasts from 2021 to 2023 and will utilizes ongoing sampling in other national monitoring programs.

ASC Certification (https://www.asc-aqua.org/) have requirements for a more sustainable and responsible aquaculture, and they have stated that in the future ASC certified producers will be required to carry out a risk assessment of potential plastic contamination, and to implement mitigation actions to minimise the impact at the farm and its surroundings. Farms will need to record all used and disposed plastic material; and should implement a plastic waste monitoring programme to ensure waste is disposed in a responsible manner and recycled when possible.

### Knowledge gaps

Lusher and Pettersen (2021) has recently described the knowledge gaps related to aquaculture and plastics. They concluded that currently there are no estimates of the amount of plastics waste generated by aquaculture, which makes it challenging to calculate the generation and release of microplastics to the marine environment. The available data are not sufficient to provide a solid estimate of the release of microplastics generated from aquaculture. Most urgently required are numbers pertaining to microplastics released through weathering/breakdown of larger plastic equipment. There is a need for a better overview of the actual amount of plastic equipment in use within aquaculture and plastic accounting, to be able to identify the losses that has the potential to become secondary micro plastics (Lusher and Pettersen 2021). Analytical methods for the detection and quantification of microplastics in the environment (water, sediments, and biota) and food should be standardized, with a focus on the smaller (less than 150 µm) particles. After this, occurrence data, including particle size, must be generated, to be used for exposure assessment and dietary intake. Toxicological data on micro/nano plastics must be generated. The smaller particles (less than 150 µm) are potentially more hazardous, and their study should be prioritized (Lusher 2017). Further data on translocation of micro plastics containing the most common polymers should be generated for aquatic organisms and humans; and studies on micro plastics as sources of pathogens to fishery and aquaculture products and humans need to be carried out (Lusher 2017). Although it has been documented that plastic debris can act as a substrate for diverse microbial communities, sufficient data on the occurrence of pathogens on micro plastics are lacking to include pathogens in the risk profiling (Lusher 2017).

Lusher et al. (2017) also stated that we need to consider applying environmental risk assessment approaches to potential micro plastic contamination impacts on fisheries resources and aquaculture operations.

### Conclusion

Studies have confirmed the presence of macro and micro plastic related to aquaculture in the environment, in higher concentrations in sediments close to the fish pens compared to the reference area, and in seawater samples taken close to the site. There have also been efforts to quantify plastics loss from aquaculture, for example from feeding tubes and fish feed, but the available data are not sufficient to provide a solid estimate of the all the release of microplastics. It is known that macro and micro plastics may adversely affect organisms in the marine environment, depending on size and type of plastics and type of organism. There are also studies that suggest that micro plastics from aquaculture may serve as vectors for contaminants in the marine environment. Furthermore, it has also been documented that plastic debris can act as a substrate for diverse microbial communities, but sufficient data on the occurrence of pathogens on microplastics are lacking. Is has been uncertain if particles of micro and nano plastics can penetrate over the gills, skin and intestine thus entering fish. Microplastics have been found in gills of farmed fish and this shows that micro plastics are concentrated enough in the aquatic environment near the net pens to increase the risk of exposure in farmed salmon. It is not known what significance it has. There has also been concerns about food safety for seafood. However, the risk of micro plastics ingestion for humans is thought to be reduced by the removal of the gastrointestinal tract (GI-tract) in most species of seafood consumed. However, there is a concern about the nano plastics, as nanoparticles can translocate across the gut epithelium resulting in systemic exposure, and a very wide distribution in all organs is likely. Although nano plastics may pose significant concerns, the data needed to perform a full food safety risk assessment of nano plastics in seafood are lacking. There has been suggested that analytical methods for the detection and quantification of micro plastics in the environment (water, sediments and biota) and food should be standardized, with a focus on the smaller (less than 150 µm) particles. There is currently a monitoring program running to measure levels and types of microplastics in Norwegian water bodies (in coastal areas, rivers and lakes) it will run from 2021-2013.

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#### 3.3.3.4 Antifoulants and metals

Fouling refers to the growth of organisms on underwater surfaces and is a challenge for everyone who has equipment in the sea, including aquaculture. In the aquaculture industry, fouling presents practical, economic and animal welfare challenges in day-to-day operations. Handling of fouling is estimated to amount to 5-10% of production costs (Fitridge et al. 2012), but this figure can vary widely between the different locations, and between the companies which often have different strategies for handling. The methods to control the fouling of nests in aquaculture is (1) by use of antifouling coatings, (2) use of antifouling combined with cleaning and (3) only cleaning. The aquaculture companies all have their own fighting strategy where use of antifouling, high-pressure cleaning, low-pressure cleaning, or combinations are frequently used. Newer grooming and low-pressure cleaning methods are under development. In terms of control, the mechanical removal of biofouling remains dominant in shellfish and fish culture, and copper coatings on fish nets was long thought to be the only effective form of biofouling prevention (Fitridge et al. 2012). The suspension, dispersal and deposition of the foulant materials are associated with some risks, for example health or disease risks and deposition and pollution risks to the benthic environment (Floerl et al. 2016). Copper, that until recently has been the most effective antifouling agent used by the industry, is now in decline as an antifoulant agent due to environmental concerns. In the inspection round of the County Governor in Vestland (Norway) in 2023, conclusion was that copper-based note impregnation will be almost completely phased out in Vestland during 2023. In recent years, the reduction has been over 90 %. The aquaculture industry is therefore now testing substances that can replace or partly replace copper, such as other types of biocides. Since 2017, Econea® has been increasingly used as a new eco-friendlier antifouling paint formulation. Econea® is a trade name for a pesticide commonly called “tralopyril” and has been used in combination with copper-based antifouling or with zinc pyrithione to reduce the amount of copper, or to offer a copper-free antifouling paint alternative. Tralopyril has been introduced into marine antifouling paints, applied to large marine vessels or static structures such as oil rig and drilling platform legs. Tralopyril is a broad-spectrum biocide approved in 2014 by the European commission (No 1091/2014) as an active substance for use in biocidal products (biocid/ product-type 21, EU 2014). This approval was accompanied by strict requirements to reduce emissions to the environment. In the product assessment it is specified that an application for approval should include special considerations related to exposure, risk and effectiveness in areas of use. These factors were not included in the risk assessment at Union level. The environmental quality standard for tralopyril in coastal water has not yet been determined.

Another source of metals from aquaculture to the environment may be the feed used. The raw materials used for feed production can contain, among other things, halogenated organic compounds such as polychlorinated biphenyls (PCBs), dioxins, furans, chlorinated pesticides, brominated flame retardants and heavy metals such as mercury (Hg), arsenic (As) and cadmium (Cd), copper (Cu) and zinc (Zn). Other substances are added to the feed in small quantities and are necessary for the fish to have good growth. These includes Cu and Zn, which therefore also come under the category of minerals when they are added to the feed. However, the amounts of Cu from feed spills and faeces are far less than what comes from copper as an antifouling agent, which is the source of greatest concern. The contribution to the environment from the use of copper as an anti-fouling agent compared to the contribution from fish feed is in the order of 100-fold higher.

**Key findings:**

- The suspension, dispersal and deposition of foulant materials are associated with some potential risks, for example health or disease risks for farmed fish and deposition and pollution risks to the environment.
- Copper that has recently been the most effective antifouling agent used by the industry, but due to environmental concern it is in decline as an antifoulant agent. The aquaculture industry is therefore now testing substances that can replace or partly replace copper, such as biocides, e.g., Econea® (containing pesticide, tralopyril) has been increasingly used.
- Copper leaks into the water and are spread with currents. Model simulations based on an assumption that 28 % of applied copper leaks from net pens into the water column, show that passively leaked copper can make a significant contribution to the total copper concentration in a fjord system.
- High-pressure cleaning of copper-impregnated nets can produce pulses with concentrations that exceed the environmental quality standard for seawater.
- The seabed under and around fish farms may contain high concentrations as deposited copper can accumulate over time. Measurements of copper level in sediment show a gradient with highest concentrations in the near zone and decreasing levels outwards in the transition zone. However high variability and patchiness of copper, also along gradients, have been shown.
- Toxicity studies have shown that early life stages of marine invertebrates are most sensitive to copper exposure, while adult stages are less sensitive, and some species are quite robust.
- The impact of copper from farming is mostly local, but since the sites are used over many years, the impact could be long-lasting.
- There is still a need for more data on what proportion of copper bleeds out and what proportion that sinks into the sediments in the near zone and is spread to the transition zone.
- Recently new substitute substances to copper have been introduced, such as Econea®, which is a trade name for a pesticide commonly called “tralopyril”. There is limited information available on the toxicity of this substance, especially for marine species. Robust environmental risk assessments on substitute agents, such as tralopyril, are required to fully evaluate environmental risk.

**QSR results**

The QSR identified 15 articles about antifoulants where 5 were found irrelevant, which left 10 studies. The studies reported on 1) efficiency of antifoulants, 2) effects on fish health and 3) possible environmental effects. Most articles (N =7) reported on field studies, while 3 were reviews. In addition, 3 reports from grey literature were included.  Since the literature search described the antifoulant biocide tralopyril and possible environmental concern related to use, a small search on this topic was preformed and 8 published articles were added to the literature pool.

**Receiver and impact**

Foulant materials are associated with some potential environmental pathways and associated risks, for example health or disease risks for farmed fish and deposition and pollution risks to the environment (Floerl et al. 2016) (see Figure 3.28).

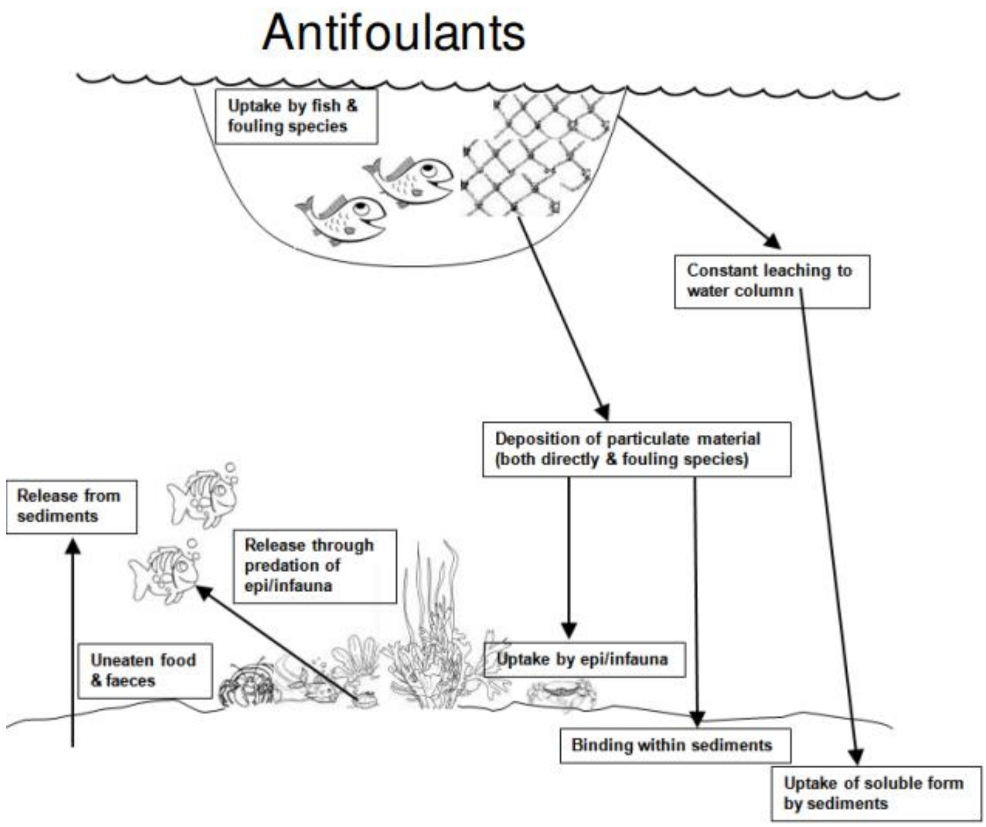


*Figure 3.28. Potential environmental pathways for assimilation of antifoulants in the environment. (NB. Factors only define the general pathways, determination of a reliable budget will need to include the various chemical forms in which antifoulants may appear). (Source: McLeod and Eriksen, 2009).*

The largest contribution of copper from aquaculture is copper(I)oxide ($Cu_2O$) used as antifoulant on net pens. At sufficient high concentrations copper can damage sensitive species and have negative impacts to the surrounding environment. In 2020, 1539 tonnes of copper were registered to be used as antifoulants for aquaculture in Norway (Grøsvik et al. 2022).

Results from measurements have shown that over time, copper leaks into the water, which is spread with the currents. The antifouling effect of the copper is achieved through dissolution and release of free cuprous ions ($Cu^{+}$) into seawater, which provide the toxic effect to organisms that grow on the net pens. Leaching tests carried out by the industry have shown that approximately 28 % of the copper content can disappear after the end of the net pen life in the sea. IMR have made model simulations where they have assumed that 28 % of the copper leaks into the water column and they show that passively leaked copper can make a significant contribution to the total copper concentration in a fjord system, in the order of 0.2-0.4 µg/l. In narrow fjords with poor water exchange, the contribution can periodically be up to 1 µg/l. Flushing or high-pressure flushing of copper-impregnated nets can produce pulses with higher concentrations (see Figure 3.28) (Grøsvik et al. 2022). The environmental quality standard for seawater is 2.6 µg/l (Direktoratgruppen, 2016, revised 2020). Some copper also falls off and sinks below the net pens, depending on particle size, sedimentation rate and current pattern. This means that the seabed under and around fish farms can contain high concentrations as deposited copper can accumulate over time. Measurements of the copper level in sediment in increasing distance from the edge of the cage show a gradient with highest concentrations in the near zone (25 m from the cage) and decreasing levels outwards in the transition zone (25-500 m) (Grøsvik et al. 2022). However, copper measured under net pens in sediment samples, often show high variability and patchiness also along gradients (APN internal data, Astrid Harendza).

Copper can be taken up (bioaccumulated) by marine organisms, but copper is not biomagnified to higher levels in the food chain. Toxicity studies have shown that early life stages of marine invertebrates are the most sensitive to copper exposure, while adult stages are less sensitive and, in some cases, quite robust (Eriksen and Mcleod, 2011). Threshold values for concentrations that produce an effect, has been investigated in two studies, both investigating a number of species; they came up with similar values 5.6 and 5.7 ug dissolved Cu/l (Grøsvik et al. 2022 and the references therein). Field data and mesocosm studies are missing therefore a safety factor of 2 were added and the PNEC for marine organisms is set at 2.6 µg/l, which is used as environmental quality standard for seawater in Norway (Direktoratsgruppen 2016, revised 2020).

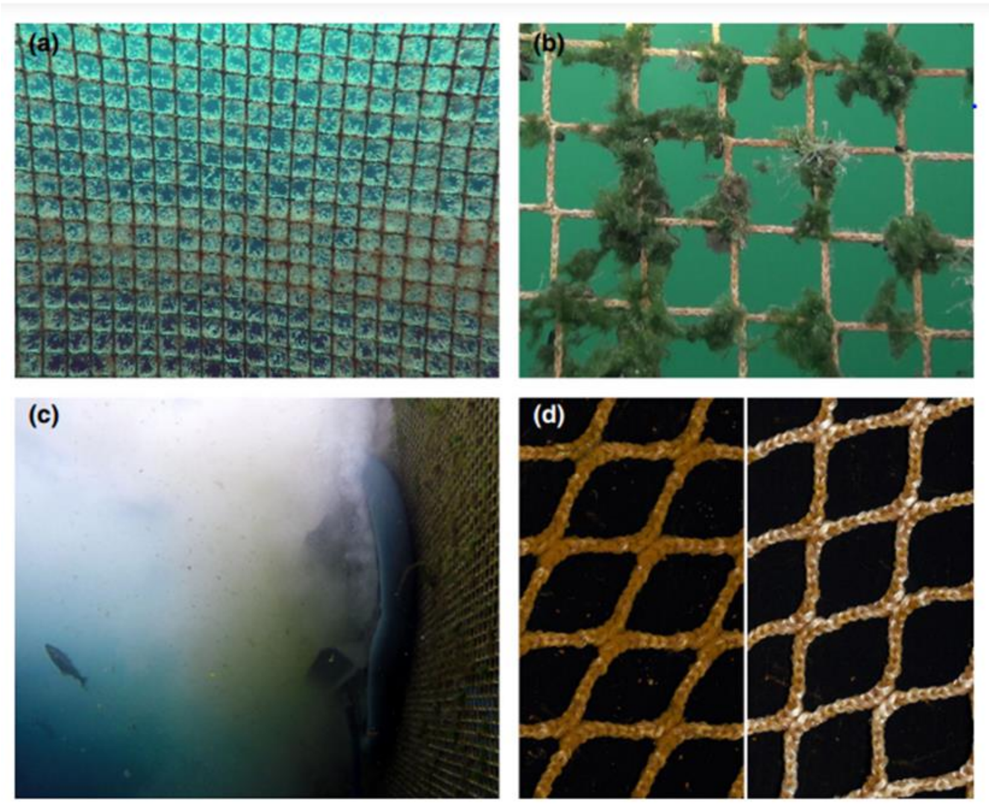


*Figure 3.29. Examples of a nylon net fouled with (a) hydroids (photo: Mai-Louise Bouwman) and (b) algae. (c) Particles released during cleaning of a biofouled net; (d) a copper-coated nylon net before (left) and after (right) a single net cleaning event using a high-pressure cleaner resulting in abrasion damage of the red copper coating. (Source; Bloecher and Floerl, 2020).*

With the now widespread use of Econea®, more attention should be paid to its potential harm the marine ecosystem and the health of humans working with the substance (for example boat maintainers). Econea® has an uncertain mode of action but it is thought to interfere with routine mitochondrial functions and Adenosine triphosphate (ATP), and therefore it may be toxic to non-target species. According to CHIRON AS (leading manufacturer and supplier of advanced chemical products for research and analysis), tralopyril represents a potential new antifouling biocide of concern. There is limited information available on the toxicity of tralopyril to aquatic organisms, but tralopyril is not considered to be persistent or bio accumulative (PBT) due to rapid hydrolysis in water.

However, recent studies demonstrated that Econea® impacts marine species with different effects. Exposure studies conducted in both in the mussel (*Mytilus galloprovincialis*) and zebra fish (*Danio rerio*), showed that Econea® affects the metabolism in both species, bioaccumulate in mussels and affect the thyroid and nervous system in fish leading to developmental toxicity and altered locomotor activities (Oliveira et al. 2014, 2016, Chen et al. 2020, 2022). Furthermore, exposure studies with Pacific oyster (*Crassostrea gigas*) showed detrimental consequences of exposure to tralopyril, it affected general stress defence responses of oyster mantle, affected energy metabolism, biomineralization and the mantle mucus secretion coverage ratio of oysters was increased with a dose-dependent pattern (Wang et al. 2022). This study indicated that the 96 h LC50 was 911 µg/L.

The toxicological knowledge of tralopyril in humans is still in its infancy. Pioneer works showed that exposure to human cells at sublethal Econea® concentrations results in the modulation of several lipids that are linked to cell death and survival. However, further investigations are needed to fill the gap of knowledge. The global ban of the antifouling biocide tributyltin (TBT) has been proclaimed as a major environmental success, however robust environmental risk assessments on substitute agents, such as tralopyril are required to fully evaluate risk (Martins et al. 2018).

Copper and other metals are also found in feed. Therefore, feed waste and faeces are a source of metal emissions from aquaculture facilities. Institute of marine research made an overview of emissions of selected substances (Mercury, Copper, Cadmium and Zink) to the environment given feed consumption per 1000 tonnes and feed losses of 0.5 or 8 % based on Sele et al. (2022) and retention data from the Institute of Marine Research (Grøsvik et al 2022). These numbers can be used to model feed releases into the environment and the sediments and further compare it to the already existing environmental quality standards in sediment (Direktoratesgruppen 2016, revised 2020) to evaluate whether the metal contamination in the feed is a risk or not for the environment.

**Monitoring**

There is no systemised monitoring of copper in Norway, although IMR has performed surveillance in some fjords in Vestland 2018-2022. However, Norwegian fish farming facilities are required to monitor the bottom under the facilities and the surrounding areas by following Norwegian Standard NS9410:2016 through the C-survey, which assesses environmental condition as site and thus supports management. Copper samples (to some degree systemized Cu monitoring) are taken as part of the C survey at one station, which is located 25-30 m from the cage edge. Copper concentrations are then classified into four classes ranging from 1 - "very good" to 4 - "very bad", with threshold values originating from the Norwegian classification guidelines 02:2018.

The Norway management sets no threshold levels for copper, even though that the water directive categorize copper into contaminant classes 1-5 class (Direktoratgruppen, 2016, revised 2020), where class 4 is considered bad at > 84 mg Cu/kg dry sediment weight. However, implications of a class 4 status at a site are not clearly defined, and no guidelines on what to do when these results exist. However, from the aquaculture industry we recognize that County Governor (Statsforvalteren) more often ask question for the copper concentration and imposes the companies to do extra surveys to delineate the contamination.

ASC standards (requirements for a more sustainable and responsible aquaculture) requires more extensive sampling, than the C survey should Cu have been used as antifoulant agent. Evidence that copper levels are < 34 mg Cu/kg dry sediment weight, or, in instances where the Cu in the sediment exceeds 34 mg Cu/kg dry sediment weight, demonstration that the Cu concentration falls within the range of background concentrations as measured at three reference sites in the water body. The ASC Certification is regarded as the most challenging and all-encompassing certification available. To achieve ASC certification, farms must complete a rigorous performance assessment and meet over 500 compliance points, but this certification is voluntary. The upper limit of Cu concentration (34 mg Cu/kg) value is therefore much lower than the contaminant class 4 of the Norwegian classification system. In this respect the voluntary system pushes forward a stronger regulation of Cu in sediments.

There is further no monitoring of copper in the water column in connection with areas with fish farming. Monitoring of ecosystems in coastal areas (Økokyst; https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/miljoovervaking/overvakingsprogrammer/ferskvann-hav-og-kyst/okokyst/) measures the content of nutrients (N, P, Si), oxygen, organic carbon, carbon and particles, depth of view, temperature and salinity in its water samples. It should be considered whether copper also should be included in this monitoring, as well as expanding the number of stations that are examined along the coast (Grøsvik et al. 2022).

Histological analyzes of mussels growing on copper-impregnated nets show high levels of copper in the soft tissue and a connection between copper exposure and tissue damage in the digestive gland (atrophy or shrinkage of the tubules) and changes in the structure of the gills. Such markers/indicators for copper exposure in mussels are now being tested in dose-response trials (Grøsvik et al 2022).

The use of replacement biocide substances has increased. However, substitute antifoulants may also pose risks to aquatic ecosystems. Robust environmental risk assessments on substitute agents, such as tralopyril and zinc pyrithione are required to fully evaluate the risk of antifoulants.

### Knowledge gaps

There is knowledge about copper concentrations under and in the immediate zone of the aquaculture facilities. However, there is a lack of knowledge about the availability of different of copper forms in sediment and of toxicity data for several of the species living in sediment (Grøsvik et al. 2022).

There is a need to gain a better understanding of the dispersion processes driving the patchy distribution of copper on the seafloor in order to improve model approaches and management. It is further a need for dispersion models of copper to evaluate its spread and impact in adjacent waters (pelagic). For example, pulses of copper created by rinsing of the nests might create a local peak of copper exceeding the environmental quality standards in the water (Grøsvik et al. 2022).

Recently new substitute substances to copper have been introduced however, there is limited information available on the toxicity of these substances, especially on relevant marine species. There are currently no environmental risk assessments (ERAs) of these substitute agents. Robust environmental risk assessments on substitute agents, such as tralopyril and zinc pyrithione are required.

**Conclusion**

There is knowledge about spread and presence of copper used as an antifouling in the environment. The copper leaks into the water and are spread with currents. Model simulations with assumption of 28 % copper leaks from net pens into the water column, show that passively leaked copper can make a significant contribution to the total copper concentration in a fjord system. High-pressure cleaning of copper-impregnated nets can produce pulses with higher concentrations than the environmental quality standard for seawater (Grøsvik et al 2022). In addition, the seabed under and around fish farms may contain high concentrations as deposited copper that can accumulate over time. Measurements of copper level in sediment show a gradient with highest concentrations in the near zone and decreasing levels outwards in the transition zone, however high variability and patchiness of copper, also along gradients, have also been shown by sediment samples.

Toxicity studies have shown that early life stages of marine invertebrates are the most sensitive to copper exposure, while adult stages are less sensitive, and some species are quite robust. Biofouling washed off the net, can furthermore irritate gills of farmed fish, and facilitate exposure to pathogens associated with biofouling (Bloecher et al. 2019).

The impact of copper from farming is mostly local and takes place in a limited geographical area, but since the sites are used over many years, the impact could be long-lasting. However, there is still a need for more data on what proportion of copper bleeds out and what proportion sinks into the sediments in the near zone and is spread to the transition zone.

Recently new substitute substances to copper have been introduced. However, there is limited information available on the toxicity of these substances, especially for marine relevant species. Furthermore, currently no environmental risk assessments (ERAs) of these substitute agents.

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#### 3.3.3.5 Pharmaceuticals (antibiotics and other)

The discovery of antimicrobial agents, particularly antibiotics, is one of the most important milestones in the history of therapeutics. Many of the antibiotics used in human and veterinary medicine are also being used in the aquaculture sector, either for therapy or as intended prophylactic agents (intended to prevent disease). However, there is increasing awareness and concern for the indiscriminate use of antibiotics and the consequent emergence of antimicrobial resistance in the aquaculture settings (Deekshit et al. 2022).

Antimicrobial use in aquaculture is governed by a variety of factors including legislation and regulation by the respective government organization (Watts et al. 2017). In general, the use of antibiotics in aquaculture depends on local regulations, which vary widely. In some countries (specifically Europe, North America, and Japan), regulations on the use of antibiotics are strict and only a few antibiotics are licensed for use in aquaculture. In Europe, for example, the practice of non-therapeutic prophylactic use of antibiotics was banned in 2001 by the EU Veterinary Medicinal Products Directive, as amended and codified in Directive 2001/82/EC. In Norway, stricter regulatory oversight of antimicrobial use, combined with increased vaccinations and excellent stewardship has been credited, in part, for a 99% fall in antimicrobial use between 1987 and 2013, despite output growing more than 20-fold (Watts et al. 2017).

The active substances florfenicol and oxolinic acid have been used in Norway during the period 2018-2021. Antibiotic consumption in kg decreased in the period 2012 – 2016, but it has been two years with higher use after 2016, in 2018 and 2021 (FHI, 2021). The 10-years (2012 – 2021) average use of antimicrobial use in Norway was 619 kg per year.

**Key findings:**

- Residue accumulation of antibiotics in the aquaculture environment may have several adverse ecological impacts. Ecological risk of antibiotics includes aquatic biodiversity toxicity, microbial community selection and antibiotic resistance.
- In Norway, strict regulatory oversight of antimicrobial use, combined with increased vaccinations and stewardship has been credited, in part, for a 99 % fall in antimicrobial use between 1987 and 2013. The active substances florfenicol and oxolinic acid are still in use in Norway.
- Since the use of antibiotics in Norwegian aquaculture is low, the risk of development of antimicrobial resistance and its transmission to humans through consumption of fish in Norway, is considered to be negligible.
- However, the potential for wide range environmental effects if more antibiotics is used, is large.

### QSR results

The QSR literature search ended up with 24 papers on the stressor antibiotics, covering the spectre from experimental laboratory work to environmental assessments. Four papers were review of the topic and most of the papers discussed resistance to antibiotics. One report from grey literature and 3 other relevant publications were added.

### Receiver and impact

Regardless the fact that most antibiotics shows rapidly degradation in the environment (Ahumada-Rudolph et al. 2016), the use of large amounts of antimicrobials, for example in Chilean aquaculture had the potential to select for antimicrobial-resistant bacteria in marine sediments (Buschmann et al. 2012). We could not find newer studies of antibiotic concentration in the environment from Norway, but in a study from Samuelsen et al. (1992) they found antibiotic in sediments under a farm where antibiotics had been used. They found that the half-life of oxyteracycline was between 87-144 days and that bacteria in the sediments was only oxyteracycline-resistant bacteria.

Residue accumulation of antibiotics in the aquaculture environment may have several adverse ecological impacts. Ecological risk of antibiotics includes aquatic biodiversity toxicity, microbial community selection. Some antibiotics for example pose definite ecological risk to algal populations (Chen et al. 2022). Generally, researchers evaluate the ecological impacts based on measured or predicted concentration of antibiotics in the environment. However, it might be underestimated because significant amounts of applied antibiotics is degraded through hydrolysis, photooxidation, and/or microbial action in aquatic environments and some antibiotics are accumulated in aquatic organisms.

Apart from ecological risk of antibiotics in aquaculture, antibiotic resistance risk in the environment is of recent major concern. The existence of residual antibiotics in the aquatic environment might facilitate the development of antibiotic resistance, community selection for antibiotic resistance and the emergence of multi-antibacterial resistant strains, thus enhancing the environmental risks of antibiotic resistance (Chen et al. 2022).

There is also a concern that the presence of antibiotics in aquaculture environment might speed up the development of resistant genes of bacteria strains, which may eventually transfer to humans through food chains. One study stated that the consumption of fish treated with antibiotics causes human health risk, particularly in children. Future studies are required on agents to restore dysfunctions induced by antibiotics in cultured fish, while attempts to prohibit them in aquaculture production are underway (Limbu et al. 2021). Another study, a review of antibiotic use in Norwegian aquaculture state that the risk of development of antimicrobial resistance and its transmission to humans through consumption of fish in Norway is considered negligible (Lillehaug et al. 2018).

The condition in modern Norwegian aquaculture is different that it was in the 1990ies with vaccinated fish and much better water-flow, but as each farm can have 100 – 500 times more fish compared to 1992, the potential for wide range environmental effect if more antibiotics is used, is large.

### Monitoring

The application of antibiotics in aquaculture is highly regulated in Norway. The Norwegian veterinary medicine wholesalers and feed mills are instructed to report their sales to pharmacies and fish farmers to the Norwegian Public Health Institute. In the last decade, the use of antibiotics in salmon production is reduced from 1.0 to 0.36 mg/kg fish production in 2014, and further to 0.16 mg/kg fish in 2019. Therefore, there it is a very low probability of developing antibiotic resistance in Norwegian aquaculture and the transmission of such resistance to humans (Lillehaug et al. 2018). There are also a maximum residue levels of antibiotics for fish prepared by European Medicines Agency (EMA 2021). In the EU/EEA area, it is currently only permitted to use medicinal products that have a defined maximum residue level value.

### Conclusion

Residue accumulation of antibiotics in the aquaculture environment may have several adverse ecological impacts. Ecological risk of antibiotics includes aquatic biodiversity toxicity, microbial community selection and antibiotic resistance. In Norway, strict regulatory oversight of antimicrobial use, combined with increased vaccinations and excellent stewardship has been credited, in part, for a 99 % fall in antimicrobial use between 1987 and 2013. The active substances florfenicol and oxolinic acid are still in use in Norway and the 10-years average use (2012 – 2021) is 619 kg per year. Since the use of antibiotics in Norwegian aquaculture is low, the risk of development of antimicrobial resistance and its transmission to humans through consumption of fish in Norway, is considered negligible. However, the potential for wide range environmental effect if more antibiotics is used, is large.

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### 3.3.3.6 Oil and oil containing mixtures.

New challenges have arisen related to increasing inclusion of vegetable feed ingredients in aquaculture feed. Substituting marine oils and meals with vegetable ingredients has decreased the level of persistent organic pollutants (POPs) in marine farmed fish such as Atlantic salmon. However, the shift in feed ingredients has led to increased levels of polycyclic aromatic hydrocarbons (PAHs) in aquafeeds. Several of the PAHs listed are on EFSAs and EPAs list of priority substances, having carcinogenic and genotoxic properties, and the ability to interact with and disrupt metabolic pathways such as vitamin metabolism and signalling in fish. In addition, chemicals (for example oil and oil containing mixtures) are present due to the machinery, vessels and other equipment, and any spill from these may have adverse effects.

**Key findings:**

- The aquaculture industry is an efficient edible protein producer and grows faster than any other food sector. Therefore, it requires enormous amounts of fish feed. New ingredient and new way of producing fish feed may solve some challenges, but also possibly introduce new ones, such as higher PAH levels in vegetable fish feed.
- PAH levels are detected in fish feed in the monitoring programs and may pose an impact on both farmed fish and the environment.
- PAHs that have toxic effects, such as immunotoxicity, embryonic abnormalities, and cardiotoxicity, for wildlife including fish, benthic organisms, and marine vertebrates. Additionally, the bioaccumulation properties of PAHs for organisms, including invertebrates, are important factors when considering PAH toxicity.
- There is no established upper limit value for PAH in animal feed or in fish feed, even though that the water directive categorizes PAHs into contaminant classes I-V class for both the sediment and water environment.

**QSR results**

Two articles on PAHs in fish feed were found in the QSR search, one of them a review. In addition, two grey literature reports concerning monitoring of unwanted substances in fish feed and risk were included. In addition, one published article was added.

**Receiver and impact**

In the program for monitoring of unwanted substances in fish feed in Norway, PAHs were investigated in feeds, vegetable flours and vegetable oils (Sele et al. 2022). PAHs were present in the feed in 2021 in the same concentration range as in 2019 and 2020. In fish feed examined in 2020, the average for sum PAH4 (which is the sum of PAH-compounds: benzo(a)pyrene, benzo(a)anthracene, chrysene og benzo(b) fluoranthene), was 1.4 µg/kg, which was somewhat lower than the average for total PAH4 in 2019 of 2.1 µg/kg. In vegetable flour and oil, the average for total PAH4 was 2.3 µg/kg and 6.1 µg/kg, respectively. One sample of vegetable flour was recorded to have a high concentration of PAH compared to the level usually measured in these samples, with a total PAH4 of 16 µg/kg, and this was reported to the Norwegian Food Safety Authority. In addition, levels of PAHs of up to 15 µg/kg were found in vegetable oils. There is no established upper limit value for PAH in animal feed or in fish feed, and thus these concentrations do not exceed any upper limit value for PAH in feed.

For each kilogram of salmon produced, about 0.5 kg of feces and uneaten feed pellets is generated (Svåsand et al. 2017). Most of this waste will, depending on bottom topography and ocean currents, slip through the open-cage net pens and accumulate in sediments beneath the fish farms. Because fish feed is nutritious and high in energy, wild organisms tend to also feed on this organic waste. Uneaten feed pellets are typically eaten by wild fish that aggregate in large numbers around fish farms (Uglem et al. 2014).

Therefore, there has been concern on impacts of substances found in feed on both farmed fish but also other organisms such as wild fish. There have been shown that the inclusion of vegetable ingredients in aquafeeds has introduced PAH congeners, including benzo[a]pyrene (BaP) and phenanthrene (PHE) in Atlantic salmon tissue (Berntssen et al. 2015 and references therein). The ability of PAHs to interact with and disrupt metabolic pathways such as vitamin metabolism and signaling, and the potential depletion of vitamin stores that follows, are of particular interest as marine ingredients are naturally rich in micronutrients such as vitamins A and D. This review focused on summarizing the current knowledge on the effect of PAHs commonly found in vegetable feed ingredients on vitamin metabolism/signalling and their possible implications in fish. However, little is known about the effects of PAHs originating from the vegetable feed ingredients in aquaculture, on the surrounding marine environments. Several researchers found that PAHs has toxic effects, such as immunotoxicity, embryonic abnormalities, and cardiotoxicity, for wildlife including fish, benthic organisms, and marine vertebrates. Additionally, the bioaccumulation properties of PAHs for organisms, including invertebrates, are important factors when considering PAH toxicity.

**Monitoring**

There is no established upper limit value for PAH in animal feed or in fish feed even though the water directive categorizes PAHs into contaminant classes I-V class for both the sediment and water environment (Direktoratsguppen vanndirektivet 2018). For traditional in-feed treatments such as de-licing agents and antibiotics environmental risk assessment are performed. However, potential environmental impacts from other contaminants in fish feed are scarce. With a growing industry requiring huge amounts of fish feed, attention to potential environmental effects would be needed, e.g., both leakage from pellets of various compounds into the environment, and excretion from fish through faeces and urine. There is currently no assessment if PAHs in fish feed represents a risk to the surrounding environment.

**Conclusion**

The aquaculture industry is an efficient edible protein producer and grows faster than any other food sector. Therefore, it requires enormous amounts of fish feed. New ingredient and new way of producing fish feed may solve some challenges, but also possibly introduce new ones, such as higher PAH levels in vegetable fish feed. PAH levels are detected in fish feed in the monitoring programs and may pose an impact on both farmed fish and the environment. PAHs have toxic effects, such as immunotoxicity, embryonic abnormalities, and cardiotoxicity, for wildlife including fish, benthic organisms, and marine vertebrates. Additionally, the bioaccumulation properties of PAHs for organisms, including invertebrates, are important factors when considering PAH toxicity. There is no established upper limit value for PAH in animal feed or in fish feed, even though the water directive categorizes PAHs into contaminant classes I-V class for both the sediment and water environment.

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### 3.3.3.7 Nanoparticles

Nanotechnology is a fast-growing field providing new products with new and unique functions. Nanoparticles (NPs) (size between 1 and 100 nm) on at least one-dimension, present unique physico-chemical properties that differ from their bulk materials, such as a greater surface area to volume ratio, resulting in a larger reactivity. Due to their unique properties, NPs have been widely used in different fields such as energy and electronics, wastewater treatment, personal care products, and medicine and agriculture. Recently, nanotechnology has also been applied in aquaculture, as it has a wide range of applications e.g., detection and control of pathogens, water treatment, sterilization of ponds, efficient delivery of nutrients and drugs. DNA-nano vaccines are used to improve fish immune system and iron-nanoparticles can also be used to improve fish growth. In a review from Khosravi-Katuli et al. (2017), the use of nanoparticles in aquaculture were reported to be either direct or indirect and is summarized in the Figure 3.30 below.

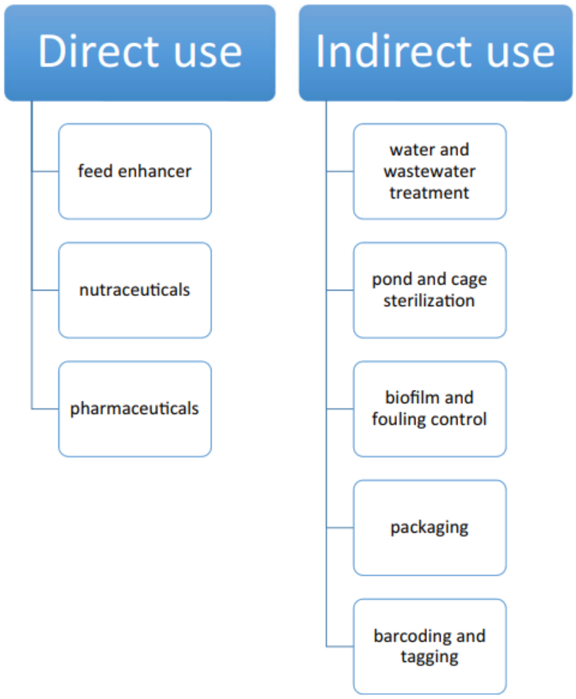


*Figure 3.30. Direct and indirect use of nanotechnology in aquaculture activities, from Khosravi-Katuli et al. (2017).*

Currently, most of applications of NPs in aquaculture are in an early stage, and high cost is considered the main limiting factor for their wide implementation.

**Key findings:**

- Utilization of nanoparticles to advance aquaculture is gaining enormous momentum. This underscores the need to study environmental impacts of this fast-growing new methodology, as their implications are still unknown.
- Nano based products can behave differently in different environments, thus, there is need to explore how nano safety could be influenced by environmental factors mainly salinity, pH, and temperature.
- Both ecotoxicological data for aquatic species and environmental fate studies should be research focus, which in turn can be used in risk assessment and possible future regulations.

### QSR results

A total of 1 article on nanoparticles relevant for environment was found in the QSR search, this was a review. And an additional publication was added.

### Receiver and impact

In the review, most of the studies existing were related to the applications of NPs in aquaculture, and it was stated that very little information exists on environmental topics. A thorough review on ecotoxicological effects were performed, and there was quite some information available on toxic effects on NPs, however, studies on aquatic organisms are scarce, and public concern raises from their use in aquaculture. Toxicity of NPs can be different in relation to the way they are administered, and toxicokinetics and toxicodynamics. Concentrations of NPs administered via feed, present in treated surfaces (i.e., cage nets), or waterborne (i.e., fishponds) can be significantly higher than environmental concentrations of NPs (Minetto et al. 2016).

The most important findings in this review relevant for environment were the following: 1) most data derived from toxicity studies on NPs are not specifically designed on aquaculture needs, thus contact time, exposure concentrations, and other ancillary conditions do not meet the required standard for aquaculture. 2) Short-term exposure periods are investigated mainly on species of indirect aquaculture interest, while shrimp and fish as final consumers in aquaculture plants are under investigated (scarce or unknown data on trophic chain transfer of NPs). 3) Little information is available about the amount of NPs accumulated within marketed organisms, how NPs present in the packaging of aquaculture products can affect their quality remained substantially unexplored.

**Monitoring**

There is currently no monitoring of nanoparticles in the environment, as far as the authors are aware of.

**Knowledge gaps**

Utilization of nanoparticles to advance aquaculture is gaining momentum. This underscores the need to study environmental impacts of this fast-growing new methodology, as their implications are still unknown. Both ecotoxicological data for aquatic species and environmental fate studies should be research focus, which in turn can be used in risk assessment and possible future regulations. Nano based products can behave differently in different environments, thus, there is to explore how nano safety could be influenced by environmental factors mainly salinity, pH, and temperature are needed. (Khosravi-Katuli 2017).

**Conclusion**

To conclude, NPs in aquaculture are a challenging topic that should be developed in the near future to assure human health and environmental safety. This to enable us to better understand possible adverse effects and in turn improve the safety of future food production and any environmental-related impacts of this activity.

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**QSR.**

Khosravi-Katuli, K., Prato, E., Lofrano, G., Guida, M., Vale, G., & Libralato, G. (2017). Effects of nanoparticles in species of aquaculture interest. *Environ Sci Pollut Res Int, 24*(21), 17326-17346. doi:10.1007/s11356-017-9360-3

**Added publication.**

Minetto, D., Volpi Ghirardini, A., & Libralato, G. (2016). Saltwater ecotoxicology of Ag, Au, CuO, TiO2, ZnO and C60 engineered nanoparticles: An overview. *Environ Int, 92-93*, 189-201. doi:10.1016/j.envint.2016.03.041

### 3.3.3.8 Other organic substances

Fish feed can contain various environmental toxins that come from the feed ingredients, and these can be added to the environment both through waste feed and through the fish faeces. Around 70% of feed ingredients are currently plant-based and 30% are based on marine raw materials (Ytrestøyl et al. 2015). The raw materials used for feed production contain, among other things, halogenated organic compounds including polychlorinated biphenyls (PCBs), dioxins, furans, chlorinated pesticides, brominated flame retardants (e.g., polybrominated diphenyl ethers (PBDE), hexabromocyclodecane (HBCDD) and tetrabrombisphenol A (TBBPA)) and perfluoroalkyl and polyfluoroalkyl substances (PFAS/PFOS). These persistent organic pollutants (POPs) are of special concern because they are chemicals that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.

It has been reported that farmed Atlantic salmon can contain POPs which are potentially hazardous to the consumers. These POPs include PCBs, dioxins [polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)], PBDEs, HBCDD, and organochlorine pesticides (OCPs) (Berntsen et al. 2016).

**Key findings:**

- The raw materials used for feed production contain, among other things undesirable substances such as persistent organic pollutants (POPs).
- Persistent organic pollutants (POPs) are of special concern because they are chemicals that persist in the environment, biomagnify through the food web, and pose a risk of causing adverse effects to human health and the environment.
- There is currently no knowledge and calculations of the amount of POP substances released from net pens, or if this represents an environmental problem.
- In order to give a complete picture of effects of fish farms on the loading of POPs to sediments below and close to fish farms it would require more comprehensive surveys to be carried out, taking account of e.g. the production cycle of the fish farm, the differences in hydrography in each location, the number of fish farms per location and any differences in feeding regimes.

**QSR results**

26 articles were found the QSR search concerning different environmental toxins. The articles were investigating: 1) the presence of substances in farmed and wild fish, 2) the transfer of substances from fish feed directly to fish both farmed and wild, and 3) laboratory studies of toxicity of substances to fish. Since some of the articles were describing presence in fish, these were excluded as no sources were described. A total of 20 articles were found to be relevant for the OSR. One grey literature report was that concerned monitoring unwanted substances in fish feed was assessed as relevant and was therefore included.

**Receiver and impact**

The results from 2021 year's analyses in Norway of fish feed, fish meal, vegetable meal, insect meal, fish oils, vegetable oils and 16 premixes showed that there are no exceedances of the upper limit values set in the regulations for undesirables' substances in animal feed. However, concentrations of some undesirable substances above normal were recorded in complete feed and feed materials in this monitoring programme by IMR. This concerned

PFAS in one fish oil, 3-MCPD in fish oil, the pesticide glyphosate in insect meal, tetrabromotrisphenol-A (TBBP-A) in insect meal, and PBDE in complete feed. Also, the previously authorized feed additive ethoxyquin (EQ), which is now suspended, was found to be present (concentrations over LOQ) in several feeds and fish meals. Many other compounds were also detected in the fish feed and described in this report (Sele et al. 2022).

Feces and uneaten feed pellets will accumulate in sediments beneath the fish farms and therefore wild organisms will be exposed to this organic waste (Russel et al. 2019). Several studies have documented the occurrence of POPs in fish food and in farmed fish. POPs can bioaccumulate in fish, therefore if the fish feed is contaminated POP concentrations can increase in the farmed fish. One study suggested that salmon farms are a source of lipid-soluble POPs to wild marine fish, but variation in life-history and habitat use seems to affect the levels of POPs in the different fish species. As these organic substances are known to act as endocrine disruptors, the authors concluded that further work is required to determine if these substances can negatively affect reproductive processes of wild fish associated with salmon farms (Bustnes et al. 2010). One study that exposed fish to PBDEs, concluded that exposure to these pollutants could have serious consequences on health in turbot and other cultured fish (Barja-Fernandez et al. 2013).

We only found one study that have measured environmental concentration in sediments below a fish farm. This study measured the concentrations of PCBs and PBDEs in sediments and concluded that concentrations were low and therefore would be unlikely to give rise to unacceptable biological effects (Russell et al. 2011). However the study stated that in order to give a complete picture of the effects of fish farms on the loading of persistent organic pollutants to the sediments below and close to fish farms it would require more comprehensive surveys to be carried out, taking account of e.g. the production cycle of the fish farm, the differences in hydrography in each loch, the number of fish farms per loch and any differences in feeding regimes.

Even though these contaminants are present in Atlantic salmon and there is a concern of human health, two studies concluded that the risk deriving from salmon intake is low, being of minor concern only for PBDE 99 and PFOS. Contaminant concentrations were well below maximum levels applicable in the European Union (Lundebye et al. 2017, Chiesa et al. 2019). Substituting marine oils and meals with vegetable ingredients has also decreased the level of some POPs in marine farmed fish. Furthermore, one study also showed that salmon can be produced with very low levels of POPs and that concentrations can be reduced significantly by careful selection of raw materials. The use of decontaminated fish oils has an important role in this process although care should be taken to use oils that are treated with protocols that reduce PCCD/Fs, dioxin like PCBs and PBDEs to ensure very low levels of POPs in commercial salmon (Bell et al. 2012).

Worldwide efforts have been undertaken by UNEP, governments, WHO and other stakeholders in order to eliminate and reduce the production, use and emission of these chemicals through the Stockholm Convention on POPs. Many of the POPs were phased out many years ago and some are being phased out today (e.g., PFAS) because of this. Therefore, many of the of the POPs are showing declining trends today and may not be a future problem. However, some chemicals of emerging concern (e.g., methoxychlor, perfluorohexane sulfonic acid (PFHxS), 6:2 fluorotelomer alcohol, and C9-C11 perfluorocarboxylic acids (PFCAs)) were either showing stable or increasing trends.

**Knowledge gaps**

There is currently no knowledge and calculations of the amount of POP substances released from net pens. In order to give a complete picture of effects of fish farms on the loading of POPs to sediments below and close to fish farms it would require more comprehensive surveys to be carried out, taking account of e.g., the production cycle of the fish farm, the differences in hydrography in each location, the number of fish farms per location and any differences in feeding regimes.

**Monitoring**

There are established upper limit values for many of the substances in animal feed or in fish feed and fish fillets. Furthermore, there are also contaminant classes I-V class for both the sediment and water environment for many of these substances. For traditional in-feed treatments, such as de-licing agents and antibiotics, environmental risk assessments are performed. However, potential environmental impacts from contaminants in fish feed are scarce. With a growing industry requiring huge amounts of fish feed, attention to potential environmental effects would be needed, e.g., both leakage from pellets of various compounds into the environment, and also excretion from fish through faeces and urine. There is currently no risk assessment if these compounds in fish feed represents a risk to the surrounding environment.

**Conclusion**

There have been many studies documenting the occurrence of POPs in raw material, fish food and in farmed fish and wild fish. There are also established upper limit value for many of the substances in animal feed or in fish feed and fish fillets and furthermore contaminant classes I-V class for both the sediment and water environment. The human health risk of eating farmed salmon is perceived as low as the contaminant concentrations in Atlantic salmon are well below maximum levels applicable in the European Union. There is currently no assessment of contaminant risk for the surrounding environment from these unwanted substances in the feed.

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### 3.3.4 Escapes

#### 3.3.4.1 Background

Norway has become a leading country in salmon farming worldwide over its 60 years of history and its standard has been studied to upgrade industrial practice and enhance production in world leading countries as China, the global largest aquaculture producer (Zhang et al. 2020). Among others, fish escaping from net-pens is an inherent side effect from fish aquaculture and given the increase in production and geographical spread of the industry (Olsen, 2020), it became a relevant socio-economic and environmental issue in early 2000s. Consequently, reporting escape events to the Norwegian Fisheries Directorate was enforced in 2001 for salmonids and 2004 for cod. Structural failure due to winds, waves and/or currents, operational related failure related to fatigue or human error, wild fauna and biological causes are the main drivers of escape events (Jensen, 2010, Uglem et al. 2014, Jackson et al. 2015, Føre & Thorvaldsen. 2021). Nearly a third of marine ecoregions of the world are to some extent at risk from the impacts of fish escapes (Atalah & Sanchez-Jerez, 2020).

#### 3.3.4.2 Search results

A total of 441 entries were obtained after duplicates removal and 237 research items were retained after complete process of data collection on this QSR (Figure 3.31). The main reason of exclusion was that the species was not relevant for the Norwegian context of the project. A steady production of research items over time was detected at a rate of 35 items per year, on average (range: 20 – 38; Figure 3.32).

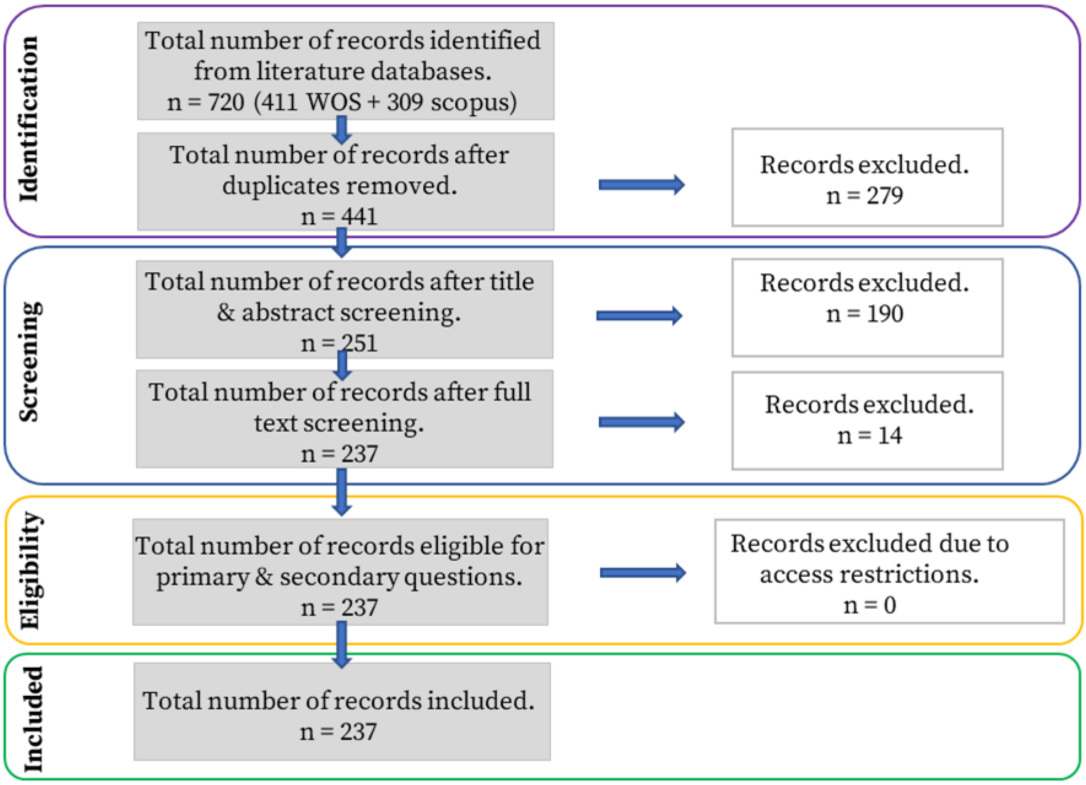


*Figure 3.31. Flow chart describing the applied QSR (Quick Scope Review) procedure on the influence of fish escaping from fish farms.*

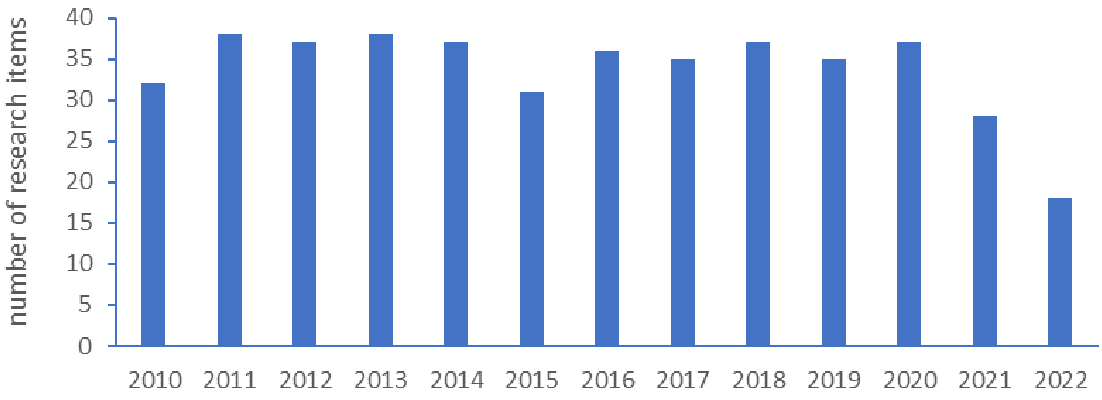


*Figure 3.32. Annual production of research items addressing the influence of escaped fish in the ecosystem.*

The geographical spread of countries contributing to unveil the implications of fish escaping from aquaculture facilities are global, with the only exception of the African continent and northern Asia (Figure 3.33). Most of the research studies were developed by research institutions based in countries around the Northern Atlantic Ocean. The countries contributing the most to unveil the effects of escaped fish from aquaculture facilities are Norway (n = 131 studies), Canada (n = 59; mostly in the East Coast), United Kingdom (n = 24; mostly in Scotland) and the US (n = 19; mostly in Washington estate), followed by Sweden (n

= 9), Spain (n = 9), Denmark (n = 8), Ireland (n = 6), Italy (n = 6), Finland (n = 4) and Argentine (n = 4). Other countries as Faroe Islands, China, Austria, Iceland, Japan, Turkey, Brazil, Malta, Belgium, Greece, France and Germany contributed with the least number of research items (i.e., ≤ 2 publications).

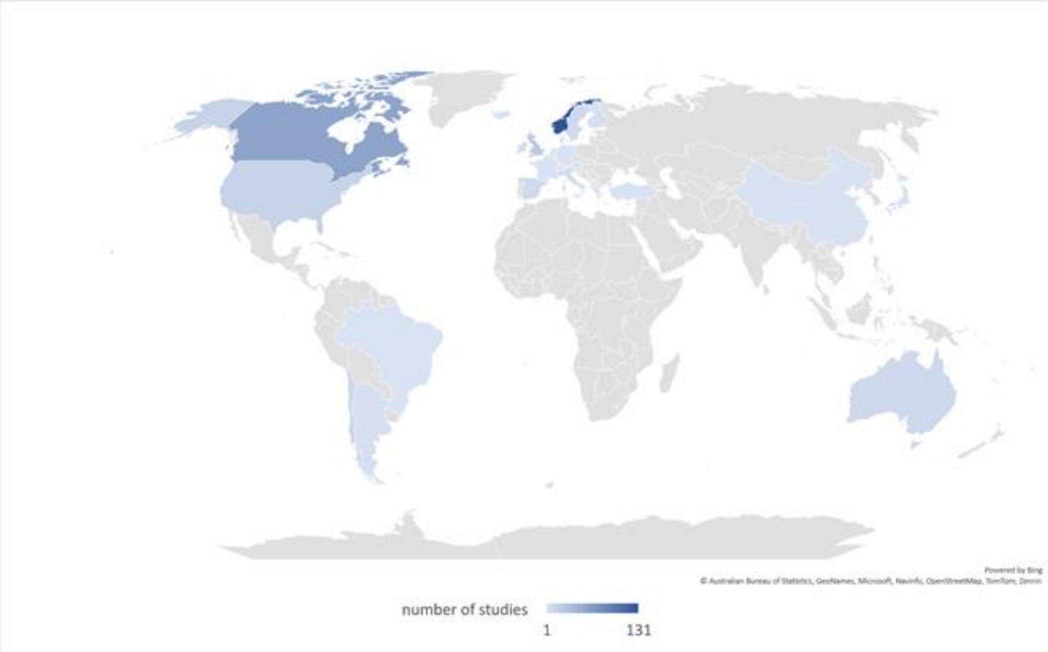


*Figure 3.33. Countries contributing to research on the implications of fish escaping from aquaculture facilities.*

In relation to the diversity of implications deriving from farmed fish escaping from rearing environments, hybridization, intra-specific competition, disease vectors, inter-specific competition and influence on fisheries were the main categories identified and aggregated in the current QSR (Figure 3.34).

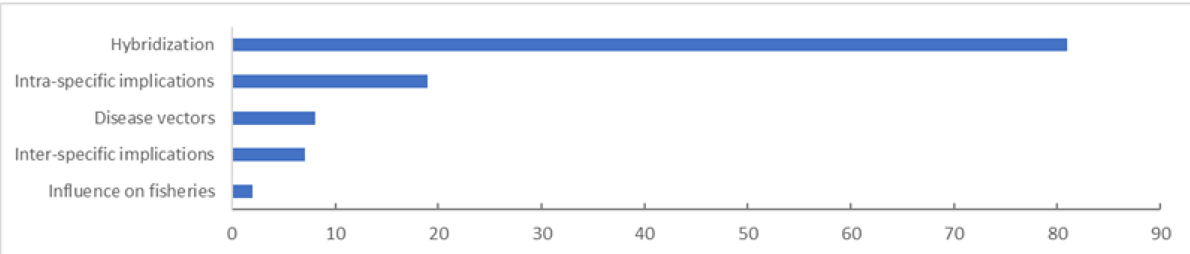


*Figure 3.34. Number of research items exploring the main implications of fish escaping from fish farms, namely: hybridization via genetic introgression of farmed into the wild populations, intra specific implications as differential competition for resources and mating, role as disease vectors (including macromolecules and chemicals), inter specific implications as predation, competition for habitat and trophic resources, as well as eventually, its influence on fisheries.*

Although a number of species have been addressed, the bulk of research has been conducted on Atlantic salmon (*S. salar*; n = 65%), Atlantic cod (*Gadus morhua*, 12%), rainbow trout (*Oncorhynchus mykiss*, 7%) and cleaner fish (*Cyclopterus lumpus, Symphodus melops, Ctenolabrus rupestris*, altogether n = 4%; Figure 3.35). Other salmonids including *Oncorhynchus kisutch* and *Salmo trutta*, were also studied (altogether n = 3.33%), as well as, Gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*) and tilapia (*Oreochromis niloticus*) (altogether n = 1.25%). Nearly 80% of the research items were addressed to hybridization effects of escapees on wild populations (Figure 3.34), followed by intra specific implications (ca. 20%), disease vectors and inter specific interactions (ca. 8%) and influence on fisheries (ca. 2%). All these five main influences have been addressed on Atlantic salmon (*S. salar*) and rainbow trout (*O. mykiss*) research, whereas in Atlantic cod (*G. morhua*), genetic influence, behavioural competition and dispersal were studied. The genetic influence of escapees was the only implication addressed on cleaner fish.

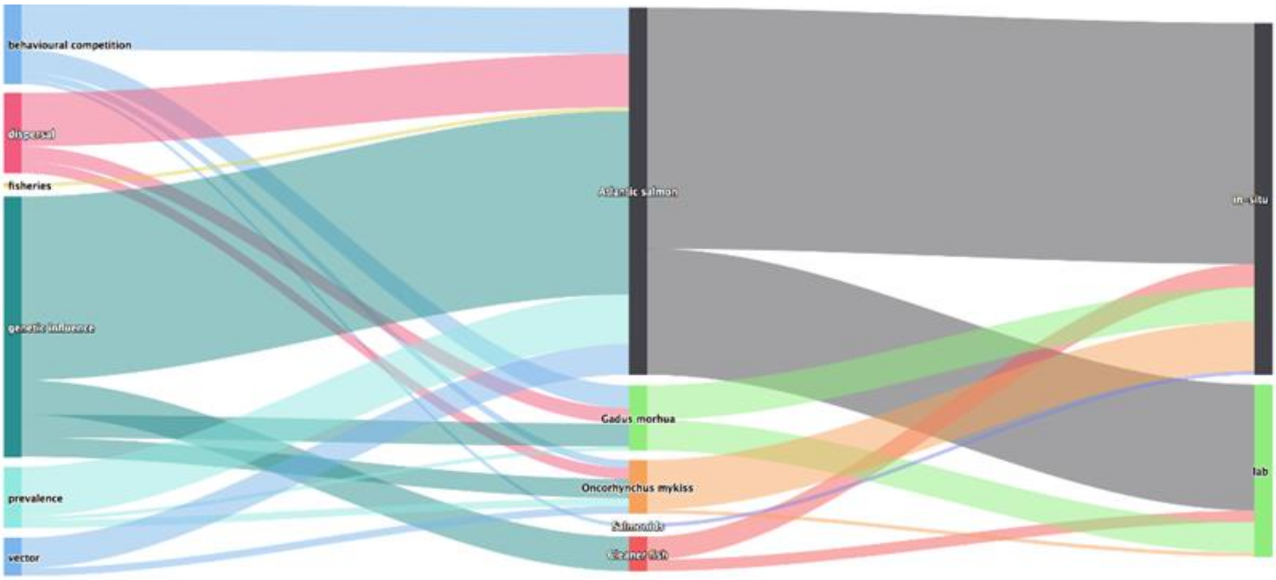


*Figure 3.35. Sankey diagram depicting proportions of study items exploring specific features of escaped fish per species and study design (i.e., laboratory or in-situ). The influences are grouped in behavioural competition (both intra- and inter-specifics), dispersal ability, influence on fisheries, genetic, prevalence and disease vector.*

The retained reviews cover a range of geographic areas (i.e., Chile, Canada, United Kingdom and Scandinavian countries) and issues including ecological and genetic interactions, impacts on pinnipeds, loss of genetic variability through introgression, potential recapture of escaped fish, use of triploid fish, decline of Atlantic salmon populations, sustainable development of aquaculture, mass marking limitations techniques, genetic interactions between farmed and wild salmon, ecological risks of genetically modified salmon, and successful applications of single nucleotide polymorphism (SNP) in fish aquaculture for ecological risk assessments.

### 3.3.4.3 Key findings

*Table 3.6. Summary of the reviews addressing escapees' implications on the environment with special focus on main results and conclusions, main focus and its applicability.*

| ID | Reference | Main results and conclusions | Main focus | Applicability |
|---|---|---|---|---|
| 1 | Braithwaite and Salvanes (2010) | Identified examples of neutral and negative influence of Atlantic salmon escapees on wild populations of Pacific salmon. | inter-species interactions | management |
| 2 | Holmer et al. (2010) | Included escapees as a potentially a high risk due to farm failure under rough weather conditions in the open sea. | overall risks | management |
| 3 | Moreau and Fleming (2011) | Gave insight on the potential impacts of aquaculture biotechnologies in the industry and forecasted these to play a major role in the sustainable development of the industry, if public and private institutions prioritize research into development of ecologically neutral technologies, e.g., close containment rearing systems, such as farmed fish cannot interbreed and have little or no impact on the ecosystem. From the genetic perspective chromosome-set manipulations, sterility transgenes, sex control, and other such technologies to complement favourable production traits would need further development as well. | reduce genetic influence and incidence | management |
| 4 | Green et al. (2012) | Reviewed the correlation between escape reports and angler's catches, concluding that only 2 per 1000 of the escaped fish is reported as recaptured with the fate of the vast majority of escapes unknown. This suggests that escaped salmon either have very low survival in the wild, disperse without returning, or are less readily caught by anglers. Escapees from Scotland were reported to migrate towards the Norwegian territory. | escapees incidence in angling | management |
| 5 | Niklitschek et al. (2013) and Quinones et al. (2019) | Covered all potential environmental issues of Atlantic salmon and trout aquaculture within Chilean waters and recommended following a strict precautionary approach of not granting new farming leases until sufficient information about the risk and magnitude of these impacts is obtained and transformed into effective management actions. | inter-species interactions | management |
| 6 | Sepulveda et al. (2013) | Identified short-term predatory effects upon native fish, long-term effects linked to the likelihood of farmed salmon establishing self-sustainable populations, and disease and pathogen transfer to native fauna. More research is needed to identify and develop reliable indicators to estimate the impact of escapees at the ecosystem level and precautionary approach encouraging local and recreational fisheries to counteract colonization is outlined as an option to be consider. | inter-species interactions | management |
| 7 | Moreau et al. (2014) | Reviewed the ecological risks of genetically modified salmon concluding that data gaps and irreducible epistemic uncertainties limit the role of scientific inference in support of ecological risk management for transgenic salmon. | use of GMOs fish | management |
| 8 | Beirao et al. (2019) | Reviewed how fish sperm competition from hatchery origin can cause loss of genetic variability both in captivity and in wild populations and suggested that mass spawning in hatcheries should be limited to give all males the same opportunities to fertilize eggs, and escaped fish can potentially fertilize eggs in the wild. | sperm, reproduction and genetics | management |
| 9 | Zhang et al. (2020) | Analyses the development of the Norwegian salmon aquaculture industry and outline recommendations for the sustainable development of Chinese aquaculture, including fish escapes within one of the major issues. | industry development | management |
| 10 | Dadswell et al. (2022) | Reviews the causes of the decline of Atlantic salmon populations in the North Atlantic Ocean. | wild populations decline | management |
| 11 | Glover et al. (2017) | Reviews the genetic interactions between farmed and wild Atlantic salmon concluding that, on the long-term, introgression is expected to lead to changes in life-history traits, reduced population productivity and decreased resilience to future challenges, and only a major reduction in the number of escapees and/or sterility of farmed salmon would hamper such impacts. | intra-species interactions | managemnet |
| 12 | Diana (2012) | Reviews current production issues and promotes production at lower intensity levels and the use of indigenous species in order to achieve a sustainable development of aquaculture. | industry development | mangemnet |
| 13 | Benfey (2016) | Covered the use of triploid fish in Atlantic salmon aquaculture and concluded that then triploids could be used as an alternative to reduce interbreeding risk between escaped and wild salmon populations. However, the poorer performance of triploids in captivity together with uncertainties existing with respect to their disease resistance and their potential to become reservoirs for the spread of pathogens, highlights the need of further research to take a decision. | triploid fish | mitigation |
| 14 | Dempster et al. (2018) | Focused on the potential recapture of escaped fish after escape events concluding that it is largely inefficient. | recapture of escapees | mitigation |
| 15 | Heredia-Azuaje et al. (2022) | Focused on pinnipeds and salmon farming over the last 50 years and identified a knowledge gap on how pollution, nutrification and/or prey subsidies related to this industry may induce trophic and social changes, on wild pinnipeds, as well as breeding and/or foraging habitat loss/change in farmed areas. | inter-species interactions | mitigation |
| 16 | Bradbury et al. (2020) | Indicated that ecological and non-reproductive genetic interactions of escaped Atlantic salmon are important, and further study is urgently needed to support an integrated understanding of aquaculture–ecosystem interactions, their implications for ecosystem stability, and the development of potential mitigation and management strategies. | genetics | mitigation |
| 17 | Glover (2010) | Reviewed the potential of using genetics for escaped fish identification back to the cage and farm origin, concluding that the method is successful for G. morhua, O. mykiss and Atlantic salmon. | use of genetics for traceabiltiy | monitoring |
| 18 | Warren-Myers et al. (2018) | Reviewed mass marking limitations techniques based on otoliths concluding that all techniques are simple, easy to apply, cost effective and highly suitable for long term monitoring of hatchery produced fish. | otholits potential for traceabilty | monitoring |
| 19 | Wenne (2018) | Reviewed and provide successful applications of SNPs in fish aquaculture for ecological risks assessments. | use of SNPs for traceabilty | monitoring |

### 3.3.4.4 Receiver and impact

The presence of escapees might affect wild conspecific populations via competition for resources, space and/or hybridization, deriving in genetic introgression and fitness decrease of wild stocks. Other taxa might be affected by competition issues for space and trophic resources, escapees playing the role of preys or predators affecting the distribution of wild taxa, with special importance if such taxa are fishing resources. From a socioeconomic perspective, the industry itself can be impacted via economic losses due to escape events or negative social awareness and concerns about sustainability of the industry. Traditional guilds as fishermen (e.g., professional and recreational) might be affected as well by the presence of escapees and might perceive the development of the industry as detrimental for the environment and their activities (Figure 3.36).

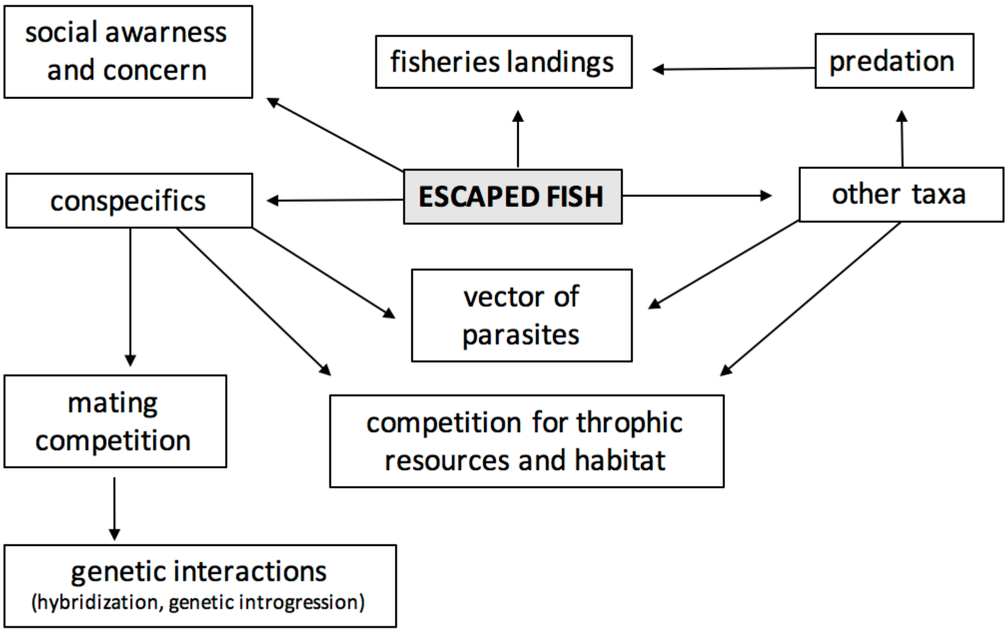


*Figure 3.36. Potential interactions of escaped fish after an escape event.*

### 3.3.4.5 Monitoring

A National Monitoring Program for Escaped Atlantic salmon in rivers was developed and enforced by the Norwegian Directorate of Fisheries, based on guidelines from the Ministry of Trade, Industry, and Fisheries in 2014. The program is led and coordinated by the Institute of Marine Research. Other institutions are involved as the Norwegian Institute for Nature Research (NINA), the Norwegian Veterinary Institute, Rådgivende Biologer AS, and NORCE LFI. Additionally, Ferskvannsbiologen AS, Skandinavisk Naturovervåkning AS, and Naturtjenester i Nord AS, are providing data to the program.

The monitoring of escaped farmed salmon quantifies the incidence of escaped salmon in water bodies of the Norwegian coastline, as well as assesses the escapees' genetic composition, their distribution and abundance in the wild. Moreover, the potential impact on wild salmon populations is evaluated. Eventually, from a mitigation perspective, the effectiveness of mitigation measures to prevent further escapes is also assessed. The number of rivers included in the monitoring program has risen from 140 in 2014 to 218 rivers in 2020, and 178 in 2021 (Figure 3.37). The need of the current monitoring program has been suggested by all the aforementioned research studies focusing on the strong evidence of the negative genetic influence of escapees on wild populations both at short and long term.

The pertinence of the monitored areas and the representativity of the final results are ensured by several criteria, including good geographical distribution, inclusion of national salmon rivers, different river size is also considered, as well as rivers with available time series and good local networks.

In terms of methodology and sampling temporal distribution the monitoring program is informed either with sport fishing catches in the summer and fall fishing, spawner surveys, and/or drift/spawning fish counts in the fall. All collected data is audited for quality. The Quality Norm for Atlantic Salmon and the Water Framework Directive, play a key role in the monitoring programs as they classify salmon stocks and rivers, among other things, in relation to escaped salmon.

The main results of the last monitoring program* for 2021 are the following:

- About 35% of the stocks are in good condition, while the 69% show different degrees of impact.
- A total of 140 rivers (79%) showed low occurrences of escaped farmed salmon (less than 4%), whereas 24 (14%) rivers showed moderate occurrences of escapees (4-10%) and 14 rivers (8%) had high incidence (more than 10%).
- Regionally, the counties of Vestland and Nordland have the most rivers with high occurrences of escaped salmon, while the southern and eastern parts of the country have mainly low occurrences.

*****https://www.fiskeridir.no/Akvakultur/Nyheter/2022/overvakingsprogrammet.

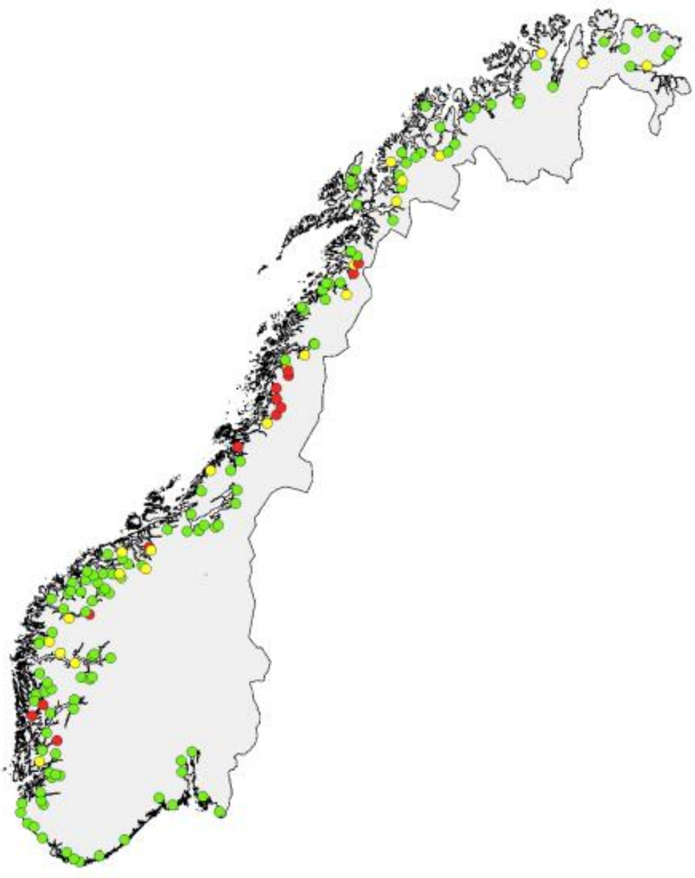

*Figure 3.37. Map showing the sampled location during the monitoring program of escaped salmon for 2021. Green dots show rivers with an incidence of escaped salmon <4%. Link to the document: https://www.fiskeridir.no/Akvakultur/Nyheter/2022/overvakingsprogrammet; figure 5.3 in page 31).*

There are two enforced regulations, both at a national and European level, that make the monitoring program of escaped Atlantic salmon very robust, namely The Quality Norm for Wild Salmon (Kvalitetsnorm for villaks) and the Water Framework Directive (Vannforskriften). The Quality Norm for Wild Salmon is informed by scientific data on the status and trends of wild salmon populations and their habitats in Norway. The norm provides guidelines for the management of wild salmon populations, and it aims to ensure that these populations are healthy and sustainable in the long term. The norm covers various aspects of wild salmon populations, such as their genetic diversity, population size, distribution, and habitat quality. It also considers factors that may affect wild salmon populations, including pollution, overfishing, and the impact of escaped farmed salmon in rivers. The norm is based on scientific studies and research, and it is periodically updated to reflect new knowledge and understanding of wild salmon populations and their habitats. The Water Framework Directive regulates the protection and management of surface, transitional, coastal and groundwater in the European Union to guarantee a sustainable ecological status requiring member states to monitor and assess the impact of potential stressors in all water bodies, including Natura2000 areas regulated by the EU habitat directive (92/43/EEC). Atlantic salmon is one of the listed species in the annex IV of the EU habitats directive 92/43/EEC, article 22. This is why the monitoring program assesses the influence of escaped salmon from fish farms.

However, despite the potential escape of farmed cod, together with its aforementioned influence in the environment, a monitoring program assessing the influence of escaped cod has not been enforced yet. Nowadays, farmed cod production is still minor but given the forecasted increase in aquaculture production, including cod, together with the existence of cod breeding program in Norway, the enforcement of a monitoring program of escaped cod is strongly recommended. Similarly, despite the genetic influence of escaped cleaner fish on wild counterpart populations, no monitoring programs have been enforced yet, and in the context of blue revolution where aquaculture is meant to become a driver of economy, including the food industry, the increase of farmed fish entails an increase of cleaner fish production so the impacts of potential escapes in the environment will continue to increase if no regulations are enforced to mitigate them.

#### 3.3.4.6 Knowledge gaps

While for salmon all main potential influences were covered by retained research items at a large geographical scale, there is no information about the potential inter-species competition of escaped Atlantic cod, feralization process, potential role as a parasite vector or potential influence of escaped cod in fisheries landings' dynamics.

Furthermore, the research addressed to escaped cleaner fish mostly focuses on hybridization and genetic issues, whereas many other aspects remain unknown, for instance, feralization process, dispersion, role as a parasite vector, survival or inter- and intra-specific competition for trophic resources and habitat.

Concerning the use of gene modified fish and triploids, the precautionary principle is still applied due to the unknown consequences for the environment in case the farmed fish escape. Therefore, further research is necessary in case such approaches are adopted.

Issues as social awareness and concern arising from fish escaping from fish farms does not seem to be covered by research, as well as the influence on recreational fisheries from a socio-ecological perspective.

### 3.3.4.7 Conclusions

The current QSR detected a range of interactions between escaped fish and the environment, including hybridization, intra-specific competition, disease spread, inter-specific interactions, and impacts on fisheries.

Efforts to mitigate the negative impacts of escaped fish have been carried out worldwide, with significant contributions from countries such as Norway, Canada, and the United Kingdom, particularly Scotland.

The majority of the research items focus on Atlantic salmon (*S. salar*; n = 65%), followed by Atlantic cod (*G. morhua*, 12%), rainbow trout (*O. mykiss*, 7%), and cleaner fish (*C. lumpus, S. melops, C. rupestris*, combined n = 4%).

The risk of genetic introgression and fitness decrease of wild populations at long term exist for all studied species and the main driver is fish escaping from fish farms.

Research on Atlantic salmon covers all the potential issues derived from escape events as hybridization, intra and inter-specific interactions and role as parasite vectors. However, research addressed to Atlantic cod and cleaner fish is not that thorough and more efforts seem to be needed to cover potential genetic, intra- and inter-specific interactions with wild conspecifics and other taxa.

Due to the expansion of the salmon farming industry in Norway and the implementation of a monitoring program to comply with the European Water Framework Directive and European Habitat Directive, the occurrence of escaped salmon in Norwegian rivers has been well documented throughout Norway. However, research on genetic introgression from farmed to wild populations is still raising concerns, indicating that the risk persists, and the development of effective prevention and mitigation measures should be prioritized.

Since the distribution area of Atlantic salmon encompasses countries with a well-developed farming industry such as Canada, United Kingdom, Ireland, Iceland, Sweden, and Norway, common policies seem an appropriate framework to preserve wild stocks.

The high dispersal of escaped fish, detected at the scale of 1000s of kms, has been detected at trans-boundary level between countries. This highlights the need for synergistic actions between governments to consistently mitigate the negative effects of escaped fish (e.g., enforcement of similar regulations). For instance, escaped salmon from Norway have been found in Swedish rivers, and salmon released in Scotland have been found as far as Northern-Norway. Additionally, Atlantic salmon individuals migrating and expanding the northern distribution of the species in its northern hemisphere show southern genotypes, and a farmed origin from northern Norwegian fish farms has been hypothesized.

The continuous update of the industry at technological and technical levels is strongly recommended so better regulations regarding technical standard (e.g., Norwegian technical standard NS 9415 effective since 2004) could be enforced to minimise escape events and thus mitigate derived issues.

So far, given the intrinsic character of escape events to aquaculture, the implementation of close containment rearing environments and on-land facilities (e.g., Recirculating Aquaculture Systems) could be the way to minimise the incidence of escaped fish in the wild.

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### 3.3.5 Disease & parasites

#### 3.3.5.1 Background

Translocation and introduction of aquaculture stocks, low genetic diversity, and high stocking densities make farmed fish vulnerable to parasites and disease outbreaks (Bouwmeester et al. 2020). This is of major concern to several stakeholder groups (Liu et al. 2010). For the fish farmer they are problematic because they directly affect the health and welfare of the farmed species which in turn leads to reduced survival, poor growth, and increases the need for treatments. The ultimate result is a reduction in revenues. Conservationists and ecosystem managers are worried about spread of diseases and parasites to the surrounding environment. Finally, passing of diseases and parasite on to wild fish populations can lead to conflicts with other businesses such as the fisheries sector and recreational fishing tourism. The impacts of diseases and parasites can be assessed at different levels; the individual animal, populations, communities and whole ecosystems can be affected.

The aetiology and pathogenesis of important infectious diseases and parasites found in Norwegian wild and farmed fish is summarized and discussed elsewhere in form of excellent books, reviews, and reports (Bruno et al. 2013, Boxaspen 2006, Johansen et al. 2011, Torissen et al. 2013, Sommerset et al. 2021) and even a very short introduction to each single pathogen included in the QSR would go beyond the scope of this report. Instead, we aimed at collecting and summarizing scientific evidence for if, how, and to what degree fish farming contributes to a spread of pathogens to the surrounding natural environment and the consequences thereof.

The cascade of impact of disease and parasites originating from fish farms on the environment depends on three elements: 1) the health situation of the farmed fish, 2) the rate and mode of transmission of the pathogen to the environment, 3) the susceptibility of the receiver (Figure 3.38). Impact occurs only if farmed fish are a source of a pathogen, the pathogen is released to the environment, and a wild host get exposed and is susceptible to the pathogen.

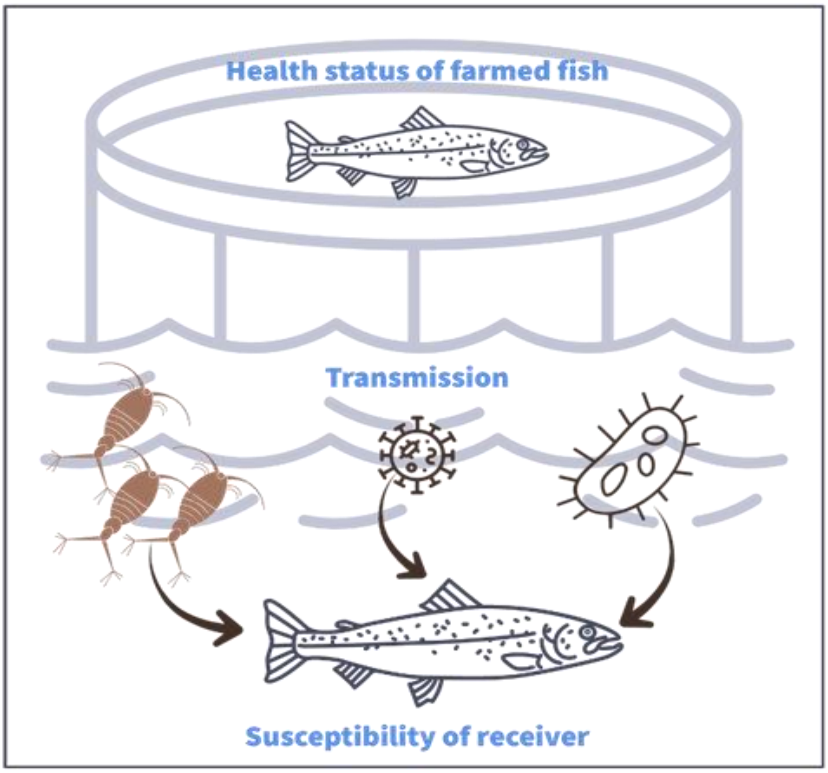


*Figure 3.38. Cascade of impact of disease and parasites from aquaculture on the environment.*

The risk for spreading from the farm site to wild fish populations is directly linked to the route of transmission of the individual pathogen. Examples of spreading potential of important pathogens relevant to the Norwegian fish farming industry is given in Table 3.7. Infection pressure at the farm site and survival of the pathogen in the absence of a host further affect the likelihood of transmission (Stene et al. 2014). Furthermore, environmental conditions such as temperature, salinity, water currents, as well as biotic aspects, for example escapees that can carry infections and parasites over longer distances, are important epidemiological factors. Another risk for long-distance spreading arises from moving farmed fish or cleaner fish between different sites, for example with well boats (Murray 2013). Finally, only if wild fish get exposed and are susceptible to the pathogen, they will be impacted.

*Table 3.7. Overview over major pathogens linked to disease outbreaks in Norwegian aquaculture and their potential for horizontal transmission via water.*

| **Pathogen** | **Disease** | **Distance infection risk = local contact network** | **Maximum distance from infection site where risk for infection > ambient levels** | **Reference** |
|---|---|---|---|---|
| Sea lice | - | na | 30 km<br><br>15 km<br><br>11 km (spring); 19 km (winter) | Krkosek et al. 2005<br><br>Salama et al. 2015<br><br>Samsing et al. 2017 |
| Salmonid alphavirus (SAV) | Pancreas disease (PD) | 5 km<br><br>8 km | 20 km<br><br>49 km | Stene et al. 2014<br><br>Aldrin et al. 2010 |
| Infectious salmon anaemia virus (ISAV) | Infectious salmon anaemia (ISA) | na<br><br>na | 15 km<br><br>11 km | Gautam et al. 2018<br><br>Aldrin et al. 2010 |
| Piscine myocarditis virus (PMV) | Cardiomyopathy syndrome (CMS) | na | na | |
| Piscine orthoreovirus (PRV) | Heart and skeletal muscle inflammation (HSMI) | na | 18 km | Aldrin et al. 2010 |
| *Renibacterium salmoninarum* | Bacterial kidney disease | Within farm, between cages | na | Murray et al. 2012 |
| *Moritella viscosa* | Winter ulcer | No evidence for horizontal transmission | na | MacKinnon et al. 2019 |
| *Tenacibaculum* | Tenacibaculosis/ mouthrot | No evidence for horizontal transmission<br><br>Possible horizontal transmission | na | Avendaño-Herrera et al. 2006<br><br>Frisch et al. 2018; Bateman et al. 2022 |

**Key findings:**

- More than half of the studies reporting impacts of pathogens released from fish farms to the environment focus on sea lice.
- Literature provides strong support that environmental sea lice levels are driven by extensive aquaculture.
- Results from release-recapture experiments of salmon smolts treated with sea lice prophylaxis are highly variable.
- The degree of impact of sea lice on wild salmonid populations depends on other factors, e.g. population status, temperature, than just sea lice levels.
- The link between individual sea lice levels on captured wild fish and population remains uncertain.
- No correlation between sea lice pressure and wild fish infestations in Norwegian production areas with generally high lice levels leaves open questions with regards to management efficiency.
- Comparable few studies on the effects of other parasites, viruses and bacterial diseases originating from fish farms on wild fish.
- Overall low prevalence of viral and bacterial diseases commonly found at fish farms in wild fish populations, with few studies assessing a potential correlation between outbreaks at fish farms and screening of wild fish.
- Knowledge gaps exist if surveys of wild fish underestimate disease prevalence due to reduced fitness of diseased fish, or if wild fish are less susceptible to certain pathogens compared with farmed fish.

#### 3.3.5.2 QSR results

The literature search resulted in a total of 947 hits, 349 of these were deemed relevant after the quick screen in Rayyan. Another 53 articles were categorized irrelevant when conducting the full text screen. The most common reasons for exclusion were “wrong species” and “focus only on farmed fish”. Review articles were, with a few exceptions, not included in the evidence extraction. The QSR did not pick up all relevant literature. A total of 10 references were added “manually” to the QSR list. Other important literature that was not falling into QRS criteria, but that is referred to in this chapter is listed under “Other references” in the reference list.

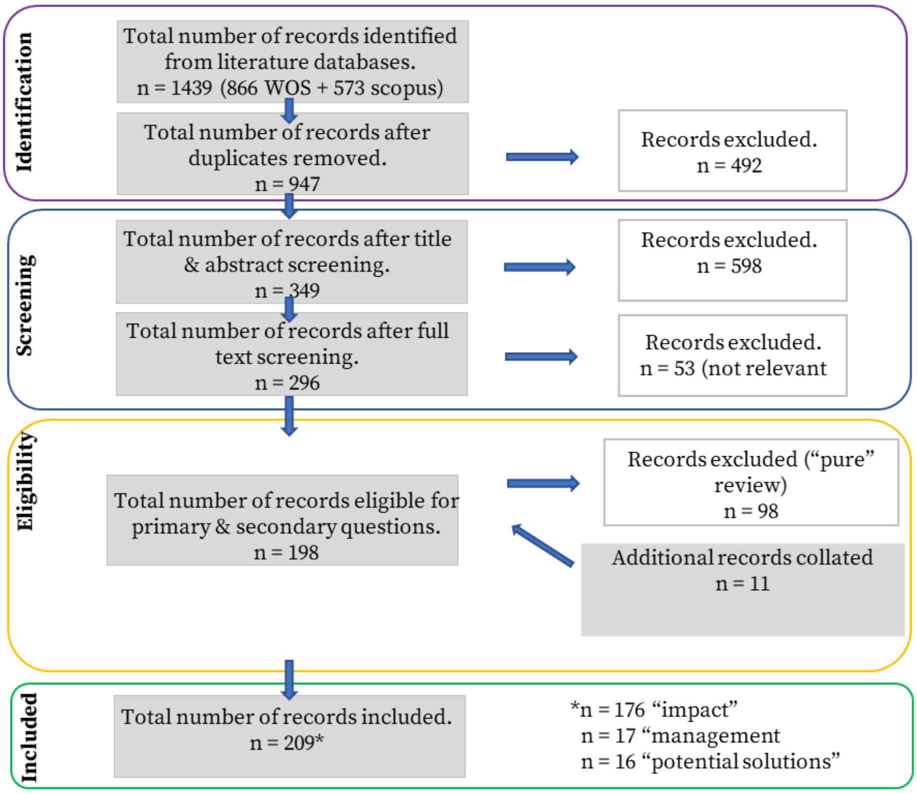


*Figure 3.39. Flow chart describing the applied QSR procedure for the topic disease and parasites.*

Over fifty percent of the literature focused on the impacts of sea lice, followed by articles describing impacts and potential risks for the environment caused by viruses. Only a few studies are published that describe transmission of diseases caused by bacteria to wild fish (Figure 3.39). The methodological approach used in most of the studies fell under one or more of the categories presented in Figure 3.41. Most of the published research assessed potential environmental impacts of parasites and diseases derived from fish farming sites based on data collected in the field (Figure 3.41, Figure 3.42).

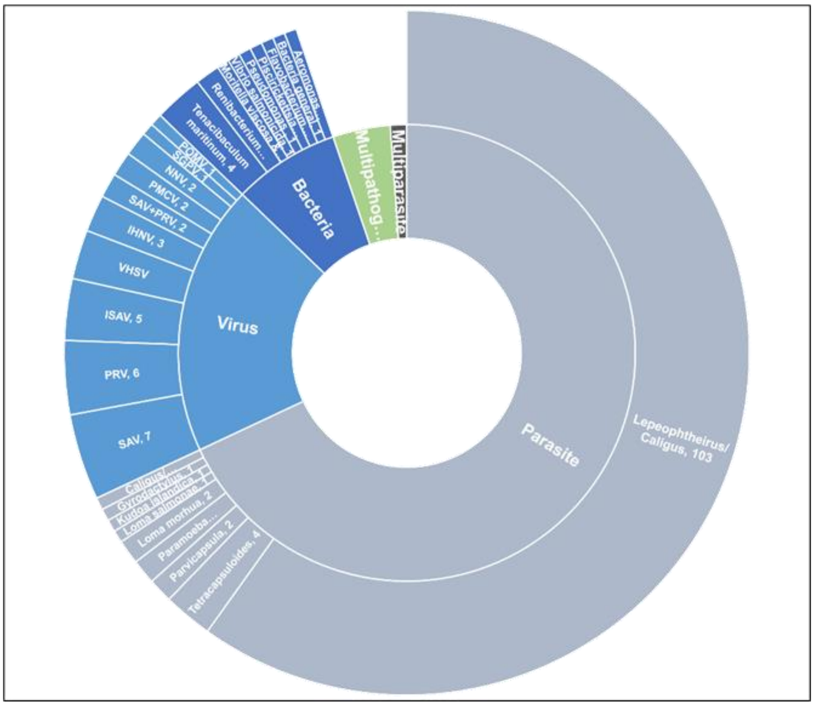


*Figure 3.40. Representation of different stressors in the QSR included in the evidence extraction.*

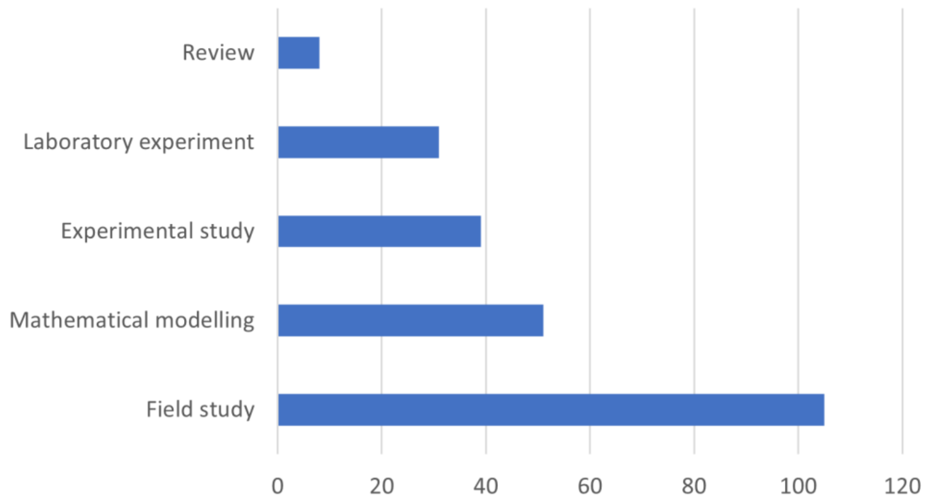


*Figure 3.41. Most common methodological approaches identified in the QSR.*

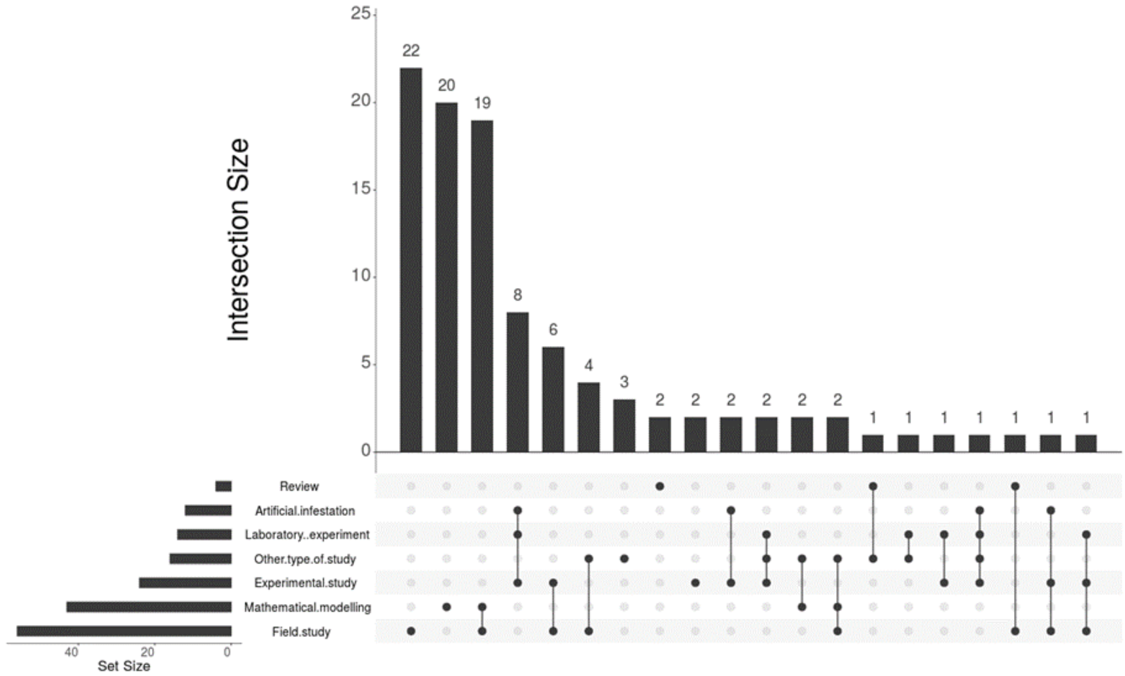


*Figure 3.42. Up-set graph illustrating the methodological approaches used to study impacts inflicted by sea lice.*

### 3.3.5.3 Receiver and impact

The receivers assessed in the different studies could be categorised into four major groups: wild salmonids, environment (e.g. water column, lower trophic levels, society), farmed fish and other wild fish than salmonids (Figure 3.43). Wild Atlantic salmon and pathogen abundance in the environment were the most abundant receivers studied, followed by other salmonids.

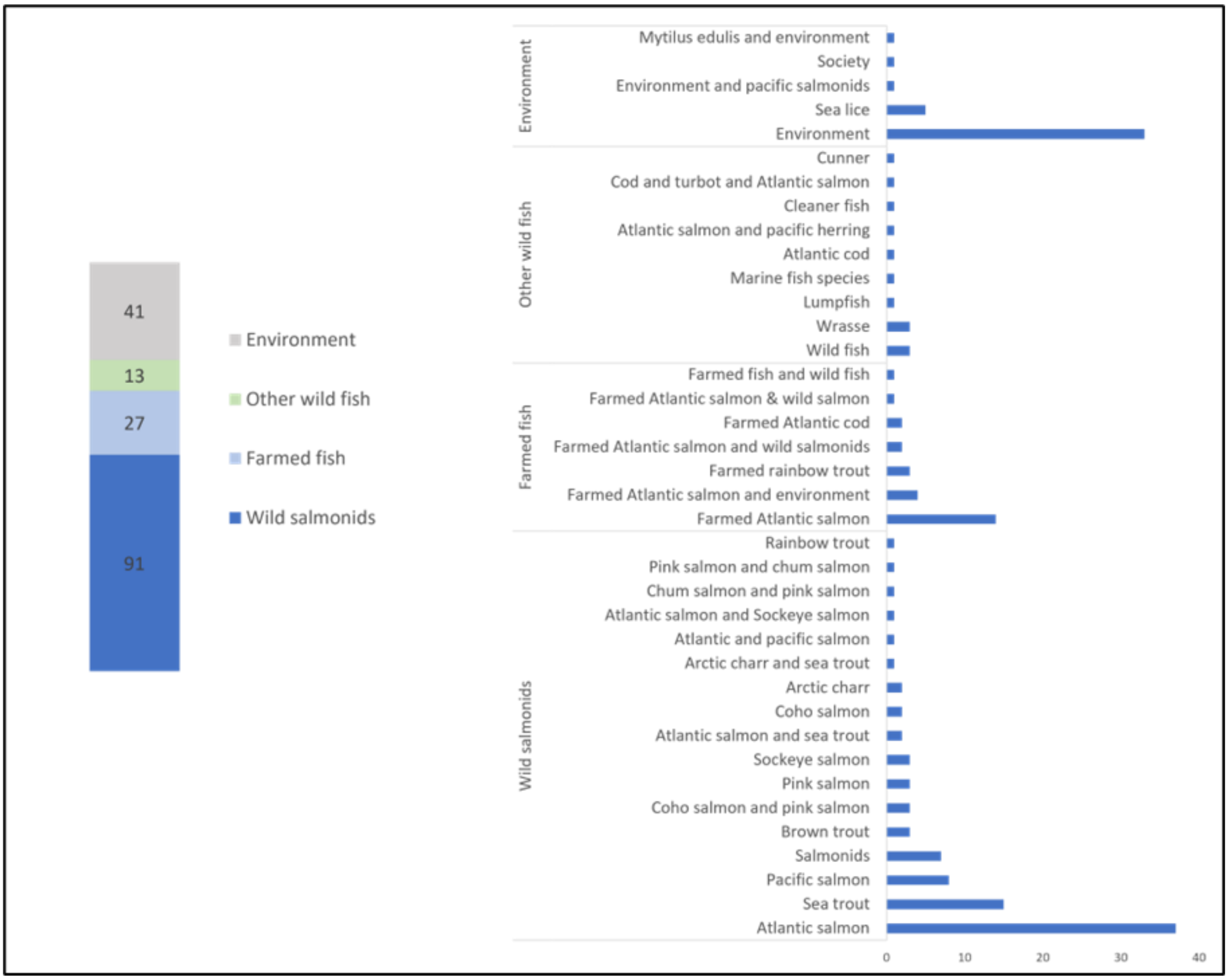


*Figure 3.43. Overview over receivers covered in the studies included in the evidence extraction.*

Most of the field studies focusing on sea lice were conducted in Norway and Canada and a similar geographical distribution was found for other diseases (Figure 3.44).

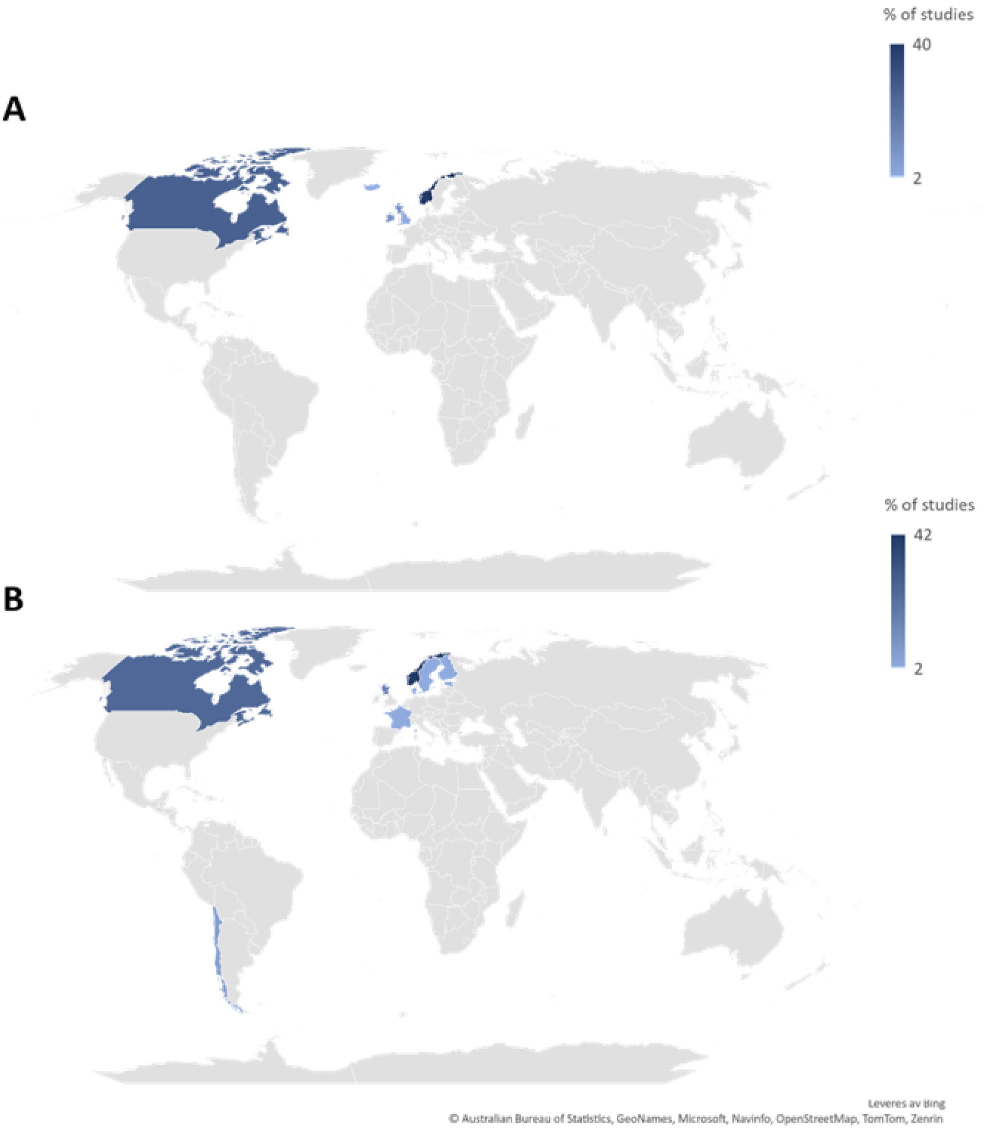


*Figure 3.44. Geographical distribution of field studies on impacts of sea lice (A) and studies focusing on other pathogens (B), identified in the QSR.*

### *Impacts of sea lice*

Sea lice was by far the most abundant stressor in the category "disease & parasite" studied. Publications presenting data from Europe focused mainly on the impacts of sea lice on Atlantic salmon, sea trout, and a few reported effects on Arctic charr, whereas studies from Canada focused on pacific salmon (mostly Coho salmon, Chum salmon, Pink salmon). Salmon farming is the major source of sea lice in Norwegian coastal waters. For 2017 it has been estimated that > 99 % of female sea lice abundance originated from salmon farms (Dempster et al. 2021). The degree of impacts caused by the amplification of sea lice numbers by aquaculture are, however, still difficult to assess.

Strong evidence exists that wild salmonids are more exposed to sea lice in regions with intensive fish farming. Several studies from Norway, Ireland and Canada have demonstrated that sea lice infestations on wild fish correlate positively with fish farming activities (Bjørn et al. 2011, Morton et al. 2011, Price et al. 2011, Halttunen et al. 2018, Shepard and Gargan 2021). In Iceland, where salmon farming is a relatively young industry, sea lice intensities on wild fish still resembled those of natural background levels in 2014 (Karbowsky et al. 2019). Studies on background levels of sea lice intensities in areas without salmon farming (Gargan et al. 2016) are valuable references for monitoring programmes.

Articles assessing sea lice induced population declines of wild salmonids report highly variable results, both between experiments within studies (e.g. Skilbrei et al. 2013; Krkosek et al. 2013; Vollset et al. 2014) and between studies. Release-and-recapture studies of hatchery reared smolts where parts of the population had been treated with anti-sea lice agents prior to release provide overall evidence that sea lice negatively affect the return rates of Atlantic salmon (Gargan et al. 2012, Skilbrei et al. 2013, Jackson et al. 2013, Krkosek et al. 2013, Vollset et al. 2014, Vollset et al. 2016, Bøhn et al. 2020). Based on these studies, sea lice induced mortality ranges from 0.6 % to 31.9 % (upper level reported in one study, Vollset 2014) and up to 98.4% added mortality in another study (Bøhn et al. 2020). Release-recapture experiments need to be interpreted with care due to some methodological limitations (Vollset et al. 2016): In these experiments, hatchery-reared smolts are released and it is likely that return rates are directly dependent on the quality of the smolts. Indeed, it has been speculated that the susceptibility to sea lice is context dependent (Vollset 2019). A metanalysis of release-recapture studies of Atlantic salmon smolts provides evidence that the treatment effects of sea lice prophylaxis vary with baseline mortality. In years with high baseline mortality, sea lice induced mortality was found to be larger in the control groups than in the treatment groups, whereas no to little effect of treatment was found in periods with high return rates (Vollset et al. 2016). Interestingly, in this meta-analysis, no relationship could be established between sea lice exposure by farms and sea lice prophylaxis treatment effects. Variation in treatment efficiency may occur due to the development of resistance against pharmaceuticals (see also chapter 3.3.3.5 of this report). Time-point of release, location, migration route and hydrodynamic conditions are other possible explanatory variables for the highly variable results found in these studies. Release-and-recapture experiments are highly labour and cost intensive and most of these studies have been conducted in areas with overall high sea lice pressure (Western Norway), whereas few studies of this kind have been conducted in Northern Norway. Similar studies have been carried out with sea trout, however, these do not provide evidence that immunisation against sea lice improve survival (Gjelland et al. 2014, Halttunen et al. 2018).

The distances between migration routes of wild salmonids and fish farms are a key factor for infestation pressure recorded on wild fish and baseline levels have been recorded in areas 30 km away from farms (Serra-Llinares et al. 2014). Yet, sea lice dispersal may vary between location, season and hydrography and a general safety zone of 30 km may not reflect site specific infestation pressure (Samsing et al. 2017).

The overall return rates of Norwegian Atlantic salmon to their natal rivers have been declining over the past decades with a historically low return of 403,000 salmon in 2021 (Thorstad et al. 2022). Sea lice infestations on wild fish depend on the migration time point (Vollset et al. 2016), distance (Harvey et al. 2019), and swimming speed (Halttunen et al. 2018). Most articles and reports presenting field data from sea lice counts on wild fish estimated population reduction effects attributable to sea lice based on the risk model developed by Taranger et al. (2015). Collection of field data is labour and cost intensive. Using a virtual post-smolt model that incorporates the risk model developed by Taranger et al. (2015) and sea lice concentrations based on a dispersion model, Johnsen et al. (2021) modelled the sea lice induced mortality of salmon from 401 rivers and calculated a sea lice induced mortality of <10% for 179 rivers, 10–30% for 140 rivers, and >30% for 82 rivers in 2019. However, Jansen and Gjerde (2021) compared the modelled mortality with field data and criticised that the model systematically overestimated lice induced mortality compared with field data.

A recent study from Ireland found on average 33 % lower return rates of Atlantic salmon to rivers migrating through coastal areas with salmon farms after years with high sea lice densities compared with salmon originating from areas without salmon farms (Shephard and Gargan 2021).

Population reduction effects of sea lice on sea trout remain inconclusive with studies reporting some impacts on survival (Shephard and Gargan 2021; Paterson et al. 2021), whereas other studies did not provide evidence for impacts (Halttunen et al. 2018; Serra-Llinares et al. 2018). Several studies reported effects on migratory behaviour (Halttunen et al. 2018; Mohn et al. 2020; Bøhn et al. 2022) and body condition (Shephard et al. 2016).

Artificial sea lice infestations affect osmoregulatory capacity, growth rate and survival in anadromous Arctic charr under experimental conditions (Fjelldal et al. 2019). Effects of sea lice on anadromous Arctic charr populations have been studied to a lesser degree in the field. A recent study from Northern Norway provides indications that sea lice infestations may alter the migratory behaviour of anadromous Arctic charr by shortening their stay at sea (Strøm et al. 2022).

Studies from Canada, especially the region Broughton Archipelago, reveal similar impacts of salmon lice on pacific salmon populations as reported for wild Atlantic salmon in Norway. Estimated lice induced mortality on pink salmon based on field data collection and mathematical modelling has been reported from 1% in years with low lice abundance to 87% in years with high lice numbers and similar numbers have been reported for coho salmon (Krkosek et al. 2011).

*Impacts of other parasites*

A total of 15 papers were found that focused on other parasites with a focus on fish farm-environment interactions. None of the included studies assessed population regulation effects. Most of the other focused on freshwater parasites. *Tetracapsuloides bryosalmonae* is the causative agent of proliferative kidney disease, and is common in wild fish, mainly brown trout, but also Arctic charr and Atlantic salmon. Outbreaks have caused problems for freshwater rainbow trout farms. It is not clear whether fish farms amplify the abundance of this parasite, but experiments have shown that the parasite infection can persist over several years (Soliman et al. 2018). A larger screening of wild fish conducted in Danmark showed that clinical symptoms of *T. bryosalmonae* are less prominent in wild fish than in farmed fish and it has been speculated that wild fish are less susceptible to *T. bryosalmonae* (Skovgaard and Buchmann 2012). Warmer water temperatures (Bruneaux et al. 2016) and interaction with other diseases (Kotob et al. 2017) may increase the risk for more severe impacts of *T. bryosalmonae*. Another freshwater parasite that has caused damage to wild salmon populations is the monogenean *Gyrodactylus*. *Gyrodactylus salaris* was accidently introduced to Norwegian freshwater systems by moving smolts from Swedish hatcheries to Norway in the 1970s (Bruno et al. 2013) with devastating consequences for salmon populations and secondary impacts on many freshwater systems because of radical eradication measures of this parasite. A study from Canada assessed the release of *Gyrodactylus* larvae from a rainbow trout farm and calculated a daily release of 230 000 larvae with discharge water (You et al. 2011), however the impacts on wild fish populations were not assessed in this study.

*Paramoeba peruans* is the causative agent of amoebic gill disease (AGD) in Atlantic salmon. Outbreaks of amoebic gill disease have been an increasing fish health problem at aquaculture farms during the past few years (Sommerset et al. 2022). In this review we found no evidence for impacts of *P. peruans* on wild fish populations. However, *P. peruans* has been detected in water samples, biofilms, cnidarians, molluscs and fish sampled in vicinity to a salmon farm and as well on salmon and cleaner fish within the farm during an AGD outbreak (Hellebø et al. 2017). This study provided high evidence that *P. peruans* is released from farms with AGD outbreaks and can be transmitted horizontally via the water column, but currently there are no reports of negative effects on wild fish populations. Filter feeders are likely not a reservoir of *P. peruans* but can potentially clear the pathogen from the environment (Rolin et al. 2016).

*Parvicapsula pseudobranchicola* is a myxosporean parasite that commonly infects farmed Atlantic salmon (Nylund et al. 2018). The development of this parasite depends on an annelid as intermediate host. Infection dynamics show a seasonal pattern in the release of mature spores into the water and farmed salmon develop immunity against this parasite (Nylund et al. 2018). No studies were found that investigated a possible higher prevalence of *P. pseudobranchicola* infection in salmonids caught in proximity to salmon farms.

*Loma salmonoae* is a microsporidian parasite that affects pacific salmon species (for example rainbow trout), but not Atlantic salmon. A study assessing the genetic diversity of *L. salmonae* found little genetic variation of *L. salmonae* isolated from anadromous populations and sea ranched fish indicating a high potential for marine transmission (Brown et al. 2010). However, this study did neither evaluate the impact on wild populations nor did the study provide evidence for a possible amplification and spill-back of *L. salmonae* to the environment by fish farms. *Loma morhua* infects cod and is a recognised problem in cod aquaculture that causes poor growth and mortality. The QSR found two studies reporting on the effects of *L. morhua* on farmed cod, and the possibilities of breeding cod families that are resistant towards *L. morhua* (Frenette et al. 2020, Frenette et al. 2022). However, no studies were found that assessed a possible transmission of *L. morhua* from farmed to wild cod.

Farmed Atlantic salmon and cod are not the only host for parasite infections, but also farmed lumpfish for sea lice control in salmon farms are susceptible to disease and parasite infections. High prevalence of *Kudoa islandica,* and the microsporidian *Nucleospora cyclopterid* have been reported (Alarcon et al. 2016) in one study, indicating a potential risk for spill-back of these parasites to wild fish populations. Natural hosts for these parasites are amongst other, Atlantic wolffish (*Anarhichas lupus*), spotted wolffish (*A. minor*) and wild lumpfish but no studies were found that assessed the infestation of these parasites in wild fish residing in areas with fish farming activity. Wild-caught cleaner fish, such as ballan wrasse, are often infected with multiple pathogens and translocation of these fish to new areas harbours a risk of pathogen introduction in these areas (McMurtrie et al. 2019).

### Impacts of viral diseases

Outbreaks of viral diseases at fish farms occur regularly, causing economic damage and fish welfare issues for the aquaculture industry. Pancreas disease (PD) caused by the salmonid alphavirus (SAV) and infectious salmon anaemia virus (ISAv) cause severe diseases and fish farmers are obliged to report any suspected outbreak to the Norwegian Food Safety Authority. Virus shedding from farm areas carries a risk of horizontal transmission to wild fish and seaway of transmission varies between viruses (Table 3.7). Several studies that were included in the QSR addressed questions concerning infectivity and transmission dynamics of SAV (Stene et al. 2014, Jarungsriapisit et al. 2020), ISAV (Vike et al. 2014; Gautam et al. 2018), Infectious Hematopoietic Necrosis Virus (IHNV) (Garver et al. 2013; Foreman et al. 2015), Haemorrhagic septicaemia virus (VHSV) (Vennerström et al. 2020), Pilchard orthomyxovirus (POMV) (Samsing et al. 2021), and Nervous Necrosis virus (Korsnes et al. 2012).

The detection of virus outbreaks in wild fish populations is a challenging task. Wild fish with clinical symptoms and resulting reduced fitness become an easy prey and will likely not be picked up by monitoring programmes (Taranger et al. 2015). Screening surveys on wild fish provide important information on the prevalence of viral diseases in wild fish populations. Articles identified in the QSR providing information about the prevalence of important viruses in wild fish are presented in Table 3.8.

*Table 3.8. Studies identified in the QSR that described the prevalence of important viral diseases in wild fish populations.*

| Virus | Prevalence in wild fish populations | Authors |
|---|---|---|
| Piscine orthoreovirus | Low<br><br>Low (5 %) in absence of fish farms; moderate (37-45 %) in wild fish exposed to fish farms<br><br>Low<br><br>Low | Madhun et al. 2018<br><br>Morton et al. 2017<br><br>Garseth et al. 2013<br><br>Madhun et al. 2016 |
| SAV | Low<br><br>Low<br><br>Low | Madhun et al. 2018<br><br>Madhun et al. 2016<br><br>Snow et al. 2010 |
| Piscine myocarditis virus (PMCV) | Low | Garseth et al. 2012 |
| ISAv | Variable, no direct correlation with farm outbreaks | Nylund et al. 2019 |
| Viral Hemorrhagic Septicemia Virus (VHSV) | Low | Sandlund et al. 2014 |
| Salmon gill poxvirus (SGPV) | High | Garseth et al. 2016 |

Only few articles provided evidence for a connection between virus outbreaks at fish farms and an elevated virus prevalence in adjacent wild fish populations (Morton et al. 2017, Nylund et al. 2019). The study by Morton et al. (2017) indicates that PRV infections negatively impact the fitness of migrating pacific salmon.

### *Impacts of bacterial diseases*

Few studies focusing on impacts of bacterial diseases were found in the QSR. Two studies provided evidence for potential indirect impacts to the environment resulting from antibiotic treatment at the fish farm and hence release of antibiotic resistant strains to the environment (Hayatgheib et al. 2021; Lozano-Munoz et al. 2021). One study assessed the prevalence of the freshwater pathogen *Renibacterium salmoninarum* in wild salmonids caught in proximity to a rainbow trout farm and found that out of 1058 caught fish, 50 fish were tested positive with only one fish showing clinical signs of bacterial kidney disease (Persson et al. 2022). During the past years, the bacterium *Tenacibaculum*, a causative agent of mouthrot disease, has become an emerging threat to farmed salmonids. *Tenacibaculum* has a poor survival in seawater and low risk for waterborne transmission over longer distance (Table 3.7). The QSR identified two papers that provide evidence for transmission of *Tenacibaculum* via non-salmonids hosts, such as jellyfish (Delannoy et al. 2011) and cleaner fish (Småge et al. 2016), indicating a risk for spill-back from farmed fish to wild fish populations through intermediate wild hosts and vice versa. Two recent studies from Canada provide evidence that the prevalence of *Tenacibaculum* in wild sockeye salmon is elevated in proximity to fish farms (Shea et al. 2020; Bateman et al. 2022).

#### 3.3.5.4 Monitoring

The full text screen revealed that the articles dealing with sea lice cover a wide range of monitoring methods spanning from sea lice counts on farms, plankton trawls, dispersion models, modelled and measured infestation pressure using of sentinel cages and prevalence and intensity of infestation levels on out-migrating smolts and other wild salmonids (e.g. NALO (Overvåkingsprogrammet for lakselus på vill laksefisk) trawls in Norway). Studies using plankton trawls are less represented than for example lice dispersion models based on lice counts, or the use of sentinel cages to estimate infestation pressure. Salmon post-smolts, sea trout and charr that migrate through a fjord system originate usually from different populations and the conservation status of these populations will affect the degree of impact by sea lice (Vollset et al. 2016). Differences in temperature across latitudes can furthermore affect the degree impacts of sea lice on salmonid populations (Vollset et al. 2019). Most of the studies assessing impacts of sea lice experimentally in the field originate from areas in South-west and mid-Norway (e.g. the Vosso region). Impacts on salmonids in Northern Norway are less well studied. In comparison to sea lice, the impacts of viruses and bacteria are more difficult to monitor. Methods used in the selected QSR articles include screening of captured wild fish in monitoring surveys (pathogen detection using molecular methods such as qPCR, histological assessment), and correlation with fish health reports from fish farms. Overall, there is only a low prevalence of common viral and bacterial diseases in wild fish populations. Two possible explanations could be that i) wild fish are less susceptible to the studied diseases, or ii) diseased wild fish will quickly disappear and will therefore be underrepresented in monitoring surveys.

#### 3.3.5.5 Knowledge gaps

To evaluate the impacts of fish farm derived pathogens on the environment, ideally a combination of data describing the health situation at farm site, release, and abundance of pathogens to the environment, and susceptibility of the receiver is needed. Most studies screened in this QSR did not consider all three elements, but focused either on the receiver, the health situation or the pathogen dynamics and transmission to the environment. In the case of sea lice, there were several studies that took all three elements into consideration.

In their much-cited review "Risk assessment of the environmental impact of Norwegian Atlantic salmon farming", Taranger and co-authors (2015) expressed some important limitations of their proposed risk model, amongst others that the link between individual lice infections and population effects is uncertain. In the QSR we did not find any recent publications that followed-up this concern, and many studies employed the salmon lice risk index referring to Taranger et al. (2015). Depending on the tolerance level of Atlantic salmon to sea lice the assumed mortality of a 20 g post-smolt infested with 2-3 sea lice can be 10%, 20%, or 40% (Johnsen et al. 2021). Such a high uncertainty in response to sea lice at the individual level will cause an even higher uncertainty when estimating population level effects and more knowledge is needed for a more precise estimate of population effects of sea lice. A relatively recent study correlated sea lice pressure and infestations on wild fish and found lowering the lice threshold has no significant impact on the share of severely infested wild salmonids (Larsen and Vormedal 2021). The lack of correlation between sea lice infestations on wild fish and sea lice counts at fish farms leaves open questions about the efficiency of the current sea lice management.

Several publications in the QSR conclude that the sea lice induced mortality cannot be assessed isolated from other factors, and show at the same time that effects of sea lice are more detrimental for salmon populations with vulnerable status. The contribution of sea lice induced mortalities considering effects of different stressors under different scenarios needs further investigation.

During the past 13 years impacts of other parasites, viral, and bacterial diseases have been much less studied than sea lice (Figure 3.39). Viruses and bacterial diseases are difficult to monitor in wild fish populations. Overall, there seems to be a much lower prevalence of viral and bacterial diseases in wild fish population than at the fish farm level. The use of sentinel cages to study effects on other fish in the fjord during a disease outbreak could be an interesting approach to study horizontal transmission of other pathogens than sea lice. It has been speculated that wild fish may be less susceptible to some of the viral diseases which may explain the lack of clinical symptoms. The question if wild fish populations are less susceptible than farmed fish could be followed up in controlled experiments. Such experiments would serve both the understanding and management of wild populations and could provide valuable information for breeding programmes.

### 3.3.5.6 Conclusions

In summary, the QSR review showed that sea lice is by far the best studied pathogen released from fish farms to the environment. There is strong evidence that fish farms increase sea lice abundance in fjords with high fish farming activity. Yet, the infestation levels of wild fish correlate weakly with sea lice counts farm sites (Larsen and Vormedal 2021). Studies reporting on sea lice induced mortality show high variation, both between experiments within a study, and between studies. Overall, there is still large uncertainty with regards to the degree of sea lice induced mortality in wild fish populations. Other pathogens have been less studied than sea lice, and the relative few studies per pathogen identified in this QSR provide only limited evidence for effects of viral and bacterial diseases originating from fish farms on wild fish populations. Yet, phylogenetic analyses reveal pathogen exchange between farmed and wild fish populations. Translocation of eggs, farmed fish and wild captured cleaner fish may introduce pathogens to novel areas and pose a risk factor. More studies are needed in order to conclude on the effects of other pathogens than sea lice from fish farms. Close monitoring of fish health and good biosecurity measures at the farm level will mitigate any possible negative effects of pathogens on wild fish populations.

### 3.3.5.7 References

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**Not QSR**

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### 3.3.6 Noise

#### 3.3.6.1 Background

Man-made noise in the sea can be defined as a type of pollution when it exceeds the natural background level. More human activity has led to increasing noise levels in the ocean the last 30–40 years (Kvadsheim et al. 2020), and noise pollution can travel long distances underwater, and hence cover large areas (Chahouri et al. 2022). The source for marine noise pollution can be both biotic and abiotic sounds (Figure 3.45).

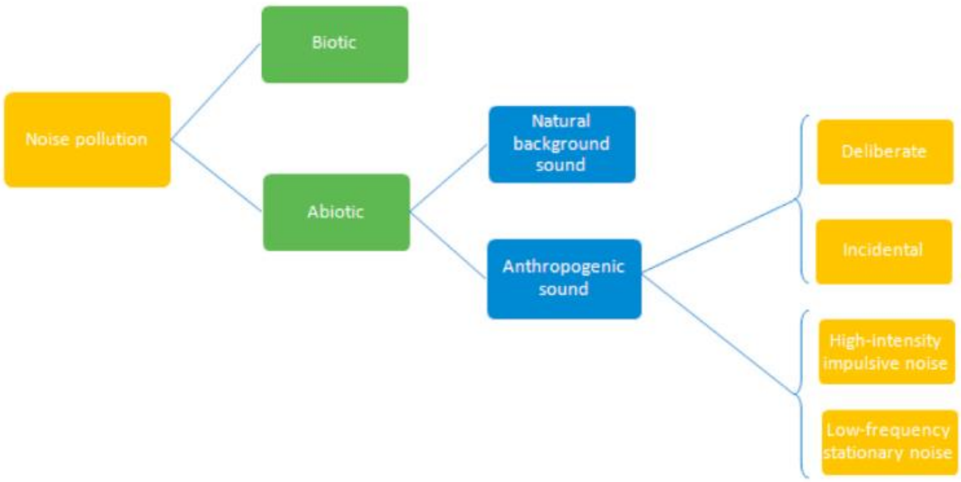


*Figure 3.45. Sources of underwater noise pollution. (Source: Chahouri et al. 2022).*

Biotic sound sources are some marine organisms, and almost all higher marine organisms use sound either to orientate, find food, avoid predators or to communicate with others. Additional noise can disturb signals to/from animals and cause negative effects.

Anthropogenic sound and noise induced by onshore and offshore aquaculture farms may be stressful to various species. Noise from aquaculture originates from normal farm operations (e.g. farm machinery, operational vessels), and is considered low frequency stationary noise. In addition, occasionally produced noise may occur in connection with e.g. construction and demolition. Noise is also sometimes used to ward off predators, particularly pinnipeds, e.g., Acoustic Harassment Devices – AHDs (cracker shells and the targeted acoustic startle technology), that may be more high-intensity impulsive noise. Acoustic deterrent devices can be effective on reducing the nearby density of several marine mammals.

There is a concern that noise related to aquaculture activities may have a variety of attraction and repulsive effects on invertebrates, fish, birds and marine mammals. This is due to noise potentially influencing behaviour that includes flight reactions, avoidance, or changes in swimming behaviour. Furthermore, negative effects on physiological processes, reproduction and welfare may also occur.

**Key findings:**

- Noise induced by onshore and offshore aquaculture farms may be stressful to various species.
- Two main noise sources have been described for aquaculture. 1) chronic noise, particularly from vessels and their sonar, and the routinely produced noise during normal operation of aquaculture facilities. 2) acoustic deterrent devices (ADD), that are more pulsed sounds at extended periods of time.
- The knowledge gathered indicates that noise associated with aquaculture is unlikely to cause permanent harm to aquatic animals, except for marine mammals exposed to pyrotechnic deterrents, or the most powerful ADDs at very close range or over extended periods of time.
- Noise from aquaculture may, however, affect biologically important behaviour such as grazing, reproduction and anti-predator behaviour in fish. It cannot be ruled out that noise affects population level, but there is still lacking knowledge of how local effects affect the population level of fish.
- The key knowledge gap is to understand whether and how levels of man-made marine noise may lead to effects at the population and ecosystem scales, particularly for vulnerable/threatened species and key functional groups, and in addition how to quantify the risk of impact at these scales.

### 3.3.6.2 QSR results

The quick scoping review identified 256 articles possibly related to the effect of noise on the marine environment, but a closer assessment of these articles revealed that only 10 papers were explicitly related to impacts from aquaculture on the environment (Figure 3.46). The studies were mostly based on field observations (n=8), but also on modelling efforts (n=2). Studies were conducted in Italy, Scotland, Canada and USA. The relevant papers were largely focussed on acoustic deterrent devices (n=7) as well as the soundscape (n=3) associated with aquaculture farms. In addition, relevant grey literature and other relevant literature (n=10) was included (Figure 3.46).

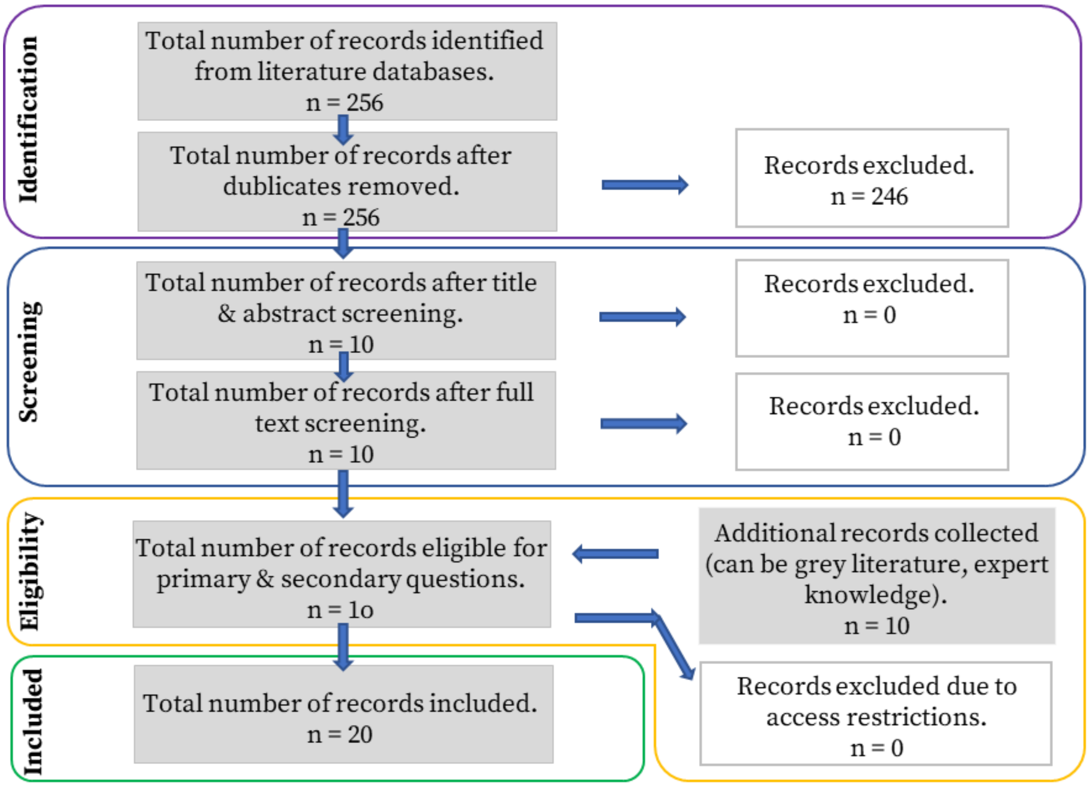


*Figure 3.46. PRISMA flowchart visualising the different steps of the selection process of the QSR for Noise.*

### 3.3.6.3 Receiver and impact

Aquaculture, like most maritime activities, generates noise, and water is an excellent medium for transmitting noise, which can propagate tens or even hundreds of kilometres from the sound source. Noise, particularly from vessels and their sonars, is produced during normal operation of aquaculture facilities and may have localized or transitory effects on aquatic animals and are contributing to the chronic problem of increasing levels of anthropogenic noise in the oceans (Olesiuk et al. 2010). Many aquatic organisms utilize sound for communication and foraging, and some species have their best hearing sensitivities within the dominant frequency ranges of sounds produced by aquaculture operations (Olesiuk et al. 2010). Noise levels and frequencies measured within intensive aquaculture systems are within the range of fish hearing, but species-specific effects of aquaculture production noise are not well defined (Davidson et al. 2019).

Most studies on the impact of noise in the aquatic environment have been performed on marine mammals, however there is an increasing awareness of the potential negative effects on other marine organisms, including invertebrates and fish (Sierra-Flores et al. 2015).

With regard to fish, the literature is sparse and does show conflicting evidence with reports of fish being attracted as well as showing avoidance reactions, depending on the sound sources. In cases where an effect is reported it has been suggested that migration patterns and reproductive behaviour may be disturbed by noise, forcing fish to find alternative routes or preventing them from settling in their usual spawning grounds and thus possibly impacting on larval settlement (Sierra-Flores et al. 2015).

In offshore cage condition, fish are exposed not only to sea background noise but also to noise generated by cage machinery and by marine traffic of different boat types. A study by

Filiciotto et al. (2017) demonstrated that the offshore aquaculture noise, and in particular the sea soundscape, adversely influences the oxidative status and the immune function of gilthead sea bream determining a mild stress condition that could affect the sea bream's welfare. It was also shown that caged Atlantic salmon themselves may alter the acoustic environment when compared to an empty net-pen, and that the acoustic fingerprint of the net-pen varies over time and mirrors the feeding status of the fish (Rosten et al. 2023).

In a study by Bjørn et al. (2021) the aquaculture facility as an aggregating device for wild fish was studied. They investigated the response of Atlantic cod, and possible related impacts, to noise produced by aquaculture facilities. Wild fish, such as Atlantic cod, communicate with "grunts" during mating, aggression, or flight. Female cod prefers males with larger bodies and long fins, but spawning success is also correlated with volume of the "grunts" from the male fish (Rowe & Hutchings, 2008). Cod exposed to long-term noise have been reported to have a lower fertilization rate, with up to a 40% reduction, than non-exposed fish. Fish exposed to short-term noise has also shown an increase in blood cortisol (Sierra-Flores et al. 2015). The results of these studies reported in Bjørn et al. (2021) show that noise-generating aquaculture activities can affect reproduction, both in terms of disruption of natural communication and through imposing stress. However, a study from farming-intensive and farming-extensive areas in Western Norway found small differences in fitness of wild cod compared to reference areas (Barett et al. 2018). Furthermore Björnsson et al. (2018) showed that native cod can be trained to associate low-frequency (250 Hz) sound with food. In addition, a study by Kvadsheim et al. (2020) concluded that most man-made noise sources are mainly low frequency, i.e. at a frequency that fish hear best. It has been proven that noise, and especially continuous noise, can affect biologically important behaviour such as grazing, reproduction and anti-predator behaviour in fish. Kvadsheim et al. (2020) concluded that it cannot be ruled out that noise affects population level, but there is still little knowledge about effects on the population level of fish. The study also concluded that there is limited knowledge on the effects of noise on invertebrates, but that existing studies suggest that noise can affect activity and hearing. It is unclear which levels of noise are required to cause physical damage.

Intense sounds have in some cases been intentionally produced to deter predator (seal and sea lion) attacks. Acoustic deterrent devices (ADD), used to deter seals attacks at salmon farms, have been shown to have far ranging effects on non-target cetaceans, such as harbour porpoise and killer whales, which can be displaced long distances from where ADDs have been deployed. In contrast, pinnipeds (seals and sea lions) appear to habituate to these devices, possibly as a result of hearing loss. They may experience hearing loss after prolonged exposure or very close approach, thus ADDs are largely ineffective as long-term predator deterrents (Olesiuk et al. 2010). Information about the amplitude and properties of the sound pulses generated by ADDs are discussed by Olesiuk et al. (2010), and it is indicated that they would be audible to marine mammals over great distances, sometimes ranging over tens or several hundred kilometres. A number of non-target species, such as porpoise, dolphins, and whales, seems to be more sensitive than seals and avoid areas where AHDs are being used. Given the large regions and travel corridors from which cetaceans can be excluded, these effects should be regarded as population-level impacts. Olesuik et al. (2010) suggested that such devices should be used with caution or even prohibited, as they may cause marine mammal auditory impacts and temporary habitat loss, in particular when applied on multiple farms that are located within a small area. From 2022, the U.S. Marine Mammal Protection Act has restricted imports of fish from salmon farms and commercial fisheries originating from countries that kill or injure marine mammals, e.g. those that use ADDs. Therefore, a new technology, the Acoustic Startle Technology (TAST), was developed. This technology claims to have a solution to seal predation in aquaculture. TAST is based on a different principle than ADDs. It sends out brief, isolated sound pulses that startle the seals and triggers their flight response, a bit like a dog whistle in reverse. Seals do not habituate to TAST, but it causes the animals to avoid the area (Holmyard, 2021). SalmonSafe with this TAST technology is now being used by aquaculture in Norway. It is the only acoustic device that will be approved by the Aquaculture Stewardship Council (ASC).

#### 3.3.6.4 Monitoring

Noise is included in the pollution regulations in Norway, but only on land. EU and US noise management measures are more advanced than in Norway, as there is currently no overall Norwegian plan for how noise pollution at sea should be regulated (Kvadsheim et al. 2020). It is recommended that the industries adopt practices to minimize noise and noise propagation, especially within or near ecologically and biologically sensitive areas (Kvadsheim et al. 2020). UK has, in their achievement of good environmental status for noise, two indicators that are used to assess underwater noise in the Celtic Sea and the Greater North Sea. These are impulsive noise indicator: records impulsive sound (developed both nationally and together with OSPAR Contracting parties (see OSPAR, 2017)) and a surveillance indicator for ambient noise; records ambient "continuous" noise.

#### 3.3.6.5 Knowledge gaps

There is considerable evidence for effects of impulsive sound on individual marine organisms. The effects can be subtle (such as hearing sensitivity reduction or physiological stress) or obvious (such as changes in behaviour, death), however, there is uncertainty in the potential impacts on individual vital rates, populations and ecosystems. The key knowledge gap is to understand whether and how levels of man-made marine noise lead to effects at the population and ecosystem scales, particularly for vulnerable/threatened species and key functional groups, and how to quantify the risk of impact at these scales. Risks to populations need to be more clearly established in order to develop proportionate measures (CEFAS, 2018). There is still lack of knowledge related to how local sound may affect fish populations. Therefore, sensitive ecosystem components, particularly cetaceans, should be monitored in the vicinity of aquaculture operations and vessel traffic.

The use of low frequency sound as an acoustic de-lice removal for farmed salmon has recently been tested. The system is supposed to bring the salmon lice into a dormant state, so that it does not infest salmons. It is still not known what kind of sound pulses that must be used or at which sound levels, but low-frequency sound propagates far, with low attenuation. Before this type of acoustic systems are adopted on a large scale by the aquaculture industry, thorough investigations into how such noise sources will affect local occurrences of fish, crustaceans, and mammals (seals and porpoises) are needed (Kvadsheim et al. 2020).

#### 3.3.6.6 Conclusions

Noise induced by onshore and offshore aquaculture farms may be stressful to various species. This anthropogenic noise soundscape has been measured and described. Two main noise sources have been identified. Chronic noise, particularly from vessels and their sonar, is routinely produced during normal operation of aquaculture facilities. In addition, acoustic deterrent devices (ADD), produce pulsed sounds at extended periods of time. The knowledge gathered indicates that noise associated with aquaculture is unlikely to cause permanent injury to aquatic animals, except for marine mammals exposed to pyrotechnic deterrents or the most powerful ADDs at very close range or over extended periods of time. This noise may also affect biologically important behaviour, such as grazing, reproduction and anti-predator behaviour in fish. It can hence not be ruled out that noise can have effects at population level, but there is still little knowledge about how local sources affect the population level of fish. The key knowledge gap is to understand whether and how levels of man-made marine noise may lead to effects at the population and ecosystem scales, particularly for vulnerable/threatened species and key functional groups, and how to quantify the risk of impact at these scales.

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### 3.3.7 Light

#### 3.3.7.1 Background

Many coastal marine ecosystems are exposed to artificial light at night (ALAN). Sources of ALAN in the marine environment vary, with shipping, aquaculture and light fisheries contributing as temporary sources in nearshore and offshore waters. The vast majority of organisms have light-sensitive receptors and react to light. Light pollution can be easily defined as when organisms are exposed to light in the wrong place, at the wrong time or with the wrong intensity.

Artificial light pollution is globally widespread in marine environments, and may alter the natural colors, cycles, and intensities of night-time light, each of which guide a variety of biological processes. It has increased exponentially over the past 150 years and has become a significant issue for the marine environment in the last 60-90 years (Carr, 2021). Light pollution in marine environments is also becoming more severe due to the increasing prevalence of LED lights. LEDs now account for roughly half of global light sources, and white LEDs produce broad spectrum light that is sensed by a wide range of organisms and have a peak at short wavelengths (blue and green light) to which many marine organisms are particularly sensitive. Moreover, these shorter wavelengths penetrate deeper into the water column, affecting organisms at greater depths (Carr, 2021).

ALAN is used in salmon farming to inhibit biological processes such as maturation and to increase somatic growth in the spring (Hansen et al. 2017). Continuous artificial illumination of ocean net-pens in the coastal waters are used throughout the winter and spring months. The benefits of ALAN to the aquaculture industry are significant; by virtually removing changes in light as an environmental variable, farms can greatly increase production and reduce the risk of early maturation prior to harvest. Placing submerged lighting at depth (versus near the surface) during night-time hours also assists in evenly distributing the fish in cage structures and reducing fish densities near the surface (Cornelissen, 2011).

ALAN directly affects the physical characteristics of the water column and as a result has the potential to become light pollution.  ALAN can influence several biological processes (such as with the salmon) surrounding the salmon farms as natural light cues structure a lot of behaviours and processes in marine ecosystems (Carr, 2021). Possible environmental effects of ALAN in the marine environment due to aquaculture have been suggested by Cornelisen (2011), to be attraction of phototaxic organisms, influence of vertical migration and benthic settlement of planktonic organisms, aggregation and visibility of prey and enhanced predation, influence on the vertical distribution of salmon, risk of parasitism and attraction of birds.

**Key findings:**

- Light pollution due to artificial lighting at night (ALAN) has received considerable attention in terrestrial systems, however the effects of artificial lighting in the marine environment are less known.
- Possible environmental effects of ALAN connected to aquaculture (based on literature), includes attraction of phototaxic organisms, influence of vertical migration and benthic settlement of planktonic organisms, aggregation and visibility of prey and enhanced predation, influence on the vertical distribution of fish, risk of parasitism and attraction of birds.
- Environmental effects of aquaculture-associated ALAN have been documented and these include attraction of invertebrates to cage structures as well as several species and life stages of fish.
- Knowledge on the physical effects of the lights is needed to determine the spatial 'footprint' of the ALAN in aquaculture (i.e., the depths that the light penetrates to and the size of the area affected within and around the cage structures), in order to assess the environmental effects.
- Knowledge is needed on which extent phototaxic organisms may be attracted to the farms, how light increases the visibility of prey and possibly levels of predation, how ALAN influences vertical migration and benthic settlement of planktonic organisms, influence on the vertical distribution of fish and to what extent ALAN attract birds.
- Gaining this knowledge can empower the aquaculture farms to make informed operational decisions that can improve farm efficiency and promote fish welfare and reduce environmental impacts of ALAN operations.

#### 3.3.7.2 QSR results

The quick scoping review identified 77 articles possibly related to the effect of light on the marine environment, but a closer assessment of these articles revealed that only one paper was related to environmental effects (McConell et al. 2010), some were related to light effects on farmed species and three of these articles were included and found relevant. Because of the limited amount of literature additional information in form of grey literature (n=4) were included, in addition to more generalized articles of ALAN that were found relevant (n=11) (Figure 3.47).

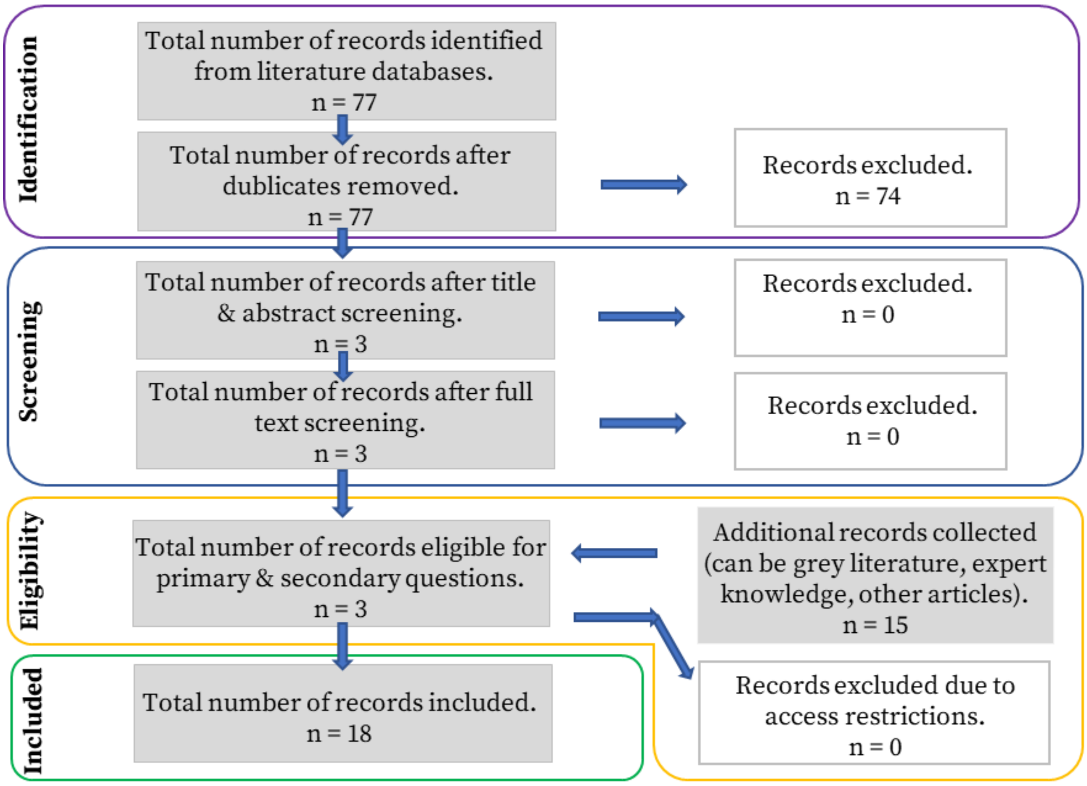


*Figure 3.47. PRISMA flowchart visualising the different steps of the selection process of the QSR for Light.*

### 3.3.7.3 Receiver & impact

Continuous artificial illumination of ocean net-pens in the coastal waters throughout the winter and spring months has become common practice for Atlantic salmon farms in the second sea winter of production (McConell et al. 2010). One study reported on a small spatial footprint of light underwater. This assumption was based on the rapid attenuation of light underwater and the small spatial area illuminated by the lights (Cornelisen, 2011). However, there is lacking information on the physical effects of the lights used by aquaculture. This includes determining the spatial 'footprint' of the artificial lights (i.e. the depths that the light penetrates to and the size of the area affected within and around the cage structures).

ALAN can cause stress responses and changes activity levels in organisms (Carr, 2021). As mentioned earlier artificial light is used to controls swimming depth and fish density of Atlantic salmon (*Salmo salar*) in production cages, to reduce exposure to suboptimal water layers and crowding of fish (Juell, and Fosseidengen 2004). However, increased densities of salmon at a given depth (i.e., near the surface) due to artificial lighting have been shown to also coincide with an increased risk of parasitism on salmon by copepods such as sea lice that are attracted by the lights (Cornelisen, 2011 and references therein). However, some lights are also

*Figure 3.48. Light installation in aquaculture (source; https://www.signify.com/global/our-mpany/news/press-releases/2020*

designed to keep the fish below the sea lice zone. A study found that post-smolt Atlantic salmon exposed to high intensity blue LED lights showed an acute stress response (increase in cortisol levels) which subsided by 24 hours after the light exposure started (Migaud et al. 2007).

There are very few published studies on the effects of artificial lighting used in salmon farms on wild fish and zooplankton. Although there is little information available on the impact of such lighting on the attractiveness of fish farms to wild fish and other organisms, using lights to fish at night for various fish and squid, is a well-known practice and thus attraction to light likely also occurs for fish cage-related lighting over some spatial scale. ALAN can therefore also function as a light trap concentrating prey species, making it easier for predators to see prey at night, and reduce natural camouflaging of prey species (Carr, 2021).

Phototaxic organisms may be attracted to the artificial light produced by fish farms. Field studies in Canada have shown that aquaculture-associated artificial light attract invertebrates (gastropods and bivalves) as well as several species and life stages of fish (e.g., Pacific herring, sand lance and threespine stickleback). This indicates that artificial light may facilitate interaction between farmed and wild species, and more invertebrates are attracted to artificial lighting, thus increasing the number of invertebrates (McConnell et al. 2010; Fernandez-Jover et al. 2016). These observations are consistent with those made during a site visit to another farm (Cornelisen & Quarterman 2010).

McConnell et al. (2010) showed that various fish species were attracted to a light typically used in salmon aquaculture in British Columbia. This effect may be due to attracted zooplankton attracting fish predators and could affect both the horizontal and vertical positions of fish around cages. Bjørn et al. (2021) suggested that an aggregation and visibility of prey, such as krill that are attracted to light (Humborstad et al. 2018) and are important prey for cod, could lead to enhanced predation as this can attract cod to the fish farms. Another study reported that saithe that aggregated around fish farms displayed behavioural patterns reported from saithe elsewhere, however, an anomaly was observed, as fish moved 10–20 m closer to the surface during mid-winter, when lights were on. The reason for this is not known, but authors suggested this to be associated with the use of artificial light to illuminate fish farm sea cages (Skilbrei and Otterå, 2016).

In the case of salmon farms, the extent to which lights influence vertical migration of phototaxic animals will be dependent on the depth to which the light penetrates relative to the bottom, the communities living beneath the light structures, and the level of water column currents. The latter is also expected to influence the spatial distribution of zooplankton. Furthermore, it is important to note that behavioral responses to artificial light vary among taxa. While some species are known to be attracted to light, such as herring and krill mentioned above, others are known to avoid light. North Atlantic and Arctic copepods, Atlantic cod, and sea bream are all species that are commercially important, and which have been shown to avoid ALAN. However, as Bjørn et al. (2021) points out attraction to prey that are phototactic can attract them to the fish farms.

These effects may be particularly important in the Arctic, as there is an increase in human activities. Natural light such as the moon, stars and aurora borealis may provide important cues to guide distribution and behaviors in the dark, including predator-prey interactions, these sources will in many places be masked by the much stronger illumination from ALAN (Berge et al. 2020). The study by Berge et al. 2020 showed that normal working-light from a ship may disrupt fish and zooplankton behavior down to at least 200 m depth across an area of >0.125 $km^2$ around the ship, in the Arctic.

There is also increasing evidence that ALAN impacts how sessile invertebrates select settlement sites and their subsequent survival rates (Carr et al. 2021). However, one study states that the effects of submerged artificial lighting from open cages on benthic settlement of planktonic organisms is expected to be very small (Cornelisen, 2011).

ALAN may also affect the distribution of marine birds, with many nocturnal ones being attracted to light sources (Montevecchi, 2006), and mammals, but there is little knowledge about this related to finfish aquaculture. Seabirds are highly visually oriented organisms and are known to become disorientated at night in the presence of ALAN, e.g., from lighthouses, oil platforms or vessels, this could lead to collisions with structures, use of unnecessary resources, or that seabirds are taken by predators (Jägerbrand et al. 2019). Merkel (2010) reported that seabirds and bird strikes were a problem when vessels navigated in icy waters and when they were using powerful lights.

The increase of light pollution levels under water may widen the photic zone at night, but also during dawn and dusk, and thus levels by ALAN could enhance the foraging of pursuit-diving visual predator seabirds, such as murres and penguins (Marangoni et al. 2022 and references therein). ALAN can also concentrate prey, which seabirds then take advantage of (as for fish described above). Several gull species have been reported to increase their foraging opportunities on marine, coastal and terrestrial lit areas also during fishing (Marangoni et al. 2022 and references therein). Gulls can furthermore also prey on seabirds and such predation can be facilitated by ALAN. At Benidorm Island (western Mediterranean), gulls increased predation on storm petrels after light levels increased by a new light installation in the nearby Benidorm city (Marangoni et al. 2022 and references therein). There is no knowledge as to whether collision and mortality of birds is a big problem on feed rafts and other installations connected to today's farming facilities. There has been a problem that is linked to the use of bird netting over the cages, but this problem has been significantly reduced in recent years following a change in the color and structure of the thread used in the nets (Guneriussen, pers.com).

However new installations such as sea farms may be much larger constructions than the current facilities. It is therefore unknown whether the use of light on these structures will lead to an increased risk of disorientation and collision with birds. Research has shown that birds migrating at night become disoriented and attracted to red and white light (visible long-wavelength light), while they are less disoriented by blue and green light (contain less visible long-wavelength light) (Poot et al. 2008). The use of ordinary white light that is visible to humans can therefore lead to collisions and death of birds, especially on nights with fog and dense cloud cover (Merkel, 2010; Poot et al. 2008). Reduction of such bird collisions may possibly be achieved by reducing light use at night (Glass & Ryan, 2013) or manipulating wavelength properties so that green light is used (Longcore et al. 2018; Poot et al. 2008). Blue light also reduces the possibility of bird collisions, but this may not be usable as work and safety light for people. Efforts such as covering the net pens with special bird mesh, reducing the use of lighting, and video monitoring (both above and below the water surface) to detect entangled birds can be used to mitigate the effects (ICES, 2021). No risk assessment on the environmental impact of aquaculture on seabirds has been conducted in the Norwegian Sea ecoregion (ICES, 2021).

As ALAN have shown to interferes with marine ecosystem processes, a conceptual map of individual- to ecosystem-level responses to ALAN has been developed by Zapata et al. (2019) also describing some interactions, changes in behavior described above (Figure 3.49**).**

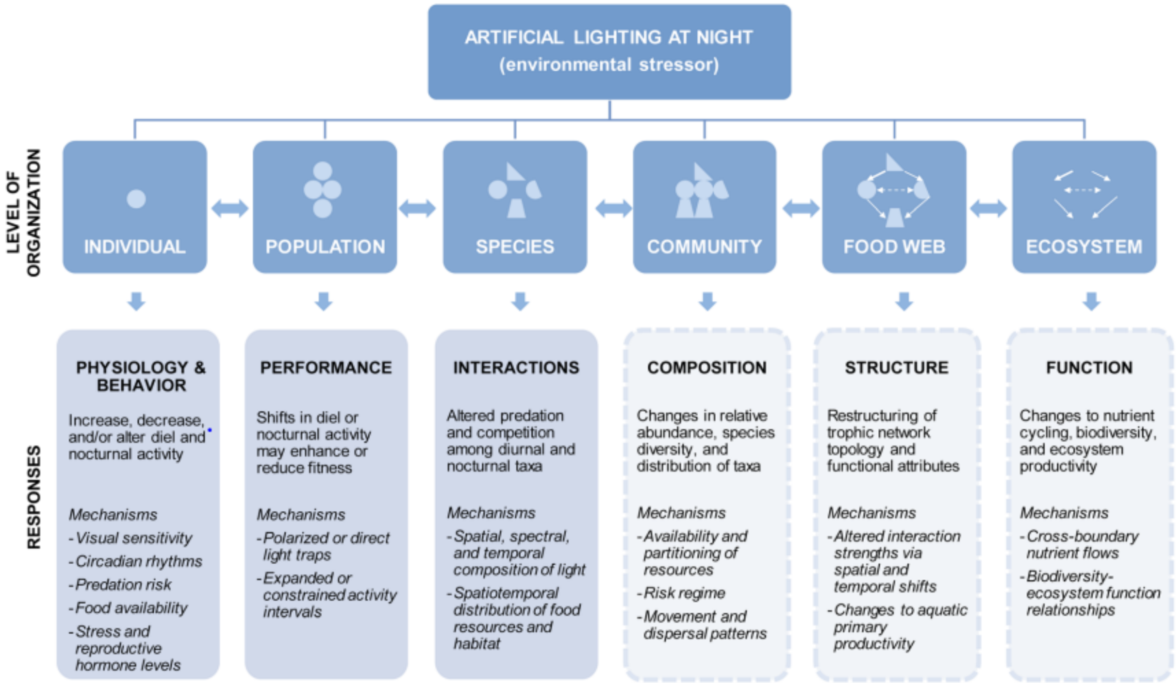


*Figure 3.49. Conceptual map of individual- to ecosystem-level responses to ALAN in estuarine ecosystems with summary of responses and example mechanisms for responses at each level of biological organization. Highlighted frames (communities, food webs, ecosystems) represent levels of organization whose response to ALAN is currently underrepresented in the literature (Source Zapata et al. (2019)).*

### 3.3.7.4 Monitoring

As far as the authors are aware of there are no current monitoring of ALAN in Norway or at aquaculture sites. However, the authors recognize that the County Governor (Statsforvalteren) in Norway, in their statement on an application for a permit for aquaculture facilities, have included light pollution from the aquaculture site on birds as a possible effect. (https://www.statsforvalteren.no/siteassets/fm-rogaland/dokument-fmro/miljo/soknad-og-loyve/akvakultur/uttalelse-laksetildelingsforskriften.pdf).

One study describes ALAN monitoring on a more general basis (Carr, 2021). They suggest that there is a need to increase the temporal and spatial resolution of ALAN monitoring, including more widespread sensing at the ocean surface and in the water column. The use of satellites may detect light emitted upward under clear sky conditions but do not provide a thorough understanding of conditions below the sea surface. The lack of spatial resolution of satellite measurements of ALAN makes it difficult to detect impacts on marine populations. In the water column, organisms are exposed to direct or scattered light and light reflected from the atmosphere, and different wavelengths attenuate at different depths. They suggest that strategic "ground-based sensing" at the ocean surface and in the water column could fill this gap. Also, they suggest more opportunistic ways to add resolution to ALAN monitoring that may include mounting sensors on coastal and offshore infrastructure such as oil platforms, aquaculture platforms, ships of opportunity, and Global Ocean Observing System buoys. They also suggest that predictive models can help to provide information on ALAN dynamics in time and space. Another study more directly related to aquaculture suggests that one could have monitoring in form of several site surveys at farms where lights are fully operational (Cornelisen, 2011). The study suggests a more 'observer' approach to monitoring effects of artificial lighting under varying conditions. Observations by farm staff could include noted changes in night-time feeding activity by fish, seabirds, and marine mammals in and around the illuminated cages. In addition, inspection of gut contents during routine inspections of fish for disease and condition would assist in determining whether the salmons' diet is subsidised by wild prey.

#### 3.3.7.5 Knowledge gaps

Light pollution due to artificial lighting has received considerable attention in terrestrial systems; widely cited examples of impacts on land include effects of tall lighting structures on mortality of migratory birds and the disorientation of sea turtle hatchlings by lights associated with coastal developments. The effects of artificial lighting in the marine environment are less known, particularly regarding salmon farms (Cornelisen, 2011). This is also reflected in this study as very limited knowledge (only few studies in the QSR) was found.

Minimizing and mitigating ALAN and its impacts on marine ecosystems will require a great deal more research, management, and policy making (Carr, 2022). Some suggestions from the literature for further ALAN research include, assessing physical effects, as well as differential effects on individuals (e.g., different life stages) and species when studying the effects of ALAN on marine organisms and ecosystems.

In order to assess the environmental effects of artificial lighting on the marine environment, from aquaculture, the physical effects of the lights need to be described first, considering light intensity, exposure cycles, spectra, and directionality. This also includes determining the spatial 'footprint' of the artificial lights (i.e. the depths that the light penetrates to and the size of the area affected within and around the cage structures).

More information is also required about to which extent phototaxic organisms may be attracted to the farms, how light increases the visibility of prey and possibly levels of predation, how it influences vertical migration and benthic settlement of planktonic organisms, how it influences the vertical distribution of fish and risk of parasitism and to what extent it leads to attraction of birds, amongst others. One study also suggests targeted research on relevant species and ecosystems which provide obvious and documented ecosystem services so that the economic impacts of changes in ecosystem structure and function can be considered in policymaking.

#### 3.3.7.6 Conclusions

Light pollution due to artificial lighting has received considerable attention in terrestrial systems, however the effects of artificial lighting in the marine environment are less known, particularly regarding environmental effects from ALAN from salmon farms (Cornelisen, 2011). There exists literature that more generalized describe the effects of ALAN in the marine environment (reviews), but this literature is more focused on ALAN that comes from coastal populations, fishing vessels, oil platforms and ships. However there exists some information on possible effects of submerged ALAN in the marine environment, also connected to aquaculture. These include attraction of phototactic organisms, influence of vertical migration and benthic settlement of planktonic organisms, aggregation and visibility of prey and enhanced predation, influence on the vertical distribution of salmon and wild fish, risk of parasitism and attraction of birds. One study showed that aquaculture-associated artificial light attracts invertebrates as well as several species and life stages of fish, which may in turn increase the visibility of prey and possibly levels of predation.

However, there is no/ very limited information on the depths that the light penetrates to, and the size of the area affected within and around the cage structures, and furthermore how this impact the surrounding marine environment. There is required more information of what extent phototactic organisms may be attracted to the farms, how light increases the visibility of prey and possibly levels of predation, how it influences of vertical migration and benthic settlement of planktonic organisms, influence on the vertical distribution of fish and risk and to what extent ALAN may attract birds. Understanding this basic can empower the aquaculture industry to make informed operational decisions that improve farm efficiency and promote fish welfare and reduce environmental impacts of operations.

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**QSR**


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### 3.3.8 Artificial structure

#### 3.3.8.1 Background

Marine farming typically occurs in relatively remote regions and involves the installation of artificial structures that are often disconnected from the shoreline and usually elevated above the seafloor or suspended on the water surface or in the water column. Off-bottom structures provide a novel hard substrate that is not present on the seafloor, where benthic predation and sediment accumulation may exert significant control over ecological communities. For example, mussel and finfish farms occupy space that was previously ‘open’ water (pelagic space) and are without natural analogues. Kelp forests are arguably the nearest equivalent, in that they provide vertical structure many meters in length, like bivalve crop lines or net pens, but do not support the development of the substantial biomass of biofouling that occurs on marine farms (Atalah et al. 2020). These marine farming developments provide extensive areas of nearshore novel habitats, with a range of potential positive and negative repercussions for regional-scale distribution of species and possible effects on ecological processes that have not been well explored to date (McKindsey et al. 2007). Artificial structures such as those associated with aquaculture farms tend to attract biota, probably because they provide both shelter and excess feed from the cages. This typically leads to higher abundances of species, including fish, near aquaculture sites as compared to control sites (also described in chapter 3.3.7 Light). Aggregation of wild biota at or near aquaculture farms may lead to biofouling or transfer of parasites between farmed and wild individuals. Furthermore, aquaculture infrastructure may facilitate the establishment of non-native species (e.g., isopods, amphipods, tunicates), some of which are considered as fouling pests.

**Key findings:**

- Maritime infrastructure, including aquaculture within regional seascapes, and its influence on species populations and biodiversity is an environmental concern.
- Marine farming developments provide extensive areas of nearshore novel habitats, with a range of potential positive and negative repercussions for regional-scale distribution of species and possible effects on ecological processes.
- Provision of physical structure (e.g., farm infrastructure) in the water column tend to aggregate fish around them and the importance of fish cage aquaculture structures as fish aggregating devices (FADs) has been demonstrated.
- FADs may have a variety of population-level effects, it may increase population biomass, it may influence the condition and fish growth, it may alter reproductive success and may alter the movement and migration patterns of fish. FADs have the potential to act as small marine reserves or ecological traps and reduce capture quality depending on the management.
- Aggregation of wild biota may lead to biofouling or transfer of parasites between farmed and wild individuals.
- Aquaculture infrastructure may facilitate the establishment of non-native species, some of which are considered as fouling pests. Structures may further act as reservoirs or so called 'steppingstones' for the dispersal of these potential marine pests.
- Marine aquafarms are even classified as anthropogenic biomes (artificial ecosystem functional groups). Ecosystems in this group are created by human activity, which continues to drive and maintain their assembly.
- A knowledge gap identified is related to the considerable uncertainty regarding the long-term and ecosystem-wide consequences of the described interactions. Recommendations have been made to use various modelling approaches to gain more knowledge regarding the long-term and ecosystem-wide consequences.

#### 3.3.8.2 QSR results

The quick scoping review identified 310 articles possibly related to the effect of artificial structure on the marine environment, but a closer assessment of these articles revealed that only 11 papers were explicitly related to aquaculture. The studies were mostly based on field observations (n=9), but also field experiments (n=1) as well as literature (i.e., review; n=1). The studies were conducted in numerous countries, including Norway, UK, Japan, Canada, Chile and the USA. Grey and additional literature were also added (n=5) (see Figure 3.50).

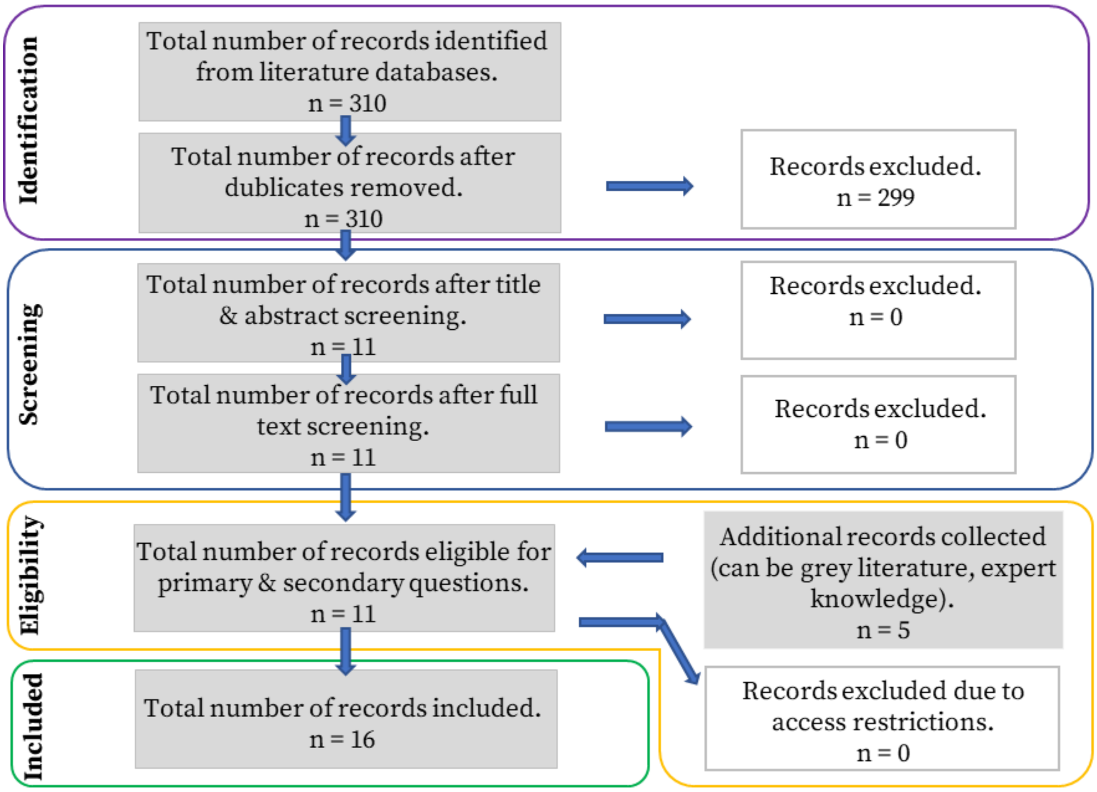


*Figure 3.50. PRISMA flowchart visualising the different steps of the selection process of the QSR for Artificial structures.*

### 3.3.8.3 Receiver and impact

Many studies of aquaculture–environment interactions have focused on interactions with sessile organisms or those with low mobility, particularly infauna. This is logical as these organisms integrate effects on benthic sediments over time and are thus commonly used as indicators of farm environmental performance (Callier et al. 2017). More mobile fauna also interacts with aquaculture operations, but the interactions are more complex and animals, including crustaceans, fish, birds and marine mammals, may react positively (attraction) or negatively (repulsion) to farm structures and operations (See graphic illustration Figure 3.51).

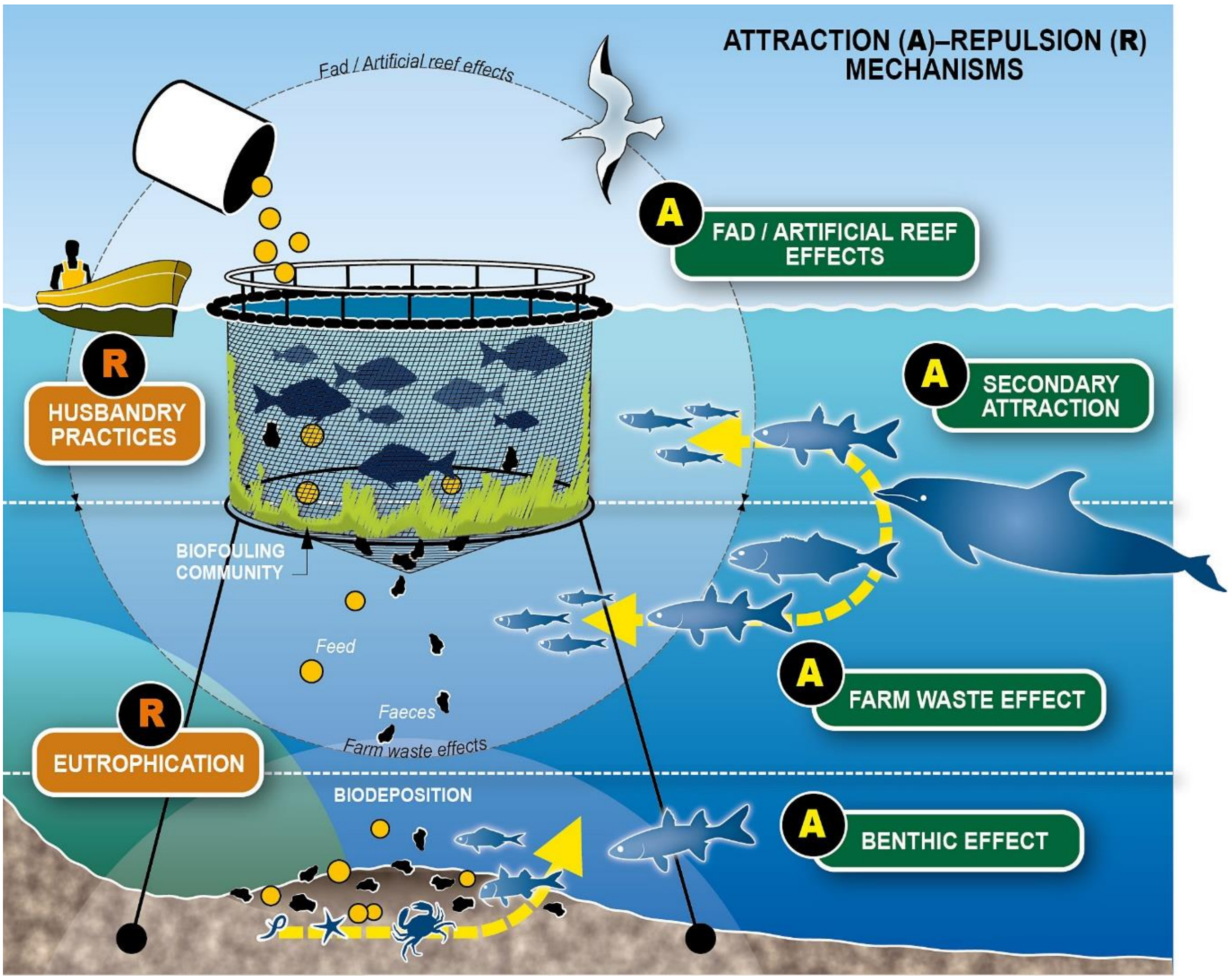


*Figure 3.51. Attraction (A) and repulsion (R) mechanisms of mobile wild populations by fish farming cages. Attraction mechanisms (in green) include: (i) Fish aggregating device (FAD) – and artificial reef (AR) effects (i.e. biofouling communities, refuge, shelter for wild population, light and noise), (ii) Farm waste effect (related to feed waste and faeces, settling of fouling organisms), (iii) Benthic effect (related to the enhancement of organic matter, abundance of benthic invertebrates attracting deposit feeders, etc.) and (iv) Secondary attraction effect (i.e. Predators). Repulsion mechanisms (in orange) include: (i) Husbandry practices (noise, light related to boating, cleaning) (ii) Eutrophication. Yellow dashed arrows illustrate trophic pathways. (Source: Callier et al, 2017; Graphic P. Lopez, Ifremer, UMR MARBEC).*

Many studies have found that the provision of physical structure (e.g., farm infrastructure) in the water column tend to aggregate fish around them and have shown the importance of fish cage aquaculture structures as fish aggregating devices (FADs) (Callier et al. 2017, Stable, 2015, Sanchez-Jerez et al. 2011). Fish farms may aggregate fish through various mechanisms: 1) a direct trophic link (i.e., a heightened availability of food in the form of waste feed and farmed fish), 2) Artificial reef structures, as the cage structure may offer refuge or shelter, 3) FADs, which may cause attraction/repulsion to light and noise (see chapter 3.3.6 and 3.3.7). These mechanisms occur synergistically to attract fish (and other taxa) and are difficult to separate (Callier et al. 2017). However, in the study by Stable (2011) changes to wild fish communities was observed up to 170 m away from farm infrastructure and this suggest that the mechanism of the attractive effects may be driven more by nutrient subsidies than the presence of infrastructure. Other effects can be disease/pathogen transfer and genetic and toxicological effects but will not be discussed in detail here as these have been previously reviewed (chapter 3.3.5 Disease & parasites, 3.3.4 Escapes and 3.3.3 Environmental contaminants). Attraction towards artificial structures is also known from other types of artificial structures, such as offshore wind farms (e.g., Reubens et al. 2014, Wright et al. 2020).

Aggregations of wild fish and other organisms around fish farms may have a variety of population-level effects on wild fish (and other taxa). Fish farms may provide one of the functions as marine protected areas by increasing the export of fish biomass, due to food resourced provided by the artificial habitat. It may influence the condition and fish growth and reproductive success and evidence suggests that fish farms may alter the movement and migration patterns of fish aggregated around them (Callier et al. 2017 and references therein). In the study of interactions between fisheries and aquaculture Sanchez-Jerez et al. (2011) discussed the potential of fish farms to act as marine reserves or ecological traps and reduce capture quality depending on the management (see Figure 3.52).

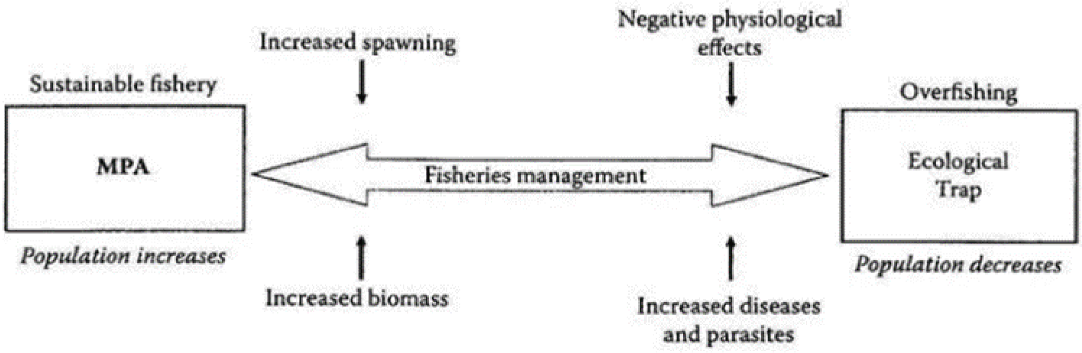


*Figure 3.52. Model representing the extremes in the interaction between aquaculture and fisheries. According to Sanchez-Jerez et al. (2011), depending on management, sea cage fish farms have the potential to act as marine reserves or ecological traps (Source Sanchez-Jerez et al. 2011).*

On one hand fish farms may act as ARs by the presence of additional food, increased feeding efficiency, and the presence of shelter to reduce predation and enhance recruitment. ARs, such as fish farms, may influence the condition and fish growth and increase reproductive success, ultimately causing population increases. This feature indicates that marine farms can provide one of the functions as marine-protected areas, by increasing the export of biomass (Sanchez-Jerez et al. 2011). If restrictions on fishing are applied within these areas, it has been suggested that coastal sea cage fish farms may act as small pelagic marine protected areas (Sanchez-Jerez et al. 2011 and references therein). On the other side evidence suggest that it may alter the movement and migration patterns of fish aggregated around them with no biomass increase (Callier et al. 2017 and references therein), and that they act as ecological traps serving super stimulus misleading fish to make inappropriate habitat selections. Fish farms could function as ecological traps if they continuously attract fish from surrounding waters and their populations are being diminished by fishing, if management does not have the right strategies to it prevent this. In addition, there has been a discussion if fish feed that is intended for salmon might interact with flesh quality of fish that consumes it (saithe), this is partly supported by scientific evidence (Sanchez-Jerez et al. 2011, and references therein), leading to conflicts. Also, aggregation of wild biota at or near aquaculture farms may lead to biofouling or transfer of parasites between farmed and wild individuals, thus have the possibility to increase diseased and parasites in wild fish. Dempster et al. (2011) investigated if coastal salmon farms act as ecological traps for wild Atlantic cod and saithe.

They compared proxy measures of fitness between farm-associated fish and control fish caught distant from farms in nine locations throughout coastal Norway. The study provided no evidence that salmon farms function as ecological traps for wild fish. They proposed that fish farms may act as population sources for wild fish, provided they are protected from fishing while resident at farms to allow their increased condition to manifest as greater reproductive output. The influence of fish farms may occur at several spatial and temporal scales, and spatial and temporal variability of fish assemblages are described in Callier et al. (2017). However, where fish farms are concentrated in coastal waters the effects are likely to be amplified and may interact with fisheries at a regional scale (Sanchez-Jerez et al. 2011). The literature mainly considers salmon farms, but suggestions have been made that also cod farms may act as FADs (Bjørn et al. 2021). Bjørn et al. (2021) stated that there were no specific studies of wild cod around cod farms, however, some observations from other studies have been made.

Studies have further shown that fouling communities on pens can receive a nutritional boost from the added fish feed and the associated fouling and related communities, including amphipods, small fish, gastropods. They may also provide additional trophic resources to aggregated fish which may then be transferred to higher trophic levels (Callier et al. 2017 and references therein). The extent of fouling on nets, and net maintenance, will influence the communities of fish and other mobile organisms associated with farms. Atalah et al. (2020) showed that mussel farm infrastructure was very suitable habitat for biofouling taxa, which generally colonized it at higher rates than surrounding natural habitats, as occurs for many urban marine man-made structures. They can also provide a refuge from benthic grazing and predation, which may control biofouling pest proliferation in less structured benthic habitats. The overall effect can be a local- and regional-scale increase in marine biodiversity, at least in terms of hard-bottom benthic species that would otherwise be limited to seafloor habitat (Atalah et al. 2020). Similar effects have been found in fish cage nets, where rich and abundant fouling communities may develop (Callier et al. 2017 and references therein). The initial direction of colonization for species on farm structures is external: species come from surrounding habitats, biofouling on visiting vessels, or fouled infrastructure and seed-stock used for aquaculture production (Atalah et al. 2020). Aquaculture infrastructure may therefore facilitate establishment of non-native species (e.g., isopods, amphipods, tunicates), some of which are considered as fouling pests (Ashton et al. 2015).

Furthermore, farm structures may act as reservoirs or so called ‘stepping stones’ for the dispersal of potential marine pests. In this way farm structures may facilitate dispersal to areas that are too distant to otherwise be reached, for example in a single generation (Atalah et al. 2020). The same study suggested that investigating distributional and dispersal patterns of fouling pests can form basis for integrated pest management efforts, focusing on spatial management strategies, such as ‘firebreaks’ in farm connectivity, avoidance of pest hotspots, and farm fallowing. Spatial and temporal variations in biofouling diversity and biomass may be driven by planktonic events, light availability, water depth and flow, etc.; fouling community biomass will typically decrease with depth (Callier et al. 2017). Establishment of introduced species seems furthermore to be climate dependent. Although aquaculture cages constitute a good substrate for various sessile marine organisms, it is not fully clear if the nutrients from the cages (e.g., feces and waste feed) may cause biofoulers to grow faster, denser or heavier than they would on comparable structures distant from farms and few studies have attempted to separate structural and nutritional effects (Callier et al. 2017).

Marine mammals and birds may also be attracted to sea cages (see also sections sound and and light 3.3.6 and 3.3.7). There is information on interactions with birds and marine mammals in other countries (see review by Callier et al. 2017), however scarce for Norway. A variety of methods are used to reduce the impacts of predators that are attracted by farmed and associated fish (both farmed and wild), with the most efficient means appearing to be anti-predator netting (Callier et al. 2017). The nets and related hardware may pose a risk of potential entanglement to seals, otters and other marine mammals, birds and sharks, although there are few verified reports of marine mammals being entangled by aquaculture gear. Data on rates of entanglement are rarely quantitative, and the extent of the problem is poorly known and no data on this were found for Norway. However, IMR has asserted that for example grey seals in Norway can interact significantly with fisheries and fish farms (https://www.hi.no/en/hi/temasider/species/grey-seal).

Marin aquafarms as artificial structures have been classified as anthropogenic biomes (artificial ecosystem functional groups) by the International Union for Conservation of Nature (IUCN) where Norwegian Environmental Agency and Ministry of Climate and Environment (Norway) are members (Keith et al. 2020). Ecosystems in this group are created by human activity, which continues to drive and maintain their assembly.

#### 3.3.8.4 Monitoring

As far as the authors know there are no monitoring of artificial structures related to aquaculture. However, researchers have created a network of more than 130 identical Autonomous Reef Monitoring Structures (ARMS) and have stated that artificial reefs may provide valuable data for monitoring ocean ecosystems, including early detection of non-indigenous species. In Sweden, the national environmental authorities already use data from ARMS located at five different observatories along the Swedish west coast to detect non-indigenous species at the earliest possible stage.

#### 3.3.8.5 Knowledge gaps

Both finfish and shellfish farms have been shown to attract and repel a wide variety of species under widely different conditions, as described above. However, there is considerable uncertainties regarding the long-term and ecosystem-wide consequences of these interactions (Callier et al. 2017). Callier et al. (2017) propose that modelling may assist in understanding these consequences, as this has been showcased for fish aggragated around fish farms and organisms impacted by scallop farming. Advances have also been made to incorporate attractive effects into food web models for bivalve, along with qualitative network models to better understand trophic links and their impacts on ecosystem functioning using only qualitative data, which is useful in coastal systems as they are commonly data-limited (Callier et al. 2017 and references therein). Results from these types of studies may help identify priorities for additional empirical research on aquaculture–environment relations. Also, as mentioned earlier, it is important for management to include these types of interactions with respect to fisheries, as this may promote a more sustainable use of coastal resources.

#### 3.3.8.6 Conclusions

In short, artificial structures such as those associated with aquaculture farms tend to attract biota, typically leading to higher abundance of fish species, including cod and saithe near aquaculture sites, compared to control sites, and act as fish aggregating devices (FADs). Aggregations of wild fish and other organisms around fish farms may have a variety of population-level effects. Fish farms may provide one of the functions as marine protected areas by increasing the export of fish biomass, due to food resourced provided by the artificial habitat. It may influence the condition and fish growth and reproductive success, and evidence suggests that fish farms may alter the movement and migration patterns of fish aggregated around them. The farms may act in extremes as marine reserves or ecological traps and possibly reduce capture quality depending on management. Also, aggregation of wild biota at or near aquaculture farms may lead to biofouling or transfer of parasites between farmed and wild individuals. Furthermore, aquaculture infrastructure may facilitate the establishment of non-native species (e.g., isopods, amphipods, tunicates), some of which are considered as fouling pests. The farm structures may further act as reservoirs or so called 'stepping stones' for the dispersal of these potential marine pests, as these farm structures may facilitate dispersal to areas that are too distant to reach for example in a single generation. There is a knowledge gap and considerable uncertainty regarding the long-term and ecosystem-wide consequences of these described interactions. Suggestions have been made to use various modelling approaches to gain more knowledge regarding the long-term and ecosystem-wide consequences.

### 3.3.8.7 References

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## 3.4 Results – macroalgae

Macroalgae aquaculture is a large industry globally with a total production of 36 million tonnes in 2020 (FAO, 2022). The production is dominated by countries in East and Southeast Asia, particularly China and Indonesia who produced 87 % of farmed macroalgae in 2020. In Norway the industry is still modest with a production of 247 tonnes in 2021, mainly of sugar kelp (*Saccharina latissima*) and winged kelp (*Alaria esculenta*). The production is predicted to increase to 20 million tonnes in 2050 (Olafsen et al. 2012). With increased production volumes and larger areas covered by macroalgae cultivation, the risk for negative environmental effects increases.

Macroalgae cultivation can have both positive and negative effects on the environment and ecosystem services (Hasselström et al. 2018, Hancke et al. 2021, Norderhaug et al. 2021). In this overview we have focused on stressors that potentially have negative environmental impacts. However, positive effects of macroalgae cultivation on the environment include:

- Uptake of nutrients from the surrounding seawater, potentially decreasing the nutrient load to eutrophic coastal areas and mitigating eutrophication effects (Jiang et al. 2019).
- Kelp cultivation may act as carbon sink, taking up carbon dioxide from the water and permanently remove some of the carbon from the cycle, either by the natural process of carbon sequestration, or by replacing products that would release more $CO_2$.
- Function as artificial habitat, leading to increased biodiversity locally, aid dispersal for species with pelagic dispersal stages, and represent habitat (refugium) for species that have lost their natural habitat and thus contribute to habitat restoration.
- Kelp photosynthesis increases pH of the sea water, and potentially reduce ocean acidification locally (Campbell et al. 2019).

Environmental effects of macroalgae cultivation have been less investigated than those of finfish production. Most studies originate from other parts of the world with higher production, higher density of production sites, different cultivated macroalgae species, and production situated in more sheltered areas than most of the production sites in Norway. International studies have nevertheless been included here since there are few studies from Norway, and even Europe, directed specifically at environmental impacts of macroalgae production. The relevance for the industry in Norway has been carefully considered for each study included in this overview.

The main stressors were identified by going through review literature on environmental impacts of macroalgae (Hasselström et al. 2018, Campbell et al. 2019, Hancke et al. 2021, Norderhaug et al. 2021). The main stressors included in this overview is listed in Table 3.9.

*Table 3.9. Stressors that were included in the literature review.*

| **Stressors included in this review:** | **Potential risk** |
|---|---|
| Particulate organic matter | Organic overload on sea bottom, effects on benthic fauna and sediment chemistry |
| Artificial structure: Spread of alien species, spread of parasites | Potentially large-scale impacts on marine ecosystems |
| Competition for nutrients | Reduced phytoplankton growth |
| Shading effect | Reduced phytoplankton growth |
| Spread of genetic material | Negative effects on local macroalgae |
| Spread of disease and parasites | Negative effects on local macroalgae |

### 3.4.1 Particulate organic matter

Throughout the production period, macroalgae biomass will be exported away from the production site. This occurs through natural loss (wear and tear) of the outermost part of the leaf, or by parts or whole plants being detached. These macroalgae particles are carried with the current and are eventually deposited on the seabed. During normal operation, it is estimated that 8-13% of the macroalgae biomass produced will be detached and lost before harvesting (Fieler et al. 2021). Biomass loss increases during the growing season from less than 5% in the first months of production to around 50% in late summer if the macroalgae is not harvested (Hancke et al. 2021). However, large quantities of macroalgae biomass may reach the seafloor during extreme weather events or other unusual circumstances.

At the seabed, macroalgae biomass may represent a food resource for benthic fauna (Renaud et al. 2015) and lead to increased biodiversity. If the supply of organic material is too large, it can lead to an organic overload, increased microbial activity and reduced levels of oxygen in the sediment. Over time this may lead to hypoxia and reduced biodiversity or in worst case, the disappearance of benthic fauna (Pearson & Rosenberg, 1978). Whether the supply of macroalgae material has a positive or negative effect depends on the quantity of settled material and physical conditions such as water circulation and temperature in combination with seabed topography.

Although the knowledge on the general response of benthic fauna to organic enrichment is extensive, there is less data on the specific response to macroalgae detritus. Results from studies on seaweed cultivation impact on benthic infauna all suggest little to no negative impact during normal operations (Hancke et al. 2021, Walls et al. 2017, Zhang et al. 2009, Zhang et al. 2020, Visch et al. 2020). Visch et al. (2020) observed an increase in benthic infaunal species diversity and abundance at a 2 ha. seaweed farm in Sweden, resulting in improved benthic quality status. However, a small pilot field trial in Norway showed that larger accumulations of kelp biomass affected the bottom chemistry and reduced macrobenthic biodiversity (Hancke et al. 2021).

In an area of large-scale kelp cultivation in China, the contribution of kelp to the pool of suspended particulate matter in the bottom sediments was estimated to be 1- 5% (Ren et al. 2014). In Norway, fresh sugar kelp material decomposed rapidly, with >90% decomposed after three months (Hancke et al. 2021). The decomposition rate varies with oxygen levels and sea water temperature, and between species, with sugar kelp (*Saccharina latissima*) being more easily degradable than winged kelp (*Alaria esculenta*) (Boldreel, 2020, Filbee-Dexter et al. 2022).

### 3.4.2 Artificial structure

Artificial structures are either man-made materials or natural materials shaped or displaced to serve a specific function for human activities. Kelp cultivation infrastructure consists of hard material frames, moorings, buoys, and long lines, and represents an artificial structure into the marine environment. Such artificial structures, and in particular structures constructed of man-made material (e.g., plastic, metal, or concrete) have been found to support significantly different faunal communities than those of adjacent areas (Mineur et al. 2012). Certain artificial structures may favor facilitation of alien species and provide steppingstones for their dispersal (Bulleri & Chapman 2010, O'Shaughnessy et al. 2020). Dispersal of alien species will depend on the size of the structure, distance to coast and other structures, water depth and currents. For example, structures placed closed together along the coast may facilitate the dispersal of alien species northwards in the direction of the main currents (Norderhaug et al. 2021). Macroalgae cultivation structures differ from other artificial structures such as finfish aquaculture or petroleum infrastructure by being covered by macroalgae part of the year.

The establishment of an alien species may cause large-scale, regional and irreversible effects on local ecosystems (Kumschick et al. 2015). Of 73 marine alien species reproducing in Norway, 34 are considered to have high or severe ecological impact (Sandvik et al. 2020).
Data on faunal communities associated with cultivated macroalgae is limited, but one study from Norway reported high abundances of the alien crustacean species *Caprella mutica* (no:

spøkelseskreps) on empty kelp farms (between harvest and seeding) as well as other artificial structures nearby (Torstensen, 2020). This species was not found in the adjacent natural kelp forest and not on cultivated kelp. Other alien species of possible concern include the ascidian *Styela clava* (no: lærsekkdyr) known from Norway since 1990 (Jelmert et al. 2018) and the recently introduced carpet tunicate *Didemnum vexillum* (no: havnespy) which was first recorded in Norway in November 2020 (Järnegren et al. 2023).

### 3.4.3 Effects on phytoplankton: competition for nutrient and shading effect

Both macro- and microalgae require nutrients for photosynthesis and growth, primarily nitrogen and phosphorus. Negative effects could occur if nutrient uptake by cultivated macroalgae leads to nutrient limitation for primary production of microalgae in the phytoplankton, and possibly out-compete the local phytoplankton production. However, field measurements from Norway (Hancke et al. 2021) and Sweden (Visch et al. 2020) indicated no effect on the nutrient concentrations in the water nearby kelp cultivation sites. This is assumed to be the case regardless of the scale of the macroalgae production, because naturally occurring microalgae have a much more efficient uptake of nutrient compared to macroalgae (Hancke et al. 2021).

The macroalgae growing on a cultivation infrastructure cause shading of the water masses below from sun light; up to a 40 % light reduction when macroalgae biomass peaks before harvest (Visch et al. 2020). The shading is predicted to have no effect on phytoplankton growth, and phytoplankton have an efficient uptake of nutrients even in the dark (Hancke et al. 2021). Walls et al. (2017) found no negative effect on eelgrass biomass (*Zostera marina*) nearby kelp cultivation in Sweden, however the specific effect of shading was not addressed in the study. However, if macroalgae is cultivated directly above an eelgrass bed, it is likely that the eelgrass would be negatively affected.

### 3.4.4 Spread of genetic material

Kelp has limited dispersal capability and therefore high genetic variability across short distances (Sjøtun and Fredriksen 2015). Population genetic studies of sugar kelp and tangle kelp (*Laminaria hyperborea*) in Norway indicated distinct genetic groups in Skagerrak, the North Sea, the Norwegian Sea and the Barents Sea. Moving macroalgae between regions for cultivation at sea could influence local macroalgae populations, because dispersal of genes from cultivated macroalgae potentially can cause hybridization and changes in competitive abilities in local populations.

There are only a few studies on the genetic effect of macroalgae cultivation on natural populations (Hancke et al. 2021). Zhang et al. (2017) could not detect any serious genetic disturbance in wild *Saccarina japonica* populations from cultivation of extensively selected and inbred populations of the same species in China. Currently, the macroalgae cultivation in Norway does not involve breeding of species with selected genotypes, but upscaling the industry will probably require some form of genetic modifications of the stock.

### 3.4.5 Spread of disease and parasites

Pest and pathogens have been a challenge for macroalgae production in Asia and Africa, especially for industry relying on genetically uniform genotypes and intense farming (Loureiro et al. 2015). Knowledge of seaweed pathogens in European species is very poor (Campbell et al. 2019). Several diseases have been observed in cultivated *Saccharina japonica* in Asia, which is closely related to *S. latissima*, the most frequently farmed macroalgae in Norway. Upscaling of commercial cultivation and introduction of genetically uniform macroalgae will increase the risk for disease outbreaks (Campbell et al. 2019). Macroalgae cultivation may thus act as vector for the spread of disease and parasites to wild populations also in Norwegian macroalgae industry in the future. There is very little knowledge on the spread of disease and parasites from cultivated macroalgae to local populations. But a disease outbreak has the potential to cause regional and irreversible effects on wild macroalgae (Norderhaug et al. 2021).

### 3.4.6 Conclusions

In this overview, we have focused on the stressors believed to have the largest risk of negative environmental impact. Generally, there is a lack of studies and data directed specifically at effects of macroalgae production, especially at large-scale cultivation outside of Asia. Most studies indicate little to no negative environmental impact of small-scale production on benthic and pelagic ecosystems. However, the potential effect on natural, coastal ecosystems by spread of alien species, genes and pathogens remains largely unknown.

Norderhaug et al. (2021) conducted a simple environmental risk assessment, based on expert opinion, for the main impact factors for small-scale macroalgae cultivation (< 300 tonnes per year). The risk associated with uptake of nutrients (competition with microalgae), shading effect and effect of particulate organic matter on the seafloor was considered to be small, because the potential effect is local and reversible. The risk associated with spread of alien species and genetic material, and disease and parasites were considered large or unknown, because the potential effect is regional and irreversible (Norderhaug et al. 2021).

### 3.4.7 Monitoring and regulation

Macroalgae cultivation in Norway is regulated through the Aquaculture Act (no: Akvakulturloven), stating that the industry must be established, operated and wound up in an environmentally sound manner. The County Municipality (no: Fylkeskommunen), in consultation with County Governor (no: Statsforvalteren), may require investigations of the recipient when applying for site allocation and concession. They may also require investigation during operation when the circumstances warrant it, but environmental monitoring is not a routine part of the operation. The Directorate of Fisheries is the management authority for wild seaweed and kelp and has guidance responsibility towards the County Municipality as the aquaculture authority.

There is currently no established monitoring program for macroalgae cultivation. Hancke et al. (2021) suggest different monitoring strategies for small (30-300 tonnes per year), medium (1 000-3 000 tonnes per year) and large (1 0000-30 000 tonnes per year) production sites. The suggested monitoring includes current measurement, survey of natural kelp and other local habitats, survey of alien species (before and after production, in natural kelp forest and on the facility), and potentially monitoring of benthic and pelagic ecosystems.

Monitoring the effect of macroalgae particulate matter on the benthic ecosystem can be adapted from the monitoring system for the salmon industry in Norway. The standard (NS 9410:2016. Environmental monitoring of benthic impact from marine fish farms) describes a methodology for risk-based environmental monitoring of marine bottom impact from salmon aquaculture facilities. The standard also specifies limit values for acceptable impact (Environmental Quality Standards (EQS)). However, we recommend development of a regulative framework adapted specifically to the macroalgae industry.

There is currently no national program for monitoring of non-indigenous marine species (NIMS) in Norway. Monitoring of species communities and alien species should be included in a monitoring strategy of macroalgae cultivation to implement suitable mitigation measures. There is an established methodology for mapping alien species (described in e.g. Rinde et al. 2017), but no methodology adapted for aquaculture facilities.

As a precautionary principle to avoid spread of genetic material from cultivated macroalgae to natural macroalgae, only plants from local populations may be used for cultivation, following the recommendations given in Fredriksen and Sjøtun (2015). As a rule of thumb, local populations are considered to be within the range of 100 km from the macroalgae cultivation site. Future large-scale seaweed cultivation practices will probably involve some form of genetic modifications. Goecke et al. (2020) recommends breeding and cultivating local populations or developing strains that are not able to establish in the wild or hybridize with wild populations.

### 3.4.8 Knowledge gaps

Although the negative consequences from macroalgae cultivation is assumed to be small compared to finfish production, further research is required over larger spatial scales, varying locations and species, and longer temporal scales to properly understand the potential impact of macroalgae cultivation on the environment. Only one Norwegian research project has included studies directed specifically to environmental effects of macroalgae cultivation (KELPPRO; Hancke et al. 2021), but the project was centred around small-scale kelp production. Future industrial scale macroalgae production in Norway should be carefully monitored until the key environmental issues have been resolved and mitigation measures identified and implemented.

The major knowledge gaps are spread of genetic material and pathogens from cultivated macroalgae to local populations. The consequences of producing macroalgae that are genetically and phenotypically distinct from natural populations is unknown, but there is potential for significant environmental effects through both direct competition with wild populations and hybridization with natural stands.

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# 4 Cumulative environmental impacts from coastal industries and risk posed to aquaculture.

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## Executive summary

Human activities on our shores (land-based activities), in estuaries, coastal waters and the open ocean (sea-based activities) provide benefits to us, but these activities also affect and change the marine environment and the health of marine ecosystems. These activities can in turn also affect other human activities and benefits (e.g., pose risk to each other). Coastal areas are the most affected because of the intensity of overlapping activities. Understanding the cumulative effects of these overlapping activities is crucial for managing the activities, understanding associated changes, risks and minimizing their effects. These wide-ranging changes are often referred to as drivers or stressors and can include for example temperature (increasing sea surface temperature), carbon dioxide and pH (ocean acidification (OA)), oxygen (deoxygenation), salinity, density, irradiance, sound, light, nutrients, eutrophication, UV exposure, plastics (entanglement from fishing/aquaculture gear), point source pollutants (chemical pollution) and physical destruction of marine habitats.

The purpose of this study was to compile a knowledge base and gain an insight in environmental risks on aquaculture from other industries and activities (direct and indirect effects) that operate in the same ecosystems along the coast and at sea. This was done through a QSR literature search, a more standard literature review and key expert evaluations. First the study assessed information of key industries operating in the same areas as the aquaculture industry, secondly an assessment of the related stressors from these industries was done. Thereafter an evaluation of knowledge on the contribution and scale of emission from the related industries was performed, and information on impact and cumulative risks was assessed. Lastly, risk on aquaculture from other key industries in terms of risks on fish health, public health and possible overlapping environmental impact was assessed.

The assessment showed that available information to identify industries and activities operating in the same areas as aquaculture was good, both for land-based industries and sea-based industries. The dominance of industry activity varied geographically especially for the land-based activities where dominance was greater in the south, whilst sea-based activities such as fisheries and aquaculture dominated in the north of Norway. A broad search showed that stressors, related to the identified key industries, overlapped well the pressure categories identified for the aquaculture industry.

The literature collection gave no results for direct impacts of other industries on aquaculture. For most of the stressors, there was limited information (easily accessible data) on the contribution of emissions of key industries on the marine environment and sometimes the information was lacking. In the few cases this information could be found (nutrients, pesticides, and copper), aaquaculture had by far the largest anthropogenic emission input into the coastal waters, due to their extensive activities. There was also lacking information on the "general" extent of pressure exposures from each of the key industries. Information on scale (spatial and temporal distribution) of emissions from key industries to the marine environment were also lacking. The assessment did not identify much information on multi-pressure effects nor cumulative impacts (although the search was not exhaustive on multi-pressure effects /cumulative impacts, as it was a too large topic for the project time frame). It seems like this knowledge does not exist to date. The lacking information on contribution,

scale, impact, and cumulative impact of the activities of the key industries, resulted in challenges to evaluate risks to aquaculture. Risk evaluations had to be based on subjective judgement of key experts on the information available, and qualified assumptions where information was lacking.

For environmental overlapping impact risk, almost all the evaluated stressors could have possible overlap with the industries emissions, and also possible overlap with each other. However, for aquaculture, we could not identify major risks from other industries on aquaculture (caged fish), based on the knowledge gathering. Plastic (nano plastics) originating from other key industries, was the only pressure identified as a possible overlapping risk for farmed fish health and human consumption, however plastic is also emitted by aquaculture itself. There is however a need for more information on this topic (see summary Table 4.17). Aquaculture may be increasingly adversely impacted in the future by sources of pollution from the external environment, from agricultural, industrial and domestic effluents, foremost if cages are installed in public water bodies or close to point source outlets. However, major and mostly adverse external environmental impacts on aquaculture are likely from climate change and ocean acidification.

This highlights the need to estimate emission contribution of each industry and the pressing need to consider many possible permutations of these stressors, and their additive and interactive effects. Understanding and gain insight on cumulative effects of ocean stressors is critical to project their impact and risk. Summary of key industries/activities, related stressors and potential impacts are presented Figure 4.1.

In Norway there is currently several ongoing research projects investigating multiple ocean stressors and cumulative impact on the oceans. Gaining new knowledge and applying results from this research in the development of Ecosystem-Based Management (EBM) strategies and informing policy decisions is crucial. EBM is an ideal science-based approach for managing the impacts of cumulative stressors on marine ecosystems, as it addresses and reduces conflicts, the negative cumulative impacts of human activities thus ensuring ecosystem resilience and sustainability. Furthermore, a better understanding of the potential cumulative impacts of fish farming itself, could help marine aquaculture become more environmentally sustainable.

It must be highlighted that this report is not an exhaustive literature review given the short time frame of the project and the broad research area. Furthermore, it has several limitations due to the project time frame, the assessment does not include all human activities operating in the same areas as aquaculture, nor all stressors, nor natural causes of impact, nor all risks to aquaculture. The report can be described as a preliminary fast screening based on a critically selected literature representative of the subject. The report can, therefore, provide a basis for the identification of knowledge gaps and possible research priorities. The output of literature collection was used as base for the case study (section 4.3) and formed the basis for a wider discussion on the feasibility of achieving an ecosystem-based management approach.

The case study assessed the feasibility of the development of cumulative impact assessment models based on the knowledge base and an advanced quantitative GIS solution. The spatially resolved output is thought to be a suitable and supportive decision-making tool for ecosystem-based management. Multi-pressure studies are complex and challenging to conduct, which clearly was reflected in the case study. The results showed that finding suitable input data for a cumulative impact assessment was challenging, and raw data, essential for a quantitative analysis, were often not available. There is a need for a database which collates CIA relevant data from various sources and to provide direct open access to raw data. GeoNorge (geonorge.no) and Marine Grunnkart already contains a wide spectrum of data and these could be used as a base to further expand upon.

A number of research effort needed to fill gap of knowledge is listed in the end of the case study (section 4.3). Shortly summarized, these key points were related to: quantifying contributions of key industries and improving tools for tracing emissions, as well as developing in-situ monitoring technology and dispersion modelling approaches. In addition, improved understanding of interactions of multi-stress across a wide range of environmental conditions were highlighted. There is a need to quantify sensitivity and susceptibility of the receiving ecosystem component towards the impact of multistress (threshold values) and identify suitable indicators for ecosystem health. Another important key point is to develop CIA models for different spatial scales and explore their suitability within the Norwegian planning framework. Finally, developing solutions to mitigate the effects of multiple stressors, and find solutions to identify and recommend which individual sources (drivers/human activities) for individual stressors that should be reduced or eliminated to limit the effects of multiple stressors most efficiently.

## Sammendrag

Menneskelige aktiviteter langs kysten (landbaserte aktiviteter), estuarier og hav (havbaserte aktiviteter) gir oss mange fordeler, men disse aktivitetene påvirker også det marine miljøet og kan påvirke helsen til marine økosystemer. Disse aktivitetene kan i sin tur også påvirke annen menneskelig aktivitet (f.eks. utgjøre en risiko for hverandre). Kystområdene er mest berørt på grunn av flere overlappende aktiviteter. Å forstå de samlede (kumulative) effektene av disse overlappende aktivitetene er avgjørende for å kunne håndtere aktivitetene, for å forstå endringer og risikoer og minimere påvirkning.

Disse endringene blir ofte referert til som drivere eller påvirkningsfaktorer og kan for eksempel inkludere temperatur (økende havoverflatetemperatur), karbondioksid og pH (havforsuring), oksygen (oksygenmangel), saltholdighet, tetthet, irradians, lyd, lys, næringsstoffer, eutrofiering, UV-eksponering, plast (for eksempel fasthenging i fiske-/akvakulturredskaper), punktkildeforurensninger (kjemisk forurensning) og fysisk ødeleggelse av marine habitater.

Formålet med denne studien var å sammenstille et kunnskapsgrunnlag for å få innsikt i hvilken risiko andre næringer og aktiviteter som opererer i de samme økosystemene som akvakultur, kan utgjøre for akvakultur (direkte og indirekte effekter). Sammenstillingen ble gjort gjennom et QSR-litteratursøk, en standard litteraturgjennomgang og ekspertevalueringer. Først vurderte studien informasjon om nøkkelnæringer som opererer i de samme områdene som havbruksnæringen, deretter ble det gjort en vurdering av hvilke typer påvirkning de påfører det marine miljø. Det ble også utført en evaluering av kunnskap om bidrag og omfang av utslipp fra relevante næringer, og informasjon om påvirkning og kumulativ miljørisiko ble vurdert. Til slutt ble det gjennomført en vurdering av hvordan andre nøkkelnæringer påvirker akvakultur, herunder risiko for fiskehelse, folkehelse og mulig overlappende miljøpåvirkning med akvakultur.

Kunnskapsinnsamlingen gav ingen resultater på direkte påvirkning av andre industrier på akvakultur. For de fleste påvirkningsfaktorene var det begrenset informasjon (tilgjengelige data) om utslipp fra nøkkelindustrier til det marine miljøet, og i noen tilfeller var tilgjengelig informasjon mangelfull. I de få tilfellene denne informasjonen ble funnet (næringsstoffer, pesticider og kobber), var akvakultur den desidert største menneskeskapte kilden til utslipp

til kystvann, på grunn av omfattende virksomhet. Det manglet også informasjon om omfang og alvorlighetsgrad for utslippene fra nøkkelnæringer til det marine miljøet. Det ble funnet lite informasjon om såkalte multistress effekter eller kumulative påvirkninger (selv om QSR søket ikke var fullstendig for kumulative påvirkninger, da det var et for stort tema for prosjektets tidsramme). Denne kunnskapen er begrenset og/eller ikke-eksisterende til dags dato. Den manglende informasjonen om bidrag, omfang, påvirkning og kumulativ påvirkning av aktivitetene til nøkkelnæringene, resulterte i utfordringer med å evaluere risikoer for akvakultur. Evalueringer måtte derfor baseres på eksperters subjektive vurderinger og kvalifiserte antagelser der informasjon manglet. For overlappende miljø påvirkningsrisiko hadde nesten alle evaluerte påvirkninger mulig overlapping med industriens utslipp, og også mulig overlapping med hverandre.

Plast (nanoplast) som stammer fra andre nøkkelnæringer, var det eneste påvirkningsfaktoren som ble vurdert som en mulig risiko for fiskehelse og konsum (folkehelse), basert på den informasjonen som er tilgjengelig. Men denne plasten slippes også ut av akvakulturnæringen selv (se Table 4.17). Det er imidlertid behov for mer informasjon om plast og mulig påvirkning. Med et bedre kunnskapsgrunnlag i fremtiden, kan følgelig utfallet se annerledes ut. Akvakultur kan bli stadig mer negativt påvirket i fremtiden av forurensning fra det ytre miljø, fra landbruks-, industri- og husholdningsavløp, først og fremst hvis installasjoner installeres i offentlige vannforekomster eller nær punktutløp. Imidlertid vil mesteparten av negative ytre miljøpåvirkninger på akvakultur sannsynligvis komme fra klimaendringer og havforsuring i fremtiden.

Vurderingen fremhever behovet for å estimere utslippsbidraget til hver industri og det presserende behovet for å vurdere mange mulige variasjoner av disse påvirkningsfaktorene, og deres additive og interaktive effekter. Forståelse og innsikt i kumulative effekter av påvirkningsfaktorer på havet er avgjørende for å evaluere innvirkning og risiko. Sammendrag av nøkkelnæringer/aktiviteter, påvirkningsfaktorer, og mulige påvirkninger er presentert i Figure 4.1.

I Norge er det for tiden flere pågående forskningsprosjekter som undersøker flere ulike press og kumulativ påvirkning på havene. Å skaffe ny kunnskap og anvende resultater fra denne forskningen i utviklingen av strategier for økosystembasert forvaltning (ØBF), samt å informere politiske beslutningstakere, er avgjørende for en bærekraftig utvikling. ØBF er en ideell vitenskapsbasert tilnærming for å håndtere virkningene av kumulativt press på marine økosystemer. ØBF adresserer og reduserer konflikter, de negative kumulative virkningene av menneskelige aktiviteter og sikrer dermed økosystemets motstandskraft og bærekraft. Videre kan en bedre forståelse av de mulige kumulative virkningene av akvakultur hjelpe akvakultur industrien til å bli mer miljømessig bærekraftig.

Det må understrekes at denne rapporten ikke er en uttømmende litteraturgjennomgang gitt prosjektets korte tidsramme og det brede forskningsområdet. Videre har vurderingen flere begrensninger på grunn av prosjektets tidsramme. Vurderingen inkluderer ikke alle menneskelige aktiviteter som opererer i de samme områdene som akvakultur, heller ikke alle påvirkninger eller naturlige årsaker til påvirkning, og heller ikke alle risikoer for akvakultur. Rapporten kan beskrives som en foreløpig rask screening basert på en kritisk utvalgt litteratur som er representativ for vurderingen. Rapporten kan gi grunnlag for identifisering av kunnskapshull og mulige forskningsprioriteringer. Resultater fra litteraturinnhentingen be brukt som grunnlag for case-studien og også som grunnlag for diskusjonen om muligheten for å kunne gjøre ØBF.

I casestudien ble det gjort en vurdering av muligheten for å gjennomføre kumulativ konsekvensutredning basert på kunnskapsgrunnlaget og en kvantitativ GIS-løsning. Output fra dette verktøyet antas å være et passende beslutningsverktøy for økosystembasert forvaltning. Kumulative effektstudier er komplekse og utfordrende å gjennomføre, noe som tydelig ble gjenspeilet i casestudien. Resultatene viste at det var utfordrende å finne egnede inputdata for analyse. Rådata, som er avgjørende for en slik kvantitativ analyse, var ofte ikke tilgjengelig. Det er behov for en database som samler CIA-relevante data fra ulike kilder og som gir direkte åpen tilgang til rådata. GeoNorge (geonorge.no) og Marine Grunnkart inneholder allerede egnede data, og disse kan brukes som en base for å utvide videre.

En rekke kunnskapshull er listet opp på slutten av casestudien (avsnitt 4.3). Kort oppsummert var disse punktene knyttet til: kvantifisering av bidrag fra nøkkelnæringer og forbedring av verktøy for sporing av utslipp, samt utvikling av in-situ overvåkingsteknologi og spredningsmodellering. I tillegg ble forbedret forståelse av interaksjoner av påvirkninger på tvers av et bredt spekter av miljøforhold fremhevet. Det er behov for å kvantifisere følsomheten til den mottakende økosystemkomponenten (terskelverdier) for kombinerte effekter av flere påvirkningsfaktorer, og det er behov for å identifisere egnede indikatorer for økosystemhelse. Et annet viktig nøkkelpunkt er å utvikle CIA-modeller for ulike romlige skalaer og utforske deres egnethet innenfor den norske planrammeverket. Det er behov for å utvikle løsninger for å dempe effektene av kombinerte påvirkningsfaktorer og finne løsninger for å identifisere hvilke individuelle kilder (drivere/menneskelige aktiviteter) for individuelle stressfaktorer som bør reduseres eller elimineres for å begrense effekten av kumulative effekter mest effektivt.

## 4.1 Introduction

Norway's coastal marine areas are diverse and host a variety of stakeholders in addition to the aquaculture industry. The aquaculture industry can be directly or indirectly affected by other industries and other industries can have concurrent environmental impacts with the aquaculture industry. Therefore, an assessment of combined (multi-pressure) influences and loads from all relevant industries is necessary in order to achieve ecosystem-based management (EBM). The aim of this work package is to present a systematic overview of activities and environmental impacts associated to other industries operating in the same ecosystems as aquaculture, as well as to look at the possibilities of assessing cumulative impact and environmental risks. The work package is divided into two parts, a literature-based assessment (chapter 4.2) and a case study (chapter 4.3).

The scope of the literature-based assessment is very broad as it aims to provide a general summary of the environmental risks on aquaculture from other industries and activities (direct and indirect effects) that operate in the same ecosystems as aquaculture along the coast and at sea, and furthermore to identify knowledge gaps. The output of this assessment will be used as base for the case study.

The case study aims to explore how the knowledge base on multistress can be used to facilitate a more ecosystem-based management. Our goal is to assess the feasibility of a practical application of EBM in selected areas along the Norwegian coastline. Building upon the outputs from the QSRs on aquaculture and multi-pressure environmental interactions (chapter 3 and 4 (literature-based assessment)), we will explore the use of advanced quantitative GIS based decision-making tools to assess cumulative impacts from multiple industries in coastal ecosystems.

The output from this work package together with results from chapter 3 will form the basis for a wider discussion on the feasibility of the implementation of an ecosystem-based management approach.

The literature-based assessment (chapter 4.2) and case study (chapter 4.3) will be presented separately followed by a common general conclusion (chapter 4.4).

## 4.2 A literature-based assessment.

Authors: Maj Arnberg, Astrid Harendza, Kristine Bondo Pedersen

An overview of priority industries/activities (land based and sea based) in Norway and related stressors, scale and extent of activities, risks and impacts is given in Figure 4.1.

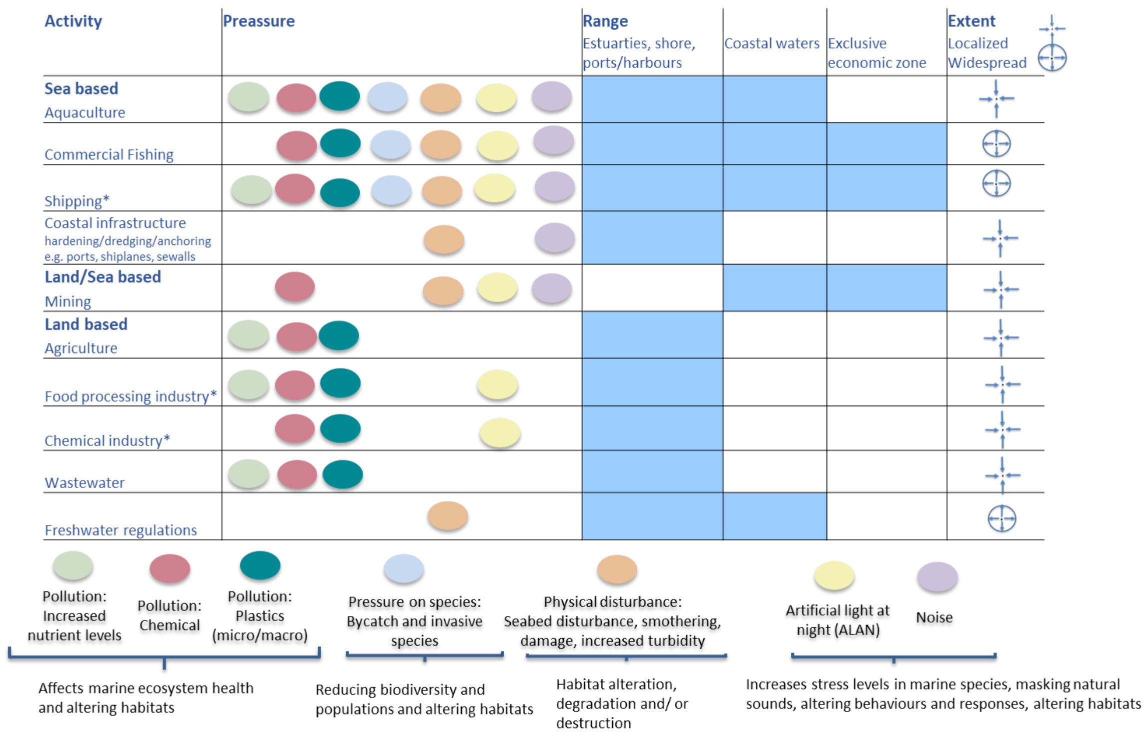


*Figure 4.1. Priority industries/activities (land based and sea based) in Norway and related stressors, scale and extent of activities, risks and impacts. The scale depends on the intensity and extent of the activities. An improved understanding of the risks and impacts is crucial for better management of our activities. * Food processing (dairy, meat, brewery, fish refining), chemical industry (pharmaceutical, oil refinery, paint, metallurgical industry) (Adopted from Ministry for the Environment (2019)).*

### 4.2.1 Background, scope and objectives

#### 4.2.1.1 Background

The aquaculture industry and related activities is not the only stakeholder in Norway's coastal and marine areas. Other coastal industries and activities such as the mining industry, oil and gas operations (offshore), maritime industry, land-based industries, fishing, tourism and renewable energy (offshore wind, floating solar, hydropower) can potentially overlap with the aquaculture industry when it comes to the need for area and resources. These industries can also have an influence on each other so that they can be mutually exclusive within an area.

Marine species and ecosystems are therefore exposed to a wide range of environmental changes (see Figure 4.2) – that could have detrimental threats due to these multiple human activities. These wide-ranging changes are often referred to as drivers or stressors and can include for example temperature (increasing sea surface temperature), carbon dioxide and pH (ocean acidification (OA)), oxygen (deoxygenation), salinity, density, irradiance, sound, nutrients, eutrophication, UV exposure, plastics (entanglement from fishing/aquaculture gear), point source pollutants (chemical pollution) and physical destruction of marine habitats (Butt et al. 2022). It is important to distinguish the scale of each of these threats, as the solutions and mitigation will differ as they are scale dependent as either local, regional, or global (see Figure 4.2). For example, the mitigation of a global problem may require a global response, which is more difficult to achieve than addressing a local problem with a local response. Furthermore, this complex matrix of changing ocean properties and threats, may for example vary from location to location (e.g., spatial scale), and may also alter with season (e.g., temporal scale) (IOC-UNESCO. 2022).

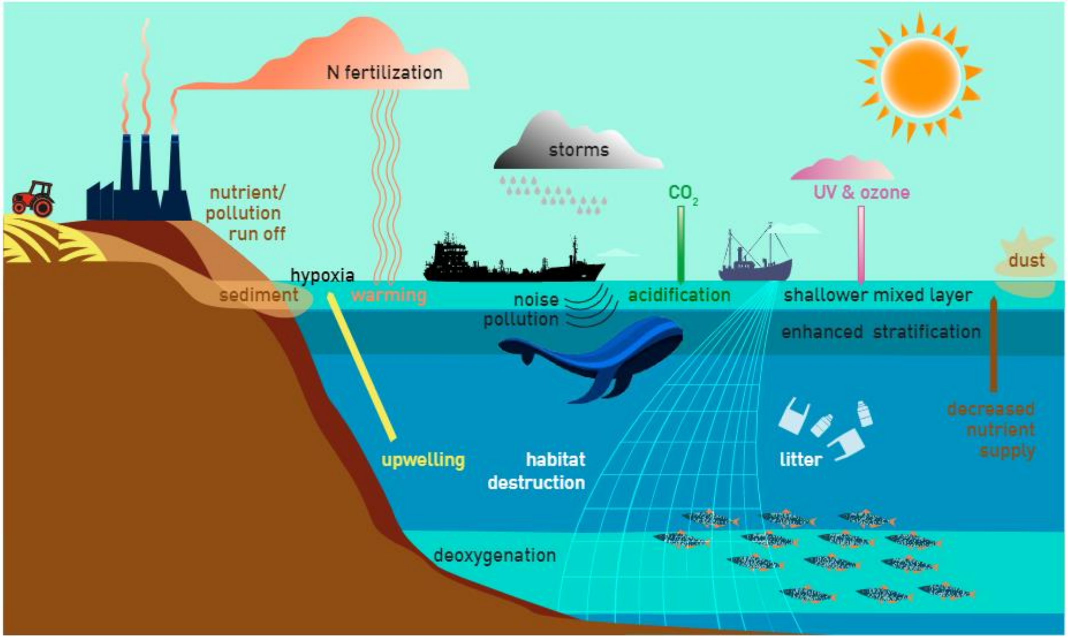


*Figure 4.2. Illustrative examples of global (warming, acidification, litter), regional (ozone, litter, atmospheric pollutants) and local (sedimentation, pollution and nutrient runoff) stressors that can affect marine life. Marine life at each location, from coastal areas to offshore waters, will encounter a unique combination of stressors, and ecosystems may be exposed to concurrent changes to multiple stressors simultaneously. (Source; IOC-UNESCO. 2022).*

According to Norwegian water regulations, which include rivers, lakes, coastal waters and groundwater in Norway, sector-wide regional water management plans for each water region must be drawn up. This implies that the management (the government and industries) must look at the overall load or impact and risk on the marine environment from all types of human activity and associated stressors. However, in practice different environmental impacts are largely assessed individually. This means that usually management assesses the direct and indirect effects of a specific pressure on multiple interacting subjects (e.g. fishing impacts on ecosystems) or multiple stressors on a single subject (see illustration class 2, Figure 4.3).

A shift towards a more comprehensive management of these activities, as with recent emphasis on ecosystem-based approaches to management, requires evaluating interactive and cumulative impacts of the stressors. Cumulative impacts result when the effects of an action or activity are added to or interact with other effects in a particular place and within a particular time. This means that the management needs to assess the direct and indirect effects of multiple interacting stressors on multiple interacting subjects (see illustration class 3, Figure 4.3).

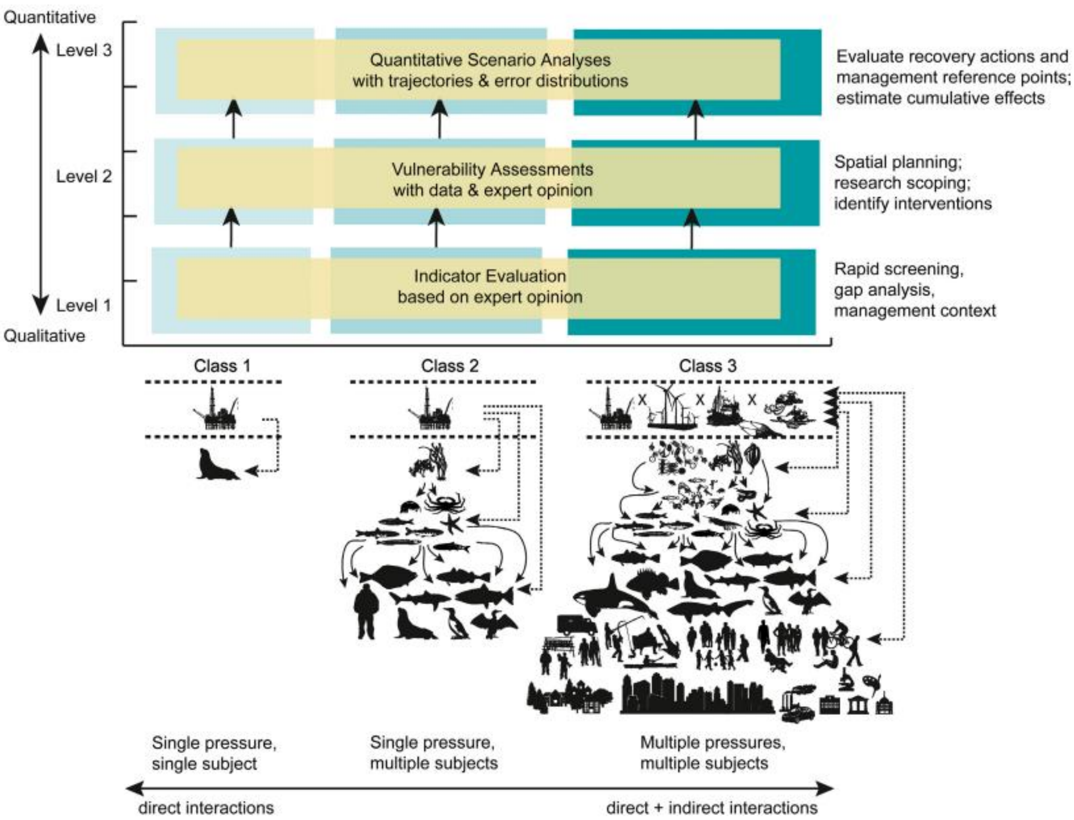


*Figure 4.3. Conceptual framework for ecosystem risk assessment. Scoping and stakeholder engagement increases left to right, and data requirements and computational costs increase diagonally from lower left to upper right. Far right column highlights example applications of each level of ecosystem risk assessment. Class 1 represents evaluations of a single pressure on a single focal subject, Class 2 analyses consider impacts of a single pressure on multiple ecosystem subjects or multiple stressors on a single subject, and Class 3 analyses consider the reciprocal and cumulative interactions among multiple (interacting) stressors and multiple interacting subjects. (Source; Holsman et al. 2017).*

The environmental management of various areas aims to become more holistic in the sense that the environmental impact from both aquaculture and other industries and activities is considered to a greater extent. The term green shift has been established as a central political goal on the Norwegian agenda, and both the industry and the governmental management want the aquaculture growth to be environmentally sustainable and follow a holistic and ecosystem-based management. Holistic ecosystem-based management requires an understanding of the ecosystem's function and structure and the overall effects of various types of human influence (stressors) on the ecosystems.

Therefore, the industries' impact on the environment in itself needs to be assessed. For a holistic ecosystem-based management it will also be important to include how the industries indirectly affect each other to assess the overall environmental cumulative impact in different ecosystems. An assessment of overall (several stressors) influences and loads from all relevant industries is necessary to be able to achieve the goal of ecosystem-based management and a sustainable development of the aquaculture industry.

Single or cumulative stressors from other industries may also pose a risk to the aquaculture industry itself. The cage aquaculture animals are for instance dependent on their local environment and thus changes to this may have direct consequences for fish health and welfare. Furthermore, it may have indirect consequences for public health / food safety (for example if aquaculture animals accumulate toxins from other industries). In addition, stressors released by other industries may overlap in geographical scale (overlapping, accumulating stressors on the ecosystem) with the release from aquaculture industry and thus cause cumulative stressors on marine ecosystems. This may cause an indirect risk for the aquaculture's further development.

#### 4.2.1.2 Scope

The scope of this literature evaluation is very broad as it aims to provide a general summary of the environmental risks on aquaculture from other industries and activities (direct and indirect effects) that operate in the same ecosystems as aquaculture along the coast and at sea, and furthermore to identify knowledge gaps. The output of this report will be used as base for the case study (section 4.3) and form the basis for a wider discussion on the feasibility of the implementation of an ecosystem-based management approach.

#### 4.2.1.3 Objectives

The literature-based assessment will identify the key industries operating in the coastal zone areas of aquaculture production. It is not possible to look at all industries that operate in the limited time frame of the project, therefore key industries (the most important industries) that operate in the same ecosystems as aquaculture will be prioritized. Their activities will be characterized and the related stressors and possible contribution to stressors (emissions) to sea will be described. Stressors and impact, and the associated spatial & temporal scale will also be described. Relevant cumulative stressors on marine ecosystems (from key industries) will be investigated. Finally, risk for aquaculture (both direct and indirect) from other industries will be evaluated.

### 4.2.2 Methods

The literature assessment was performed using a combination of the QSR method (See chapter 3 section 2, methods) and a more standard literature review. A scoping process was performed initially, before the actual literature searches began. This was done to identify focus industries and focus stressors in searches, but also due to a limited time frame of the project, and the considerable size of the research area.

A QSR was then developed for each stressor by the respective focus group. Librarians from the University of Oslo Library of Medicine and Science supported the review team with their technical knowledge and advice. They also assisted with expert help for the search for contaminants as this was challenging, to reduce irrelevant hits.

The QSR search was followed by a standard more focused search for each stressor. And finally, a risk evaluation was performed based on the literature results and by subjective key expert opinion. This chapter provides a general overview on the different stages of the literature assessment.

#### 4.2.2.1 Selection of relevant key industries & stressors

The scoping prosses resulted in a list of approx. 32 industries that operate in Norwegian coastal waters. The list was compiled and used as a starting point for selection of relevant industries for the literature-based assessment (see Objectives 1.3). This list included various industries/activities which hold discharge permits to water (Norwegian Environment Agency), as well as other industries that operate in the marine waters (fishing, renewable energy, shipping, tourism, agriculture, military activity etc.), or have emissions from wastewater as these can have a concurrent environmental impact with aquaculture (based on expert opinion).

Prioritization of key industries was done by identifying the presence of these various industries and dividing them into the various salmon production areas (1-13) for commercial permits for the aquaculture (see Figure 4.4).

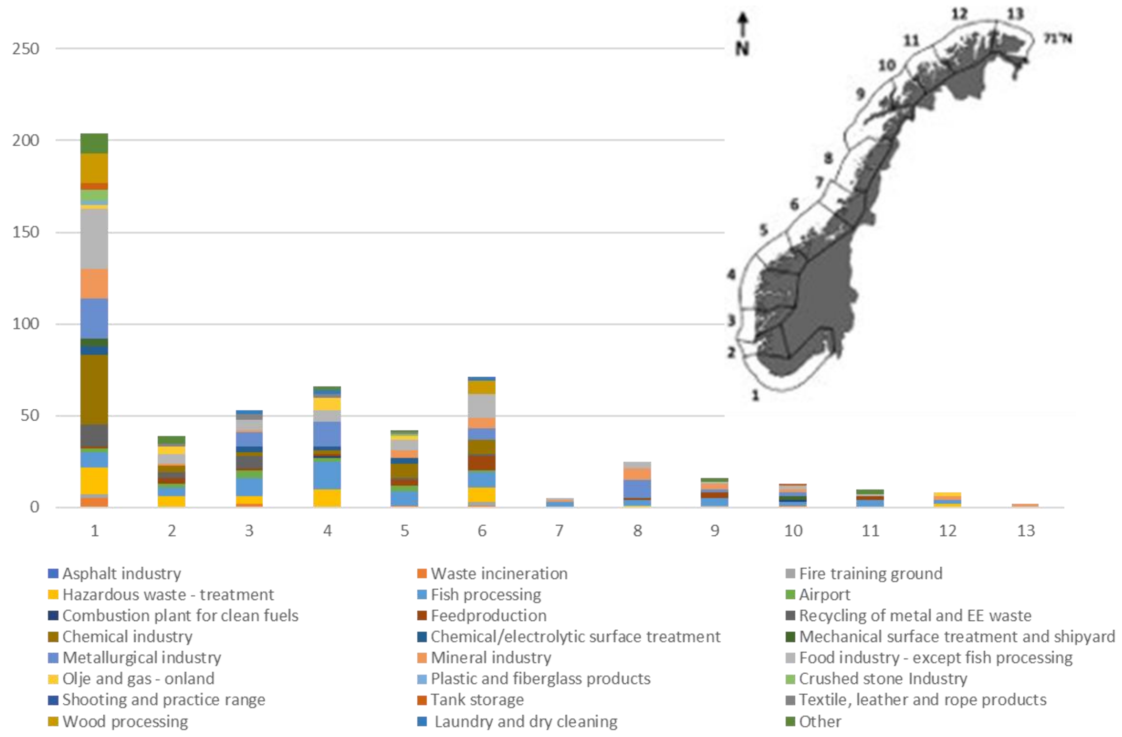


*Figure 4.4. Industries with number of discharges permits to water (y axis), based on the Norwegian Environment Agency (https://www.norskeutslipp.no/), divided into the different salmon production areas (1-13) for commercial permits for the aquaculture (x axis).*

Although dominance of industry activity varied geographically (Figure 4.4), this approach allowed us to identify the six most prominent key industries within the Norwegian coastal zone that operates in the same ecosystems as aquaculture:

1. Fisheries
2. Shipping (including cruise traffic)
3. Agriculture
4. Food processing industry (dairy, meat industry, brewery, fish refining)
5. Chemical industry (pharmaceutical industry, oil refinery, paint industry, metallurgical industry)
6. Mining.

Although not an industry, wastewater (in this study wastewater from wastewater plants (sewage)) was added as proxy for population density. Hydropower was also considered as it can significantly affect river run off and thus input of freshwater, natural sedimentation and contaminants from land-based activities including agriculture.

A broad quick literature investigation was preformed to map the most prominent emissions of the priority key industries (for aquaculture – see chapter 3) and wastewater (Table 4.1). The identified emissions were assigned to the pressure categories, outlined in chapter 3: particles, dissolved nutrients & contaminants. It was obvious that stressors related to the identified industries overlapped well with the pressure categories identified for the aquaculture industry. Using identical pressure categories also allows for a more efficient comparison and assessment. Accordingly, the remaining relevant WP1 pressure categories: contaminants, particles, nutrients, disease/pathogens, noise, light, artificial structure, were assigned to each industry where relevant. The pressure categories were further expanded with stressors mostly relevant to the priority industries: physical disturbance, warming and run-off.

As the search results from QSR in chapter 4 from different themes were extensive it was not possible to do an exhaustive literature review given the short time frame and the broad research area (see QSR results in 2.2). Therefore, the focus has been on obtaining an overview of the eight priority industries and wastewater, and the contributing stressors to the same stressors from aquaculture, illustrated in Figure 4.5. Based on this, the three pressure groups which had the most contributing industries were identified (see Figure 4.5), namely contaminants, particles, and nutrients. Accordingly, these three stressors were the focus of the literature assessment, however the other stressors will also be briefly described and assessed swiftly.

*Table 4.1. Priority industries and associated emissions, these lists are not exhaustive as they were performed by a broad quick literature investigation to get an overall picture of emissions similarities between industries.*

| Industry | Emissions |
|---|---|
| **Fishery** | *Organic micro-contaminants*: disinfection, wastewater, oil, oil containing mixtures, PAH; *Antifouling:* organotin tributylin (TBT) (now prohibited but on old ships), copper, metals, heavy metals, pesticides; *Scrubbers*: acidic wash water (ocean acidification), elevated concentrations zinc, vanadium, copper, nickel, phenanthrene, naphthalene, fluorene and fluoranthene; *Sewage/Grey water**: nutrients, phosphate, nitrogen, , particles, organic waste; *Plastic*: marco & microplastic. |
| **Shipping (including cruiseships)** | *Organic micro-contaminants*: disinfection, oil, oil containing mixtures, PAH, pesticides; *Scrubbers*: acidic wash water, elevated concentrations zinc, vanadium, copper, nickel, phenanthrene, naphthalene, fluorene and fluoranthene *inorganic substance*; *Antifouling*: tin, metals, heavy metals; *Plastic*: Marco & microplastic; *Wastewater (can be released 300m from land)*: nutrients, phosphate, nitrogen, particles, organic waste. |
| **Wastewater** | *Organic micro-contaminants:* chlorinated organic compounds, pharmaceuticals, pesticides, disinfection, oil, oil containing mixtures, PAH; *inorganic substances*; *metals:* copper, zinc; *Heavy metals:* mercury, arsenic, nickel; *Salt/Acid*: sulphate; *Plastic:* microplastic; *Nutrients*: phosphate, nitrogen, Particles*:* organic waste, dry matter suspended |
| **Agriculture** | *Particles; Nutrients:* phosphate, nitrogen, organic matter; *Organic micro-contaminants:* pesticides; *Plastic:* microplastics |
| **Food processing industry** | *Particles*: Dry and organic matter suspended; *Nutrients*: organic matter (proteins, milk sugar, fat, blod, urin) chemical oxygen consumption; *Organic micro-contaminants*: disinfection, wastewater(pH), oil, oil containing mixtures, PAH, detergents, alkaline water. |
| **Fish refining** | *Wastewater:* nutrients, phosphate, nitrogen, organic waste; *Disinfectants*: chlorine; *Plastic:* microplastic (pipes etc). |
| **Metallurgical industry** | *Dust particles; Leachates from landfill; Wastewater*: oil, oil containing mixtures, PAH, acids, hydrochloric acid (HCL), sulfuric acid ($H_2SO_4$), arsenic acid ($H_3AsO_4$), pH, phenols, metals, heavy metals, tar; *Plastic,* microplastic. |
| **Chemical industry** | Pharmaceutical industry: *Particles*: Organic matter suspended; *Nutrients:* chemical & biological oxygen consumption; *Organic micro-contaminants; Pharmaceuticals;* Oil refinery: *Organic micro-contaminants:* oil, oil containing mixture, PAH, undefined chemicals; Paint and varnish industry: *Organic micro-contaminants*: oil, oil containing mixtures, PAH, undefined chemicals; *metals/heavy metals* |
| **Mineral industry** | *Mine waste rock and tailings:* heavy metal contamination & leaching, arsenic, cobalt, copper, cadmium, lead, silver, zinc, nickel, chromium, mercury: *Processing Chemicals Pollution:* chemical agents (used by mining companies to separate the target mineral from the ore) cyanide, sulphuric acid, xanthates. *Erosion and Sedimentation*: Excessive sediment can clog riverbeds and smother watershed vegetation, wildlife habitat and aquatic organisms; *Microplastics* |

*> 300m from land, prohibition against the discharge of sewage and grey water, requirement for an environmental instruction and prohibition against incineration of waste on board ships in the world heritage fjords. South of Lindesnes to the dividing line Norway–Denmark and in the waters from there to the Swedish border, untreated sewage can only be discharged at greater than 12 nautical miles from land.

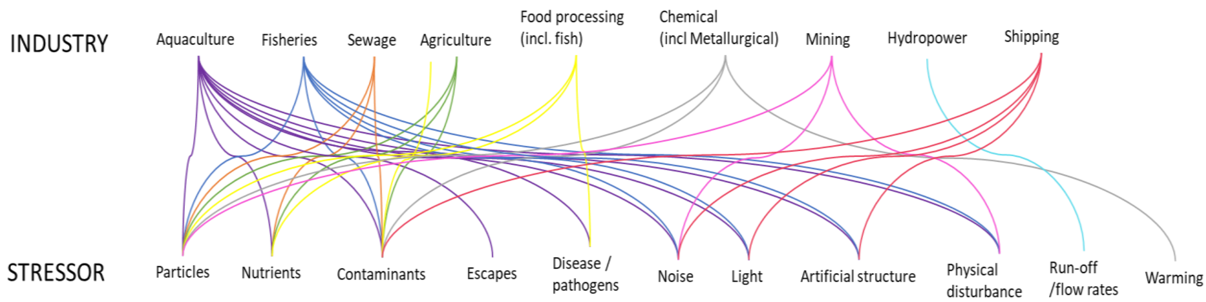


*Figure 4.5. A schematic overview of the eight priority industries and their contribution to each pressure. The three pressure groups with the highest number of contributing industries were contaminants, particles and nutrients.*

Furthermore, the QSR identified 17 articles related to climate change/ocean acidification impacts and risks on marine aquaculture. The report will however not describe the different industries contribution to greenhouse gas emission as this is slightly out of scope and not possible in the time frame of the project. But as the aquaculture industry depends on water quality and weather circulation conditions in the fjords, an increase of ocean temperatures, higher frequency of extreme weather, ocean acidification and changing water salinity due to increased freshwater inflow into the fjords, will affect the aquaculture industry in the long run. Therefore, a small section describing the main climate change impacts and associated risk will be included.

#### 4.2.2.2 Literature assessment – Quick Scoping Review and literature review

The procedure for compiling the literature for the literature assessment was a combination of using a QSR as a work tool, and a standard literature review.

The search framework for the QSR (database, date and language restrictions etc.) was identical to the description in chapter 2. Before the development of the QSR, however, a survey of industries as well as the most relevant industries and the associated stressors as described above, was carried out. Since many of the stressors overlapped between several industries, it was decided to conduct a 'pressure' specific QSR rather than focusing on each individual industry. This is reflected in the main questions and in the concept overview (see below).

Example - Main question:

Pressure specific example: "What is the impact of emissions of particles from anthropogenic activity on the marine environment?"

Industry specific example: “What is the impact of aquaculture, mining, agriculture, food processing, etc. on the marine environment?

The search profile was expanded to also include the additional industries. The search profile for AP2 thus consists of the following:

| |
|---|
| Concept 1: "Population" - aquaculture & focus species. |
| Concept 2: "Impact" or "Intervention" part 1 - The industries |
| Concept 3: "Impact" or "Intervention" part 2 - description of the pressure |

Drafts of search profiles for each pressure are outlined in supplementary material (chapter 8.2), but an example of nutrients are presented here.

Dissolved nutrients

Primary question: What is the impact of change of nutrient levels due to anthropogenic activity on aquaculture (direct & indirect)?

| |
|---|
| Concept 1 (salmon and trout):<br><br>TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen*" OR netpen* OR "net pen*" OR farm* OR fishfarm*) AND (salmon OR salmo OR salmonid* OR trout* OR oncorhynchus mykiss)) |
| Concept 2 (industry):<br><br>TS=((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/2 (industr* OR sector OR harvest*)) OR shipping OR cruise*OR ((maritime OR marine OR naval) NEAR/3 (industr* OR sector* OR transport* OR freight*)) OR sewage OR sewerage OR (sewage NEAR/3 (sludge OR wastewater OR effluent)) OR agriculture OR farming OR (food NEAR/2 cultivation) OR (food NEAR/3 industr*) OR (food NEAR/2 process*) OR slaughter* OR dairy* OR brewer* OR (("fish process*" OR "fish-process*") NEAR/3 (industr*)) OR "fish process*" OR "fish-process*"OR (pharmaceutic* NEAR/3 industr*)) |
| Concept 3 (pressure):<br><br>TS=((dissolve* NEAR/2 (nutrient*) OR phosphor* OR phosphate OR phosphorus OR nitrogen OR ammoni* OR ((dissolve* OR solub*) NEAR/2 waste*) OR ("organic* NEAR/2 waste*"))) |

The results of the initial QSR (aquaculture combined with priority industries) for the three chosen stressors (particles, nutrients, and environmental contaminants) did not provide much relevant results. Many of the results were not relevant to stressors, concerned freshwater or were not relevant to the Norwegian context of aquaculture. Subsequently a more targeted search was carried out to describe the industry-specific impacts (spatial and temporal). The objective of this search was in addition to identifying scientific articles that went under the radar in the initial QSR, to find relevant work that has not been published in peer-reviewed journals, but rather in reports and reviews from different institutes and governmental organizations (grey literature). The search therefore included a standard literature search in international scientific journals as well as websites of relevant organizations and respective databases. Examples are given in Table 4.2, suitability and relevance varied with pressure.

*Table 4.2. Examples of sources for grey literature.*

| Organisation & website | Country |
|---|---|
| Norwegian Environment Agency (https://www.environmentagency.no/) | Norway |
| Scottish Environment Protection Agency (https://www.sepa.org.uk/) | UK |
| Institute of Marine Research (https://www.hi.no/hi/en) | Norway |
| Ministry of the environment (https://environment.govt.nz/) | New Zealand |
| European commission (https://commission.europa.eu/index_en) | Europe |
| Internal project results (https://www.niva.no/en/reports) | Norway |
| Databases (Vannmiljø, the Norwegian Seafood Database, Barents Watch, the Norwegian Institute of Public Health) | Norway |
| Monitoring programs (e.g. MILKYST, ØKOKYST etc.) | Norway |

For each pressure group, contributing industries and activities pressure will be described. Spatial and temporal distribution of the pressure will be discussed and the possible receiver of the pressure, and their vulnerability to the impacts from the pressure will be described. Furthermore, risks to the aquaculture industry from the prioritized industries contributing to the pressure group will also be described (see chapter 4.2.2.3).

#### 4.2.2.3 Risk assessment to aquaculture

Industries that operate within the same marine waters as aquaculture may also pose a risk to current aquaculture activity and development. Environmental risk assessments or investigations aim to quantify the probability of undesirable events along with their consequences.

This report will investigate and describe direct and indirect risks of other industries on aquaculture related to the stressors identified. This assessment only addresses risks relevant to Norwegian aquaculture, which mostly produces Atlantic salmon, focusing on the growing phase in the sea, and it does not include all extreme incidents (see graphic illustration of risk dimensions in aquaculture Figure 4.6).

Assessment of direct risks will focus on cage environment and aquaculture animals (fish health/welfare), as the farmed fish are reliant on good surrounding water quality.

Indirect risks will include public health / food safety (for example if aquaculture animals accumulate toxins from other industries) (Figure 4.6).

Indirect risk also includes culmulative environmental impact and has already been described for aquaculture (see chapter 3). Accordingly in this part we will  focus on potential overlap of the preassures released by other industries in geographical scale (overlapping, accumulating stressors on the ecosystem) with the release from aquaculture industry as another indirect effect. We will investigate if there is a possible cumulative  impact on marine ecosystems from each preassure.

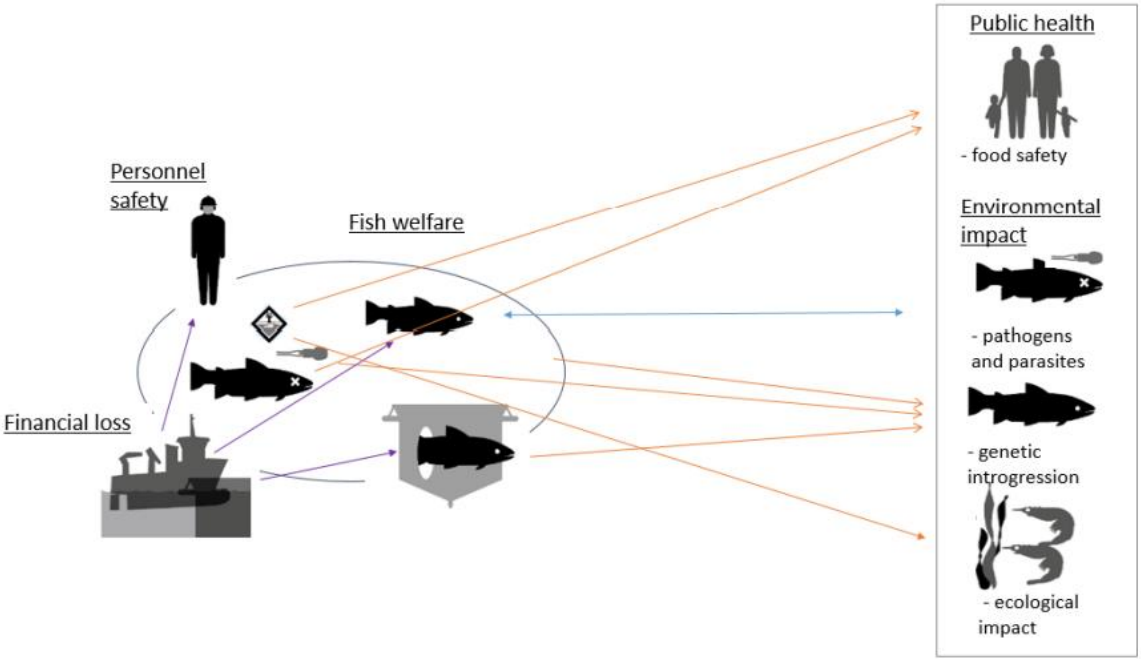


*Figure 4.6. Risk dimensions in aquaculture. (Source; Holen, et al. 2019).*

The report focuses on environmental risks and will not include institutional risks or social/ market risks that could lead to financial loss as these are out of scope of the current project. Institutional risks include governmental policy, planning, extension services and financial assistance, and controls, any of which can have impacts or risks to the development of aquaculture. The effects of aquaculture on the environment may for instance lead to stricter regulations. Market/reputation risk includes risk connected to traditions, customs, religious beliefs which affect fish consumption and the social acceptability of aquaculture as an individual, group, or community activity, that again can affect markets. Furthermore, we will not evaluate personal safety.

#### 4.2.2.4 Limitations

Natural causes of impact and changes in ecosystems and risk for the aquaculture industry are not included in the assessment. This includes for example disturbance regimes (e.g., storms, floods), ambient environmental (e.g., Seasonal productivity, interannual variability), biotic interactions (e.g., Herbivory & predation, Decomposition).

### 4.2.3 Results

#### 4.2.3.1 Industries & stressors

Table 4.3 shows the retrieved records for the QSR searches in web of science for each pressure. Particles, dissolved nutrients and environmental contaminants were investigated thoroughly (all QSR records were investigated), for the other stressors reviews are based on more quick assessments. All the stressors and related search results will be described individually. A graphic summary of the prioritized industries/ activities, related stressors and main impact of stressors are presented in Figure 4.1. A summary of the risk evaluations to aquaculture are presented in Table 4.17.

*Table 4.3. Retrieved records for each pressure by the QSR search in web of science. * Are stressors that were thoroughly investigated.*

| Pressure | Retrieved records (QSR) |
|---|---|
| **Particles*** | 595 |
| **Dissolved nutrients*** | 424 |
| **Environmental contaminants*** | 2198 |
| **Noise** | 52 |
| **Light** | 7 |
| **Artificial structures** | 73 |
| **Physical damage** | 1062 |
| **Freshwater regulation** | 3 |

#### 4.2.3.2 Particles

Particles in water masses are all sorts of non-dissolved aggregates of variable size. The term can include living organisms such as bacteria and plankton and non-living particles of both organic and inorganic origin. This report focused on the non-living particles, both of organic and inorganic origin. Particles can enter the environment from natural sources such as river outlets and thereby possibly be influenced by the hydropower industry and from all the other sources defined as "industry" in Figure 4.1.

The QSR for particles pressure towards aquaculture identified 1086 scientific articles. However, the evaluation only found 7 articles of relevance for the topic of other man-made impacts toward the aquaculture industry. The detailed evaluation of the 7 QSR articles revealed that detailed descriptions of potential interactions with aquaculture were lacking. There was however interesting knowledge related to impacts of particles potential interactions with the marine environment. As the QSR did not provide a satisfactory foundation on its own, supplementary knowledge and information from more specific searches in scientific as well as grey literature (reports, websites, databases etc.) were included in the assessment.

The exposure of fish to particles in fish pens occurs when particles are in suspension. Suspended particles are associated with negative effects on the spawning, growth and reproduction of fish, and the gravity of effects depends on their developmental stage. In the early life stages (egg, larvae) the effects on physiology, behaviour and habitat can lead to physiological stress and reduced survival rates (Bilotta and Brazier 2008, Reinardy et al. 2019). The exposure of prolonged elevated concentrations of suspended particles to juvenile and adult fish rarely lead to lethal effects and is more likely to lead to sublethal and behavioural effects that may compromise fish health (Dale et al. 2008). Examples of these are increased activity and stress, reduced growth, suppressed immune system leading to osmotic dysfunction and reduced resistance to disease, physical abrasion, and clogging of gills. For free-living fish, the effects can also include loss of or reduction in foraging capability and interfere with their natural movement and migration (Au et al. 2004, Kjelland et al. 2015, Redding et al. 1987).

There are a wide range of anthropogenic and natural sources of particle suspension from land to waterways that may eventually lead to periodic or continual elevated levels of suspended particles in coastal waters. Human activities on land that may lead to increased particle concentrations include logging, grazing, agriculture, mining, road construction, urbanization, and discharge of waste streams (municipal/industries). Natural sources of particle transport from land to coastal waters are related to river discharge. These can result in continuous or periodic (e.g. snowmelt, flooding, erosion) transfer of sediments from rivers to coastal waters, and may also be affected by human activities, e.g. hydroelectric plants, urbanisation. Human activities at sea that may affect the concentration of suspended particles include vessels (upwelling), navigation and maintenance construction (dredging), port construction, land reclamation and submarine discharge and disposal. Natural processes that can cause upwelling and resuspension of sediments at sea include waves, currents, and erosion. In the following an assessment is made on the potential risk of impacts of these sources on aquaculture.

*Natural processes* that affect the concentration of suspended particles in coastal waters include river discharge of sediments, currents, waves, and erosion. Dominant natural processes and their consequence for particle concentrations vary according to quantity of sediments transported by rivers, currents, and tidal conditions, amongst others, and therefore the effect of the natural processes on the marine environment also varies. In a study of particle transport in Norwegian fjords, it was for instance found that the flux of particles in Hardangerfjorden was more affected by natural processes than aquaculture (Lalande et al. 2020). The effect on aquaculture was not part of the study, however seeing that the fjord has a high density of fish farms the natural processes have not prevented the development of aquaculture. Areas with natural processes that result in permanent or periodic high particle concentrations with high risk of affecting fish health are not likely to be exploited for aquacultural activities. The risk of impact of natural processes that are well mapped (and not extreme) are hence assessed as posing a low risk on aquaculture.

*Agriculture, grazing and logging* can result in the loss of particles from the land. Although concentrations of suspended particles in adjacent water streams can be high (Wu et al. 2004), these are diluted prior to transport to coastal waters. The monitoring of rivers in Norway includes the measurement of suspended particles and in the period 1990-2021 a river flowing through agricultural land had low particle concentrations. In addition, no increase in particle concentrations was observed from 1990 to 2021 (Kaste et al. 2022). For agricultural land located close to the shoreline, there is a risk of run-off more or less directly to coastal waters, however high dilution in most places ensure that suspended particles will not occur in concentrations with risk of effect on aquaculture. Pollutants adsorbed to the particles are more likely to cause an effect. In this assessment extreme events like erosion have not been included, e.g. extensive logging could increase the risk of erosion.

*Road construction, urban activities and development, and industry* all include activities that produce dust or discharge of particles. On a worldwide scale there are examples of particle emissions from industry that impact the marine environment. In Bahrain, runoff, and a sand wash plant north of Askar for instance resulted in discharge of large quantities of fine particles impacting the water quality to such an extent that it influenced the benthic flora and fauna (Ali 2022). While fish health was not part of the study, the reduced oxygenation and light penetration could affect marine fish. Although this case may not apply directly to Norway, emissions and discharge of particles do take place, most of the information related to this was found in the grey literature.

In 2021, the effect of particle runoff from four different construction sites in southern Norway on the aquatic environment was investigated. The results showed no negative effects on population levels and in several streams the trout density increased during and after construction. The long-term effects were not studied, and the authors of the study recommended compilation of data from environmental monitoring of streams, rivers and lakes during large construction projects be compiled for better understanding and prediction of effects on the aquatic environment affected by such activities (Roseth et al. 2021).

Particulate matter emissions from human activities amount to approximately 35,000 ton per year (SSB 2021). The main sources of particulate matter emissions in Norway are wood stoves (50%), industry and mining (27%), road traffic (18%) and fishing and shipping (5%) (Ibenholt et al. 2015). In some areas the industry is the main contributor, e.g. the metallurgic industry in Mo i Rana or Titania landfill of mine tailings. The dispersion of particulate matter from the latter has for instance resulted in periodic transport and fallout to nearby villages. The potential effect of particle matter dispersion and fallout to waterbodies has not been investigated, as far at the authors are aware of.

There are clearly some gaps in knowledge as to the fate and effects of particulate matter discharge and emissions in the environment and there appears to be a need for compiling knowledge and assessing the impacts on aquatic environments in Norway more thoroughly. Based on the existing studies and knowledge, there are no major issues for the marine environment related to industry, construction or urban activities. Fairly strict regulations for emissions and discharge are already in place in Norway, as well as requirements for emissions/discharge during industrial and urban activities. For those reasons construction, industry and urban activities are assessed as posing a low risk for aquaculture. In areas where industrial emissions/discharge/fallout dominates in periods, more investigations may be needed to assess whether these activities would affect aquaculture.

*Vessels, dredging, land reclamation and port construction* are all activities at sea that may cause upwelling and resuspension of sediment particles. Ships and vessels can cause upwelling, mainly during docking operations. In the guidelines of environmental risk assessment of polluted sediments from the Norwegian Environment Agency (M-409), are included calculations for assessing upwelling of sediments during ship docking. Studies, summarised in the guidelines report, conducted in Norway have shown upwelling of 40-2,800 kg particles per ship docking. In some harbour and port areas several thousand tons of particles are hence upwelled per year. The large variations in upwelling are due to sediment composition (higher content of fine material results in larger upwelling), bottom conditions (hard vs. soft bottom) and depth. According to the Norwegian Environment Agency upwelling of sediment in depths deeper than 20 m does not occur (Norwegian Environment Agency 2015). Other ship/vessel activities that can cause upwelling is trawling. Upwelling is greatest for soft bottom conditions with high content of clay and silt. Few studies have been carried out in Norwegian waters, one study in Eidangerfjord was summarised in a report on the effects of trawling (Løkkeborg et al. 2023). A 1.8 km trawl produced a cloud of 3-5 million $m^3$ sediment containing 9 tonnes of silt. The sediment plume had a width of 120-150 m and height of 15-18 m above the seabed. Most of the upwelled sediments settle on the seabed again within a few hours, apart from fine particles that can remain in suspension for days.

Dredging to increase navigational depth or remove polluted sediments, land reclamation and port construction all involve activities that result in upwelling of sediments. The extent to upwelling depends on the methods used. Dredging, land reclamation and construction projects along the coastline all have to be approved by the environmental authorities due to the risk of adverse impact on the marine environment. In most cases the authorities will also require that actions to control dispersion of particles are implemented. In Norway, the use of silt curtains is most often used to limit the dispersion of particles outside the dredging/construction area. The silt curtain will prevent the passing of particles of a certain diameter (Winther-Larsen 2013). Nevertheless, there are examples of dispersion of particles outside silt curtain due to insufficient sealing of the curtain along the seabed, strong influence of wind and currents, minor tears in the curtain or construction work resulting in such strong currents that the silt curtain cannot contain. In addition, finer particles of sizes smaller than the mesh will also be dispersed and have an impact on the marine environment. For this reason, particle dispersion is measured during dredging/construction works and in the events of turbidity exceeding set threshold values on the outside of the silt curtain for a prolonged time period, works are temporarily suspended until turbidity has reached an acceptable level.

The risk of overlap between vessel, dredging, land reclamation and construction activities is assessed as being low. Dredging, land reclamation and construction projects are time-limited with the possibility of controlling particle dispersion. In most cases the distance to aquaculture pens will ensure that sedimentation of suspended particles occur prior to reaching the pen. In the event that such projects are conducted in the vicinity to aquaculture pens, there are possibilities that threshold values for particle dispersion can be set in a way that is acceptable to aquaculture. Short-term exposure to elevated particle concentrations could occur, but long-term exposure will be prevented by suspending work in the dredging/construction areas if/when particle concentrations exceed threshold values. Docking of ships in ports/harbours is unlikely to result in particle plumes that will reach aquaculture pens, mainly due to the distance between them. The highest risk of overlap is between trawling activities and aquaculture, and the risk of particle plumes from trawling activities reaching aquaculture pens is still assessed as being low. Despite there being few studies for assessing particle plumes from trawling, the few existing studies show that particle plumes are not transported higher up than 20 m from the seabed. An overlap in the environmental footprint may exist between trawling and aquaculture, i.e. overlap in sedimentation of plumes and hence effect on the marine environment. This has however not been investigated and further studies are needed to make an assessment of a potential overlap.

*Submarine disposal* has been and is a common practice in Norway, mainly used for disposal of sediments in connection with increasing navigational depths or development of harbours, as well as disposal of mine tailings. One of the first and largest projects involving dredging and disposal of 440,000 $m^3$ in the Malmøykalven sea disposal, was in connection with remediation of Oslo harbour 2006-8. Since then, sea disposal of sediments is a common practice, whether for development or remediation of harbours. Mine tailings are a by-product produced during the separation of metals from mined ore and are often a slurry of fine material with a high content of water. The quantity of mine tailings is large from several thousand to million cubic meters per year. In Norway, submarine mine tailings disposal has been a common practice of waste management and there are currently 5 active mines that use the practice. Historically, dispersion of mine tailings several kilometres from the discharge point has been one of the main environmental issues. Today whether submarine disposal of dredged sediments or mine tailings, there are strict regulations to limit dispersion of particles outside the area that has been authorized for submarine disposal. Some of the requirements for disposal areas is that there is low risk of re-suspension after disposal (e.g. low currents to upwhirl particles). This means that the highest risk of particle dispersion is during discharge or release of sediment/mine tailings. There are also requirements for limiting the dispersion during discharge, e.g. by the addition of flocculants to ensure fast sedimentation of the fine particles or method of release from a barge (sediments). In the disposal area the environmental authorities acknowledge and accept environmental impacts, e.g. to the benthic community. However, the marine environment should not be affected outside the disposal area. In the case of particles, environmental permits for disposal contain threshold values for particle concentrations and if these are exceeded, the discharge must be temporarily suspended to solve issues resulting in the elevated concentrations. There may be a difference in the effects of sediment and mine tailings on fish health, a study for instance found that sponges on the seabed dealt better with natural sediments than crushed rock (Kutti et al. 2015).

The risk of overlap between submarine mine tailings disposal and aquaculture is assessed as low. This is mainly due to aquaculture not being permitted to be established in disposal areas. In the event of placement in the same fjord, outside the disposal area, the risk of particle dispersion to the aquaculture pens are related to extreme events in which particle concentrations exceed threshold values. Due to strict regulations of elevated concentrations in environmental permits this should be limited to short-term exposure, and low risk for fish health.

***Conclusion***

In general, the risk of elevated concentrations of suspended particles in aquaculture pens due to other sources is assessed as low. The risk of effect on fish health is therefore also assessed as low. The main reason for the low risk is due to limited overlap between other activities, that can cause elevated particle concentrations, and aquaculture. Even in situations with potential overlaps, such as trawling in the same location, the resulting plume of particles is unlikely to be dispersed to the aquacultural pens. An overlap of trawling and aquaculture may exist in the environmental footprint. This has however not been investigated and further studies are needed to make an assessment of the consequences of a potential overlap.

#### 4.2.3.3 Dissolved nutrients

Dissolved nutrients are vital for life in the oceans, as building blocks for growth and survival of marine life. Although there are many kinds of nutrients, the most critical are nitrogen and phosphorus because plants cannot survive without them (therefore termed limiting nutrients). In the oceans, more than 95% of nitrogen occurs as inert dissolved $N_2$ gas, unavailable to most species. Other forms of nitrogen, available for plant uptake in oceans include nitrate, ammonium, and nitrite. The composition of these reactive nitrogen compounds in the oceans depends on environmental conditions. *Nitrate* is generally the most abundant and is stable over a wide range of environmental conditions. *Ammonium* can be used directly by phytoplankton; it is however not as stable as nitrate in the aquatic environment and the majority of it is converted to nitrite or nitrate. *Nitrite* is an intermediate product between ammonium and nitrate and in oceans with sufficient levels of dissolved oxygen, nitrite is easily transformed into nitrate. Phosphate is the most common and biologically available form of phosphorus in oceans.

The effect of nitrogen and phosphorous on aquatic life depends on the form as well as the concentration. Although both elements are vital for the fertility of the sea, too much can lead to detrimental effects. A major concern of elevated concentration of nitrogen and phosphorous in the sea is when this leads to eutrophication. This enrichment of nutrients leads to the increased growth of aquatic plants. This can for instance result in algal blooms, and in some cases, algae grow faster than ecosystems can handle. This can in turn lead to poor water quality and decrease in dissolved oxygen in the water that aquatic life needs to survive. In extreme cases, eutrophication can result in fish kills. The enrichment of nutrients in coastal waters can occur naturally, human activities have however increased the input. The input of nutrients from land occurs via rivers and groundwater. In addition to this nitrogen also has an input via the atmosphere, partly affected by human activities (e.g., from combustion exhaust). A natural source of nutrients is from the open sea via upwelling, winter mixing, eddies and diffusion from below a permanent or seasonal thermocline.

Some of the land-based sources of nutrients originating from human activities include agriculture, wastewater, industries, and combustion exhaust. Sea-based sources include aquaculture and wastewater from ships. To assess the relative impact of anthropogenic nutrient sources on aquaculture, a QSR on nutrients was conducted. This resulted in identifying 689 scientific articles of nutrients, however of these only 11 were considered relevant as foundation for the assessment. The 11 articles spanned a wide geographical area with four covering Asia, 2 covering the Pacific Ocean, 3 covering North and South America and 2 covering Europe. All of the articles included assessments of the nitrogen loads, but none included phosphorous.

The differences in local/regional environmental conditions as well as the composition of the nutrient input to coastal waters over the span of such a large geographical area have low comparative relevance to conditions in Norway. However, in nine of the papers the articles used methods to fingerprint the origin of nitrogen in coastal waters, and this may be of relevance to future studies of source fingerprinting in Norway. The foundation of the fingerprinting used was measurements of nitrogen isotopes and different statistical analysis methods. The fingerprinting methods used were able to distinguish between land-based sources such as agriculture, sewage, and wastewater, and natural sources of nitrogen. None of the articles distinguished between land-based sources and aquacultural sources.

One of the papers concerned a study from Bodø, Norway in which the authors undertook an investigation of the impact of nutrients from agricultural fertilizer and impact from a local fish farm. They found that there was a difference in the effect of enhanced nutrient concentrations on the growth of algae (Streicher et al. 2021).

As the scientific articles did not include conditions specific to Norway, there was a need to further explore the sources and monitoring activities of dissolved nutrients in river- and coastal waters of Norway in the grey literature.

In Norway, the water quality in rivers has been monitored since 1990 and has included the measurements of dissolved nutrients. These have served as a measure of the runoff and discharge of nutrients from land-based sources such as agriculture, industry, wastewater as well as natural land to river, and eventually coastal waters. Even though the monitoring results do not include all nutrient sources in coastal waters, they still have value as indications of general trends for dissolved nutrient concentration from land-based sources in a long-term period of 40 years. The results of the monitoring are reported annually, reports found on the website of the Norwegian Environment Agency. The latest report presents results from 2021, and in addition to the results also include assessments of long-term trends in the water quality of the rivers. In 2021 the water quality was evaluated in 20 rivers along the Norwegian coast (Kaste et al. 2022). The highest concentrations of nitrogen were observed in 2 rivers, assessed to be due to respectively urban and agricultural run-off. Monitoring results from the 20 rivers showed no significant differences in the concentrations of nitrogen and phosphorous in the previous five years. For 9 of the rivers, it was possible to assess long-term trends in the nitrogen and phosphorous concentrations, with a baseline of 1990. There was either no significant change or decrease in the concentration of inorganic nitrogen (nitrate, ammonium). In 5 of the rivers, all located in the south, there has been an increase in concentrations of phosphate, but no increase in concentrations of total phosphorous.

In addition to the monitoring data and on behalf of the Norwegian Environment Agency, NIVA has also estimated the dissolved nutrient fluxes to the coastal waters of Norway. The estimations are reported annually to the Norwegian Environment Agency, the latest report includes data from 2021 (Sample 2023). The estimations have been done by the model TEOTIL2 (specifications and model principles are described in *Tjomsland et al. 2010*). The calculations of the dissolved nutrient loads are based on Norwegian national statistics on population, effluent treatments, and the annual reported discharge from industrial and agricultural point sources (see *Sample 2023* for information on the collection of data). It also includes estimated loss of nutrients from agricultural fields (subsurface and surface run-off), as well as natural run-off from forest and mountain areas. The model also includes estimations of the retention of nutrients along the pathway to the coastal waters. The results of the model calculations for 2021 are presented in Figure 4.7, and includes results from 1990 as a baseline. The input of dissolved nutrients has increased since 1990, for phosphorous there is a three-fold increase, while nitrogen increased 20%. The increase is largely due to increases in the fluxes of nutrients from aquaculture. In 2021, the input of phosphorous from aquaculture was approximately 84% of the anthropogenic sources (excluding background fluxes), while the input of nitrogen was approximately 60% of the anthropogenic sources. The calculations of nitrogen and phosphorous fluxes are similar to those calculated by SINTEF in 2020 by other methods (Broch and Ellingsen 2020).

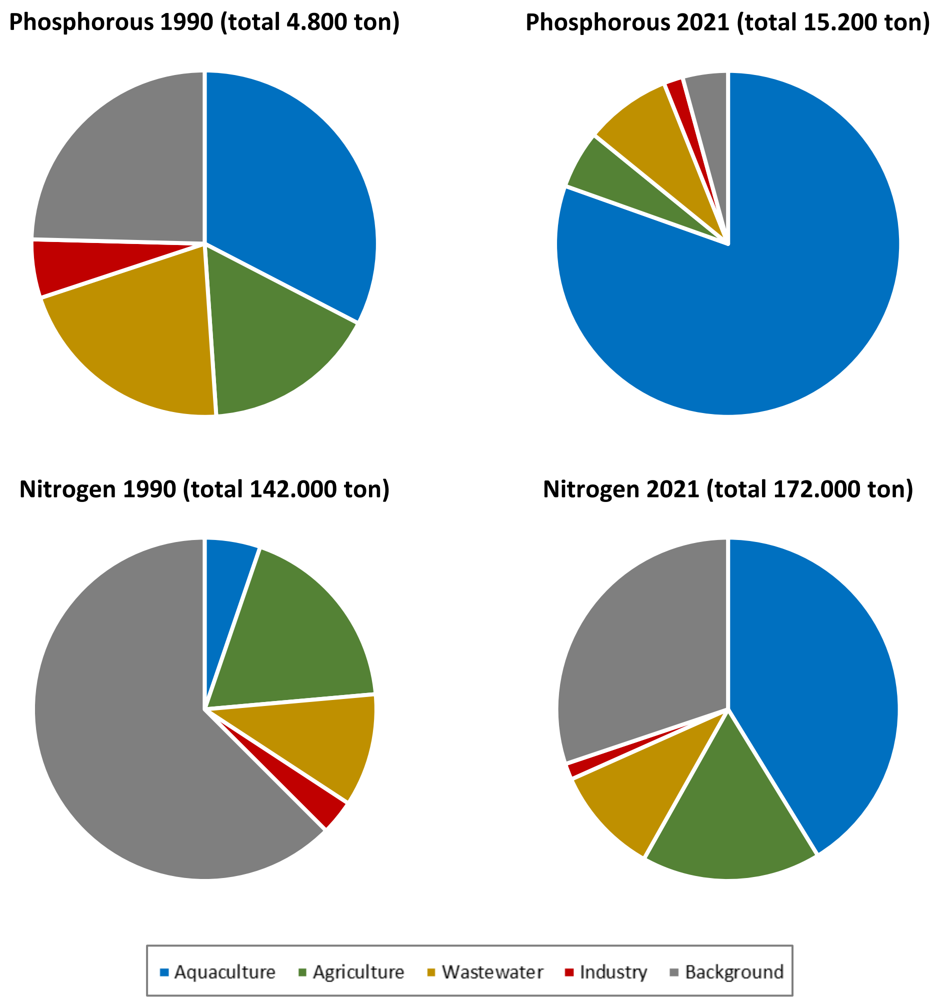


*Figure 4.7. Source-distributed inputs of nitrogen and phosphorous to coastal waters in Norway in the years 1990 and 2021. The figures are based on data from (Sample 2023), in which inputs have been estimated for each source by the use of the TEOTIL2 model. The total input of phosphorous and nitrogen for 1990 and 2021 are given in each pie-chart title.*

One of the industries that could potentially overlap with aquaculture is fish processing plants, which discharge wastewater with high content of nutrients (Jamieson et al. 2010; Naschoug and Busch 2015). The total load is lower than aquaculture, however if the processing plant is located in the vicinity of aquaculture pens, there is a risk of overlap. The consequences of this on fish health has not been fully studied and is unknown. In general, the risk is assessed as low, however if a fish processing plant is located in the vicinity of aquaculture pens there is a risk of overlap, and the effects of this should be further investigated to enable making a qualified risk assessment.

In addition to the land-based sources and aquaculture sources, there is also a natural input of nutrients from the sea. In 2020, SINTEF made estimations for of the natural inputs of dissolved inorganic nitrogen in the aquaculture production areas (0-30 m) in Norway and found that these were 5-20 times as large as the inputs from aquaculture (Broch and Ellingsen 2020).

One of the sources that has not been included in the estimation of nitrogen and phosphorous is discharge from ship traffic. Input of nutrients is mainly related to the discharge of wastewater making cruise ships the main focus due to their large capacities for passengers. In 2019 the cruise ships in Norwegian waters had capacity for up to 7,000 passengers, with most ships (67%) having capacity for 500-3,000 passengers (Krugerud and Kjærvik 2021). According to The Norwegian Coastal Administration the amount of cruise ship docking increased from 2.593 in 2019 to 3.469 in 2022 and is expected to increase further in the years to come. In accordance with the Norwegian pollution control regulations no. 23 (Forurensningsforeskriften kap. 23), different rules apply for discharge of untreated wastewater in coastal waters. In the area west and north of Lindenes, the discharge must take place 300 m from land, apart from the world heritage fjords, in which discharge is prohibited. In the area south and east of Lindenes discharge of wastewater is permitted 12 nautical miles from land. In the future, increasing demands of wastewater treatment systems on cruise ships are expected, in accordance with requirements of MARPOL Annex IV. The requirement for the treatment is removal of at least 70% nitrogen and 80% phosphorous prior to discharge of treated wastewater.

*Conclusion:*

Aquaculture has by far the largest anthropogenic input of dissolved nutrients into the coastal waters of Norway, accounting for approximately 84% and 60% of the total anthropogenic load of phosphorous and nitrogen, respectively. The input from aquaculture is however still lower than the natural input from oceans. The studies uncovered in this investigation, whether from science or grey literature, have not source-distinguished the effects of nutrient enrichment. However due to the large difference in scale of input, land-based sources of nutrients there is a low likelihood of these posing a risk for aquaculture. Little information on the potential differences in effects of nutrient loads from land-based sources and aquaculture were found in this investigation. To further explore on the findings of difference in algae growth from respectively fertilizer and a specific fish farm, more studies are needed. The impact of cruise ships on nutrient loads in coastal waters of Norway is unknown.

#### 4.2.3.4 Environmental contaminants

A wide range of chemical pollutants and plastics can contaminate our coastal waters, impacting the environment and possibly also pose a risk to the aquaculture industry. Most contaminants enter the environment from many industrial and commercial facilities; oil and chemical spills; non-point sources such as storm drains; wastewater treatment plants and sewage systems; and long-range transported contaminants. There are also many polluted sites (for example harbor areas) that have been contaminated for decades and may continue to affect the environment (Harman et al. 2019).

The QSR literature search was very broad for contaminants released by other industries in relation to the aquaculture industry and resulted in 2183 articles. Most were, however, irrelevant due to inappropriate topics, geographical scale etc. 77 articles were found to be relevant in the first screening (see Figure 4.8). These articles covered risks to aquaculture (including climate change risks to aquaculture), fishery and aquaculture interactions, and in addition reviews of different stressors to connecting or specific industries. The articles that described risk to aquaculture mainly described risk on fish health produced by the aquaculture industry itself, or risks of aquafeed on fish health, however one described effects of noise, one of nanomaterials and one mentioned plastic as a risk for food safety. One also discussed sustainability needs local participative governance in Chile, looking at several stressors in the fishery and aquaculture industry.

After further investigation (full screening) 8 articles were found to be relevant and included in the literature assessment.

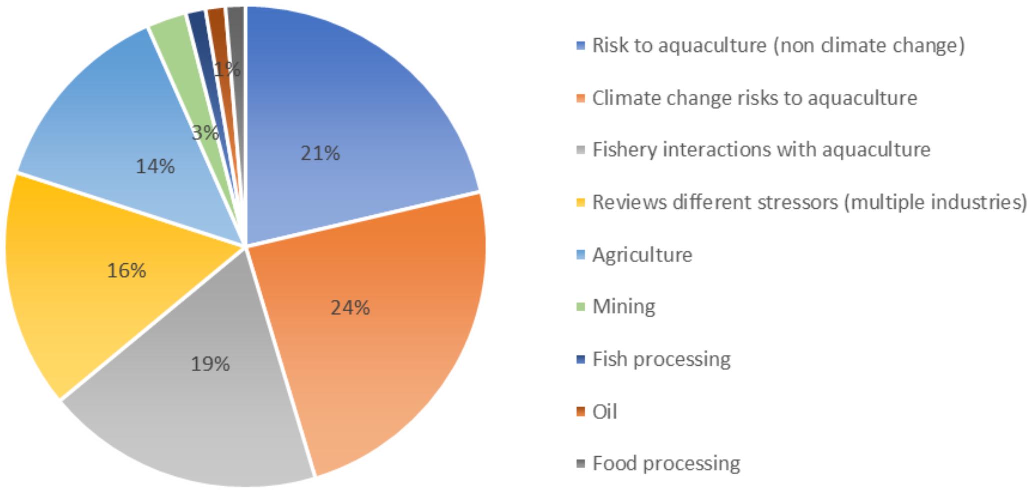


*Figure 4.8. Articles (n = 77) from the QSR search divided by different topics that they covered in percentage.*

It was evident from the QSR screening and our knowledge on the topic that supplementary knowledge had to be gathered in grey the literature. Therefore, a more targeted search was carried out to describe the industry-specific impacts and direct and indirect risk of other industries on aquaculture related to the stressors (see description chapter 4.2.2.3). 24 grey literatures were included in the assessment in this report, in addition to 13 other relevant articles for contaminants.

**Pesticides including delousing agents, biocides, and disinfectants.**

*Pesticides*

Aquatic pest management is required to keep aquaculture industries safe (see chapter 3.3.3.2). Equally pest management such as chemically synthetic sprays or pesticides are considered necessary in large parts of conventional agriculture, therefore this may be a land-based source of pesticides to marine waters. Many of the pesticides used by aquaculture today are or have also been used by agriculture previously. An example of a pesticide previously used in agriculture is imidacloprid, which has since been prohibited for land use but is currently being used as delousing agent by the aquaculture industry (see chapter 3.3.3.2). Agricultural areas are often continuously sprayed with pesticides during the growing season. The runoff from the fields is continuously measured in Norway, and pesticides have been found in runoff waters (Bechmann et al. 2017) and could potentially end up in the oceans (see Table 4.4).

The main pathway of pesticides from agricultural land is mainly run-off into rivers and streams. Most off the findings in water are due to the use of pesticides in adjacent agricultural areas, therefore mostly related to a local scale. Most of the detected pesticides are or have been approved for use in Norway during the monitoring period. However, persistent agents that have since been prohibited can be detected a long time after use has ceased due to the persistency and subsequent long-term leaching of residues from the soil during extreme rainfall and runoff episodes (Bechmann 2017). A Swedish study showed that bays/fjords are also affected by pesticide residues from the agricultural usage, but to a much lower extent than smaller watercourses such as lakes, due to dilution (Wiwstad 2005). The review of

Carvalho 2017 revealed that pesticides used by agricultural activity may end up in coastal areas (Figure 4.9).

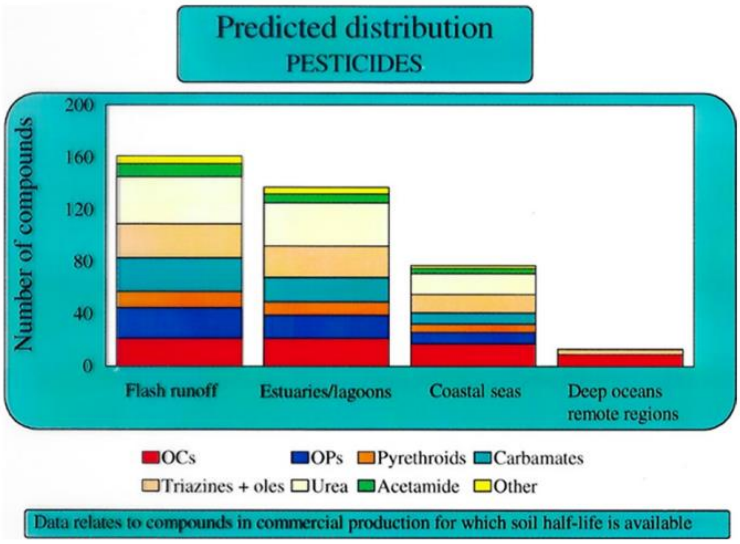


*Figure 4.9. Potential for transport, dispersion and fate of pesticides in the environment. The data relate to compounds in commercial production for which half-lives in soil are available (Source; Carvalho 2017).*

*Table 4.4. Prioritized industries and connected activity/source responsible for the pressure, and scale of emissions for the pressure pesticides.*

| Industry | Pressure source/activity for emissions | Scale of emissions |
|---|---|---|
| **Aquaculture** | De-licing agents are used to treat lice infestations. Pesticides in antifouling on nets (these will be discussed in antifouling). Pesticides can also be found as residues in feed due to plant material used in feed. Discharges directly into marine recipient. | Local/Regional |
| **Agriculture** | Agricultural applications may enter the environment through surface runoff from soil into rivers and the marine recipient. Pesticide residues in plant material from agriculture used as raw material in feed. | Local/Regional |

Pesticides is a group of substances with great variation in the physico-chemical properties and the undesirable effect on the environment varies accordingly (Wiwstad 2005). It is not within the scope of this report to describe all relevant ecotoxicological effects of all substances used in agriculture. However, generally the substances used in agriculture are toxic to aquatic organisms, and pesticide concentrations exceeding threshold values for toxic effects are found in water systems (Carvalho 2017). The threshold levels depend on the type of substance, some substances are for instance toxic at very low concentrations, below detection limit and some substances can bioaccumulate and thereby carries a risk of a long-term impact (Wiwstad 2005, Carvalho 2017). Potential toxicity of these substances is often based on tests of freshwater organisms, and generally, algae and small arthropods are more sensitive to pesticides than animals higher up in the food chain.

In 2021 approximately 4065 tonnes of active ingredients of pesticides (delousing agents) were used by aquaculture (FHI 2021), comparable 880 tonnes of active substance were used by the agricultural industry (this including hobby use) (Mattilsynet 2022). Therefore, aquaculture is likely the largest emission source of pesticides to the marine environment, especially since there are no estimates (data is lacking) and highly unlikely that considerable amounts of pesticides from agriculture end up in the marine environment. Comparing amounts of active ingredients may however not be the most accurate to estimate the possible impact or risk by different industries, as mentioned above some substances are very toxic in low concentrations, others in larger amounts and some of the substances bioaccumulate and carries a risk of a long-term impact.

It is unlikely that there is overlap between the emissions of pesticide released from both industries that could impact ecosystems at local scale, also because aquaculture sites are unlikely to be located in areas with a lot of run off from agricultural activity. At a more regional scale in areas that have a lot of agricultural and aquacultural activity there might be an issue of overlap, but there exists no knowledge of this. It is also unlikely that pesticide run off from land by agriculture could pose a risk for fish health for the same reason. However, there might be a small risk for fish health and human consumption indirectly as raw material used by the aquaculture industry from the agriculture industry may contain residues from pesticides. Berntsen et al. 2021 studied sensitivity of Atlantic salmon to the pesticide pirimiphos-methyl, present in plant-based feeds, and found health effects in the salmon. However, this risk is mitigated by monitoring programs of feed substances and fish fillets in Norway, and maximum residue levels (MRLs) of several substances for feed and fish prepared by European Medicines Agency (EMA).

*Conclusion*

Two industries in this investigation released pesticides into the environment, this is the aquaculture and agricultural industry. Since aquaculture in total uses approximately 5 times as much pesticides as agriculture, aquaculture is probably the main contributor to emissions of pesticides to the marine environment. Although information about the usage of pesticides from agriculture exists, information about the presence and the distribution (spatial scale) into the marine environment of pesticides used in Norway is lacking. Therefore, it is difficult to evaluate possible risks of this use to the aquaculture industry. Based on existing knowledge on location and dispersion of pesticides it is, however, unlikely that there will be a pressure spatiotemporal overlap between agriculture and aquaculture industry. Furthermore, due to dilution it is unlikely that there will be direct risks on fish health and fish consumption by emissions of pesticides by the agriculture into the marine environment. There might be a small risk of pesticide residues in raw material used in fish feed to fish health and fillet transfer therefore human consumption, however the risk seems to be negligible as this is mitigated by monitoring programs of feed and fish fillets.

*Disinfectants*

The use of disinfectants is important hygiene for combating fish diseases in the aquaculture industry (se chapter 3.3.3.2). There are several other industries that uses disinfection agents such as the fish processing industries, food processing industries and shipping industry (ballast water treatment) (Table 4.5, miljøkommune.no 2022, Sjøfartsverket 2021, Grote et al. 2022, Jamieson et al. 2010). Disinfectants can also be a release from sewage however this depends on the type of wastewater that comes into the wastewater plant. Some of the disinfection products generates disinfection by-products (DBPs), which are also discharged into the marine environment (Grote et al. 2022). The use and amounts of disinfectants used by the various industries and the discharges to sea are not very well described in reports and literature. It is possible to have a look at the annual discharge permits for the different separate companies ( https://www.norskeutslipp.no/no/Forsiden/?SectorID=90). Even if the emissions are documented, it does not provide information about how these discharges are distributed temporarily and at what geographical scale discharges are made, and therefore difficult to predict if and where they end up in the marine environment. It is therefore very difficult to predict risks from the various industries' emissions of disinfectants on the environment, not to mention risks they pose on the aquaculture industry. However, Grote et al. 2022 stated that applications from aquaculture and sewage may be more locally relevant, whereas applications from shipping may be more globally relevant. Furthermore Grote et al. 2022 stated that a general conclusion on environmental risks of DBPs in marine water are not possible. For local risk assessment PEC/PNEC < 1 indicates that no unacceptable risks to the aquatic (see chapter 3.3.3.2 for explanation PEC/PENEC). PNEC values for the most important DBPs observed in marine water have been proposed by GESAMP (2019). As environmental DBP concentrations depend on specific discharge conditions and dilution in receiving waters, and any risk assessment process is site- or scenario-specific. However, Grote et al. 2022 show that most known DBPs are not bio accumulative and are quickly eliminated and thus not considered to bioconcentrate in aquatic organisms nor to bio magnify in the food chain (GESAMP 2019). The low bioaccumulation potential of major known DBPs and the important dilution rate in ocean water suggest that the risks for the aquatic environment posed by DBPs are low on larger scales and distances from discharge. However, in specific exposure situation such as in harbours and close to industrial discharges, local effects on aquatic organisms may occur.

Overall, the effects of disinfectants in the marine environment appear to be poorly studied. Grote et al. 2022 suggest more harmonized studies on the different major DBPs identified in oxidant-treated effluents are warranted to allow a more systematic overview on DBP variation in the different industries and regions. Also, to strengthen international efforts in ocean science to build up a better database on concentrations of these compounds in the marine environment.

*Table 4.5. Prioritized industries and connected activity/source responsible for the pressure disinfectants.*

| *Industry* | Pressure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| ***Aquaculture*** | *Disinfecting's equipment and well boats discharged into sea.* Disinfectants used in smolts production possibly released to sea. | *Local may be regional if much is used* |
| ***Sewage*** | *Discharges from plants, depending on type of wastewater that comes into the plant.* | *Local* |
| ***Shipping*** | *Oxidative treatment as disinfectant of seawater in coastal and shipboard installations is applied to control biofouling and/or minimize the input of noxious or invasive species into the marine environment.* | *Local/regional/global* |
| ***Fish processing industry*** | *Disinfection of wastewater from slaughterhouses and manufacturing facilities is carried out to prevent and limit the spread of infectious diseases of aquatic organisms. Discharges into sewage or sea.* | *Local* |
| ***Food processing industry (meat, dairy, brewery)*** | *Disinfecting's equipment, discharges into sea or sewage.* | *Local* |

*Conclusion*

As far as the authors know there is very little information of disinfectants (also shown for aquaculture, chapter 3.3.3.2) in their presence in the marine environment. There are very few data available regarding the presence of disinfectants, and particularly of formulation products, in the marine environment. Studies need to be conducted to document the patterns of use by various industries and the discharges to the marine environment, further the temporal and spatial scales over which compounds can be found. Therefore, it is not possible to evaluate risks of disinfectants used by other industries on aquaculture. However as for the pressure release from other industries spatiotemporal overlap with fish cages, one can think that aquaculture facilities that are not placed near outlets of wastewater or processing plants and therefore the risk for aquaculture (fish health and fish consumption) might be negligible.

**Plastics (macro, micro and nano)**

For definition of macro, micro (MP) and nano (NP) plastics see chapter 3.3.3.3.

*Macro plastics*

Both Sea and land-based activities are responsible for the continued input of macro plastic into the ocean. Coastal waters and shorelines often contain a considerable number of plastic debris originating from different anthropogenic sources including land-based input of debris, aquaculture, shipping, fisheries, and high coastal populations (Lusher 2018, see Table 4.6).

*Table 4.6. Prioritized industries and connected activity/source responsible for the pressure macro plastics.*

| *Industry* | Pressure source/activity for emissions | Scale of emissions |
|---|---|---|
| ***Aquaculture*** | *Daily operations: discharge; parts of cages, wrasse hides, rope, buoys, strips etc.* | *Local/Regional/global* |
| ***Fisheries*** | *Daily operations: discharge: trawling and commercial netting operations, cages, rope, buoys etc.* | *Local/Regional/global* |
| ***Agriculture*** | *Plastics used in operations, run off transported by rivers into oceans.* | |
| ***Other maritime activities including shipping*** | *Plastic litter can be generated from all types of boats, ships and offshore platforms in the ocean. This can be through accidental loss, indiscriminate disposal, or illegal dumping.* | *Local/Regional/global* |

Depending on physical properties as well as environmental conditions macro plastics can be found in the five different compartments of the marine environment: coastlines, water surface, the water column(pelagic), the seafloor (benthic), and in biota. The dispersal macro plastics are influenced by wind, surface currents and geostrophic circulation (Law et al. 2010) and can therefore be distributed over long distances and can be globally distributed. It is difficult to estimate the percentage of marine litter that originates from maritime and land-based sources as there is little certainty behind the available data. However, in Norway, aquaculture, petroleum, and fisheries are some of the biggest maritime sectors, whereas windfarms and decommissioning are smaller. Those smaller maritime sectors may only be contributing to a small proportion of the overall emissions to the marine environment, but no data currently exists to allow such a comparison to be made (Lusher and Pettersen 2021). Furthermore, near river outlets in Hardangerfjorden, Norway one of the main contributors was the agricultural industry (agricultural related plastics) (Buhl-Mortensen 2023). For environmental impact of macro plastics see chapter 3.3.3.3.

### *Microplastics (and nano plastics):*

Lusher et al 2021 pointed out nine predefined sea-based sources for emissions of MP. These included maritime coatings (which have been defined as a cross-sectoral source), maritime traffic, ports marinas and shipyards, decommissioning activities, land-based industry (with discharges into the marine environment), fisheries, aquaculture, petroleum-related activities, and other offshore activities (Figure 4.10). Primary MP/NP are released by both the aquaculture industry, by wastewater, agricultural and chemical industry (). Secondary MP/NP are by-products of fragmentation and weathering of larger plastics and therefore has the same sources as macro plastics (see previous section and Table 4.7).

*Table 4.7. Activities connected to the different prioritized industries that is the source of microplastics (MP) and nano plastics (NP) to the marine environment.*

| *Industry* | *Pressure source/activity primary MP/NP* | *Pressure source/activity secondary MP/NP** | Scale of emissions |
|---|---|---|---|
| ***Aquaculture*** | *Fishmeal for aquaculture feed contains MP* | *Daily operations: discharge; parts of cages, wrasse hides, rope, buoys, strips etc. Wear in feed hoses or chipped ropework, and wear of nanotech plastic-based anti-biofouling agents and paints etc.* | *Local/regional/ global* |
| ***Fisheries*** | | *Daily operations: discharge: trawling and commercial netting operations, rope, buoys etc.* | *Local/regional/ global* |
| ***Other maritime activities including shipping*** | *Sewage, operational discharges* | *Plastic litter can be generated from all types of boats, ships and offshore platforms in the ocean. This can be through accidental loss, indiscriminate disposal, or illegal dumping. Weathering of maritime coatings.* | *Local/regional/ global* |
| ***Wastewater*** | *Discharges from plants most MP/NP in untreated water, some also after filtration, when too small for retention by wastewater treatment.* | | *Local* |
| ***Agriculture*** | *Agricultural applications may enter the environment through surface runoff from soil.* | | *Local/regional* |
| ***Land based industry. (Chemical industry)*** | *Direct discharges to marine recipients from industries such as plastic and paint production facilities.* | | *Local* |

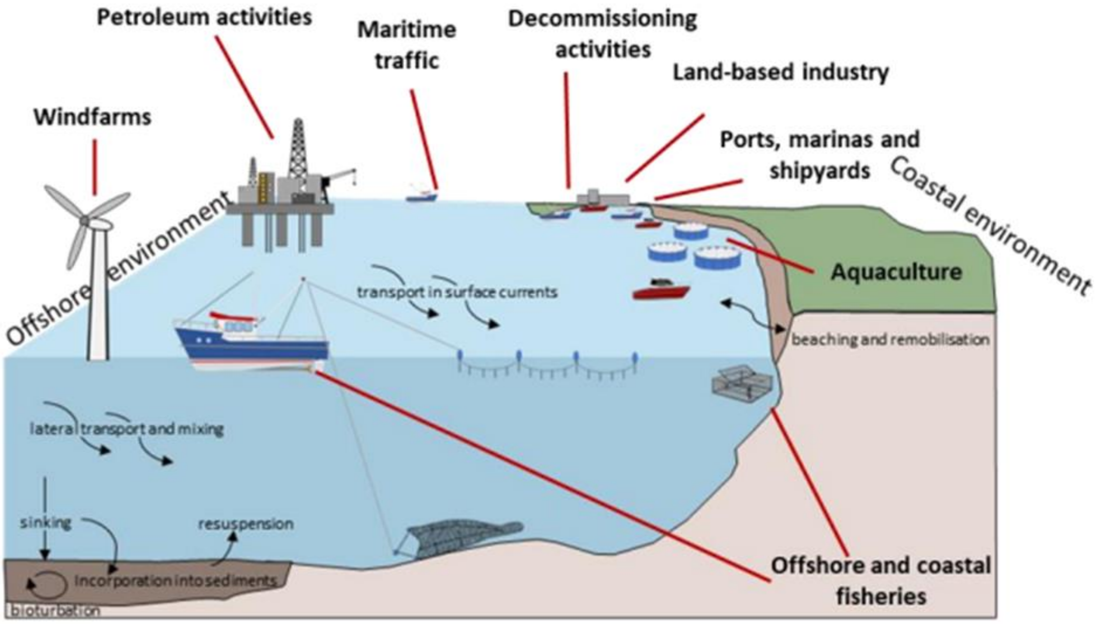


*Figure 4.10. Conceptual diagram showing potential sources of MP into the marine environment on a national scale (Source: Lusher 2021).*

It is impossible to determine which sea-based or land-based source is the biggest contributor to microplastics in the Norwegian marine environment as there is little certainty behind the available data (Lusher et al 2021). The dispersal secondary sources of microplastics/nano plastics are the same as for macro plastics and distribution can therefore be global. This discharge is continuous as many national and global sources are contributing. The exception is aquaculture itself with locally distributed secondary MP close to pens as there will be wear and tear release from feed hoses. The primary MP/NP will be more locally distributed for example from wastewater (close to outlets), agriculture (input from rivers close to outlets) or discharges from the chemical industries (close to the discharge point). Wastewater discharges will be continuous while discharges from the aquaculture and chemical industry will depend on production cycle, and runoff from agriculture will most likely be influenced by season. MP/NP plastics are found in the surface, in the water column and seabed depending on the properties of the particles. Particles which have a greater density than seawater and those which are bio fouled will readily sink to the seafloor. For environmental impacts micro plastics/nano plastics see chapter 3.3.3.3.

*Conclusion*

Plastics can be released by several industries into the marine environment. It is not possible to estimate the percentage of marine litter that originates from maritime and land-based sources as there is little certainty behind the available data. However, in Norway, aquaculture, petroleum, and fisheries are some of the biggest maritime sectors and therefore may contribute more than smaller sectors such as windfarms. Information and data on dispersion and fate of plastics in the environment is also largely lacking. There however appears to be a potential for spatiotemporal overlap pressure between the different industries when it comes to macro plastics as it spreads globally. For primary MP/NP there seems to be potential for more of a local impact, and a larger potential for overlap when it comes to secondary microplastics which in addition may be more globally distributed. However,

studies need to be conducted to document the patterns of use by various industries and the temporal and spatial scales over which these plastics can be found. There are currently no requirements for industries to report loss of plastics, only waste products.
As described in chapter 3.3.3.3 fish are generally considered to be less vulnerable to macro plastic. For microplastics, studies have shown concentrations that increase the risk of exposure in farmed salmon, and microplastics have been found in the gills of the salmon. The significance of these findings is however not known and whether it constitutes a risk for the farmed fish itself. The risk of MP ingestion for humans by eating fish is thought to be reduced by the removal of the gastrointestinal tract (GI-tract) in most species of seafood consumed. There is a concern however about the nanoparticles for public health, as nanoparticles can translocate across the gut epithelium and result in systemic exposure, and a very wide distribution in all organs is likely. However, the data that are needed to perform a full food safety risk assessment of nano plastics in seafood are completely lacking. Therefore, MP and NP from other industries may pose a risk for fish health and nano plastic may further have risks for food safety. A study by Holen et al. 2019, also considered plastics as one of the risks to food safety.

**Antifoulants and metals**

Antifoulants are used by aquaculture (see chapter 3.3.3.4) and by the shipping and the fishery industry (see Table 4.8 ). Anti-fouling paints are applied as the outer (outboard) layer to the hull of a ship or boat, to slow the growth of and facilitate detachment of subaquatic organisms that attach to the hull and can affect a vessel's performance and durability. Antifoulant paint is also used by the oil industry to avoid antifouling and by recreational vessels. Both the aquaculture, fishing and shipping industries release antifoulant substances into the surrounding water, ships release antifouling particles from paints (for aquaculture release see chapter 3.3.3.4). Antifouling biocides consist of metallic compounds that effectively kill marine organisms that attach to ship hulls, but also have serious environmental impacts due to their longevity and accumulation in the food web (see chapter 3.3.3.4). Copolymers of methacrylate and methyl methacrylate that contain tributyltin groups (TBT), as well as copper (I) oxide for an extra antifouling effect, were very widely used and effective self-polishing ship paint until TBT was banned on ships for environmental reasons in 2008 (Gopikrishnan et al. 2015). The ban against TBT AF paints has largely been effective, although even after 2008 some suppliers continued to produce and sell these products in several countries, even at the present time (Beyer at al. 2022, Russel et al. 2021). Furthermore, the product ECONEA® (active ingredient tralopyril, see chapter 3.3.3.4 for effects) is also recently used by both the shipping, fishing, and aquaculture industry.

Although ship paints containing antifoulant compounds may contribute to emissions to water, these are usually confined to limited areas, especially around shipyards and harbours. There has been concern about the accumulation of copper and TBT compounds in high ship traffic areas, for example, in harbour areas. Some studies have also correlated ship traffic to an increase in Cu concentrations in marine environment (Carić et al 2021, Schiff et al. 2005).

*Table 4.8. Activities connected to the different prioritized industries that is the source of antifoulants to the marine environment.*

| *Industry* | Pressure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| *Aquaculture* | *Antifoulants used in nets.*<br>*Antifoulants in boats* | *Local* |
| *Fishery* | *Antifoulants in boats* | *Local/global* |
| *Shipping* | *Antifoulants in boats* | *Local/global* |

As mentioned in chapter 3.3.3.4 the aquaculture industry may also be a source of metals to the marine environment, through excess feed and faeces that may contain metals and heavy metals through raw ingredients used and additions. However, the amounts of copper from feed spills and faeces for example are far less than what comes from copper as an antifouling agent, which is the emission of greatest concern.

Shipping as mentioned above, and other industries also contribute to emissions of copper to the marine environment. As far as the authors know there is no knowledge on emissions of copper from shipping (apart from harbours) in Norway. However, if one compares the emissions of copper to water in year 2021 from sewage (7 tons) and land-based industries (5 tons) to aquaculture (770 tons) one finds that aquaculture has largest emission of copper compared to these industries (see Figure 4.11).

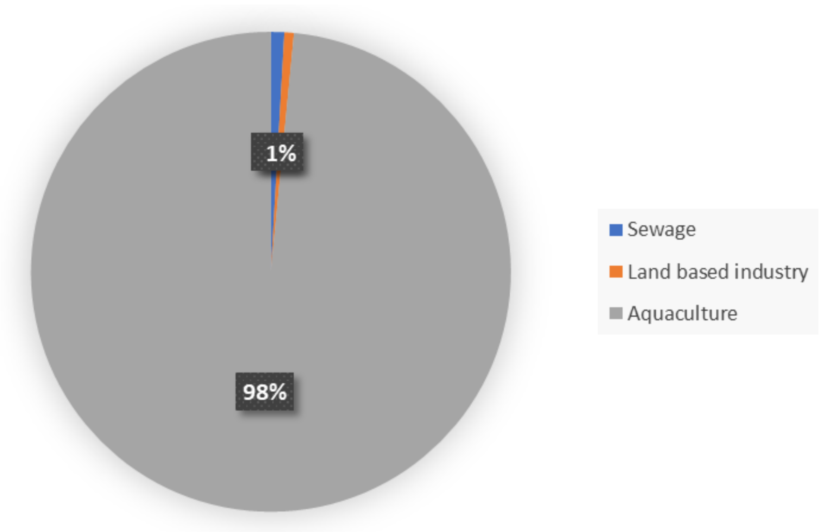


*Figure 4.11. Emissions of copper to water in 2021 for land-based industry, sewage (wastewater) and aquaculture in percentage. Sources: (https://www.norskeutslipp.no/no/Forsiden/?SectorID=90).*

There are also many other anthropogenic sources of metals and heavy metals to the marine environment. Examples are mining, combustion of coal and petroleum, diffuse sources in the urban environment, waste management and agriculture (Mikkelsen 2021). As the contribution of aquaculture to the marine environment of other metals and heavy metals than copper is poorly understood (see chapter 3.3.3.4), a closer look on other industrial sources of other metals and heavy metals to the marine environment are therefore not performed, as an assessment of potential overlap is not possible. However, there are examples of high concentrations of Cu in harbours, but not of concern regarding aquaculture (due to distance to harbours). There might also be potential overlap with point sources of metals and aquaculture, but the authors have no overview on this topic.

*Conclusion*

Antifoulants are released by both the aquaculture, shipping, and fisheries industry. The emission from aquaculture is thought to be mostly local underneath the pens, and the concern regarding shipping and fishery emissions is mainly high ship areas such as harbours. So there seems to be unlikely with spatial temporal overlap between the pressure release, however there might be regional overlap of impact if there is high presence of both aquaculture and shipping/ fishery activity in the area. As it was shown in chapter 3.3.3.4 there is a small risk of antifoulants for fish health, however this was associated with release from the aquaculture industry itself, for example by biofouling washed off the net, which can irritate gills, or facilitate exposure to pathogens associated with biofouling (Bloecher et al. 2018).

**Pharmaceuticals (other than delousing chemicals).**

Pharmaceuticals are defined as prescription, over the counter and veterinary therapeutic drugs used to prevent or treat human and animal diseases, while personal care products (PCPs) are used mainly to improve the quality of daily life. The aquaculture industry uses pharmaceuticals, mainly antibiotics, although this use is considered low in Norway (see section 3.3.5). Other industries also release pharmaceuticals and personal care products (PPCPs) such as antibiotics to the marine environment. This includes the chemical industry (pharmaceutical industry), and pharmaceuticals are also discharged via wastewater/ sewage (from households and hospitals), and agricultural activity (see Table 4.9 and Figure 4.12) (Chaturvedi et al. 2021). Pharmaceuticals and Personal Care Products or "PPCPs" are substances used by individuals for personal health or cosmetic reasons, and products used by agribusiness to boost growth or health of livestock. PPCP includes a very extensive number of compounds and includes analgesics and anti-inflammatories, antibiotics, antiseptics and germicides, anti-fungals, hormones (synthetic and natural), cardiac, blood pressure medicine and diuretics, fragrances, UV-filter compounds and Mosquito repellents (PPCP monitoring in the Nordic Countries – Status Report). These products, their constituents, and their metabolites, end up mainly in rivers, lakes, fjords and in the sea either directly or via the wastewater system and sewage treatment plant.

*Table 4.9. Prioritized industries and connected activity/source responsible for emissions of pharmaceuticals.*

| *Industry* | **Pressure source/activity for emissions** | *Scale of emissions* |
|---|---|---|
| ***Aquaculture*** | *Pharmaceutical/antibiotics to treat disease outbreak.* | *Local* |
| ***Wastewater*** | *Discharges from plants, depending on type of wastewater and treatment facilities, and quantity, for example larger amounts from hospitals.* | *Local/regional* |
| ***Chemical industry (pharmaceutical industry)*** | *Direct discharges to marine recipients from industries such as pharmaceutical production facilities.* | *Local* |
| ***Agriculture*** | *Municipal wastewater may be used for irrigation with the biosolids (treated sludge) potentially applied as fertilizer to agricultural land. Also, animal manure (treated animals). Run off from land to sea treated with sludge/manure.* | *Local/regional* |

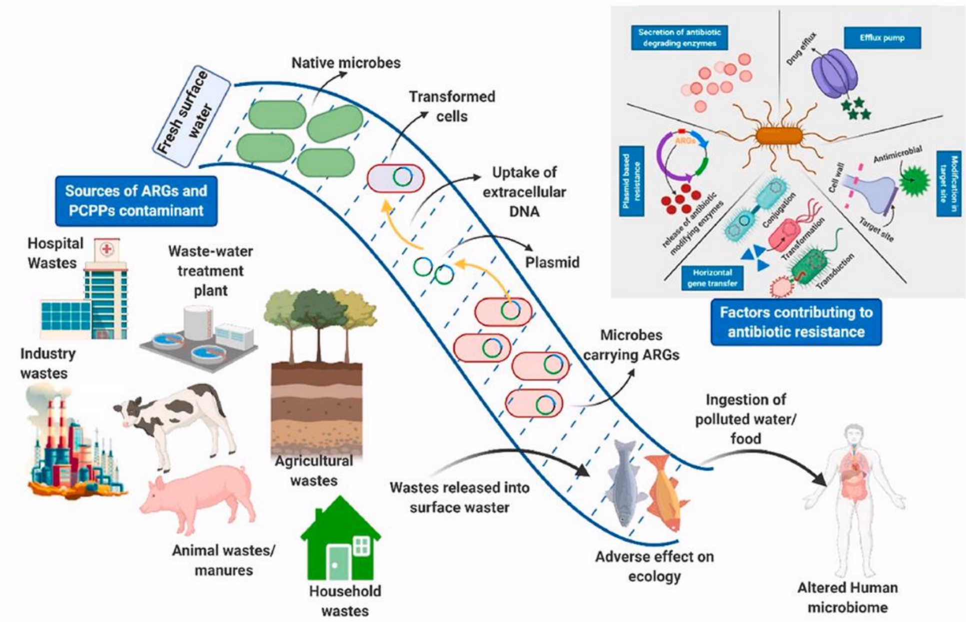


*Figure 4.12. Graphical abstract from Chaturvedi et al. 2021, showing sources Pharmaceuticals and Personal Care Products or "PPCPs" and antibiotic resistant genes (ARGs) and impacts.*

The major sources of PPCPs to the environment are via wastewater treatment plants. Once released into the environment, there is a possibility of long-range transport of some PPCPs depending on the physicochemical properties of the compound and the characteristics of the receiving environment (Ebele et al 2017). However, PPCPs have relatively short half-lives and are not expected to be transported far from the source, and they are also generally confined to large population centres (PPCP monitoring in the Nordic Countries and references therein). Upon discharge they can be present in surface waters, pelagic environments, and several studies have reported accumulation of PPCPs in sediments. Sorption/desorption in sediment is another mechanism through which PPCPs are transported to the aquatic environment. The sediment acts as a sink and accumulates these environmental contaminants (sorption) which may be released back to water (desorption). Several studies have shown some PPCPs (e.g. sulfamethoxazole, carbamazepine, triclosan and ciprofloxacin) to be more persistent in sediment than water. The use of large amounts of antimicrobials in Chilean aquaculture consequently has the potential to select for antimicrobial-resistant bacteria in marine sediments (Buschmann et al. 2012). Presence of PPCPs in aquatic environments can affect aquatic life through persistence, bioaccumulation, and toxicity.

The unwanted effects on the environment vary just as much as the physicochemical properties of the PCCPs: They range from increasing antibiotic resistance caused by antibiotics and biocides, via carcinogenic/genotoxic/reproductive harm to different types of hormone-mimicking effects such as imposex and intersex. A study by Mottaleb et al 2015 (and references therein) for instance reported that municipal wastewater effluent can act as endocrine disruptors at concentrations capable of inducing fish feminization. The feminization has been linked to exposure to compounds that mimic oestrogen activity. However, it has also been determined that thousands of the compounds have the potential to interact with components of the endocrine system, altering the natural action of hormones in both freshwater and marine fish species. The occurrence of some substances ECs correlates with ecological effects and sexual abnormalities in fish.

Since many PPCPs, whether used as human or veterinary drugs, have been deliberately designed for the purpose of causing biological effects, high levels may not be needed to produce effects in exposed marine wildlife. However, in this report more general effects are described as it is slightly out of scope to describe all substances in detail, including all relevant ecotoxicological effects of these substances, furthermore this topic is not fully understood either.

*Conclusion*

Pharmaceuticals are released by both aquaculture, agriculture, the chemical industry (pharmaceutical), and discharge of wastewater. The emission from aquaculture is thought to be mostly local underneath the pens. The discharge of wastewater and emissions from the chemical industry are point source releases and therefore also local. The dispersion pathway from agriculture is runoff from land into rivers and streams and may also be local. It is unlikely that there is a pressure spatiotemporal overlap between aquaculture and the other industries as farm site is not likely to be located in the vicinity of a point source outlet. For this reason, there seems to be a low risk of pharmaceuticals to fish health from other sources, mainly due to the distance from outlets and dilution. However, it is important to keep in mind that the substances can affect fish health and assessments of relevant location of fish farms needs to take this into account. Furthermore, for the same reason the risk for human consumption seems low. However, one must consider risks if farms are situated near outlets. As the usage of pharmaceuticals in the aquaculture industry today is low, it seems unlikely that there may be regional overlap impacts.

**Oil and oil containing mixtures.**

Several industries contribute to oil pollution, including accidental oil spills as well as leaks and spills due to a large variety of human activities related to oil refining, handling and transport, storage, and use of oil products (see Table 4.10). Accidental spills may occur in various circumstances, most often during storage, handling, and transportation. Oil spills may also occur during routine maintenance activities, e.g. cleaning of ships may release oil into waters. Although this may seem insignificant; due to the large number of ships even a few gallons spilled per ship maintenance could build up to a substantial quantity when all ships are considered. Discharge of oil polluted water occur in the following circumstances: via wastewater or discharge of waste oil or spent oil into the marine waters. In addition, oil products are present due to the machinery, vessels and other equipment, and any spill from these may in adverse effects for the environment. As the contribution of oil and oil related compounds of aquaculture to the marine environment is poorly understood (see section 3.3.3.6), an assessment of potential overlap is not possible. However, risks for fish health in aquaculture due to oil pollution from other industries must be seen in connection with the degree and length of exposure, sustained exposure to oil can for instance have negative effects on fish. An acute large oil spill (such as that from an oil tanker failure) could have disastrous effects on fish due to the high concentrations of released oil components. For food safety it has been shown that polyaromatic compounds, which are components of oil quickly metabolised in fresh fish and do not accumulate in the muscle meat, therefore there is no maximum limit for PAH in fish meat (EU 835/2011).

*Table 4.10. Prioritized industries and connected activity/source responsible for the pressure oil and oil containing mixtures.*

| *Industry* | Pressure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| ***Aquaculture*** | *Feeding: substances in aquaculture feed, PAHs commonly found in vegetable feed. Boats: waste from fuel oil spills* | *Possible local* |
| ***Fisheries*** | *Daily operations: waste from fuel oil spills.* | *Local* |
| ***Shipping*** | *Daily operations: waste from fuel oil spills, accidental oil spill from oil tankers.* | *Local* |
| ***Sewage*** | *Discharges from plants, depending on type of wastewater* | *Local/regional* |
| ***Food processing industry (brewery)*** | *Direct discharges to marine recipients from industries such as brewery production facilities* | *Local* |
| ***Metallurgical industry*** | *Direct discharges to marine recipients from industries such as metallurgy production facilities* | *Local* |
| ***Chemical industry (Oil refineries)*** | *Direct discharges to marine recipients from industries such as oil refinery production facilities* | *Local* |

## Nanoparticles

Coastal seas and oceans receive engineered nanoparticles (ENPs) that are released from nano-enabled consumer and industrial products and incidental nanoparticles that are formed as by-products of combustion and friction. Recently, nanotechnology has also been applied in aquaculture, as it has a wide range of applications e.g. detection and control of pathogens, water treatment, sterilization of ponds, efficient delivery of nutrients and drugs, however the usage and emissions are not well known (see chapter 3.3.3.7). Several studies have been conducted on the fate and impact of ENPs in natural waters, such as rivers, lakes, and estuaries. Fewer studies have focused on marine water because it is expected that ENPs would quickly aggregate and settle on the sediments (Godikas et al. 2020 and the references therein).

Godikas et al. (2020) described both terrestrial sources and marine sources to the ocean. Terrestrial sources of ENPs to the sea include effluents of wastewater treatment plants, transport and deposition through wind, etc. Marine sources include cargo, leisure, and transportation ships. Maritime transport, in particular, is responsible for 90% of the world trade and release of ENPs from shipping (e.g., from NP used in antifouling paints) is likely gradual and in small amounts but impacting very large areas. In addition, they found that engineered (ENPs) from nano-enabled consumer and industrial products may enter coastal seas and oceans through indirect routes after their use and disposal, e.g., effluent discharge from wastewater treatment plants and long-range atmospheric deposition. In this case, ENPs are likely to be physical and/or chemical altered prior to entering the aquatic environment. Direct routes, such as emissions from shipping, water-based leisure activities, discharge of wastewater, and other anthropogenic activities are more likely to release ENPs closer to their engineered form.

When ENPs enter the environment, their fate will eventually determine their potential toxicity, a factor that has been ignored by many toxicological studies. It is therefore necessary to develop a clear understanding of the processes that regulate the fate of ENPs in the environment (Gondikas et al. 2020 and refernces therein).

Evidence suggests that nanometals (nanoparticles) can cause a range of sublethal effects in fish including respiratory toxicity, disturbances to trace elements in tissues, inhibition of Na(+)K(+)-ATPase, and oxidative stress (Handy et al. 2011).

As nanoparticles represent a quite new issue in aquaculture with few/no risk assessments reported, it remains a challenging topic to assess (Khosravi-Katuli et al. 2017). Other industrial sources are also poorly described in literature. More studies are needed in the near future to assure human health and environmental safety (Khosravi-Katuli et al. 2017). Therefore, no risk evaluations were attempted.

**Other organic substances**

Fish feed can contain various environmental toxins that come from the feed ingredients, and these can be added to the environment both through waste feed and through the fish faeces. These persistent organic pollutants (POPs) are of special concern because they are chemicals that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment. The raw materials used for feed production contain, among other things undesirable substances, such as halogenated organic compounds including PCBs, dioxins, furans, chlorinated pesticides, brominated flame retardants (e.g. PBDE, HBCDD and TBBPA) and perfluoroalkyl and polyfluoroalkyl substances (PFAS/PFOS) (Sele et al. 2022). It is however unknown if they pose a risk to the marine environment (chapter 3.3.3.8)

Other industrial sources of pollution from POPs include the improper use and/or disposal of agro- and industrial chemicals, elevated temperatures and combustion processes, and unwanted by-products of industrial processes or combustion (UNEP 2023 and references therein). POPs are chemicals that are characterized by their properties of persistence (which gives potential for long-range transport), bioaccumulation and toxicity (AMAP 2023). Although concentrations of POPs are highest close to the source, they can circulate globally, and chemicals released in one part of the world can therefore be deposited at far distances from their original source through a repeated process of evaporation and deposition. This makes it very hard to trace the original source of the chemical (UNEP 2023). POPs are lipophilic, which means that they accumulate in the fatty tissue of living animals and human beings. They biomagnify in the food chain and the concentrations can become magnified by up to 70 000 times higher than the background levels (UNEP 2023). As you move up the food chain, concentrations of POPs tend to increase so that animals at the top of the food chain such as fish, predatory birds, mammals, and humans tend to have the greatest concentrations of these chemicals, and therefore are also at the highest risk from acute and chronic toxic effects.

POPs may originate from a number of different sources, and it is known that there is long-range transport of POPs to Norway, there are however limited studies to assess the fate in the environment, and hence also for fish. In general, local sources have higher impact on the marine environment than long-range transported pollution. However long-range transported POPs may affect a geographically larger area. The effect of long-range transported POPs on wild and farmed fish are unknown. However, the effect on farmed fish is likely lower than on wild fish due to a lower exposure time (approximately 2 years in fish pens). The risk of long-range transported POPs is likely low, however more studies are needed to confirm this assumption. As it is uncertain if POPs found in fish feed from aquaculture pose a risk or not to the environment, therefore no risk evaluation was performed.

### 4.2.3.5 Noise

The increase in urbanization and the progressive development of marine industries have led to the appearance of a new kind of pollution called “noise pollution” (Chahouri et al. 2022). Noise pollution can travel long distances underwater, cover large areas, and have secondary effects on marine animals; by masking their ability to hear their prey or predators, finding their way, or connecting group members (see chapter 3.3.6).

The aquaculture industry is one of the emitters of noise to sea (see see chapter 3.3.6). Other sources of anthropogenic noise from the key industries are the fisheries, shipping and mining industry (see. Other industrial sources are oil and gas industry (e.g., seismic activity, construction, operation), military (e.g., sonars), offshore renewable energy, recreational vessels (see Figure 4.13) (EC 2023).

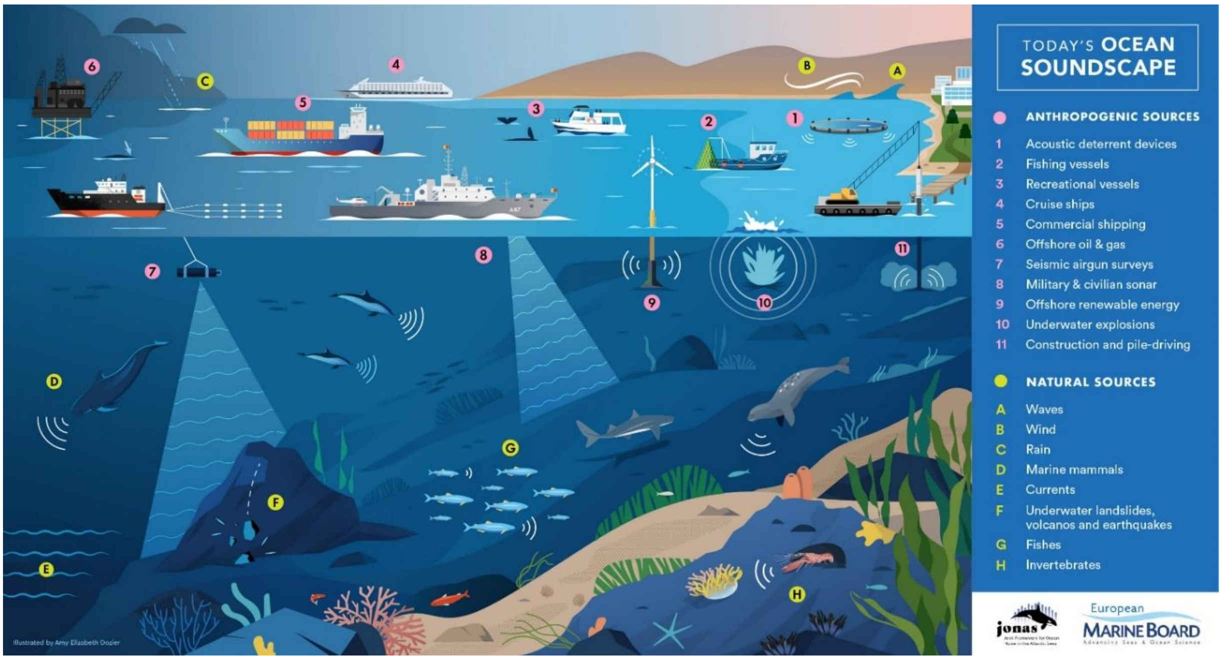


*Figure 4.13. Today’s Ocean soundscape. Source: Amy Dozier / European Marine Board / JONAS project (https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-11/index_en.htm).*

The spatial distribution, temporal extent, and levels of anthropogenic noise is not evenly distributed. As ocean traffic is not evenly distributed and some areas are more frequented than others, like travel and commercial routes, these particular spots in the ocean experience significantly increased sound levels when a vessel passes by. This is also true for ports and harbors, as they are typically places of ship concentration. This may also be true for areas where there is a lot of aquaculture or fishing activity.

*Table 4.11. Prioritized industries and connected activity/source responsible for the pressure noise.*

| *Industry* | Pressure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| ***Aquaculture*** | *Farm operations (e.g., farm machinery, operational vessels), low frequency stationary noise. Noise produced occasionally (e.g., construction and demolition) and that specifically used to ward off predators, (e.g. Acoustic Harassment Devices – AHDs, cracker shells and the targeted acoustic startle technology).* | *Local/regional* |
| ***Fisheries*** | *Underwater-radiated noise from fisheries ships. Primary sources of underwater noise, namely on propellers, hull form, on-board machinery, and various operational and maintenance recommendations such as hull cleaning.* | *Local/regional/global* |
| ***Shipping*** | *Underwater-radiated noise from fisheries ships. Primary sources of underwater noise, namely on propellers, hull form, on-board machinery, and various operational and maintenance recommendations such as hull cleaning. Construction activities in the ocean harbours etc.* | *Local/regional/global* |
| ***Mining*** | *Noise from deep sea machinery, waste dumped at sea is also a source of anthropogenic noise as in dredging.* | *Local/regional* |

Most studies on the impact of noise in the aquatic environment have been performed in marine mammals, however there is an increasing awareness of the potential negative effects on other marine organisms including invertebrates and fish (Sierra-Flores et al. 2015). However, literature is scarce on the effects of noise on health status of caged fish, therefore it is difficult to evaluate risk. In offshore cage conditions, fish are exposed not only to sea background noise but also to noise generated by cage machinery and by marine traffic of different boat typologies. A study by Filiciotto et al. (2017), demonstrated that the offshore aquaculture noise, and in particular the sea soundscape, adversely influences the oxidative status and the immune function of gilthead sea bream determining a mild stress condition that could affect the sea bream's welfare. Another study showed that caged fish lessened response after repeated exposure to noise, likely driven by increased tolerance or a change in hearing threshold and helps explain why fish that experienced 12 weeks of impulsive noise showed no differences in stress, growth or mortality compared to those reared with exposure to ambient-noise playback (Radford et al. 2016). It also showed that caged Atlantic salmon may alter the acoustic environment when compared to an empty net-pen, and that the acoustic fingerprint of the net-pen varies over time and mirrors the feeding status of the fish (Rosten et al 2023).

The soundscape from aquaculture and the spatial scale on where it occurs is not well described, however it seems likely that this pressure is overlapping in areas with high human activity (e.g., aquaculture industry, fishing and shipping routes).

#### 4.2.3.6 Light

Artificial light at night (ALAN) is used in salmon farming to inhibit biological processes maturation and to increase somatic growth in the spring (Hansen et al. 2017). Continuous artificial illumination of ocean net-pens in the coastal waters are used throughout the winter and spring months. However, ALAN in the marine environments comes from several different sources and activities (Table 4.12), and sources of ALAN in the marine environment vary, with shipping, aquaculture and light fisheries (Khanh and Winger 2019) contributing as temporary sources in nearshore and offshore waters. ALAN also comes from coastal development (e.g., buildings, streetlights, billboards, ports, piers, docks) and offshore infrastructure such as oil rigs.

*Table 4.12. Prioritized industries and connected activity/source responsible for the pressure light.*

| ***Industry*** | **Pressure source/activity for emissions** | ***Scale of emissions*** |
|---|---|---|
| ***Aquaculture*** | *Farm operations: continuous artificial illumination of ocean net pens throughout winter and spring months. Light on platforms.* | *Local* |
| ***Fisheries*** | *The use of artificial lights (metal halide lamp, incandescent lamp) for attracting fish and increasing catch is a common practice in the world fisheries. Lights at the surface, but more recently, low-powered LED lights installed directly on fishing gear have also become common.* | *Local* |
| ***Shipping*** | *Light pollution caused by the bright beams from ships* | *Local* |

ALAN has increased exponentially over the past 150 years and has become a significant issue for the marine environment in the last 60-90 years. Light pollution in marine environments is also becoming more severe due to the increasing prevalence of LED lights. Artificial light pollution is globally widespread in marine environments, and may alter the natural colors, cycles, and intensities of night-time light, each of which guide a variety of biological processes (Figure 4.14).

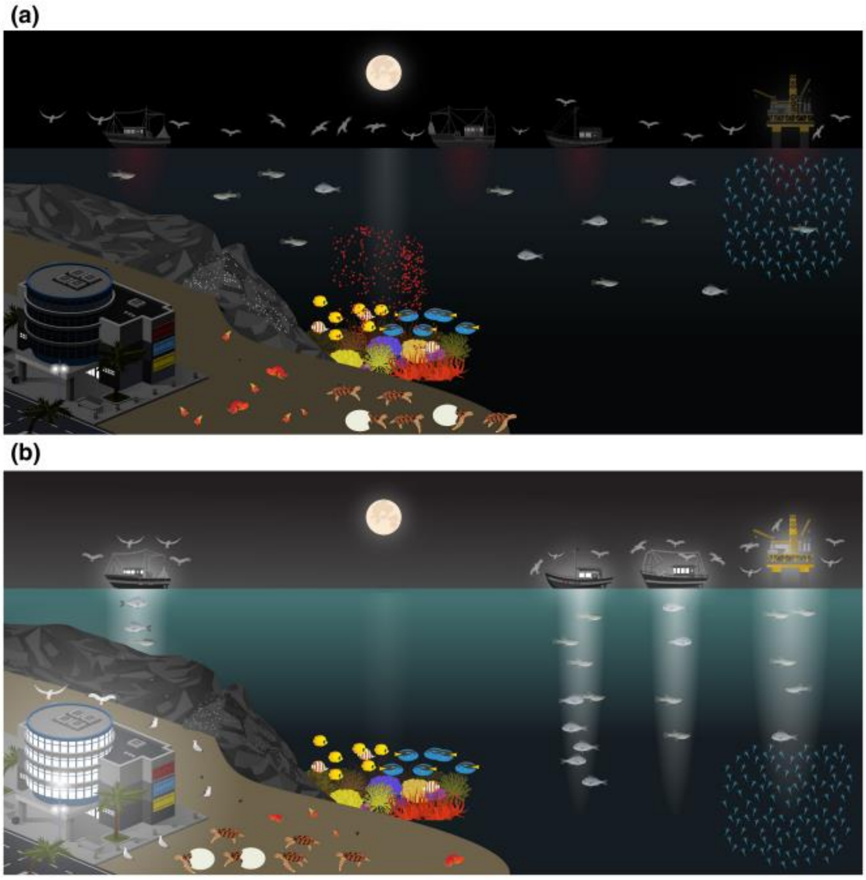


*Figure 4.14. (a) Different marine environments not affected by Artificial Light Pollution at Night (ALAN), and (b) marine environments under the potential impacts of ALAN: (i) Sandy beaches effects on invertebrate species day-night activity rhythms and biodiversity (ii) Rocky intertidal shores – influence in metabolic activity/ behavior of primary producers, sessile and mobile animals; (iii) Shallow water coral reefs – effects on gamete release in prominent coral species, and negative impacts over fish reproduction, (iv) Pelagic environment – inhibition of vertically migrating zooplankton, and disorientation and mortality of seabirds. (Source; Marangoni et al. 2022).*

As far as the authors know, there is not much information on the effects of ALAN from other light sources than aquaculture on farmed species and how it could affect fish health. Therefore, one cannot evaluate the risk from ALAN from other industries on fish health. However, ALAN is used in salmon farming to inhibit biological processes maturation and to increase somatic growth in the spring, to control swimming depth and fish density of Atlantic salmon in production cages, and to reduce exposure to suboptimal water layers and crowding of fish (chapter 3.3.7). The ALAN originating from aquaculture and the spatial scale on where it occurs are not well described, however it seems likely that this pressure from aquaculture may overlap in areas with high human activity (e.g., fishing and shipping routes).

#### 4.2.3.7 Artificial structure

The rapid increase in the number of 'man-made structures' (MMS) also called artificial structures in the coastal and marine environment is often called the " Ocean sprawl" (Bugnot et al. 2021). Aquaculture installations are such structures and are described in chapter 3.3.8). Other artificial structures include ship hulls; infrastructure associated with land reclamation and urbanization (e.g., seawalls, bridges, floating docks); fisheries (artificial reefs); coastal defense structures (e.g., breakwaters); resource extraction (oil and gas rigs, renewable energy devices); and shipwrecks (Lemasson et al. 2021). The key industries and connected artificial structures are described in Table 4.13.

The sprawl of marine construction is one of the most extreme human modifications to global seascapes. Nevertheless, its global extent remains largely unquantified compared to that on land (Bugnot et al. 2021). The area of seascape modified around structures was 1.0–3.4 × 106 km$^2$ in 2018 and it is projected to increase by 50–70% for power and aquaculture infrastructure, cables and tunnels by 2028 (Bugnot et al. 2021).

*Table 4.13. Prioritized key industries and connected activity/source responsible artificial structures.*

| *Industry* | Preassure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| ***Aquaculture*** | *Aquaculture installations.* | *Local/Regional* |
| ***Fisheries*** | *Shipwrecks, artificial reefs, defense structures in harbors* | *Local* |
| ***Shipping*** | *Shipwrecks, defense structures in harbors* | *Local* |

Firth 2021 described the impacts of artificial structures on the marine environment in the following way: the placement of these fixed artificial structures modifies the local physical and chemical environment with cascading impacts on the composition, functioning, and service provision of surrounding species, habitats, and ecosystems. These structures also provide novel habitat which can offer surface for attachment, food, and protection for myriad marine species. They can act as fish aggregating devices (Uglem et al. 2014, Sanchez-Jerez et al.2011), attracting fishing and other human activities. These structures may also have wide-reaching impacts through acting as barriers or conduits to ecological connectivity—the movement of organisms, materials, and energy between habitat units within seascapes.

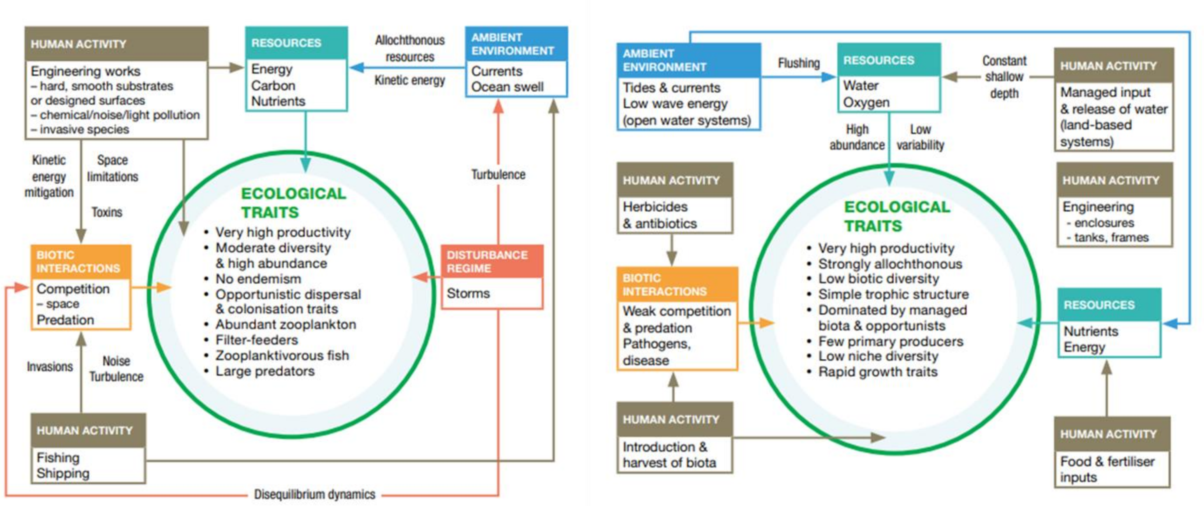


*Figure 4.15. Artificial structures classified as anthropogenic biomes (artificial ecosystem functional groups). Left; submerged artificial structure biomes, right; Marine aquafarm biomes (source: Keith et al. 2020).*

Submerged artificial structures such as submerged structures with high vertical relief including shipwrecks, oil and gas infrastructure, and designed artificial reefs, as well as some low-relief structures (i.e. rubble piles) and marine aquafarms are even classified as anthropogenic biomes (artificial ecosystem functional groups) (Keith et al 2020). Ecosystems in this group are created by human activity, which continues to drive and maintain their assembly (see Figure 4.15).

Possible impacts from aquaculture installations on the environment are described in chapter 3.3.8, however these installations differ from other artificial structures submerged in sea as they provide food and fertilizer to their surroundings. Given the wide-reaching impact of artificial structures on the surrounding marine environment it is likely that they may impact the aquaculture industry itself, however no knowledge on this issue exists as far as the authors are aware of.

#### 4.2.3.8 Physical disturbance

Physical disturbances are related to actions that physically affect the seabed environment or cause damage to pelagic species. Some of the industries and activities that causes physical disturbance to the marine environment include fisheries (trawling and dredging), marine installations, construction work (e.g., dredging, land reclamation) and mining (submarine disposal of mine tailings). Physical disturbance has some overlaps with particles, the risks of which are described in detail in chapter 4.3.2. Particles that are upwelled or disposed of in large quantities may for instance also cause physical disturbance by smothering benthic organisms, reducing survival rates of early life stages of fish, cause physical abrasion or clogging of gills in juvenile and adult fish (Bilotta and Brazier 2008, Dale et al. 2008, Reinardy et al. 2019). Despite these overlaps with effects of particles, the focus in this section will remain on the effects caused by physical disturbance to the seabed, and not the particles in themselves.

The QSR conducted as part of this study identified 134 publications, however none of these investigated the overlap in multistress between aquaculture and other industries. For this reason, supplementary knowledge and information was sought out via more specific searches in scientific as well as grey literature (reports, websites, databases etc.) to include in our assessment of the potential risks of physical disturbance on aquaculture.

The prioritised industries that have potential activities that overlap with aquaculture in disturbance to the seabed are listed in Table 4.14. For *fisheries* the activities that entail physical disturbance to the seabed includes dredging/trawling, which has been known to affect the benthic fauna. Studies have found that megafauna are most likely to be affected, either by physical abrasion or by being caught in the trawling gear. It has however also been acknowledged that the effects of bottom trawling on sediments, habitats and organisms are complex, site-specific, and difficult to predict due to differences in vulnerability of different species and regional variations in fishing intensity. Although it has been well documented that trawling/dredging affects and changes the composition of the benthic communities, the consequences for the ecosystem has been subject of little research (Løkkeborg et al. 2023). While there are some gaps in knowledge of the implications of effects on benthic fauna for the ecosystem, the effects on benthic fauna are confined to the areas being trawled/dredged.

*Table 4.14. Prioritized key industries and connected activity/source responsible for physical disturbance of the seabed.*

| *Industry* | Pressure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| ***Fisheries*** | *Dredging* | *Local* |
| ***Marine installations*** | *Offshore oil & gas, marine renewables, aquaculture* | *Local* |
| ***Construction work*** | *Sediment disposal, substrate extraction* | *Local* |
| ***Mining*** | *Release of particles - smothering* | *Local* |
| ***Aquaculture*** | *Release of particles – smothering* | *Local* |

*Marine installations* include offshore oil and gas, and renewable energy installations, in addition to aquaculture. The physical impact of offshore oil and gas installations, including discharge of drill cuttings on the ocean floor has been well documented. Studies have found that the impact of water-based drill cuttings are mainly physical and include elevated mortality in benthic fauna. The effects are however local, between 500-1,000 m from the platforms (Bakke et al. 2013). Structures, whether oil and gas installations, renewable energy installations, bridge/tunnel constructions or harbour/port constructions, will affect the biodiversity locally (Røysland et al. 2017). The long-term effects of structures on the benthic fauna and the implications for ecosystems have not been well-studied (de Jong et al. 2020), however the effects of physical disturbance of the structures are likely local.

*Dredging, land reclamation* and *port construction* involve activities that affect the seabed by destroying habitats and decreasing biodiversity (Moog et al. 2018, Ryabchuk et al. 2017). The long-term effects depend on the ability of a given area to regenerate and recolonise and the implications for the eco-system has not been well studied (Virtanen et al. 2023). The physical disturbance is however confined to the area of construction/development/dredging resulting in a local scale of impact. *Shipping* in areas with shallow navigational depths may also result in physical disturbance to the seabed, expected to have similar effects to those of fisheries dredging/trawling, albeit in a smaller scale. The scale of effects is therefore also expected to be local.

*Submarine disposal* of mine tailings and sediment causes physical disturbance to seabed habitats due to the large quantities disposed in a confined space (up to several million tons mine tailings produced per year per mine), with up to several meters of tailings/sediments covering the natural seabed. Physical impacts include smothering, physical/geochemical alteration of the bottom sediment and reduced biodiversity (Kutti et al. 2015, Ramirez-Llodra et al. 2015). The physical disturbance is confined to the disposal area and therefore also local.

For all the described activities in this section, there is a local scale of the physical disturbance. The risk of particle dispersion is however also present, with the risk of causing physical effects on the marine environment spanning a larger geographical area. In most cases this will however be of local scale (see chapter 4.3.2). The impacted seabed areas of physical disturbance will start to regenerate and recolonize after the activities have ceased. The regeneration will depend on site-specific conditions as well as the specific activity. For fisheries and dredging activities, regeneration within 1 year has been reported, while as submarine mine tailings disposal will take several years to recover (Burd 2002, Trannum et al. 2023), due to the properties of the mine tailings such as low content of organic material and sharp particle shapes (Sweetman et al. 2020). The recolonization may result in a long-term change in biodiversity compared to the original benthic fauna, and consequences for the eco-system is not fully understood. Based on existing information, the scale of effects is assessed as being local.

Activities causing physical disturbance to the seabed by the industries listed in Table 4.14 are at low risk for aquaculture activities. This is due to the scale of effect being local with very low potential for overlap with aquaculture, and hence very low risk to fish health in the pens. In cases in which there is a geographical overlap, e.g., fisheries trawling in the same fjord, the physical disturbance to the seabed does not have a magnitude to affect the affect the aquaculture pens (see chapter 4.3.2) for assessment of potential risk to fish health due to upwelling and dispersion of particles caused by physical disturbance to the seabed). In the cases of geographical overlaps between the industrial and aquacultural activities there are however risk of overlap in the implications of the activities for the marine environment. For most of the industrial activities described here there is currently a low potential for geographical overlap, mostly related to the confined and local scale of the physical disturbance effects. A geographical overlap may appear with mining activities if aquaculture is established in the same fjord as submarine mine tailings disposal (although placement in disposal area is not expected to be permitted). At this point in time the risk of this is considered low as aquaculture pens have not been established in vicinity of submarine disposal sites, however with the expanding aquaculture industry there may be a risk of overlaps in the future. This will be few, since there are limited number of active (5) and expected future sites for submarine mine tailings disposal. The highest probability of geographical overlap is related to fisheries and their trawling/dredging activities in the same fjords as aquaculture pens. A geographical overlap between fisheries and aquaculture could result in joint implications for the marine environment, e.g., the physical disturbance in trawling causing impact on benthic fauna, and sedimentation and physical effect of sedimentation of re-suspended particles along with particles discharged from aquaculture, increasing the strain on the benthic fauna (e.g., smothering). To the authors' knowledge, combined effects of overlapping activities have not been studied, and the implications for the marine environment are not possible to assess. The probability of trawling taking place in the dispersion zone of the particle discharge from aquaculture is generally low. However, for some aquaculture locations, this probability may be considered moderate-high.

#### 4.2.3.9 Freshwater regulation

Hydropower is the form of energy that harnesses the power of water in motion to generate electricity. Norway's steep mountainous landscape and high annual precipitation makes it most suited for harnessing energy from its numerous river systems. Implementing the first hydropower schemes in the late 19$^{th}$ century, most of Norway's industrialisation was driven by hydroelectric power. To date 90% of Norway's total power production is from hydropower, making Norway also Europe's largest producer. A total of 1767 hydropower plants with a capacity of 33.710 MW are installed in Norwegian catchment areas (NVE, 2023).

*Table 4.15. Overview of activity and scale of impact for hydropower.*

| *Industry* | Pressure source/activity for emissions | *Scale of emissions* |
|---|---|---|
| ***Hydropower*** | *Regulation of freshwater.* | *Local & regional* |

Harnessing the energy of water in motion comes, however, also at a cost. The construction of small-scale power schemes and large storage or pumped storage hydropower plants involves blocking, diverting, or changing the natural course and flow of river systems. Although hydropower schemes do not change the total volume of water released, they adapt when and where it happens. It causes a major change in the seasonal cycles as the higher demand for energy in the winter months leads to an increased run-off, whilst the lowered demand results in decreased discharge during summer (Myksvoll et al. 2014). Freshwater run-off is an important driver of the physical conditions in a fjord. High freshwater run-off creates and drives an outward-bound current in the surface layer of a fjord, which often is connected with an inward bound flow in deeper layers (estuarine circulation). The difference in density between freshwater and saltwater also affects the stratification of the waterbody and thus the potential for vertical mixing of water masses. Both aspects drive biological processes and changes in freshwater supply can thus have secondary ecological consequences (Myksvoll et al. 2014).

The QSR conducted as part of this study detected three publications, none of which were relevant to the topic. Only a few studies have investigated the impacts of anthropogenically regulated freshwater run-off on marine ecosystems (Myksvoll et al. 2014 and references herein; Nøst & Gaardsted, 2021). These studies show significant changes in salinity, stratification and consequently hydrodynamic patterns and highlight the importance of gaining a better understanding of the impact of freshwater regulation on coastal ecosystem dynamics. Hydropower has accordingly also been included as a risk factor for coastal ecosystems in IMR's strategic research program "Coastrisk", where it is shown to be contributing significantly to the cumulative anthropogenic stressors in some of Norway's coastal regions (IMR, 2022).

The extent of impacts from hydropower will vary locally as it depends on the physical characteristics of the fjord system affected and the scale of deployed hydropower int the catchment areas. Significant changes in the physical environment of the fjord system could, however, also affect the cage environment (salinity, oxygen, mixing) and impact fish welfare directly. Secondary ecological consequences, such as a shift in phytoplankton growth due to changes in nutrients availability, could also indirectly influence aquaculture production. There are, however, still too many unknowns to make objective predictions and overall we require more knowledge on the impacts of hydropower developments on fjord ecosystems.

#### 4.2.3.10 Climate change and ocean acidification

Marine aquaculture relies on coastal habitats that will be affected by both pollution and climate change and ocean acidification. Edwards et al 2015, discusses aquaculture environment interactions, the study states that aquaculture may be increasingly adversely impacted by sources of pollution from the external environment, e.g., from agricultural, industrial, and domestic effluents, foremost if cages will be installed in public water bodies or close to point source outlets, in the future. However, the same study maintains, that the major and mostly adverse external environmental impacts on aquaculture are likely from climate change and ocean acidification (Edwards et al. 2015 and references therein). Another study communicates that the sustainability of the aquaculture sector is at stake due to the predicted effects of climate change that are not only a future but also a present reality (Maulu et al. 2021). Several other studies identified in the QSR also affirm that climate change is affecting and will affect aquaculture sector (Callaway et al. 2012, Bricknell et al. 2021, Oyinlola et al. 2020, Klinger et al 2017, Pernet et al.2021; Reid et al. 2019).

Various elements of a changing climate, such as rising temperatures, sea-level rise, ocean acidification, diseases and harmful algal blooms, changes in rainfall patterns, the uncertainty of external inputs supplies, changes in sea surface salinity, and severe climatic events are expected to have both negative and positive impacts on aquaculture production and sustainability, although, the negative effects outweigh the positive ones (Maulu et al. 2021).

There are both direct and indirect effects of a changing climate (see Figure 4.16). The direct effects include influencing the physical and physiology of finfish and shellfish stocks in production systems (and can pose a risk for fish health and public health). Indirect effects may occur through altering the primary and secondary productivity, the structure of the ecosystems, or input supplies, or by affecting product prices, fishmeal and fish oil costs, and other goods and services needed by aquaculture producers. This can potentially pose a risk for environmental impact (as possible overlaps).

Both the negative and positive effects of the various elements of the changing climate will not be described in detail here, but an overview by Maulu et al. (2021) is presented in Table 4.16.

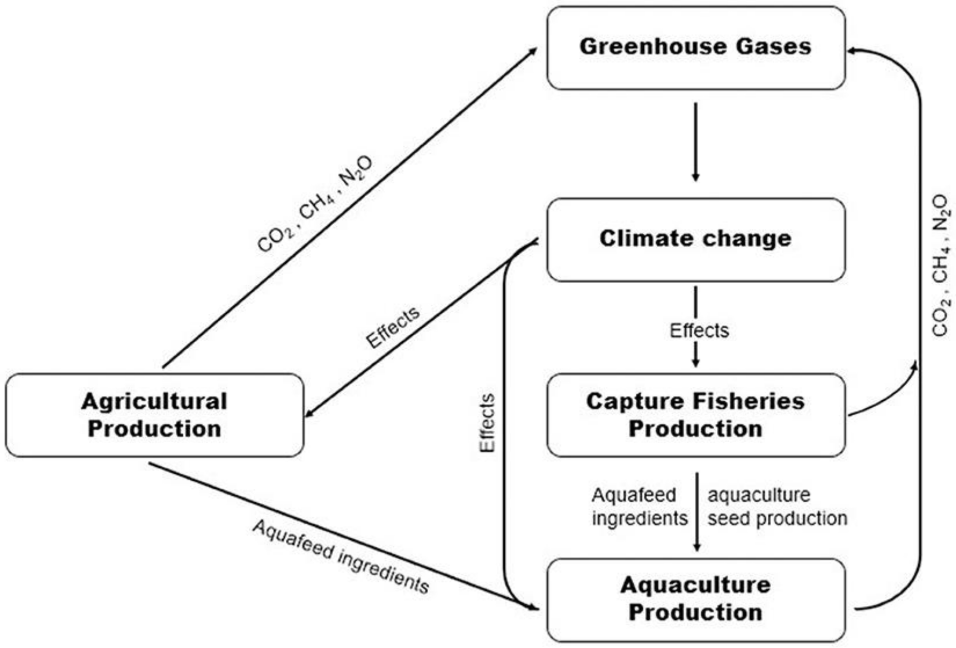


*Figure 4.16. A simple illustration of the direct and indirect pathways through which climate change will affect aquaculture production. (Source; Maulu et al. 2021).*

Troell et al. (2017) reviewed the implications of climate change for aquaculture in Arctic Norway. This study indicated positive effects from warming water temperatures on Arctic aquaculture. Direct effects related to storm frequencies and intensities could be relatively well anticipated, but with high uncertainty. Other indirect effects, such as diseases and pest species and freshwater runoff, were much harder to predict. However, the study stated that it is certain that environmental conditions will change, and that the aquaculture industry will have to adapt to these changes.

The study further stated that to enable the industry to adapt, there is a need to look over existing regulatory frameworks and start a multi-stakeholder dialogue to find out where and how aquaculture operations can move or change their operations. As the Arctic Region is undergoing multiple changes, involving changes in economic conditions and large-scale environmental changes, the different ways that aquaculture in the Arctic can adapt will be linked to the overall changes occurring in the region. Thus, a broader integrative approach is needed for successful governance of the Arctic system (Troell et al. 2017, and the references therein). Furthermore, the study by Maulu et al. (2021) stated that adapting to the predicted changes in the short-term while taking mitigation measures in the long-term could be the only way toward sustaining the aquaculture sector's production. However, successful adaptation will depend on the adaptive capacity of the producers.

*Table 4.16. Summary of the various elements of climate change and their effects on aquaculture (Source; Maulu et al. 2021).*

| Effects \ Element | Rising temperatures | Ocean acidification | Diseases and harmful algal blooms | Changes in rainfall/precipitation patterns | Sea level rise | External input supplies uncertainty | Sea surface salinity | Climatic events |
|---|---|---|---|---|---|---|---|---|
| Negative effects | - Poor growth and survival of cold-water species (Hamdan et al., 2012; Gubbins et al., 2013)<br>- Water quality deterioration (Ngoan, 2018)<br>- Weakened immune system of cold-water species (Gubbins et al., 2013)<br>- Weakened ocean carbon sink capacity (Cochrane et al., 2009)<br>- Thermal stratification (Seggel et al., 2016)<br>- Increased virulence of warmer water pathogens (Sae-Lim et al., 2017) | - Reduced species growth performance and survival (Clements and Chopin, 2016; IPCC, 2018)<br>- Poor coral skeleton development for shell-forming species (Hoegh-Guldberg et al., 2007; Weatherdon et al., 2016; Kibria et al., 2017)<br>- Increased water acidity levels (Rodrigues et al., 2015; Clements and Chopin, 2016)<br>- Increased production costs in marine areas (Munday et al., 2011; Frommel et al., 2012) | - Poor species growth and reduced survival (Marcogliese, 2008; Sae-Lim et al., 2017)<br>- Deterioration of water quality (Ngoan, 2018)<br>- Increased production costs due to disease outbreaks (Gubbins et al., 2013).<br>- Increased outbreaks of exotic diseases (Gubbins et al., 2013). | - Droughts could increase production costs (Hambal et al., 1994)<br>- Competing use of water during periods of drought (Handisyde et al., 2006; Cochrane et al., 2009)<br>- Flooding may increase loss of organisms in low land areas (Bell et al., 2010; Rutkayova et al., 2017)<br>- Flooding could deteriorate water quality and pollute the environment (Kibria et al., 2017)<br>- Destruction of production facilities (Bell et al., 2010; Rutkayova et al., 2017) | - Destruction of several coastal ecosystems (Kibria et al., 2017)<br>- Possible intrusion of saline water into freshwater systems and culture facilities in some regions (Handisyde et al., 2006; Kibria et al., 2017)<br>- May affect species richness, abundance and distribution, and phonological shifts. | - Increased costs of production due to possible increase in the costs of inputs, such as fish feeds and seed (Hardy, 2010; Blanchard et al., 2017; Bueno and Soto, 2017; Khatri-Chhetri et al., 2019) | - Reduced ocean's heat storage capacity (Seggel et al., 2016)<br>- Reduced carbon and nutrients circulation (Seggel et al., 2016)<br>- Increased species mortalities (Jahan et al., 2019) | - Destruction of production systems (Hamdan et al., 2012)<br>- Increased management costs (Canadian Institute for Climate Studies, 2000)<br>- Increased loss of culture species (Hamdan et al., 2012) |
| Positive effects | - Extended growing seasons for warmer water species (Pickering et al., 2011; Gubbins et al., 2013; Troell et al., 2017; Guyondet et al., 2018)<br>- Further developments in genetic breeding possibility (Gubbins et al., 2013; Blanchard et al., 2017) | - Increased production feasibility in hatcheries (Gubbins et al., 2013)<br>- Identification of more marine species for culture (Gubbins et al., 2013) | - Possible elimination of cold-water pathogens (Sae-Lim et al., 2017)<br>- May facilitate the development of species with better resistant to diseases (Sae-Lim et al., 2017)<br>- Possible identification and development of new species (Blanchard et al., 2017) | - Flooding may increase suitable areas for aquaculture production in some regions (Bell et al., 2013)<br>- Droughts could promote developments in wastewater management (Beveridge et al., 2018) | - May increase areas suitable for brackish water culture species, such as shrimps and mud crab (Handisyde et al., 2006; Kibria et al., 2017) | - Possible identification of alternative and sustainable input supplies, such as protein sources to replace conventional sources (Hardy, 2010) | - Possible increase in the cultivation of tolerant species (Jahan et al., 2019) | - Better mixing of water column and nutrients (Seggel et al., 2016)<br>- May minimize rising temperature pressures by minimizing the temperature (Seggel et al., 2016) |

**Key findings:**

- The information to identify industries and activities operating in the same areas as aquaculture was good, both for land-based and sea-based industries.
- The dominance of industry activity varied geographically especially for the land-based activities where dominance was greater in the south, whilst sea-based activities such as fisheries and aquaculture dominated in the north of Norway.
- A quick broad search showed that stressors related to the identified key industries overlapped well the pressure categories identified for the aquaculture industry.
- For most of the stressors, there was limited information (easily accessible data) on contribution of emissions of key industry on to the marine environment and sometimes the information was lacking. In the cases this information could be found (nutrients, pesticides, and copper) aquaculture has by far the largest anthropogenic emission input into the coastal waters. Information on the "general" extent or scale (spatial and temporal) of emissions of stressors to the marine environment was also lacking.
- The literature search did not result in much information on multi-pressure effects nor cumulative impacts (although this search is not exhaustive on multi-pressure /cumulative effects). It seems like this information is limited and is missing to date.
- The lacking information on contribution, scale, impact, and cumulative impact of the activities of the key industries, resulted in difficulties to evaluate risk to aquaculture. Risk evaluations had to be based on subjective expert judgement on the information available, and expert assumptions where information was lacking.
- One pressure plastic (nano plastics) was identified as a possible risk for fish health and human consumption from emitting key industries (shipping, fisheries, wastewater, and chemical industry), but this pressure is also emitted by aquaculture sector itself.
- For environmental impact risk, almost all stressors could have possible overlap between the industries emissions, and possible overlaps with each other. This highlights the need to estimate each emissions contribution of each industry and the pressing need to consider many possible permutations of these stressors, and their additive and interactive effects. Resolving cumulative effects of ocean stressors is critical to project their impact.
- The aquaculture sector may be increasingly adversely impacted by sources of pollution from the external environment, e.g. from agricultural, industrial and domestic effluents, foremost if cages will be installed close to point source outlets, in the future. However, that the major and mostly adverse external environmental impacts on aquaculture are likely from climate change and ocean acidification.
- Applying results from research in the Ecosystem-Based Management development and informing policy decisions is crucial. EBM is an ideal science-based approach for managing the impacts of cumulative stressors on marine ecosystems as it is addressing and reducing conflicts as well as the negative cumulative impacts of human activities thus ensuring ecosystem resilience and sustainability.
- A better understanding of the potential cumulative impacts of aquaculture itself, could help aquaculture sector to become more environmentally sustainable.

### 4.2.4 Discussion and conclusions

Human activities on coasts, shores (land-based activities), estuaries, and oceans (sea-based activities) provide benefits to us, but these activities also affect the marine environment and the health of marine ecosystems. Everyday activities in cities and towns and rural areas and at sea have altered the state of many of our coastal ecosystems already. Coastal areas are also the most affected because of the intensity of overlapping activities. These activities can in turn also affect other human activities and benefits (e.g., pose risk to other industries such as fisheries and aquaculture). Understanding the effects of these activities is crucial for managing the activities and minimizing their effects.

The main goal of this work package was to assess and summarize the knowledge base on environmental risks on aquaculture from other industries and activities (direct and indirect effects) that operate in the same ecosystems along the coast and at sea in Norway.

The first step was to assess the human activities and industries operating in the same areas as aquaculture along the coast in Norway. The knowledgebase and information to identify industries and activities operating in the same areas as aquaculture was good, both for land-based industries (e.g., discharge permits to water, Norwegian Environment Agency) and sea-based industries (various databases, expert opinion). The dominance of industry activity varied geographically especially for the land-based activities where dominance was greater in the south, whilst sea-based activities such as fisheries and aquaculture dominated in the north of Norway. Due to high number of identified activities and limited timeframe in project, prioritization of industries and wastewater that operate in the same area were made.

The identified activities at sea and on land are putting increasing pressure on the ocean and the species that live there. Therefore, a broad quick literature investigation was performed to map the most prominent activities and related emissions and possible stressors of the priority key industries and wastewater. An aquaculture risk assessment is in place and is routinely updated to inform managers on impacts from a range of stressors associated with the aquaculture sector (Risikorapport for norsk fiskeoppdrett 2023). However, although there exists risk assessment tool for other industries/activities, no similar risk assessments (with the same disposition and regularity) are established for the other sectors operating in the coastal regions. Therefore, information and knowledge for this part was a bit more difficult to find and scattered around in many places. For the large industries such as shipping and fishing some of this information could be found in review articles, grey reports, and governmental webpages. For the land-based industries risk assessments naturally do not necessarily focus on the marine environment, as the aquaculture, shipping and fishing assessments do. Therefore, this information was a bit more challenging to find, in some instances information was lacking and was not gathered in one risk assessment but a bit more fragmented. There is some information of discharges to sea by the land-based industries (https://www.norskeutslipp.no/), but this information is not divided for the different land-based industries. Here one had to look through grey reports, webpages specialized discharged permits, municipal reports and ask for expert opinion from experts in other scientific fields.

It became obvious, after this overall broad search, that stressors related to the identified key industries overlapped well the pressure categories identified for the aquaculture industry. Using identical pressure categories allowed for a more efficient comparison and assessment in the QSR literature search. However, the 'pressure' specific QSR search that was performed also included a lot of irrelevant knowledge to the topic. Therefore, a more targeted search was carried out to describe the industry-specific impacts and direct and indirect risk of other industries on aquaculture related to the stressors.  Knowledge also had to be gathered elsewhere as much more information could be found in other published literature, mostly in grey literature (reports, websites, databases etc).

No published information (peer review/grey literature) on direct and indirect risks on aquaculture from other industries was found. Therefore, to make an overall assessment of risk one needed to know the geographical extent or severity or degree of pressure exposures from each of the key industries. Hence, the search was concentrated to find information on, 1) contribution to emissions of stressors for each key industry compared to aquaculture and 2) the geographical and temporal extent (or severity) of pressure exposures from the industries and 3) information on overlap of stressors and impact.

For most of the stressors, there was limited information (easily accessible data) on the contribution of emissions of key industry on to the marine environment and sometimes the information was lacking. A summary figure of all industries and related stressors and impact was provided at the beginning of this report section (Figure 4.1). Many review papers of the "newer" stressors, less researched, also stated that this information was lacking, or the data quality was too poor to estimate contributions (e.g., plastics). In the cases this information could be found (nutrients, pesticides, and copper) it seemed that aquaculture has by far the largest anthropogenic input of these stressors into the coastal waters of Norway.

There was also lack of information/knowledge on the "general" scale (spatial and temporal) of emissions of stressors from key industries to the marine environment in literature. The reason for this could be that there has been focus on potential contribution from industries for some stressors. Furthermore, some of the stressors are quite new and not well studied (e.g., plastics, nanoparticles). Lastly the scale also depends a lot on location, as for example environmental pressure concentrations depend on specific discharge conditions and dilution in receiving waters, and its therefore difficult to determine a "general" scale and, therefore any risk assessment process might be site- or scenario-specific.

The literature assessment did not result in much information on multi-pressure effects nor cumulative impact. This may be due to the search not being exhaustive on multi-pressure /cumulative effects search, as it was too a large topic for the project time frame. The same trend was observed in chapter 3 where not much information was found on impact of more than one pressure at a time (although this search was not focused on multi stressors either). It seems like this information limited or is largely missing. In addition, the "general" effects and impacts are known for many of the stressors, however for stressors that are less studied there is lacking information, and some stressors also lack information on impact on relevant species (marine species, or species relevant for Norway). Also, impact of the pressure is often described in a general way not connecting specific impact to an activity or industry.

As there is lacking information on contribution, scale, impact, and cumulative impact of the activities of the prioritized industries, risk evaluations on direct and indirect risks on aquaculture from these industries are thus difficult to perform. Therefore, in this study, the risk evaluation had to be based on expert judgement on the information available, and expert assumptions where the information was lacking. For some of the stressors there was not enough information to make qualified evaluation of the risk to aquaculture industry at all.

Risk evaluations are summarized in Table 4.17. Only one pressure, plastics (nano plastics), was identified as a possible risk for fish health and human consumption in the aquaculture industry from shipping, fisheries, wastewater, and chemical industry. This is because nano plastics have been identified as a possible threat to fish health and human consumption in literature and this pressure may overlap with the aquaculture sites as it may be transported over long distances. However, literature states that more information is needed to evaluate this topic and possible impact. For noise, sound, (no information on impact) and nutrients from cruising (no information on release) there was not enough information to evaluate risk. For nanoparticles and other organic substances, the use and dispersion from aquaculture was not known in itself and therefore not evaluated. For all the other stressors, risk was identified as low, mainly because there is low likelihood for placing aquaculture sites close to point sources of land-based industries, or outlets of wastewater, neither in areas with high runoff from the agricultural areas or in mine disposal areas, where aquaculture would not be permitted. However, risk should be considered for some of the stressors if this is not the case. Aquaculture may be increasingly adversely impacted by sources of pollution from the external environment, e.g. from agricultural, industrial and domestic effluents, foremost if cages will be installed in public water bodies or close to point source outlet, in the future. However, major, and mostly adverse external environmental impacts on aquaculture are likely from climate change and ocean acidification.

For environmental impact almost all the evaluated stressors could have possible overlaps and impact. An exception from this nutrient from land bases industries, due to the large difference in scale of input, land-based sources of nutrients there is a low likelihood of these affecting aquaculture. For some of these stressors it was not possible to evaluate possible overlap as the scale of the emissions from some industries were unknown.

The large number of identified possible overlap of emissions from the key industries in this study show the need to estimate each industries emissions contribution to the single pressure. Furthermore, several of these stressors will also overlap with each other in the marine environment, therefore there is a pressing need to consider many possible permutations of these stressors, and their additive and interactive effects. Resolving cumulative effects of ocean stressors is critical to project their impact and evaluate efficiency of strategies aiming at the mitigation of stressors and adaptation to impacts, and sustainable use of the ocean.

The effect of a combination of stressors on marine life remains an ongoing important field of research. Recommendations for future focus/studies in this field has been proposed by Boyd et al. (2022) in a scientific summary of multiple stressors for policy makers, and furthermore supported by the findings in this literature assessment study to be:

1. Identification and monitoring of stressors at key locations (e.g., sites of high ecological and economical value, sites with high vulnerability to ocean change, sites with different levels of anthropogenic impact) and temporal scales.
2. Development of scientific capacity should go hand in hand with technological advances (e.g. sensor development).
3. Understanding the sensitivity of marine species and ecosystems to stressors and their tolerance thresholds, across a wide range of environmental conditions covering present and future natural variability.
4. Developing a mechanistic understanding of the nature of the biological response to each pressure (mode of action) and how stressors may interact to alter the mode of action. This knowledge is critically needed to improve understanding of how different stressors interact and how biological impacts can be projected.
5. Research should also focus on identifying and developing solutions to counteract the effects of multiple stressors.

In Norway there is currently several ongoing research projects investigating multiple ocean stressors and cumulative impact on the oceans (e.g., Cumulative impact of multiple stressors in High North ecosystems (CLEAN; https://framsenteret.no/forskning/clean/), and in silico and experimental screening platform for characterizing environmental impact of industry development in the Arctic (EXPECT; https://www.niva.no/en/projectweb/expect), and Assessing cumulative impacts on the Norwegian coastal ecosystem and its services (Coast-Risk NRC-project 299554 ).

Boyd et al. (2022) also stated that next steps related to multiple ocean stressors must extend from the implementation of identified research priorities to applying the results from these projects in the development of Ecosystem-Based Management (EBM) strategies and informing policy decisions. Ecosystem-Based Management (EBM) recognizes the complex and interconnected nature of ecosystems, and the integral role of humans in these ecosystems. EBM integrates ecological, social and governmental principles. It considers the trade-offs and interactions between ocean stakeholders (e.g., fishing, shipping, energy extraction, aquaculture) and their goals, while addressing the reduction of conflicts and the negative cumulative impacts of human activities on ecosystem resilience and sustainability. Thus, EBM is an ideal science-based approach for managing the impacts of cumulative stressors on marine ecosystems. Furthermore, a better understanding of the potential cumulative impacts of the aquaculture sector itself, could help the aquaculture sector to become more environmentally sustainable.

It must be highlighted that this report is not an exhaustive literature review given the short time frame of the project and the broad research area. The report can be described as a preliminary fast screening based on a critically selected literature representative of the subject. The report can, therefore, provide a basis for the identification of knowledge gaps and possible research priorities and science-based decision making to assess risks better as well as provide a broad basis to allow Norway to reach its goal in the development of Ecosystem-Based Management strategies.

*Table 4.17. Summary of risks to aquaculture of prioritized industries.*

| Activity | Fish health | Public health | Environmental impact (potential overlapp) | Comment |
|---|---|---|---|---|
| **Particles** | | | | |
| Mining | Low | Low | Possible | |
| Submarine mine tailings (Mining) | Low | Low | Possible | |
| Vessels, dredging, land reclamation and port construction (Shipping, Fisheries) | Low | Low | Possible | |
| Trawling (Fisheries) | Low | Low | Possible | |
| Agriculture | Low | Low | Possible | |
| **Nutrients** | | | | |
| Crusie ships (Shipping) | Unknown | Unknown | Unknown | |
| Land based (Chemical, Food prossesing, Agriculture, Sewage) | Low | Low | Low | |
| **Contaminants** | | | | |
| **Pesticides** | | | | |
| Agriculture | Low | Low | Possible | Migth be risk for residues in fish feed/fish health |
| **Disinfectants** | | | | |
| Fish prossesing | Low | Low | Unknown | |
| Food prosessing | Low | Low | Unknown | |
| Sewage | Low | Low | Unknown | |
| Shipping | Low | Low | Unknown | |
| **Plastics** | | | | |
| Fisheries | Possible | Possible | Unknown | Concern is nanoplastics, most emissions migth come from aquaculture itself |
| Shipping | Possible | Possible | Unknown | |
| Sewage | Possible | Possible | Unknown | |
| Agriculture | Possible | Possible | Unknown | |
| Chemical industry | Possible | Possible | Unknown | |
| **Antifoulants** | | | | |
| Shipping | Low | Low | Possible | In areas with high traffic |
| Fisheries | Low | Low | Possible | In areas with high fishing activity |
| **Pharmaceuticals** | | | | |
| Sewage | Low | Low | Possible | |
| Chemical industry (pharmaceutical) | Low | Low | Possible | |
| Agriculture | Low | Low | Possible | |
| **Oil and oil containing mixtures** | | | | |
| Fisheries | Low | Low | Unknown | Must be seen in connection with the degree of exposure |
| Shipping | Low | Low | Unknown | |
| Sewage | Low | Low | Unknown | |
| Food processing industry | Low | Low | Unknown | |
| Chemical industry (Oil refineries; metalurgical industry) | Low | Low | Unknown | |
| **Nanoparicles** | Not assessed | Not assessed | Not assessed | Not known use/spreading from Aquaculture |
| **Other organic substances** | Not assessed | Not assessed | Not assessed | Not known use/spreading from Aquaculture |
| **Noise** | | | | |
| Fisheries | Unknown | Unknown | Possible | In areas with high human activity |
| Shipping | Unknown | Unknown | Possible | |
| Mining | Unknown | Unknown | Possible | |
| **Light** | | | | |
| Fisheries | Unknown | Unknown | Possible | In areas with high human activity |
| Shipping | Unknown | Unknown | Possible | |
| **Artificial structure** | | | | |
| Fisheries | Low | Low | Possible | Given the wide-reaching impact of artificial structures |
| Shipping | Low | Low | Possible | |
| **Physical destruction** | Low | Low | Possible | |
| **Freshwater regulation** | Unknown | Low | Unknown | Requires more knowledge |

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## 4.3 Case study – feasibility of ecosystem-based management.

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### 4.3.1 Background, objective and scope

Ecosystem-based management (EBM) aims to achieve good ecosystem health and supports sustainable use of marine resources by balancing ecological, social and governance principles at appropriate temporal and spatial scales (Long et al. 2015). An understanding of ecosystem function as well as interaction of ecosystem components and anthropogenic activity is one of the essential foundations for the successful application of EBM. A combined assessment of cumulative impacts of anthropogenic activities and environmental change is required to accomplish this goal. Assignment of associated ecological risk is an additional element required as it will allow for implementation of suitable mitigation measures.

It is often challenging for decision makers and other stakeholders to assess and consider all ecological interactions within an EMB process as the case on hand is too comprehensive and complexity is too high (Figure 4.3). The practical implementation of EBM requires thus evidence-based and easy-to-use tools that support managers, regulators and stakeholders in their decision making. Analytical approaches range thereby from conceptual models constructed though expert opinion to advanced quantitative models (Figure 4.3) (Holsman et al. 2017).

Conceptual models rely upon a rapid evaluation of qualitative data - via expert opinion and/or stakeholder input—of the risk of a given pressure posed to an ecosystem. In Norway, Vann-nett (Norwegian Environmental Agency, https://vann-nett.no/portal/) provides the base for such rapid assessments and seem to be used for qualitative assessments of cumulative impacts and associated risk by local authorities. Its' set up is addressing requirements outlined by the European Water Directive Framework and data input is closely linked to Vannmiljø, a database for environmental monitoring data collected in Norwegian coastal waters (Norwegian Environmental Agency, https://vannmiljo.miljodirektoratet.no/). The coastal zone is thereby subdivided into ecosystem relevant components (waterbodies) based on their hydro- and geographical characteristics. For each waterbody an overview on physical characteristics, conservation areas, environmental/chemical status and stressors (industry activities) is collated and presented. Input data are graded based on associated classification systems and visually easily distinguishable. This portal forms a good base for qualitative assessments but lacks spatial visualization. Geographic Information System (GIS) is widely applied to collate and visualise spatial data. Combined with statistical or mathematical models, GIS can provide an effective tool to quantitatively identify pressure "hotspots" and thus support managers in their decisions on where certain activities/industries can or cannot be placed (Example of a "hotspot" map: Figure 4.17). This approach, however, requires a substantial amount of input data, which have to be publicly accessible.

Our goal with this case study is to assess the feasibility of a practical application of EBM in selected areas along the Norwegian coastline. Building upon the outputs from the QSRs on aquaculture and multi-pressure environmental interactions (chapter 3 and 4.2), we will explore the use of advanced quantitative GIS based decision-making tools to assess cumulative impacts from multiple industries in coastal ecosystems. The practical application of GIS based models requires considerable resources for data post-processing, i.e. preparation of input data and associated decision matrixes, something that is beyond the scope of this project. Accordingly, our main focus will be to map and qualitatively assess availability and suitability of data required to successfully implement a GIS based decision-making tool. This will be done generally for the Norwegian coastline as well as for two focus areas. Gaps in knowledge and/or data will be highlighted and associated limitations will be discussed. Overall, the emphasis will solely be on ecological interactions, which nonetheless provides an important baseline to further assess economic and social implications for the area.

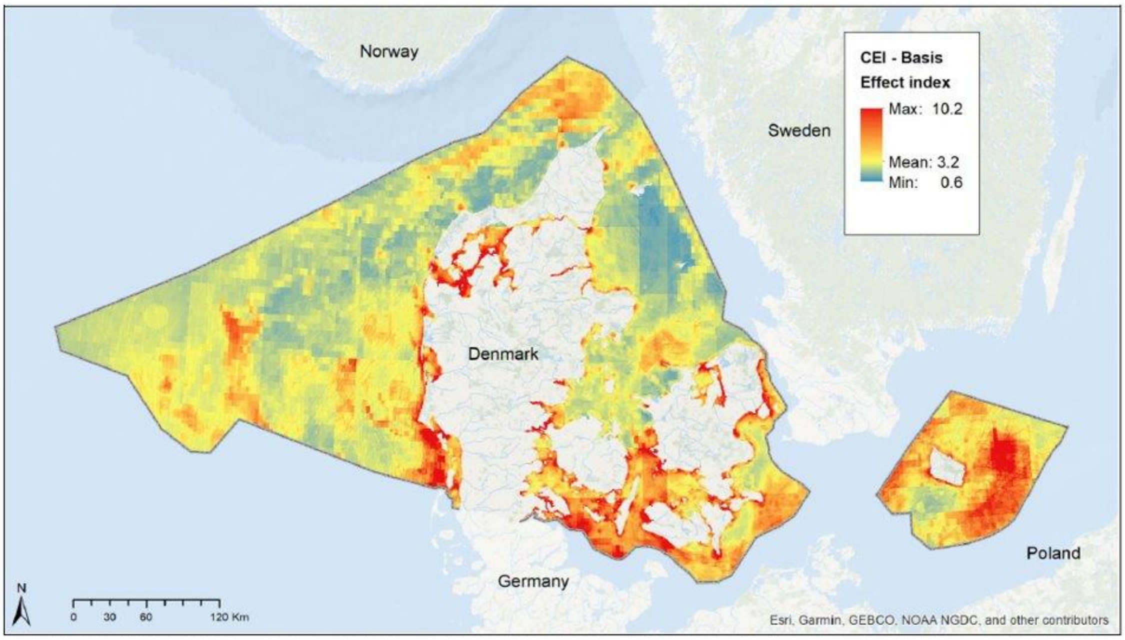


*Figure 4.17. Map of intensities and spatial variations in the estimated combined effects of human stressors and activities developed for Danish waters by Andersen et al. (2020). Red indicates a higher effect impact and blue lower.*

### 4.3.2 Methods

#### 4.3.2.1 Model approaches & data requirements

Cumulative impact assessments (CIA) are used to map and assess additive, synergistic and antagonistic effects of multiple human activities on different ecosystem components. Originally developed for marine environments by Halpern (2008), CIA models evolved over time and, although still showing shortcomings (Korpinen & Andersen, 2016; Lonsdale et al. 2020), are now recognised as a crucial element to operationalise EMB approaches (Kirkfeldt & Andersen, 2021). There are various approaches to conduct a CIA (Lonsdale et al. 2020).

The generic CIA principles outlined by Halpern (2008) formed the base for the development of marine spatial plans in Danish and Swedish waters (Korpinen et al. 2012; Andersen et al. 2020). The suggested model approach is simplified as it considers only direct effects and addresses combined effects as additive. It provides a snapshot in time and cannot account for temporal changes, but models can be adapted to represent different scenarios in space and time. These will give an indication of pressure hotspot areas (Figure 4.17). The current model can also be expanded upon should more advanced model approaches emerge in the future.

Estimating the cumulative impacts of multiple stressors generally requires four types of information:

1. Spatial distribution of relevant pressure source.
2. Spatial distribution of relevant ecosystem components (receiver).
3. Effect distance of each pressure, i.e. how far from the source of the pressure can a measurable effect be expected.
4. Sensitivity or susceptibility of the receiving ecosystem component towards the impact of a pressure.

The main emphasis of this work will be on the data that allow to spatially resolve the distribution of pressure sources and relevant ecosystem components, i.e. addressing point 1 & 2. These data form the base input for a CIA model. Here it is important to highlight that the spatial coverage of the data input has to be suitable to the spatial scale of the study area. The input data have to spatially resolved the complete study area, i.e. the data extent has to be equal to that of the study area. Point data, as for example collected under monitoring at sampling stations, are only applicable if the placement of associated stations forms a network that allows for data interpolation to the required resolution. The resolution of the data layers has to be sufficient to resolve the processes of interest within the study area. Ideally all data layers should fulfil this criterion, as the quality of the model is based on the data layer with the lowest resolution. A data layer with a too low resolution can be sub-gridded into a higher resolution, but the quality of the data within the higher resolved data layer will not improve and thus weakening the overall model output. A CIA model developed for Norwegian coastal waters requires thus data input that covers the complete coastline with a resolution that resolves the dynamic nature of coastal waters as well as relevant ecosystem components and human stressors. Data for smaller scaled areas, i.e. fjords, sounds etc, will require a smaller spatial extent of input data, but a higher resolution to fully resolve the associated smaller scale processes. Here we will firstly explore the availability of data describing key physical processes, human stressors and biological ecosystem components (receiver), followed by a qualitative assessment of suitability of spatial extent and resolution. The categories "Good", "Moderate" and "Poor" were assigned to classify coverage and resolution. For the development of a CIA model covering the full extent of Norway's coastal waters, we consider a resolution of 500x500 m to be sufficient for input data layers. For smaller scaled approaches, i.e. CIA models developed for fjords and sounds, data layers are assessed against a resolution of 150x150 m. This, however, is a rough guide which should be re-evaluated for areas and activities of interest.

Effect distance of stressors and sensitivity of ecosystem components, i.e. point 3 & 4 on the list of relevant input data for a CIA model, were addressed in chapter 3 for aquaculture and in chapter 4 for other industries and potential multistress. The conclusion in chapter 3 and earlier sections in chapter 4 is that the effect distance is dependent on the interactive nature of the pressure as well as the local environmental conditions which drive dispersion. Effect distance is thus specific to each pressure and highly variable along the Norwegian coastline with its multitude of complex interlinked environments ranging from the exposed outer coast to sheltered inner fjords. This part of the study will thus not directly address these CIA input parameters, but instead we refer to chapter 3 and earlier sections in chapter 4 for more detailed information on current knowledge and potential limitations.

#### 4.3.2.2 Data sources

An overview on data sources for human activities, related stressors and ecological components (section 4.3.2.1) is established by exploring Norwegian and European databases. In Norway a range of different governmental departments and institutions as well as the private sector collect data and display these in thematic, GIS based map solutions, which the user can access via a website and visually adapt after their needs. These simplified, semi-interactive map solutions provide an informative visual tool, but they have limited analytical power. More advanced analysis requires access to raw data, which can be adapted towards and incorporated into suitable model approaches such as EcoImpactMapper (Stock, 2016).

In Norway Geonorge's Kartkatalogen (geonorge.no) provides a platform that collates all publicly available geographic data from different stakeholders. It thus formed the key source for the search of suitable data. Also, publicly available databases of governmental departments and institutions were scanned for suitable datasets. These included:

- Norwegian Environmental Agency
- Norwegian Mapping Authority
- Directories of Fisheries
- Institute of Marine Research
- Geological Survey of Norway
- Norwegian Meteorological Institute
- Norwegian Water Resource and Energy Directorate
- Norwegian Biodiversity Information Centre.

In addition, international sources such as the ICES database, Copernicus (EU's earth observation programme) and the "European Marine Observation and Data Network" (EMODnet) (https://emodnet.ec.europa.eu/geoviewer/ ) were assessed for suitable data. EMODnet is thereby a European long-term marine data initiative formed by a network of organisations and supported by the EU's integrated marine policy. Similar to Geonorge it provides free access to data covering European marine areas, divided into different subjects such as seabed habitats and human activities.

#### 4.3.2.3 Areas of interest

In this study we assess data availability, spatial coverage and resolution for a) the length of the Norwegian coastline and b) two focus areas. Subsequently the feasibility of estimating cumulative impacts of anthropogenic activity will be assessed for the areas of interest (Figure 4.18). The smaller scaled focus areas cover the fjordsystems north of Stavanger (Marine Grunnkart pilot area) in the South and Skjerstadfjorden in the North. They vary in their spatial extent and represent different coastal environments. Finfish aquaculture is present in all areas, whilst seaweed farming is located in one of the areas. In addition, both focus areas host a varied range of other industries, including those identified as main industries in Deliverable 3.1. Their shores border multiple municipalities.

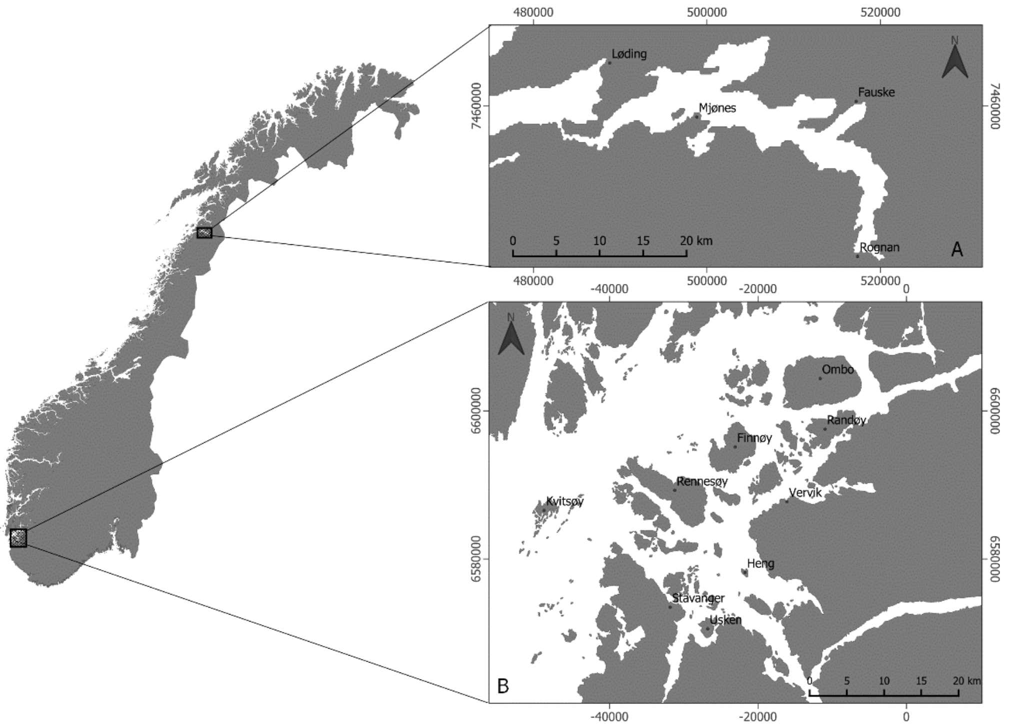


*Figure 4.18. Selected focus areas. A – Skjerstadfjorden, inner Saltfjorden and associated waterbodies and B – fjordsystems north of Stavanger.*

### 4.3.3 Results

#### 4.3.3.1 Data sources

**Baseline data**

*Physical environment*

An overview on sources for data on physical parameters of the marine environment are given below. These data form an important baseline for the characterisation of the marine ecosystem(s) within an area of interest and thus are crucial in the beginning of a management process. A summary with more detailed information on format and accessibility if given in Table 4.18.

**Bathymetry** – The Norwegian Mapping Authority collects high resolution bathymetry data (multibeam) in Norwegian waters. Bathymetry data coverage is still patchy and data with a higher resolution than 50m are classified (Norwegian Armed Forces) in Norwegian coastal waters. The use of data with a higher resolution than 50 m is thus restricted and access for limited areas is only given by application. Bathymetry data can, however, be imported into GIS software as image file via WMS link or viewed in GIS based online map solution. For analytical purposes access to raw data (.geotiff) is required.

**Seabed / Substrate type** – *Acoustic backscatter data* can provide an indication on seabed type, i.e. soft- vs. hardbottom. These data are collected and post-processed by the Norwegian Mapping Authority using multibeam sonar (same as bathymetry). Data with a higher resolution than 50 m are classified (Norwegian Armed Forces) in coastal waters and access for limited areas is only given by application. Data can be viewed in GIS software via WMS link or in GIS based online map solutions. Raw data are required for more advanced analysis. Detailed maps on *grain size distribution* are made available by the Norwegian Geological Survey. Whilst large areas on the continental shelf have been classified by into different sediment categories, limited data are available in coastal waters. The data are only available as image via WMS link, which restricts their use for analytical purpose. They will most likely be made accessible on request.

**Hydrodynamics & waves (exposure)**– Data on current speed (mean) and direction for the bottom layer (close to seabed) as well as data on significant wave heights & wave exposure (seabed) have been published by the Institute for Marine Research (IMR) for the three Marin Grunnkart pilot areas. Data on current flow are extracted from the three-dimensional hydrodynamic model ROMS / Nordkyst800, which has a resolution of 160x160 m. Data on wave exposure have been calculated using the numerical wave model SWAN and are presented at a resolution of 150x150m. Whilst data on current flow and wave heights are available via a WFS link, wave exposure data are currently only accessible via the Marine Grunnkart's GIS online web application. IMR also contributes with data from their coarser scaled Nordkyst800 model (800x800 m) to the daily forecasting of the Norwegian Meteorological Institute (MET Norway). IMR provides access to these data on request. MET Norway forecasts wave heights along the Norwegian costs using their numerical wave model MyWaveWam (800x800 m). Access via WMS/WFS to current and wave data is currently tested on MET's server, but when attempted access was unsuccessful. The data, however, could be downloaded and post-processed using different tools (Matlab / Phyton). The data have a lower resolution, but would provide valuable input as they cover the length of the Norwegian coast.

**Salinity & temperature** – IMR offers datasets on mean salinity in the bottom water and temperature for Norwegian waters. The data originate from the hydrodynamic model NordKyst800 (resolution: 800x800m). In addition, data with a higher resolution of 150x150m and based on the coastal hydrodynamic model ROMS have been published for the three pilot areas of the Marin Grunnkart project. The data (except temperature / Marine Grunnkart) should be available via WFS link, but server connection failed at time of request. The data will most likely be available when directly requested from IMR.

**Oxygen** – Oxygen profiles of the water column are commonly taken as part of standard monitoring. Accordingly, in-situ data related to the respective station are available via "Vannmiljø", a database which collates monitoring data for Norwegian waters and is run by the Norwegian Environmental Agency (https://vannmiljo.miljodirektoratet.no/). These point data are, however, not sufficient to resolve oxygen levels within a fjord area on a larger spatial scale. Spatially resolved data of oxygen in bottom water could not be found. The Norwegian Fisheries Department (FDir) provides data on "Fjords with low water exchange", which highlights coastal areas with low bottom water exchange, i.e. predominantly sill fjords. These areas are often characterised by naturally low oxygen levels in the bottom water and thus are potentially more sensitive to anthropogenic stressors, in particular an increased nutrient load.

**Turbidity** – On some occasions turbidity is measured as part of standard monitoring ("Vannmiljø" – see above), but the station network is also here in most areas not sufficient for interpolation. The EU's earth observation programme "Copernicus" provides satellite images on ocean colour, which are used to calculate surface turbidity levels. This dataset could be a useful contribution to a CIA model as the stated resolution is high in coastal waters (100x100m). It is, however, limited to surface waters. Total coverage of Norwegian coastal waters should be achievable by combining datasets developed for Arctic waters and the North West Shelf Region. This, however, would have to be further explored.

*Ecological status*

Norwegian coastal waters are sub-divided into regions following the EU Water Framework Directive (WFD) and assigned environmental status based on long-term monitoring data using threshold values provided by WFD for different biological and chemical parameters relevant to the marine environment. These data form the baseline for the ecological classification and environmental status of each focus area, which is continuously updated. Classification data on ecological and chemical status for the coastal waters of the focus areas are retrieved from the Norwegian Water Resources and Energy Directorate (https://nedlasting.nve.no/gis/, theme: "Vanndirektiv"). Input data (in-situ and modelled) for the classification can be accessed via Vann-nett, a portal initiated by the Norwegian Environment Agency. Vann-nett provides a visualisation of the classified data via their own GIS based web application (https://vann-nett.no/portal/#/mainmap , 16.12.2022) and allows extraction of data used for the classification in table format via an internal database (https://vann-nett.no/portal/#/ → select relevant theme and define selection criteria). Although direct access to this database via an external GIS tool is not given, the base data extracted from the tables could be downloaded and allocated to a GIS friendly format via the unique ID number assigned to every Norwegian waterbody (VannforekomstID). Base data for classification are also available via "Vannmiljø" (https://vannmiljo.miljodirektoratet.no/).

*Table 4.18. Overview of physical parameters of the marine environment, their data sources, format and suitability for implementation into GIS analysis (Yes – data are provided in a format that allows post-processing / analysis; No – access to raw data is not given).*

| Baseline | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Physical environment** | **Proxy** | **Format** | **Units** | **Scale** | | **Location / download** | **Analysis** | |
| | | | | Spatial | Temporal | | Yes | No |
| **Bathymetry** | Depth - shadow relief | geotiff via WMS<br>Based on high resolution multibeam data.<br>Classified (Norwegian Armed Forces) within territorial boundaries - access by application | meter [m]<br>Resolution: 5, 25, 50 & 200 m | Norway<br>EPSG:25833 (any preferance) | Expanding & updated over time | Norwegian Mapping Authority / 09.12.2022<br>https://openwms.statkart.no/skwms1/wms.havbunnraster2 | (x) | |
| | Depth - base for nautical charts | FGDB | meter [m]<br>Depth curve intervals: 50 m | Norway / per county | Continuously updated | Norwegian Mapping Authority / 09.12.2022<br>https://kartkatalog.geonorge.no/<br>--> search "Sjøkart - Dybdedata", select "nedlasting" | | x |
| **Waves** | Wave exposure - seabed | .geotiff | m/s | Norway - Marine Grunnkart Pilot areas<br>150x150m | | Institute of Marine Research<br>--> availbale via online web application of Marine Grunnkart project:<br>https://marinegrunnkart.avinet.no/<br>--> raw data maybe on request | (x) | |
| | Wave heights (significant) | | meter [m]<br>(mean, 10 & 90 percentil) | UTM Sone 33 (WGS84) | | Geonorge / 12.12.2022<br>--><br>https://kart.hi.no/mareano/magik/bolgehoyde_gjennomsnitt/ows?request=GetCapabilities&service=WFS | x | |
| | Wave heights (significant) | .nc | meter [m] | Norway - coastal waters<br>800x800 m | Updated daily | Norwegian Meteorological Institute<br>https://thredds.met.no/thredds/catalog.html<br>--> Ocean & Sea Ice --> Waves | (x) | |
| **Oxygen** | Spatially resolved oxygen concentration (surface or bottom water) for coastal water – could not be found in public databases | | | | | | | |
| | Fjords with low water exchange | .shp | Presence | Norway<br>EPSG:25833 (any preferance) | Continuously updated | Directorate of Fisheries / 15.01.2023<br>--> "Fjorder med skjelden utskifting av bassengvatn"<br>https://portal.fiskeridir.no/nedlasting | x | |

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| Baseline | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Physical environment** | **Proxy** | **Format** | **Units** | **Scale** | | **Location / download** | **Analysis** | |
| | | | | **Spatial** | **Temporal** | | **Yes** | **No** |
| **Hydro-dynamics** | Bottom current - direction & speed | .geotiff (WMS) & point data (WFS) | direction = degree<br>speed = m/s<br>(mean) | Norway - Marine Grunnkart Pilot areas<br>150x150 m<br>UTM Sone 31 (WGS84) | Simulation: April 2017 - March 2019 | Institute of Marine Research, Geonorge / 09.12.2022<br>--> select Vannmasser - Bunnstrøm<br>https://kart.hi.no/mareano/magik/Bunnstromretning_og_hastighet_gjennomsnitt/ows?request=GetCapabilities&service=WFS | x | |
| | | | | Norway - coastal waters<br>800x800 m | Simulation: 2004-2015 | Institute for Marine Research (on request)<br>www.hi.no/hi/forskning/marine-data-forskningsdata/modeller-og-modellering/sirkulasjonsmodeller<br><br>Norwegian Meteorological Institute<br>https://thredds.met.no/thredds/catalog.html<br>--> Ocean & Sea Ice --> Ocean & Sea Ice | (x) | |
| **Seabed** | Sediment - grain size | image/png (WMS) | Sediment type | Norway - selected areas<br>EPSG:25833<br>(any preferance) | Continuously updated | Geological Survey of Norway / 09.12.2022<br>Dataset - "detaljert" covers coastal areas<br>https://geo.ngu.no/mapserver/MarineGrunnkartWMS | | x |
| | Bottom reflectivity - indication on bottom type (hard, soft) | image/png (WMS) | meter [m]<br>Resolution: 1-50 m | Norway - selected areas<br>EPSG:25833<br>(any preferance) | Continuously updated | Norwegian Mapping Authority / 09.12.2022<br>Dataset - "Relative Bunnhardhet"<br>https://geo.ngu.no/mapserver/MarinBunnsedimenterWMS/?request=getcapabilities&service=wms&version=1.3.0 | | x |

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| Baseline | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Physical environment | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Salinity** | Bottom layer | .geotiff | psu<br>(mean, 10 & 90 percentil) | Norway<br>800x800 m | Simulation:<br>2005-2014 | Institute of Marine Research, Geonorge / 09.12.2022<br>--> NorKyst-800 Gjennomsnittlige salinitet ved havbunn<br>https://kart.hi.no/data/oseanografi/norkyst800_gjennomsnittlig_salinitet_ved_havbunn/wfs?service=WFS&request=GetCapabilities<br>(no access via link at time of request) | (x) | |
| | | | | Norway - Marine Grunnkart Pilot areas<br>160x160 m | Simulation:<br>April 2017 - March 2019 | Institute for Marine Research, Geonorge / 09.12.2022<br>--> select Vannmasser - Bunnsaltholdighet<br>https://kart.hi.no/mareano/magik/Bunnsalinitet_gjennomsnitt/ows?request=GetCapabilities&service=WFS<br>(no access via link at time of request) | (x) | |
| **Temperature** | Bottom layer | .geotiff | Celsius degree (°C) | Norway<br>800x800 m | Simulation:<br>2005-2014 | Institute of Marine Research, Geonorge / 09.12.2022<br>--> NorKyst-800 Gjennomsnittlige temperatur ved havbunn<br>https://kart.hi.no/data/oseanografi/norkyst800_gjennomsnittlig_temperatur_ved_havbunn/wfs?service=WFS&request=GetCapabilities<br>(not accessabile at time of request) | (x) | |
| | | | | Norway - Marine Grunnkart Pilot areas<br>150x150 m | Simulation:<br>April 2017 - March 2019 | Institute of Marine Research<br>--> availbale via online web application of Marine Grunnkart project:<br>https://marinegrunnkart.avinet.no/<br>--> raw data maybe on request | (x) | |

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| **Baseline** | **Data** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Physical environment** | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Turbidity** | Surface layer | netCDF-4 via FTP | FNU | 20 km coastal zone, 100x100 m | Monthly, based on daily averages | Copernicus, 08.03.2023<br>-->Arctic Region, Bio-Geo-Chemical, L4, monthly means and interpolated daily observation<br>https://data.marine.copernicus.eu/viewer/expert?view=dataset&dataset=OCEANCOLOUR_ARC_BGC_HR_L4_NRT_009_207<br><br>--> North West Shelf Region, Bio-Geo-Chemical, L4, monthly means and interpolated daily observation<br>https://data.marine.copernicus.eu/viewer/expert?view=dataset&dataset=OCEANCOLOUR_NWS_BGC_HR_L4_NRT_009_209 | x | |

**Industries and associated stressors**

Here we provide an overview on the data describing presence of key industries and related anthropogenic stressors. Table 4.19 is thereby summarising sources and format of data related to the different industries, whilst Table 4.20 provides an overview on data availability for respective pressure parameters.

*Industries*

**Aquaculture** - A dataset with information on aquaculture site location and license details is provided by FDir. Here, data on the location of active aquaculture sites for salmon, trout, cod and macroalgae can be extracted for areas of interest. FDir provides in addition a dataset with information on production intensity per waterbody, i.e. number of location and mean biomass. The latter is useful for an approach on a larger spatial scale where a lower resolution is sufficient.

**Fisheries** – Area use by fisheries is well described by datasets compiled by the Norwegian Fisheries Department. Trawl gear, i.e. active, mobile fishing gear with bottom contact, significantly affects the seabed. A quantitative dataset on trawling intensity per area based on VMS and AIS tracking data from 2018-2021, has been created as part of the evaluation of offshore wind developments. This dataset also covers coastal waters and whilst the spatial resolution is low (1x1km), it provides an extremely useful input for a CIA model. The data are visualised in a GIS based web application: https://portal.fiskeridir.no/portal/apps/webappviewer/index.html?id=8c733df16bd442c6a6726a9fb29b4d6e (accessed: 08.03.2023). The data source is unclear and access to raw data is not provided. It is, however, expected that these data will be made available on request. The Norwegian Fisheries department also provides a dataset that broadly describes areas in which active fishing gear is regularly deployed as well as a dataset highlighting common grounds for shrimp fishing. Whilst these datasets lack information on fishing intensity, they provide in some cases more detailed information on temporal use and thus could be an informative add on to the trawling intensity dataset. The footprint and environmental impact of passive, stationary fishing gear (nets, lines and seines) is negligible compared to active, mobile fishing gear. Area use, however, is an important factor to consider in particular in coastal waters. Accordingly, a dataset that highlights areas commonly used for passive fishing gear deployment was also added.

**Kelp dredging** – FDir provides a dataset, which outlines the spatial boundaries of allocated dredging areas for kelp, associated no-take zones and reference areas. Information on seasonal usage is also given.

**Shipping** – Shipping activity is quantified using Automatic Identification System (AIS) positioning data as density estimate. The Norwegian Coastal Administration provides a density plot for vessels longer >15 m as yearly average for 2016. In addition, density data subdivided into AIS class A (larger, commercial vessels) and B (smaller fishing vessels & recreational crafts) are available as yearly average for 2020. Data presented as georeferenced image file can be accessed via WMS link, whilst access to raw is given on request only. The data are embedded in universal mapping tool (kart.kystverket.no), where a further subdivision of AIS data by commercial sectors (fisheries, oil tankers, chemistry tankers etc) is optional. The respective data should be available via WMS link, but were at the time of this study not accessible. In addition, shipping density data as annual average provided by EMODnet were extracted. These data are presented in a 1x1km grid where density is expressed as hours per square kilometre per months. The data are very coarse, but provide an easy to handle input into further analysis.

**Landbased industries** –Norway's Environmental Agency provides a dataset with an overview on all landbased industries which hold a permit for emissions to water and air – 'Utslipp fra landbasert industri". From this dataset all active wastewater outlets located in the sea are extracted and relevant industries and their emissions identified for the focus areas. The dataset includes for each industrial activity a link to reported quantities of emissions per year. Industries with a freshwater / river release were only included if clearly connected to a degraded environmental status of the adjacent marine waterbody (mining, Skjerstadfjorden). These data are available as shapefile (download) or via WMS.

**Sewage** – A dataset with information on sewage outlets is provided by Norway's Environmental Agency. Here sewage outlets, which release wastewater directly into the sea were identified, extracted and classified by their treatment method. The dataset also provides a direct link to a summary table with details on yearly emissions per outlet, which could be used for more detailed analysis. Data are available as georeferenced .jpg for use in simplified mapping tools or general data (Geonorge).

**Hydropower** – Information on rivers, dams & hydropower developments was extracted from a dataset provided by the Norwegian Water Resources and Energy Directorate (NVE). The webportal Vann-Nett offers access to a datalayer, which shows coastal water bodies affected by hydropower developments. Status of impact is classified in three categories: low, medium, high. Assessment criteria are not clearly stated, and it is unclear how to export the respective data layer. The data are still of relevance and can be found here: https://temakart.nve.no/link/?link=vannkraft_med_paavirkningsgrad (accessed: 15.12.2022).

**Agriculture** – Agriculture affects the marine environment indirectly through river-run off and groundwater contamination. Sources are therefore diffuse, and output is often related to landbased water networks. Contributions by agriculture will therefore be covered in pressure proxies outlined in the next section.

*Table 4.19. Overview of proxies used for selected industries, the data sources, format and suitability for implementation into GIS analysis (Yes – data are provided in a format that allows post-processing / analysis; No – access to raw data is not given).*

| Industry | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| | Dredging intensity | unknown | Number of trawlline / km$^2$ | Norwegian waters | 2018 - 2021 | Directorate of Fisheries / 08.03.2023<br>Visual map, download unclear - most likely on request<br>--> Statistikkruter antall spor (raster)<br>https://portal.fiskeridir.no/portal/apps/webappviewer/index.html?id=8c733df16bd442c6a6726a9fb29b4d6e | x | |
| **Fisheries** | Areas - deployment of active fishing gear | Directorate of Fisheries<br>.shp (polygon)<br><br>Geonorge<br>FGDB | Presence | Norway or county<br>.shp: EPSG:25833<br>FGDB:<br>EUREF89 UTM zone 33<br>(or any preference) | Continuously updated | Directorate of Fisheries / 28.11.2022<br>https://portal.fiskeridir.no/portal/apps/webappviewer/index.html?id=bed4faeea84e4d6dbc548d43cc134c96&layer=<br>--> select "Tema":<br>* Fiskeplasser - aktive redskap<br>* Fiskeplasser - passive redskap<br>* Rekefelt - aktive redskap<br>* Låssettingsplasser<br>Geonorge / 27.12.2022<br>https://kartkatalog.geonorge.no/<br>--> search topic (see above) & select "nedlasting" | x | |
| | Areas - deployment of passive fishing gear | | | | | | x | |
| | Shrimp fishing fields | | | | | | x | |
| | Temporal storage of catch | | | | | | x | |
| **Shipping** | Shipping density (AIS)<br>Class A - 2020<br>Class B - 2020<br>Trackdensity 2016 | WMS (raw data on request) | Presence / absence | Norway<br>50 x 50 m | Average / year | Kystverket, Geonorge / 26.11.2022<br>https://wms-geo.kystverket.no/density?version=1.3.0&request=GetCapabilities&service=WMS | | x |
| | Shipping density (AIS) | 32 bit floating point Tagged Images File Format (.tif) | Presence / absence | EPSG:3035 - ETRS89 / LAEA Europe<br>1x1 km | 2017 - 2021<br>Average hours / km^2 / month | EMODnet / 16.12.2022<br>https://emodnet.ec.europa.eu/geoviewer<br>--> "Vessels density" - "All types (Annual average 2017-2021)<br>--> select area of interest & download | x | |

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| Industry | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Aquaculture** | Aquaculture sites | .shp | Presence | Norway EPSG:25833 (any preferance) | Continuously updated | Directorate of Fisheries / 08.03.2022<br>--> Lokaliteter<br>https://portal.fiskeridir.no/portal/apps/webappviewer/index.html?id=bed4faeea84e4d6dbc548d43cc134c96&layer=Akvakulturregisteret | x | |
| | Production intensity / water body | | | | | Diretorate of Fisheries / 08.03.2022<br>-->Produksjonsintensitet (year)<br>https://portal.fiskeridir.no/nedlasting | x | |
| **Landbased industries** | Locations with license for release of emissions to waterbody | FGDB | Presence | Norway | Continuously updated | Geonorge / 08.03.2022<br>https://kartkatalog.geonorge.no/<br>--> search "Utslipp fra landbasert industri", select "nedlasting"<br>Included only industries with active release point to marine waters. | x | |
| **Sewage** | Sewage outlets | FGDB | Presence | Norway EPSG:25833 (any preferance) | Continuously updated | Environmental Agency, Geonorge / 28.11.2022<br>https://kartkatalog.geonorge.no/<br>--> topic "Avløpsanlegg"<br>--> select "Kystvann" and "Utslippspunkt" | x | |
| **Hydropower** | River network / catchment | .shp | Presence | Norway or municipality EUREF89 | Monthly updated | Norwegian Water Resource and Energy Directorate / 08.12.2022<br>https://nedlasting.nve.no/gis/<br>--> select:<br>* "Elv" - "Hovedelv" & "Elvenet"<br>* "Vannkraft" - "Vannkraftverk", "Dam punkt", "Vannvei" | x | |
| | Dams & hydropower developments | | | | | | x | |
| **Kelp dredging** | Allocated area for kelp dredging (seasonal), including no access zones and reference sites | .shp | Presence | Norway EPSG:25833 (any preferance) | Continuously updated | Diretorate of Fisheries / 03.01.2023<br>-->Tare - høstefelt<br>https://portal.fiskeridir.no/nedlasting | x | |

*Stressors*

**Heavy metals and other inorganic contaminants + organic contaminants (in sediment)** – Datasets collected by IMR and the Geological Survey of Norway. Substrate samples originating predominantly from cruises associated to their mapping projects Mareano and Marine Grunnkart, but data from other monitoring cruises were also included (Barentssea). Patchy data coverage in coastal water. Relevant data can also be found in Vannmiljø, a data portal where results from samples collected in relation to industry activity and general monitoring programs are compiled. These data would have to be located, extracted from the database for the area of interest and interpolated. The latter requires a dense station network.

**Plastic** –Plastic pollution has to date not been systematically mapped along the Norwegian coastline, but a new national monitoring program started in 2021. The mapping projects Mareano and Marine Grunnklart have recorded plastic along their video survey transects and analysed substrate samples for microplastic. Most data are available for the offshore regions, whilst coastal waters have been covered in some areas. Data are provided per station, i.e. have a limited spatial extent. FDir provides in addition a dataset on lost fishing gear for offshore and coastal waters.

**Invasive species** – A national monitoring program for invasive species does not exist in Norway, but some targeted activities on selected species and organism groups are ongoing (Husa et al. 2022). Artsdatabanken provides a dataset with presence data of marine and terrestrial invasive species classified as being of very high and high risk (Artsdatabanken, 2018).

**Escapes** – A dataset on number of escapes as reported by the fish farmer and divided in initial estimates and finally confirmed numbers is provided by FDir.

*OBS:* The above-mentioned data on environmental contaminants and invasive species are associated to sample stations (point data) and thus have a limited spatial extent. Feasibility of interpolation between stations, and thus suitability for a GIS based cumulative impact approach, is depending on the station network, environmental conditions and the anticipated spatial extent. This will have to be assessed on a case-to-case basis.

**Dissolved nutrients (phosphor & nitrogen) –**The Norwegian Institute for Water Research (NIVA) developed in the early 90's the TEOTIL model ("TEOretiske TILførselsberegninger"; Tjomsland et al. 2010) to simulate fluxes of nitrogen (N) and phosphorus (P) for river catchment networks along the Norwegian coastline. It integrates nutrient inputs from a variety of sources and accumulates them downstream. Key datasets for simulating nitrogen and phosphorus include: diffuse background inputs from forests & uplands; diffuse human inputs based on population density & agricultural activities; and point discharges from industry, sewage treatment & aquaculture. It is validated with monitoring data collected through a network of stations in rivers and coastal areas. A graphic user interface is lacking, but data can be extracted and assigned using catchment network ID as provided by the database "Regine".

**Noise** – The International Council for the Exploration of the Sea (ICES) manages a data portal for impulsive noise (shortlived events of high energy sound such as pile driving and underwater explosions), and continuous noise (lower energy sound of a longer duration, such as shipping traffic). Data are provided by members of OSPAR (Northeast Atlantic) and Helcom (Baltic Sea). Norway is OSPAR member, but data submission has been low and predominantly focused on airgun use offshore. A noise map such as presented by OSPAR for impulsive noise in the North Sea, Baltic Sea & Irish Sea and for continues noise in the Baltic Sea does thus not exist for Norwegian waters and this pressure can to date not be considered.

**Light** – A study by Smyth et al. (2021) developed a global atlas of artificial light at night (ALAN) under the sea. The data set is derived from satellite data describing artificial night sky brightness and in-water inherent optical properties dataset. It aims to quantity the critical depth to which biologically relevant ALAN penetrates throughout the global ocean's estuarine, coastal and near shore regions, in particular the area defined by an individual country's Exclusive Economic Zone. The dataset covers the southern parts of Norway, i.e. Skagerrak. Other data on marine light pollution are not available for Norwegian waters.

**Particles** – Turbidity is correlated with the amount of particles in the water. Satellite data, as outlined in section 'Physical environment', can also used as a proxy for particles. These data, however, are limited to the surface area and will only detect an overall increase in turbidity based on continuous particle release. For information on data source see Table 4.18.

*Table 4.20. Overview of selected stressors, associated data sources, format and suitability for implementation into GIS analysis (Yes – data are provided in a format that allows post-processing / analysis; No – access to raw data is not given).*

| Pressure | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Heavy metals and other inorganic elements** | List of contaminants: https://register.geonorge.no/data/documents/Produktark_tungmetaller-og-andre-miljoelementer-i-marine-sedimenter_v1_produktark-marin-uorganisksedimentkjemi_.pdf | .png | Element / component specific scale | Norwegian waters / Mareano + IMR cruises | 2006 - to date continuously updated | Geological Survey of Norway & Insitute of Marine Research, Geonorge / 03.01.2023<br>--> Tungmetaller og andere uorganiske miljøelementer i marine sedimenter<br>https://geo.ngu.no/mapserver/MarinGeokjemiWMS/?request=getcapabilities&service=wms&version=1.3.0 | | x |
| **Organic contaminants** | List of contaminants: https://www.mareano.no/resources/files/Produktark-Organiske-miljogifter.pdf | image | | | | Institute of Marine Research, Geonorge / 03.01.2023<br>--> Organiske Miljøgifter i marine sedimenter<br>https://wfs.geonorge.no/skwms1/wfs.organiskegiftermarinesedimenter?service=WFS&request=GetCapabilities | | x |
| **Environmental contaminants** | | | | | | Vannmiljø<br>--> Miljøgifter i kystområdet<br>--> Overvåkning I industriresipienter<br>--> Overvåkning av forunrenset sjøbunn<br>--> Kartlegging av nye miljøgifter<br>https://vannmiljo.miljodirektoratet.no/ | | x |
| **Invasive species** | Species of interest | .gml | Presence | Norwegian waters | continuously update | Norwegian Biodiversity Information Centre, Geonorge / 03.01.2023<br>--> Artskart Fremmende Arter WFS<br>https://kart.artsdatabanken.no/WMS/artskartfa.aspx?version=1.0.0&service=WFS&REQUEST=GetCapabilities | x | |
| **Escape** | | .shp | Number of escape (estimate and quantitative) | Norwegian waters | continuously update | Directorate of Fisheries / 15.02.2023<br>-->Rømming<br>https://portal.fiskeridir.no/nedlasting | x | |

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| Stressor | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Plastic** | Microplastic | .jpg | number of particles / dryweight kg surface substrate (0-2/3 cm) | Norwegian waters | unknown | Geological Survey of Norway, Geonorge / 15.12.2022<br>--> Marin Geokjemi --> Mikroplast<br>https://geo.ngu.no/mapserver/MarinGeokjemiWMS/?request=getcapabilities&service=wms&version=1.3.0 | | x |
| | Diverse > 5cm | .shp | cm quantified along video transects | Norwegian waters | unknown | Institute of Marine Research, Geonorge / 15.02.2022<br>https://kart.hi.no/mareano/mareano_stasjoner/soppel_100m/wms?service=WFS&request=GetCapabilities | x | |
| | | .shp | | Norwegian coastal waters - Marine Grunnkart EPSG 32633 | | Institute of Marine Research, Geonorge / 15.02.2022: NB - layer failed to load<br>--> Menneskelig påvirkning - Marint søppel per videotransekt<br>https://kart.hi.no/mareano/magik/menneske_soppel/ows?request=GetCapabilities&service=WFS | (x) | |
| | Lost fishing gear | .shp | | Norwegian waters | yearly | Directorate of Fisheries / 05.01.2023<br>--> Tapte redskap 2022<br>https://portal.fiskeridir.no/nedlasting | x | |
| **Noise** | No data for Norwegian waters / 04.01.2023 | | | | | ICES database<br>Impulsive & cumulative noise:<br>https://www.ices.dk/data/data-portals/Pages/impulsive-noise.aspx | | x |
| **Light** | critical depth ($Z_c$) to which biologically relevant ALAN penetrates. | .nc / raster | meter [m] | North Sea & Skagerrak resolution: 1x1 km | monthly | https://doi.pangaea.de/10.1594/PANGAEA.929749?format=html#download | x | |
| **Dissolved nutrients** | Phosphor & nitrogen | .csv | varied | River catchments | continuously | https://github.com/NIVANorge/teotil2 | (x) | |

**Ecosystem components, areas of ecological importance and conservation**

In this section an overview on data availability for various ecosystem components, i.e. presence of specific species and habitats, areas of importance during certain life stages of some species and areas of conservation are presented. A summary with additional information on data format, extent and access is given in Table 4.21. It has to be noted that data presented in this section are often based on presence records. "Blank" areas can indicate recorded absence, but could also mean that mapping of the area for a specific species has yet not occurred.

*Seabirds*

Seabirds are currently monitored and mapped in Norway through the research projects SEAPOP (seapop.no) and SEATRACK. Based on a combination of in-situ abundance counts of selected key species during breeding and non-breeding periods and results from population models, these projects have been able to classify (low to high) Norwegian waters based on their ecological value to seabirds. Although these projects provide a wide range of informative and essential spatial, temporal and ecological data for seabirds, the ecological value dataset is seen as suitable for cumulative impact modelling. It is also a format, which is easy assessable and informative for management. Currently this layer is only available via WMS server, but should be provided on request. Other datasets can be accessed and downloaded via the project's mapping application.

*Marine mammals*

Marine mammals in Norwegian waters include the blue whale, fin whale, minke whale, humpback whale, killer whale, harbour porpoises as well as grey and harbour seal (Bjørge et al. 2010). IMR provides distribution maps for these species. Their resolution, however, is based on either oceanic subareas (based on large scale migratory patterns) or broad regional scales in coastal waters, where some of these species are permanently or temporarily resident. IMR undertakes regular abundance counts and is involved in research projects that investigates the spatial movements of these species. Although higher resolution data for coastal waters are not publicly available, IMR or the North Atlantic Marine Mammal Commission (NAMMCO, https://nammco.no/) might be able to supply input on request. Alternatively, a dataset which contains data on the ecological value of Norwegian waters to marine mammals is available via the Norwegian Environmental Agency. Currently it is only available as WMS layer, but data might be made available on request.

*Pelagic*

**Plankton** – Chlorophyll a (Chl a) is commonly used as proxy for phytoplankton presence. In-situ data on Chl a are collected as part of regular monitoring ("Økøkyst" program - https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/miljoovervaking/overvakingsprogrammer/ferskvann-hav-og-kyst/okokyst/ ) and reported per station via "Vannmiljø", a database which collates monitoring data for Norwegian waters and is run by the Norwegian Environmental Agency (https://vannmiljo.miljodirektoratet.no/). These point data are, however, not sufficient to resolve chlorophyl a levels within a fjord area on larger spatial and finer temporal scales. The EU's earth observation programme "Copernicus" provides free, open, regular and systematic reference information on the physical and biogeochemical ocean state, variability and dynamics across the global ocean and European regional seas. Here data on Chl a from a biogeochemical model (numerical), which was validated using satellite images, are freely available. The spatial resolution, however, is limited (0.25°x0.25°). Data on the spatial distribution of zooplankton in coastal waters could not be found.

**Spawning grounds** – FDir provides several datasets, which give an overview on the spatial extent of spawning areas for cod and other fish species as well as the temporal restriction for access. The presented information is based on data collected by IMR, the fishing industry and other local stakeholders. "Gytefelt tosk MB" are spawning grounds for coastal cod as mapped by IMR. "Gyteområde forskjellige arter" includes important spawning grounds in the outer coastal zone (such as Lofoten and Vesterålen) as well as offshore. "Gyteområder" represents data which indicate spawning grounds for a wide range of fish. Data have been reported by fishermen and local stakeholders and have not been verified by IMR.

**Nursery & feeding grounds (fish)** – This dataset is also provided by FDir and includes the estimated spatial extent of nursery (juvenile fish) and feeding (adult fish) grounds for a range of fish species. The data have been collected via interviews with fishermen and local stakeholder and might thus be biased towards "good" fishing grounds whilst other important areas might be underrepresented.

*Benthic*

**Benthic biotopes** – The classification system "Natur i Norge" has successfully been implemented for the use in terrestrial ecosystems and is now also developed for the marine environment. Large efforts have been made over the past years to characterise and refine the classification system for shallow water biotopes. The classification of subtidal biotopes is, however, still in its infancy and solely based on physical parameters whilst lacking biological information. Accordingly, there is a paucity of classified spatial data for general benthic biotopes in coastal waters, i.e. not sensitive or of commercial relevance. The only available datasets are provided by IMR and are associated to the pre-project (Sør-Troms) and pilot project (3x focus areas) of Marine Grunnkart. Mareano has also developed benthic biotope maps. Their extent, however, is restricted to offshore areas. Data are currently published as image file only, but access to raw data will most likely be given on request.

**Northern shrimp (*Pandalus borealis)* –** IMR provides a generalised distribution map for the northern shrimp. This, however, is very large scale and without detail on population hotspots. Fisheries activities (Shrimp fishing fields) will most likely provide a better proxy of presence in coastal waters.

**European lobster (*Homarus Gammarus*) –** IMR provides a generalised distribution map for European lobster. Higher resolved population data could not be found. "No fishing" zones for European lobster have been established in some areas along the Norwegian (see also Table 4.23).

*Table 4.21. Overview of relevant ecological components, associated data sources, format and suitability for implementation into GIS analysis (Yes – data are provided in a format that allows post-processing / analysis; No – access to raw data is not given).*

| Ecological components | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Fish** | Spawning grounds<br>--> Coastal cod<br>--> other | .shp | Presence | Norwegian waters EPSG:25833 (any preference) | Continuously updated | Directory of Fisheries, 10.01.2023<br>--> Gytefelt torsk MB (coastal cod)<br>--> Gyteområder forskjellige arter (other species, verified by IMR)<br>--> Gyteområder (other species, unverified by IMR)<br>https://portal.fiskeridir.no/nedlasting | x | |
| | Nursery & feeding areas | | | | | Directory of Fisheries, 10.01.2023<br>--> "Oppvekst - beiteområde"<br>https://portal.fiskeridir.no/nedlasting | x | |
| **Plankton** | Phytoplankton - Chl a | netCFD4 (WMS), raw data available for further post-processing | mg/m$^3$ | Global, 0.25°x0.25° | 2 years timeseries, daily and monthly, weekly updated | Copernicus, 15.01.2022<br>--> Global Ocean Biogeochemistry Analysis and Forecast<br>https://data.marine.copernicus.eu/viewer/expert?view=datasetServices&dataset=GLOBAL_ANALYSIS_FORECAST_BIO_001_028<br>--> Mass concentration of chlorophyll a in sea water<br>https://nrt.cmems-du.eu/thredds/wms/global-analysis-forecast-bio-001-028-daily?request=GetCapabilities&service=WMS | (x) | |
| | Zooplankton | | | | | Not available | | x |
| **Seabirds** | Ecological value | WMS | Classified: low to high | Norwegian waters EPSG:25833 (any preference)<br>10x10 km | As required | Norwegian Environmnetal Agency, Geonorge / 22.01.2023 --> Miljøverdi, hav WMS --> sjøfugl<br>https://kart.miljodirektoratet.no/geoserver/miljoverdi_hav/wms?service=wms&version=1.1.1&request=getcapabilities | | x |

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| Ecological components | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Benthic biotopes** | | .png (WMS) | NiN classification / 15.01.2023 https://artsdatabanken.no/Pages/172020/Saltvannsbunnsystemer | Test area: Sør-Troms & 3x focus areas Marine Grunnkart | Sør-Troms: 2012 Other areas: 2020 - 2022 | Insitute of Marine Research, Geonorge / 15.01.2023 --> Marine biotoper i Sør-Troms http://metadata.nmdc.no/metadata-api/landingpage/9530cc50d6919526b5beb29fd3ca4966<br><br>--> NiN grunntyper og hovedtyper av saltvannssjøbunn, predikert WMS https://kart.hi.no/mareano/magik/nin_grunntyper_polygon//ows?request=GetCapabilities&service=WMS | | x |
| **Crustacea** | European lobster (*Homarus gammarus)* | .shp (WFS) | Distribution area | | As required | Institute of Marine Research, Geonorge / 22.01.2023 --> Artsutbredelse Sjøpattedyr WFS --> select "Hummer" https://kart.hi.no/data/utbredelseskart/wms/ows?request=GetCapabilities&service=WFS<br><br>see also: Conservation areas - no fishing zone | (x) | |
| | Northern shrimp (*Pandalus borealis)* | .shp (WFS) | Distribution area | Validation area | As required | Insitute of Marine Research, Geonorge / 22.01.2023 --> Dypvannsreke WFS https://kart.hi.no/data/utbredelseskart/Dypvannsreke/ows?request=GetCapabilities&service=WFS<br><br>--> see also Industry table - "Fisheries", "Shrimp fishing fields" | (x) | |

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| Ecological components | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| Marine mammals | Whale, porpoise, dolphins & seals | .shp (WFS) | Distribution, high density and validity area | Oceanic subregions & Norwegian waters | As required | Institute of Marine Research, Geonorge / 22.01.2023 --> Artsutbredelse Sjøpattedyr WFS https://kart.hi.no/data/utbredelseskart/wms/ows?request=GetCapabilities&service=WFS | (x) | |
| | Ecological value | WMS | Classified: low to high | Norwegian waters EPSG:25833 (any preference) 10x10 km | | Norwegian Environmnetal Agency, Geonorge / 22.01.2023 --> Miljøverdi, hav WMS --> sjøpattedyr https://kart.miljodirektoratet.no/geoserver/miljoverdi_hav/wms?service=wms&version=1.1.1&request=getcapabilities | | x |

**Sensitive species and habitats** can often be assigned one or more of the following characteristics: 1. unique & rare, i.e. they are rare / threatened or endangered and/or occur only in discrete areas; 2. fragile, i.e. they are highly susceptible to degradation of anthropogenic stressors as they can be long-lived, have a slow growth rate and/or population connectivity and reproduction is thought to be limited, although knowledge is often lacking; 4. important ecological function, i.e. their presence is associated with high biodiversity, they can provide breeding, spawning and/or nursery grounds and some are though to provide carbon sinks. Sensitive species and habitats thus form an important part of marine ecosystems and Norway is obliged to their protection by national and international agreements. Accordingly, in-situ and predictive mapping efforts have been focused on identifying presence of respective species and habitats and various datasets are available (Table 4.22).

A number of sensitive habitats were mapped and predicted under the National Program for mapping of marine biodiversity (coast), which was initiated in 2001 (Direktoratet for Naturforvaltning, 2007): Large kelp forests, Ice marginal deposits, soft sediments in the littoral zone, eelgrass meadows and other seagrass meadows, shellsand habitats, øyster areas, large scallop occurrence and corals. The data are provided by the Norwegian Environmental Agency and contain areas of species / habitat presence categorised in different priority categories.

The national mapping programs Mareano and Marine Grunnkart have in addition mapped sensitive species & habitats and provide observation data (presence records) as well as predicted occurrence maps for some habitats. Habitats covered by Mareano are: Soft- and hard-bottom sponge aggregations, deep arctic sponge aggregations, sublittoral seapen communities, bathyal seapen communities (*Umbellula*), soft- and hard-bottom coral gardens and cold-water coral reefs. Mareano also provides presence data for horn corals including *Isidella lofotensis, Paragorgia arborea, Paramuricea placomus, Primnoa resedaeformis* and *Radicipes*. Spatial coverage of Mareano's predicted habitat distribution maps is limited to the offshore areas of Northern Nordland, Troms and the Barent Sea and, whilst observation data are also provided for some parts of the Norwegian coast. Data from the Marine Grunnkart project are spatially restricted to the three pilot areas of the project. Here observational data for the following habitats are provided: Cerianthide aggregations, dead coral reefs and associated presence of *Acesta excavata*, coral gardens - hardbottom, sponge garden-hardbottom, seapen communities, maerl beds and eelgrass meadows. Predicted habitats models have been developed for sponge gardens, seapen communities and to estimate kelp biomass. IMR also provides observational data for presence of coral reefs and associated habitats.

*Extremely valuable and sensitive areas of importance* – These areas have been created for management purposes and host sensitive species & habitats or commercially valuable species. The dataset is provided by the Norwegian Environmental Agency. It can't be used for analytical purposes, but is thought to support management.

*Table 4.22. Overview of sensitive species & habitats, associated data sources, format and suitability for implementation into GIS analysis (Yes – data are provided in a format that allows post-processing / analysis; No – access to raw data is not given).*

| Sensitive species / habitats & areas of ecological importance | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Large kelp forests**<br>**Ice marginal deposits**<br>**Soft sediments in the littoral zone**<br>**Eelgrass and other seagrass meadows**<br>**Shellsand**<br>**Øyster areas**<br>**Large scallop occurences**<br>**Corals** | | SOSI, FGDB, GML, GeoJSON .jpg (WMS) | Presence | Norwegian waters EPSG:25833 (any preference) | 2007 - 2019; Continuously updated | *DN-Håndbok 19*<br>Naturbase, Norwegian Environmental Agency / 06.01.23 (only WMS layer available at time of access)<br>--> Naturtyper DN-Håndbok 19<br>https://karteksport.miljodirektoratet.no/ (download not available at time of access)<br>WMS:<br>https://kart.miljodirektoratet.no/arcgis/services/naturtyper_marine_hb19/MapServer/WMSServer?service=wms&version=1.1.1&request=getcapabilities | (x) | |
| **Horn corals (*Octocorallia*)** | | FGDB, GML, PostGIS, SOSI | Presence | Mareano mapping areas | Continuously updated, yearly | *Mareano*<br>Insitute of Marine Research, Geonorge / 06.01.2023<br>--> "Hornkoraller"<br>Download & WFS:<br>https://kartkatalog.geonorge.no/metadata/hornkoraller/fa06de24-a6b9-464c-9c46-fbb33ebb1482 | | x |
| **Extremely valuable and sensitive areas** | | .shp (WFS) (point) | Presence | Norwegian waters EPSG:25833 (any preferance) | | Norwegian Environmental Agency, 25.01.2023<br>-->Hav og kyst; SVO (Svært verdifulle og sårbare områder)<br>https://kartkatalog.miljodirektoratet.no/MapService | (x) | |

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| Sensitive species / habitats & areas of ecological importance | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| Coral garden - hardbottom<br>Coral garden - softbottom<br>Coral reefs<br>Sponge garden - softbottom<br>Sponge garden - hardbottom<br>Deep arctic sponge aggregations | | *Predicted*: .geotiff | *Precicted*: Expected presence, n/100m² | Predicted: offshore Troms, Nordland & Barents Sea EPSG:25833 resolution: 1x1 km | Continuously updated Yearly | *Mareano*<br>Insitute of Marine Research, Geonorge / 06.01.2023<br>--> Sårbare marine biotoper - modellert utbredelse<br>Download & WFS:<br>https://kartkatalog.geonorge.no/metadata/saarbare-marine-biotoper--modellert-utbredelse/d2cf65bf-6d10-4bc8-a803-0e14349f575e | x | |
| Sublittoral seapen communities<br>Bathytal seapen communities | | Observation: FGDB, GML, PostGIS, SOSI | Observation: presence | Observations: Mareano mapping areas Density/500m EUREF89 UTM sone 33, EUREF89 / ETRS89-LAEA Europe, EUREF 89 Geografisk (ETRS 89) | | --> Sårbare marine bunndyr - observasjoner<br>Download & WFS:<br>https://kartkatalog.geonorge.no/metadata/saarbare-marine-biotoper--modellert-utbredelse/d2cf65bf-6d10-4bc8-a803-0e14349f575e | | x |
| Coral reefs | *Lopehlia pertusa / Desmophyllum pertusum* Live & dead reef, coral rubble | FGDB, GML, PostGIS, SOSI | Presence | Norwegian waters - mapped areas, EUREF89 - various 1x1 km | Continuously updated | Insitute of Marine Research, Geonorge / 06.01.2023<br>--> Korallrev<br>Download & WFS:<br>https://kartkatalog.geonorge.no/metadata/korallrev/31edb985-138e-46a7-a910-a0c1cd9baf4c<br><br>--> Artsmangfold - Videoobserverte korallbunntyper<br>Download & WMS:<br>https://kartkatalog.geonorge.no/metadata/artsmangfold-videoobserverte-korallbunntyper-wms/70d9c11e-4522-40e2-a5aa-f0b3484b1b8c | (x) | |

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| **Sensitive species & habitats & areas of ecological importance** | Data | | | | | | Analysis | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale: Spatial | Scale: Temporal | Location / download | Yes | No |
| **Cerianthide aggregations** | | | | | | | | |
| **Dead coral reef**<br>***Acesta excavata*** | | *Observation:* .shp | *Observation:* Presence / absence | | | *Marine Grunnkart*<br>Institute of Marine Research, Geonorge / 06.01.2023<br><br>*Observations:*<br>--> Naturtyper - Sårbare Marine habitater<br>WFS: https://kart.hi.no/mareano/magik/nin_hi-vme/ows?request=GetCapabilities&service=WFS | | |
| **Coral garden - hardbottom** | Observation | | | | | | | x |
| **Maerl bed** | | | | | Unknown | | | |
| **Eelgras and other seagrass meadows** | | | | Marine Grunnkart pilot areas | | | | |
| **Sponge garden - hardbottom** | Observation & predicted | | | | | | | |
| **Seapen community** | | *Predicted:* .geotiff | *Predicted: Estimated presence* | | | Predicted: (WMS did not work at time of access)<br>--> Naturtyper - Svamphage, prediktert<br>https://kart.hi.no/mareano/magik/svampehage_prediktert/ows?request=GetCapabilities&service=WFS<br>--> Naturtyper - Sjøfjærbunn, prediktert<br>https://kart.hi.no/mareano/magik/sjofjaerbunn_prediktert/ows?request=GetCapabilities&service=WFS<br>--> Naturtyper - Tarebiomasse, predikter<br>https://kart.hi.no/mareano/magik/tarebiomasse_predikert/ows?request=GetCapabilities&service=WFS | x | |
| **Kelp biomass** | Predicted | | | | | | | |

*Species, habitats and areas of conservation*

Here we focus on datasets that describe conservation measures for marine species and habitats. Naturally this will overlap in parts with datasets referred to in the earlier sections of 'Ecosystem components, areas of ecological importance and conservation', but will add another level of usage restrictions due to the specific conservation status in defined areas.

**Salmon** – The population of the Norwegian wild salmon *Salmon Salar* is classified as "Near threatened" on the Norwegian redlist and Norway is protecting areas important to the wild salmon's lifecycle. An overview of spatial extent of the nationally protected salmon fjords and watercourses is given in a dataset published by FDir.

**Red listed species** – A number of marine species are in decline and some are threatened to disappear from Norwegian waters. These species are added to the Norwegian red list where they are assigned to one of six categories, ranked by their risk of extinction. The categories are: Regionally Extinct (RE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Data Deficient (DD). Artsdatabanken provides a dataset which contains presence data for red listed species.

**Marine conservation areas** – Following the Norwegian national plan for marine conservation, 36 areas distributed along the Norwegian have been suggested as dedicated marine conservation areas. These areas are representative for habitats characteristic to Norwegian waters. The Norwegian Environmental Agency provides a dataset where these areas are summarized and classified as "implemented" and "planned".

**Conservation areas –** Conservation areas non-specific to the marine environment, but still overlapping and closely related to the coastal area can be accessed in a dataset provided by the Norwegian Environmental Agency. This dataset includes areas protected after different Norwegian nature conservation acts implemented in between 1910 and 2009.

**No fishing zone –**No fishing zones have been implemented to provide extra protection for areas known to host habitats of high ecological value or areas which are important to sensitive species and under anthropogenic pressure. The dataset with an overview of these zones along the Norwegian coast is provided by the Directorate of Fisheries.

*Table 4.23. Overview of species/habitats and areas of conservation, associated data sources, format and suitability for implementation into GIS analysis (Yes – data are provided in a format that allows post-processing / analysis; No – access to raw data is not given).*

| Species/habitats & areas of conservation | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Proxy | Format | Units | Scale | | Location / download | Analysis | |
| | | | | Spatial | Temporal | | Yes | No |
| **Salmon** | National salmon watercourse | .shp (point) | Presence | Norwegian waters EPSG:25833 (any preferance) | Continuously updated | Directory of Fisheries, 10.01.2023<br>--> "Nasjonale laksefjorder"<br>--> "Nasjonale laksevassdrag"<br>https://portal.fiskeridir.no/nedlasting | x | |
| | National salmon fjord | .shp (polygon) | | | | | | |
| **Redlisted species** | | FGDB, PostGIS | Presence | Norwegian waters EPSG:25833 (any preferance) Precision: 1km | Continuously updated, daily | Norwegian Biodiveristy Information Centre, Geonorge / 15.01.2023<br>--> Artskart rødlistearter WFS<br>Download and WFS:<br>https://kartkatalog.geonorge.no/metadata/artskart-roedlistearter-wfs/a9e500fb-c188-4601-81b4-072c36a60c8c | x | |
| **Marine conservation areas - implemented and planned** | | WMS | Presence | Norwegian waters | Status as of 2022 | Norwegian Environmental Agency, Geonorge; 15.01.2023<br>--> Marine Verneplan WMS<br>https://kart.miljodirektoratet.no/geoserver/marin_verneplan/wms?service=wms&request=getcapabilities | | x |
| **Conservation areas - implemented and planned** | | SOSI, FGDB, GeoJSON | Presence | Norwegian waters EPSG:25833 (any preferance) | Status 2021 | Norwegian Environmental Agency, 15.01.2023<br>--> Naturvernområder<br>--> Foreslåtte naturvernområder<br>https://karteksport.miljodirektoratet.no/ | x | |
| **Conservation areas - no fishing zone** | European lobster, Benthic habitats, Corals | .shp, SOSI, FGDB, GeoJSON etc | Presence | Norwegian waters EPSG:25833 (any preferance) | Status as of 2022 | Directory of Fisheries; 15.01.2023<br>Tema --> Hummer - fredningsområder<br>--> Korallrev - forbudsområdet<br>--> Verneområdet - bunnhabitat<br>https://portal.fiskeridir.no/portal/apps/webappviewer/index.html?id=bed4faeea84e4d6dbc548d43cc134c96&layer | x | |

### 4.3.3.2 Data availability, accessibility, coverage and resolution

A qualitative assessment of data coverage and resolution is being made to delineate the potential of developing a CIA model for Norwegian coastal waters and selected focus areas. The focus of the assessment is on the identified data describing basic processes in the coastal zone (section 'Baseline data'), industries and associated stressors (section 'Industries and associated stressors') and ecological components (section 'Ecosystem components, areas of ecological importance and conservation'). An overview of the assessment will be presented in tables, which show if data for the respective parameters are available (yes/no) and accessible (yes/no). Data coverage and resolution were then assessed and classified using three categories: "Good", "Moderate" and "Poor". Background information for the assignment of the categories will be given in the associated text. It has to be noted that the overall quality of the data and associated uncertainties are not assessed as part of this project. Both aspects should, however, be considered when finalising the data input for a CIA model.

**Norwegian coastal waters**

Data on the **physical environment** form an essential **baseline** for the characterisation of coastal waters. With exception of oxygen, spatially resolved datasets were identified for all key parameters (Table 4.24). Information on bathymetry and seabed/substrate is thereby based on high-resolution multibeam sonar data, which are collected by the Norwegian Mapping Authority. Data with a resolution of ≥50 m are freely accessible, whilst data with a higher resolution are classified (Norwegian Armed Forces) within territorial boundaries and require an application for access. Nonetheless, for the areas where these data have been collected, the resolution is excellent. The coverage of coastal waters, however, is still limited and thus was classified as moderate. Associated substrate maps require groundtruthing and classification and are more demanding in data input and post-processing effort. Compared to the extent of the bathymetry data, the spatial coverage of highly resolved substrate maps is to date poor. Modelled data on hydrodynamics, waves and temperature are available for the whole coastline and coverage is good. Whilst data in some coastal areas are available at a resolution of 150x150m, the majority of coastal waters is resolved by the standard resolution of 800x800 m. The latter won't be able to resolve small scale processes very well and resolution has thus been classified as moderate. Satellite images of ocean colour as provided by Copernicus, were the only source found for turbidity data. The total extent of the associated data could not be viewed, but they should cover the Norwegian coastal zone at a good resolution of 100x100m. The latter would, however, be confirmed when downloading and processing the data. The data will also only cover surface waters. Based on the uncertainty and the limitation to surface waters, coverage and resolution were set to be moderate.

*Table 4.24. Assessment of baseline data input (physical environment) for Norwegian coastal waters.*

| Baseline- physical environment | Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Accessible | | Coverage | | | Resolution | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Bathymetry | (green) | | (green) | | | (yellow) | | (green) | | |
| Seabed / substrate | (green) | | (green) | | | | (red) | (green) | | |
| Hydrodynamics | (green) | | (green) | | (green) | | | | (yellow) | |
| Waves | (green) | | (green) | | (green) | | | | (yellow) | |
| Temperature | (green) | | (green) | | (green) | | | | (yellow) | |
| Salinity | (green) | | (green) | | (green) | | | | (yellow) | |
| Oxygen | | (red) | | | | | | | | |
| Turbidity | (green) | | (green) | | | (yellow) | | | (yellow) | |

Key **industries** are generally well covered and resolved along the Norwegian coastline and thus will not be further assessed for the small scaled focus areas. Pressure sources are thus well mapped on large and small spatial scales (Table 4.25). Data describing **stressors**, however, are in general spatially poorly resolved with a moderate or poor coverage (Table 4.26). The only exception forms escape, for which data are systematically collected following escape events as well as through standardized monitoring. Here coverage and resolution were classified as good for the spatial scale required. Information on contaminant levels is solely based on monitoring data, i.e. in-situ sampling at stations. The coverage is related to national monitoring programs as well as industry specific monitoring. Stations are placed along the Norwegian coast, but the station network is too coarse to allow for spatial interpolation on a national scale. Resolution has thus been classified as poor. Monitoring of delicing agents is not part of standard monitoring programs and data are not publicly available. Data on plastic and invasive species are available, but coverage and resolution is poor. Here a lack of systematic monitoring is evident Turbidity can be a proxy for particles. As explained in the previous section, these data are limited to the surface area. In the context of stressors, the resolution is thus seen as poor. Increased particles levels in deeper waters, as typically released from dredging, mining etc., cannot be assessed with this dataset. Turbidity data collected for the water column as part of monitoring are too sparse to be spatially interpolated. Output of dissolved nutrients is modelled by the TEOTIL model for each catchment area along the Norwegian coast. The coverage is thus good. The resolution, however, is only set to moderate as nutrient outputs will have to be assigned a large catchment area, losing any information on potential gradients. Data on light and noise pollution are not existent.

*Table 4.25. Assessment of data base for key industries.*

| **Industry** | **Data** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Accessible** | | **Coverage** | | | **Resolution** | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Aquaculture | | | | | | | | | | |
| Fisheries | | | | | | | | | | |
| Kelp dredging | | | | | | | | | | |
| Shipping | | | | | | | | | | |
| Landbased industries | | | | | | | | | | |
| Sewage | | | | | | | | | | |
| Hydropower | | | | | | | | | | |
| Agriculture | | | | | | | | | | |

Data on coverage and resolution of **ecosystem components** is overall moderate to poor (Table 4.27). An exception is formed by seabird data, where two extensive research programs provide well resolved spatial data on populations, nesting sites and movement. In addition, information on marine conservation areas is well resolved as these are set and identified by regulators. The latter will thus not be further addressed for the small scaled focus areas. The suitability of the remaining data for CIA models is limited. Spatial data on marine mammals is based on either oceanic subareas (based on large scale migratory patterns) or very broad regional scales in coastal waters, where some of these species are permanently or temporarily resident. This provides limited information to a CIA model. Proxy data for fish are linked to areas of high ecological importance to commercial fish species, i.e. spawning areas, nursery and feeding areas. Although these data don't provide information on general spatial distribution, they are a sensible input to a CIA model. Nonetheless, coverage and resolution are broad. The input has sometimes also not been validated by experts and thus these data have been classed as moderate. Information on plankton is very limited. Data on zooplankton could not be found. For chlorophyll a (proxy for phytoplankton) only modelled data with a limited coverage in coastal waters and a very coarse and thus poor resolution are available.

*Table 4.26. Assessment of data describing stressors along in Norwegian coastal waters.*

| Pressure | Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Accessible | | Coverage | | | Resolution | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Heavy metals and other inorganic elements | | | | | | | | | | |
| Organic contaminants | | | | | | | | | | |
| Environmental contaminants | | | | | | | | | | |
| Delicing agents | | | | | | | | | | |
| Plastic | | | | | | | | | | |
| Dissolved nutrients | | | | | | | | | | |
| Noise | | | | | | | | | | |
| Light | | | | | | | | | | |
| Invasive species | | | | | | | | | | |
| Escape | | | | | | | | | | |
| Particles (see turbidity) | | | | | | | | | | |

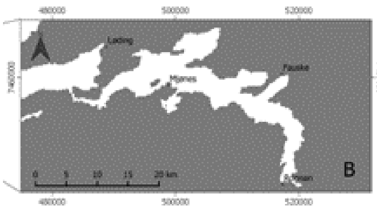
The coverage of benthic biotopes is generally poor. Reasons for this are varied and described in more detail in the discussion (systematic mapping, NiN). Crustacea are thought to be in particular sensitive to delicing. Distribution data for the commercially highly valued Northern shrimp and the protected European lobster, however, are moderate as given at a very large scale and without detail on population hotspots (poor resolution). Shrimp fishing areas as well as "no fishing zones" established for the conservation of the European lobster could be used as substitute of highly important presence areas but are certainly not a reflection on general population distribution along the Norwegian coast.

Sensitive species and habitats are typically characterized by being of high ecological importance and very sensitive towards anthropogenic stressors. Conservation measures are high and gaining an insight on their spatial distribution is essential for sustainable management. Considerable efforts have been put into the development of predicted habitat models for shallow water sensitive habitats along the Norwegian coast. Coverage and resolution are still categorized as moderate as these data have not yet been completely validated. They provide, however, a good assessment base. Maerl beds were not included in the model effort and here we are lacking general information on presence. Very little is also known about the spatial distribution of deep-water sensitive species/habitats, i.e sponges, corals and seapens. Surveying deep-water species and associated habitats is challenging and costly as they are often located at greater depth, along complex bathymetry and in some cases also exposed, energetic locations. Although the mapping survey effort has gradually increased over the past years due to expanding industries in coastal waters, the overall spatial extent of these species is largely unknown and restricted to some presence records. The limited understanding of their ecology, i.e. what drives their presence, also prohibits the development of good predicted habitat models.

*Table 4.27. Assessment of data describing relevant ecosystem components for Norwegian coastal waters.*

| **Ecosystem components** | **Data** Yes | No | **Accessible** Yes | No | **Coverage** Good | Moderate | Poor | **Resolution** Good | Moderate | Poor |
|---|---|---|---|---|---|---|---|---|---|---|
| Seabirds | green | | green | | green | | | green | | |
| Marine mammals | green | | green | | | | red | | | red |
| Fish | green | | green | | | yellow | | | yellow | |
| Plankton | | | | | | | | | | |
| Phytoplankton | green | | green | | | yellow | | | | red |
| Zooplankton | | red | | | | | | | | |
| Benthic biotopes | green | | green | | | | red | | yellow | |
| Crustacea | | | | | | | | | | |
| European lobster | green | | green | | | yellow | | | | red |
| Northern Shrimp | green | | green | | | yellow | | | | red |
| **Sensitive species & habitats, areas of ecological importance** | **Data** Yes | No | **Accessible** Yes | No | **Coverage** Good | Moderate | Poor | **Resolution** Good | Moderate | Poor |
| Deep water | | | | | | | | | | |
| Coral species & habitats | green | | green | | | | red | | | red |
| Sponge species & habitats | green | | green | | | | red | | | red |
| Seapen habitats | green | | green | | | | red | | | red |
| Shallow water | | | | | | | | | | |
| Large kelp forests | green | | green | | | yellow | | | yellow | |
| Ice marginal deposits | green | | green | | | yellow | | | yellow | |
| Soft sediments in the littoral zone | green | | green | | | yellow | | | yellow | |
| Eelgrass and other seagrass meadows | green | | green | | | yellow | | | yellow | |
| Shellsand | green | | green | | | yellow | | | yellow | |
| Øyster areas | green | | green | | | yellow | | | yellow | |
| Large scallop occurences | green | | green | | | yellow | | | yellow | |
| Maerl beds | green | | green | | | | red | | | red |
| **Species/habitats & areas of conservation** | | | | | | | | | | |
| Salmon | green | | green | | green | | | green | | |
| Redlisted species | green | | green | | | yellow | | | yellow | |
| Marine conservation areas - implemented and planned | green | | green | | green | | | green | | |
| Conservation areas - implemented and planned | green | | green | | green | | | green | | |
| Conservation areas - no fishing zone | green | | green | | green | | | green | | |

## Skjerstadfjorden, inner Saltfjorden and associated waterbodies



Skjerstadfjorden is located in Nordland County within the municipalities of Fauske and Bodø. It is a sill fjord with water exchange to the outer coast only via two straits – Godøystraumen and the renowned tidal strait of Saltstraumen. Skjerstadfjorden is highlighted as fjord with infrequent bottom water exchange, making it more vulnerable to anthropogenic pressure. It is boardered to the East and West by Saltfjorden and thus forms to some extent the middle part of this fjord. Here we only focus on Skjerstadfjorden, the inner part of Saltfjorden and the adjacent waterbodies: Valnesfjorden, Klungsetvika and Fauskevika to the North and Misværfjorden to the South.

*Table 4.28. Assessment of baseline data (physical environment) available for Skjerstadfjorden, inner Saltfjorden and associated waterbodies.*

| Baseline- physical environment | Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Accessible | | Coverage | | | Resolution | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Bathymetry | | | | | | | | | | |
| Seabed / substrate | | | | | | | | | | |
| Hydrodynamics | | | | | | | | | | |
| Waves | | | | | | | | | | |
| Temperature | | | | | | | | | | |
| Salinity | | | | | | | | | | |
| Oxygen | | | | | | | | | | |
| Turbidity | | | | | | | | | | |

A summary of the assessment of the **baseline data** (physical environment) is given in Table 4.28. The coverage and resolution of bathymetry data for this area is rated as overall good. There is a lack of data for the shallower water areas, i.e. parts of Valnesfjorden and Klungsetvika. Data for Misværfjorden are also lacking. Overall, however, the main parts of the fjord system are well covered with a good resolution. Seabed classification data, i.e. substrate type, is not available for this area. Modelled data on hydrodynamics, waves, temperature and salinity exist, resolution is however seen to be moderate considering that the data are based on the 800x800 m NordKyst model. Data on oxygen and turbidity are available for a few stations related to the monitoring of the aquaculture production and the national monitoring program Økokyst. The station network for these parameters is, however, seen to be insufficient for interpolation and thus resolution is classed as poor. Turbidity data from Copernicus could be available, but this would have to be explored further.

*Table 4.29. Assessment of data describing anthropogenic stressors for Skjerstadfjorden, inner Saltfjorden and associated waterbodies.*

| Stressor | Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Accessible | | Coverage | | | Resolution | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Heavy metals and other inorganic elements | | | | | | | | | | |
| Organic contaminants | | | | | | | | | | |
| Environmental contaminants | | | | | | | | | | |
| Delicing agents | | | | | | | | | | |
| Plastic | | | | | | | | | | |
| Dissolved nutrients | | | | | | | | | | |
| Noise | | | | | | | | | | |
| Light | | | | | | | | | | |
| Invasive species | | | | | | | | | | |
| Escape | | | | | | | | | | |
| Particles (turbidity) | | | | | | | | | | |

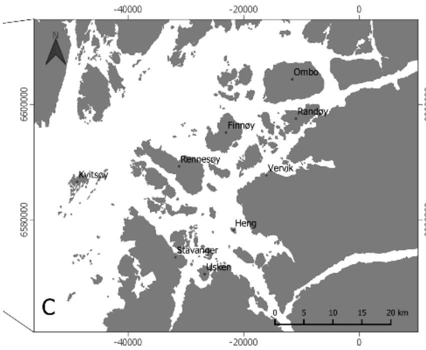
**Industries** and thus the sources of stressors reflect the same detail seen on national level, i.e. they are well mapped. The area hosts today six fish farms producing Atlantic salmon in open net pans, two landbased hatcheries and one macroalgae farm. There has been a long history of aquaculture production in this area with several closed locations being widely spread along its shores. Other anthropogenic stressors include shipping, fisheries, wastewater discharge from spread settlements, towns and villages in the area as well as landbased industries including mining in one of the associated catchment areas, a shipyard, agriculture and hydropower. The data availability for associated **stressors** reflects the national level (see section 'Norwegian coastal waters') (Table 4.29). The resolution for contaminants, however, has been rated as moderate based on the denser station network and smaller spatial scale. Interpolation will still be challenging, but pressure related information along gradients and at reference stations could be interpolated on site level and integrated. Data on plastic pollution were not available for this area.

*Table 4.30. Assessment of data describing relevant ecosystem components for Skjerstadfjorden, inner Saltfjorden and associated waterbodies.*

| Ecosystem components | Data | | Accessible | | Coverage | | | Resolution | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Seabirds | [green] | | [green] | | [green] | | | [green] | | |
| Marine mammals | [green] | | [green] | | | | [red] | | | [red] |
| Fish | [green] | | [green] | | [green] | | | [green] | | |
| Plankton | | | | | | | | | | |
| Phytoplankton | [green] | | [green] | | | [yellow] | | | | [red] |
| Zooplankton | | [red] | | | | | | | | |
| Benthic biotopes | [green] | | [green] | | | | [red] | | | [red] |
| Crustacea | | | | | | | | | | |
| European lobster | [green] | | [green] | | | | [red] | | | [red] |
| Northern Shrimp | [green] | | [green] | | | [yellow] | | | [yellow] | |
| **Sensitive species & habitats, areas of ecological importance** | **Data** | | **Accessible** | | **Coverage** | | | **Resolution** | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Deep water | | | | | | | | | | |
| Coral species & habitats | | [red] | | | | | | | | |
| Sponge species & habitats | | [red] | | | | | | | | |
| Seapen habitats | | [red] | | | | | | | | |
| Shallow water | | | | | | | | | | |
| Large kelp forests | [green] | | [green] | | | [yellow] | | | [yellow] | |
| Ice marginal deposits | [green] | | [green] | | | [yellow] | | | [yellow] | |
| Soft sediments in the littoral zone | [green] | | [green] | | [green] | | | [green] | | |
| Eelgrass and other seagrass meadows | [green] | | [green] | | [green] | | | [green] | | |
| Naturally low oxygen | [green] | | [green] | | [green] | | | [green] | | |
| Shellsand | [green] | | [green] | | | [yellow] | | | [yellow] | |
| Øyster areas | [green] | | [green] | | | [yellow] | | | [yellow] | |
| Large scallop occurences | [green] | | [green] | | | [yellow] | | | [yellow] | |
| Maerl beds | | [red] | | | | | | | | |

Also, the data on **ecosystem components** largely reflect those on national level (see section 'Norwegian coastal waters') (Table 4.30). The exceptions will be outlined in more detail in the following. The coverage of fish was seen as good with a good resolution. Skjerstadfjorden, inner Saltfjorden and associated waterbodies accommodates regionally and locally important spawning grounds for coastal cod, which extent have been defined and validated by IMR. Accordingly, coverage and resolution were classed as good. Information on "general" benthic biotopes are completely lacking. Also, information on the presence or absence of European lobster is not available, whilst the broad scale national maps indicate this region to be still within the population range. Commonly used areas for shrimp fisheries are highlighted and could be used as proxy for population presence. Coverage and resolution were thus set to moderate. Records on presence or absence of deep-water sensitive species and the calcareous shallow water red algae maerl are not available for this region. Three sensitive shallow water habitats (1. Soft sediments in the littoral zone, 2. Eelgrass and other seagrass meadows, 3. Naturally low oxygen) have been identified by observation. Coverage and resolution are thus seen as good.

### Fjordsystems north of Stavanger (Marine Grunnkart pilot area)




The fjordsystems north of Stavanger have been one of the focus areas of the pilot mapping program "Marine Grunnkart". The pilot area is defined by the boundaries of Stavanger municipality, which stretches from the city of Stavanger in the south over an array of island northwards. It covers a range of fjords and sounds. Due to the restriction to regulative boundaries some of the ecosystems are only partly covered, an approach that is not advisable for an ecosystem applied management approach, but certainly acceptable within the framework of a pilot mapping project.

The area is densely populated (wastewater) and hosts a varied range of industries, including the traditional marine industries (aquaculture, shipping, fisheries) and landbased industries such as chemistry industry, food processing industry, shipyards, agriculture, hydropower and oil & gas supply industry. Also, in this case the industries are well mapped.

The Marine Grunnkart project provides spatially resolved high resolution data for all mapping relevant input parameters. Baseline data of the physical environment are generally provided with a good coverage and resolution (Table 4.31). Bathymetry data and substrate maps are available for the complete extent of the survey area. Modelled data for hydrodynamics, waves, temperature and salinity are available at a resolution of 150x150m. Data on oxygen values, however, could not be found and turbidity is poorly resolved.

*Table 4.31. Assessment of baseline data (physical environment) available for the Marine Grunnkart pilot area located in the municipality of Stavanger.*

| Baseline- physical environment | Data | | Accessible | | Coverage | | | Resolution | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Bathymetry | [green] | | [green] | | [green] | | | [green] | | |
| Seabed / substrate | [green] | | [green] | | [green] | | | [green] | | |
| Hydrodynamics | [green] | | [green] | | [green] | | | [green] | | |
| Waves | [green] | | [green] | | [green] | | | [green] | | |
| Temperature | [green] | | [green] | | [green] | | | [green] | | |
| Salinity | [green] | | [green] | | [green] | | | [green] | | |
| Oxygen | | [red] | | | | | | | | |
| Turbidity | [green] | | [green] | | | [yellow] | | | | [red] |

A dense station network resolves the extent of the survey area and guarantees for a good coverage suitable for interpolation or predicted habitat modelling approaches. The station network is complemented by standard monitoring undertaken for the respective industries in the area. Sampling covers a wide range of contaminants, benthic infauna as well as video surveys to identify presence of sensitive species and habitats (Table 4.32,

Table 4.33). Based on the collected biological data, predicted habitat models were set up to provide a spatial coverage for benthic habitats (after NiN) as well as shallow and deep water sensitive species/habitats. All of these components are thus marked as good coverage and resolution. The only data missing is information on delicing agents, noise and light as well as zooplankton. Also an improved coverage and resolution of invasive species, marine mammals, phytoplankton and crustacea is not available from the Marin Grunnkart project. This reflects the national level. Overall, however, it is obvious that the systematic mapping effort undertaken in this project provides valuable data for a CIA model.

*Table 4.32. Assessment of data describing anthropogenic stressors for the Marine Grunnkart pilot area located in the municipality of Stavanger.*

| **Pressure** | **Data** | | **Accessible** | | **Coverage** | | | **Resolution** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Heavy metals and other inorganic elements | green | | green | | green | | | green | | |
| Organic contaminants | green | | green | | green | | | green | | |
| Environmental contaminants | green | | green | | green | | | green | | |
| Delicing agents | | red | | | | | | | | |
| Plastic | green | | green | | green | | | green | | |
| Dissolved nutrients | green | | green | | green | | | green | | |
| Noise | | red | | | | | | | | |
| Light | | red | | | | | | | | |
| Invasive species | green | | green | | | | red | | | red |
| Escape | green | | green | | green | | | green | | |
| Particles (turbidity) | green | | green | | | yellow | | | | red |

*Table 4.33. Assessment of data describing ecosystem components for the Marine Grunnkart pilot area located in the municipality of Stavanger.*

| **Ecosystem components** | **Data** | | **Accessible** | | **Coverage** | | | **Resolution** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Seabirds | green | | green | | green | | | green | | |
| Marine mammals | green | | green | | | | red | | | red |
| Fish | green | | green | | green | | | green | | |
| Plankton | | | | | | | | | | |
| Phytoplankton | green | | green | | | yellow | | | | red |
| Zooplankton | | red | | | | | | | | |
| Benthic biotopes | green | | green | | green | | | green | | |
| Crustacea | | | | | | | | | | |
| European lobster | green | | green | | | yellow | | | | red |
| Northern Shrimp | green | | green | | | yellow | | | | red |
| **Sensitive species & habitats, areas of ecological importance** | **Data** | | **Accessible** | | **Coverage** | | | **Resolution** | | |
| | Yes | No | Yes | No | Good | Moderate | Poor | Good | Moderate | Poor |
| Deep water | | | | | | | | | | |
| Coral species & habitats | green | | green | | green | | | green | | |
| Sponge species & habitats | green | | green | | green | | | green | | |
| Seapen habitats | green | | green | | green | | | green | | |
| Shallow water | | | | | | | | | | |
| Large kelp forests | green | | green | | green | | | green | | |
| Ice marginal deposits | green | | green | | green | | | green | | |
| Soft sediments in the littoral zone | green | | green | | green | | | green | | |
| Eelgrass and other seagrass meadows | green | | green | | green | | | green | | |
| Shellsand | green | | green | | green | | | green | | |
| Øyster areas | green | | green | | green | | | green | | |
| Large scallop occurences | green | | green | | green | | | green | | |
| Maerl beds | green | | green | | green | | | green | | |

### 4.3.4 Discussion and conclusions

**Key findings**

- Finding suitable CIA input data was challenging and raw data, essential for analytical analysis, were often not available. There is a need for a more systematic online database, which also provides direct access to raw data.
- Coverage and resolution of identified data is predominantly moderate or poor. This applies to national, but also local scales.
- The scope for the development of CIA models for the Norwegian coastline or more localised focus areas with the currently available database is limited or implementation is not feasible.
- The systematic mapping effort undertaken in the pilot project of Marine Grunnkart provides valuable data for a CIA model. Marine Grunnkart pilot areas would provide a good test area for the development of a CIA model on a small, local spatial scale.
- A classification system for pelagic and benthic habitats is essential to standardize CIA input. The marine section of the Norwegian classification system NiN (Natur i Norge) is to date rudimentary, but should evolve together with increasing mapping efforts.

The development of quantitative CIA models requires a substantial amount of input data, which can describe the physical environment, industries and stressors and relevant ecosystem components. The spatial coverage and resolution of these data have to be suited to the area and impact of interest and related raw data have to be publicly available.

As part of this study, we firstly aimed to gain an overview of availability of data suitable for the development of a CIA model for Norwegian coastal waters and smaller scaled areas (fjord, sound systems). It proofed to be challenging to locate relevant data and access to raw data was often not given via public websites. In Norway a range of different governmental departments and institutions as well as the private sector collect data and display these in thematic, GIS based map solutions, which the user can access via a website and visually adapt after their needs. Whilst these simplified, semi-interactive map solutions provide an informative, thematic visual tool, they can't be used for analytical approaches. GeoNorge's Kartkatalogen provides a platform that collates all publicly available geographic data from different stakeholders. It offers a good starting point for the search of data, but also here the level of background information for each dataset was highly variable, raw data were often not available and not all data shown in interactive mapping tools were linked to GeoNorge. The data presented in this document are thus a compilation from a wide range of sources, but provide a good input for the assessment of CIA model feasibility. There is certainly a need in Norway for a more systematic online database, which also provides access to raw data as a basic requirement.

Data were found for most key input parameters. Their coverage and resolution are, however, often moderate or poor and thus their application in the development of CIA models for Norwegian coastal waters or smaller spatial scales is limited or not suitable (see section 'Norwegian coastal waters' and 'Skjerstadfjorden, inner Saltfjorden and associated waterbodies'). The only well resolved input parameter was presence of industries. The general lack of suitable data is a known challenge for CIA modelling (Kirkfeldt & Andersen, 2021). The collection of abiotic and biotic data in the marine environment is time consuming and costly. In Norway an extensive mapping program for Norwegian offshore areas (MAREANO) has been initiated in 2005/2006. Since MAREANO's kick-off the program has covered vast offshore areas, contributed to a better understanding of the associated ecosystems and thus led to improved management of environmental resources and human activities in these areas. An equivalent mapping program for

Norwegian coastal waters is to-date not in place but will hopefully be established soon. A pilot project for the mapping of coastal waters (Marine Grunnkart) has been initiated in 2020 and three trial areas were successfully covered. The Marine Grunnkart pilot project collected baseline data relevant to the physical environment, biotic data with the main focus on benthic habitats and data on a selected range of anthropogenic stressors. Numerical models were used in addition to simulate physical processes and to predict distribution of benthic habitats within the focus areas. Although the Marine Grunnkart projects has not covered some stressors (delicing agents, noise, light, turbidity) and is lacking the pelagic compartment, it contributes substantially to the formation of a solid base for CIA models and consequently also for an ecosystem-based management approach (see section ' Fjordsystems north of Stavanger (Marine Grunnkart pilot area)'). Marine Grunnkart pilot areas would provide a good test area for the development of a CIA model on a small, local spatial scale.

In order to standardize mapping outputs and thus CIA model inputs an appropriate classification system is required. The Norwegian classification system NiN (Natur i Norge) has been initially development for terrestrial habitats and its marine section is still in it's infancy with a substantial revision expected at the end of 2023 (NiN 3.0). NiN uses existent biotic and abiotic datasets, applies multivariate statistics to identify main driver of change and then divides the respective habitats into appropriate sub-categories. Anthropogenic stressors can be added as extra variable to the final habitat code. The poor data coverage for the marine environment also provides challenges for the development of the NiN classification for pelagic and benthic habitats. Mapping efforts and classification system will benefit from each other and should grow together.

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## 4.4 Summary and research needs

The United Nations Sustainable Development Goal 14 (UN SDG 14), Life Below Water, was formulated with the objective to “Conserve and sustainably use the oceans, seas and marine resources for sustainable development” (UN, 2015). One way to increase the chances of reaching this objective is through marine spatial planning, which globally has been recognized as a way to foster sustainable use of marine ecosystems and to promote ocean conservation. Guidelines and regulations emphasize that MSP should be driven by ecosystem-based management and this is also a goal for Norwegian marine spatial planning (see next chapter 5.3.1). Ecosystem based management aims to achieve good ecosystem health and supports sustainable use of marine resources by balancing ecological, social and governance objectives at appropriate temporal and spatial scales. An understanding of ecosystem function as well as interaction of ecosystem components and anthropogenic activity is one of the essential foundations for the successful application of EBM. Assignment of associated ecological risk is an additional element required as it will allow for implementation of suitable mitigation measures.

In this part of the study we aimed therefore to provide an overview on industries co-existing and operating in coastal waters, their associated stressors, potential environmental impacts and an assessment of potential risks towards aquaculture production. In addition, a case study was used to assess the feasibility of the development of cumulative impact assessment models based on an advanced quantitative GIS solution. The spatially resolved output is thought to be a suitable and supportive decision-making tool for ecosystem based management.

The literature review showed that information on industries (land & sea-based) operating in the same areas as aquaculture was good and accessible. The type of anthropogenic activities varied geographically with land-based industries dominating in the south of Norway, whilst sea-based activities such as fisheries have their holdfast in the north of Norway. Stressors related to the identified key industries overlapped with the pressure categories identified in chapter 3 for the aquaculture industry. Data on the overall contribution of emissions from key industries to the marine environment was, however, limited or lacking. The available data, however, show that the aquaculture industry represents the largest anthropogenic contributor of nutrients, pesticides, and copper to coastal waters in areas of operation. Information on spatial and temporal scale of stressors and related impacts was also limited. Literature investigating cumulative impacts from aquaculture and other identified key industries could not be found as part of this literature assessment. Multi-pressure studies are complex and challenging to conduct, which clearly is reflected in this output.

The limited information on contribution, scale and impact (individual and cumulative) of stressors related to the key industries made it challenging to evaluate the risk of other industry activity on aquaculture production. Risk evaluations had to be based on subjective expert judgement of the available information and/or expert assumptions where information was lacking. Plastic (nano plastics) was identified to pose a possible risk to fish health and thus human consumption. There is, however, a need for more knowledge on this subject. When assessing risk to the environment, it became clear that stressors from all key industries could to some extent overlap with each other. In addition, many industries are source of not just one, but several stressors which can interact and create multi-pressure environmental impacts. This highlights the complexity of multi-pressure studies. There is a need to gain a better understanding of the contribution from each industry to total emissions of relevant stressors and to consider their many possible permutations as well as their additive and interactive effects. Resolving cumulative effects of ocean stressors is critical to project their impact and risks to the marine environment and to the industries themselves. Overall, it is anticipated that in the future the aquaculture sector may be increasingly impacted by sources of pollution from other anthropogenic activities, e.g. agricultural, industrial and domestic effluents (foremost if cages will be installed close to point source outlets). Climate change and ocean acidification, however, are expected to affect the aquaculture industry more adversely.

The case study showed that finding suitable input data for a cumulative impact assessment was challenging, and raw data, essential for a quantitative analysis, were often not available. There is a need for a database, which collates CIA relevant data from various sources (governmental, institutional, research etc.) and provides direct open access to raw data. GeoNorge (geonorge.no) already contains a wide spectrum of data and thus could be used as a base to further expand upon. Furthermore, the coverage and resolution of identified data was predominantly moderate or poor. This applies to national, but also local scales. Therefore, the scope for the development of CIA models for the Norwegian coastline or focus areas with a smaller spatial scale is limited or implementation is not feasible. The systematic mapping effort undertaken in the pilot project of Marine Grunnkart, however, provides valuable data for developing a CIA model. Establishing a systematic, large-scale mapping program for coastal water would support the implementation of MSP and EBM. Furthermore, a classification system for pelagic and benthic habitats is essential and needed to standardize CIA input. The marine section of the Norwegian classification system NiN (Natur i Norge) is to date rudimentary but should evolve together with increasing mapping efforts.

The literature review has revealed knowledge gaps regarding understanding, projecting, and assessing cumulative environmental impacts and risks on the marine environment as well as other anthropogenic activities co-occupying coastal space. Input data for the development of quantitative cumulative impact assessment models are poor or lacking, leaving managers and decisions makers with limited options on suitable spatially resolved management tools. Whilst a number of research projects with a focus on multi-pressure assessment have been recently initiated in Norway, more knowledge is clearly needed. Research efforts should focus on:

1) Quantify contributions of key industry activity and improve tools for tracing of emissions. Continue to develop suitable in-situ monitoring technology and modelling approaches (dispersion models).
2) Gain more understanding of interactions of multistress from key industries and their cumulative impact on ecosystem components across a wide range of environmental conditions including current and future climate scenarios. Both multi-pressure interactions and the resulting impact on ecosystem components have the potential to be additive, synergistic or antagonistic. Identifying the correct mode of effect is essential for

suitable management. Ideally controlled laboratory experiments should be combined with validating in-situ field studies.

3) Quantify sensitivity and susceptibility of the receiving ecosystem component towards the impact of multistress (threshold values) and identify suitable indicators for ecosystem health in areas exposed to multistress. Both are critical for management as they allow to take action and apply mitigation measures when nearing unacceptable conditions.
4) Improve our understanding of the spatial distribution of physical drivers and relevant ecosystem components (receivers to stressors) through mapping efforts, as already started by the pilot project Marine Grunnkart. Data collected by coastal mapping projects should in addition be used to: a) further evolve the NiN classification system for pelagic and benthic habitats as it is essential to standardize CIA input. b) create knowledge to improve predicted habitat models, which can provide a cost-efficient alternative to large scale biological in-situ mapping.
5) Develop CIA models for different spatial scales and explore their suitability within the Norwegian planning framework, to achieve high usefulness for planning and management of relevant industries and stressors. This implies that the models should be co-developed by researchers and authorities involved in planning and management.
6) Identify, improve and/or develop solutions to mitigate the effects of multiple stressors, and find solutions to identify and recommend which individual sources (drivers/human activities) for individual stressors that should be reduced or eliminated to most efficiently and effectively limit the effects of multiple stressors.

# PART 2: Forvaltningsregimer og muligheter for mer presis regulering av akvakultur (*Kapittel 5* and *6*).

Kapittel 5 Forvaltning av miljøpåvirkning.

Kapittel 6 Utforsking av mulighetsrommet for mer presis regulering av miljøpåvirkning.

# 5 Forvaltning av miljøpåvirkning

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## Sammendrag

Hovedformålet med dette kapitlet har vært å se på hvilket kunnskapsgrunnlag og hvilke vurderinger som gjøres i viktige regimer for forvaltning av miljøpåvirkning i kystsonen. Analysen er sentrert om forvaltningen av miljøpåvirkning fra akvakultur i akvakulturforvaltningen, og hvordan miljøpåvirkning fra akvakultur er håndtert sammen med andre typer lignende miljøpåvirkning i forvaltningsregimer hvor disse skal vurderes samlet. Dette siste er gjort for kystsoneplanlegging og vannforvaltning.

Kapitlet gir også en oversikt over forvaltning av miljøet i kystsonen og sammenhengen mellom de ulike forvaltningsregimene. For de forvaltningsregimene vi særlig ser på presenterer det regelverket som gjelder for miljøforvaltning, basert på lover og forskrifter. Retningslinjer og veiledere for hvordan saksbehandling og vurderinger skal gjøres er også gjennomgått, med vekt på å få fram kunnskapsgrunnlag og vurderingsmetoder.

Vi har samlet eksempler på saker og planer og gjennomgått disse for å se på hvordan dette gjøres i praksis, og også gjort intervjuer og på andre måter fått innspill og utdypinger om dette.

Forvaltningen av miljøeffekter i kystsonen fra ulike typer påvirkninger er kompleks og omfattende og inkluderer mange forvaltningsregimer og -aktører. Det er ingen stressorer som bare er vurdert i ett regime eller bare av én forvaltningsmyndighet. Dette er naturlig gitt oppbyggingen av det norske forvaltningssystemet for kysten, hvor ulike sektormyndigheter og myndigheter på ulikt administrativt og demokratisk nivå er involvert.

For alle forvaltningsregimene finner vi at det er et bredt kunnskapsgrunnlag for vurderinger og beslutninger. I **akvakulturforvaltningen** pekes det allikevel på manglende kunnskapsgrunnlag om miljøeffekten av løste næringssalter, om partikulært organisk utslipp på hardbunn, om sårbare arter og habitater, om mulig effekt fra akvakultur på marin fisk, og miljørisiko fra torskeoppdrett. For vurderinger som gjøres er det en betydelig grad av skjønn som legges til grunn. Det er en del bruk av standardiserte indikatorer for å vurdere tilstand på resipienter eller mulig påvirkning fra akvakultur, men dette er begrenset.

I kommunal **kystsoneplanlegging** legges det juridiske føringer for arealbruken i kystsonen, som igjen kan ha stor betydning for miljøpåvirkning og miljøtilstand. De juridiske føringene inkluderer at akvakulturlokaliteter skal plasseres i arealer satt av til akvakultur i kommunenes arealplaner. Det er særlig i konsekvensutredning av alternative arealdisponeringer at systematisk innsamling av kunnskap og vurdering av miljøeffekter av akvakultur kommer inn. For den planen vi særlig studerte, som vi vurderer som blant beste praksis i Norge, kom det én innsigelse på grunn av manglende kunnskapsgrunnlag - om effektene av taredyrking. For vurderinger i konsekvensutredningen inngår det en rekke kvantitative kriterier eller ordinale kvalitative kriterier, men også skjønnsmessige kriterier. Det varierer hvor klart de skjønnsmessige vurderingene er beskrevet i konsekvensutredningen for hvert foreslått akvakulturområde. Det skal også gjøres samlet og helhetlig vurdering av alle forslagene i en kystsoneplan. Det inkluderer å se på virkninger for vannmiljø (inkludert vurdering etter vannforskriftens §12), samt å vurdere samlet risiko. Vi finner at gjennomgangene har grundige beskrivelser av både status, risikofaktorer og

vurderinger. Siden det er brukt skjønn i de fleste tilfeller, og det er krevende å beskrive utfyllende, kan det allikevel være vanskelig å fullt ut få grep om avveininger eller hva som gjør at det vurderes som forsvarlig i ett tilfelle og ikke i et annet.

**Vannforvaltningen** skal klassifisere miljøtilstand for vannforekomster og lage vannforvaltningsplaner hvor det settes miljømål som skal nås i planperioden, identifisere aktuelle tiltak for å forbedre eller forhindre forverring av miljøtilstanden, og sørge for overvåkning. Prioritering og gjennomføring av tiltak er imidlertid opp til ulike sektormyndigheter innenfor sine ansvarsområder, og ikke noe som kan bestemmes i vannforvaltningen. For vurdering av **miljøtilstand** er det klart definerte mål og vurderingskriterier, og det er etablerte overvåkningsprogram knyttet til dette. For å identifisere eksisterende og mulige **påvirkninger** gis det klar veiledning, og databaser, andre informasjonskilder og metoder for å gjøre dette er tilgjengelig. De største utfordringene er knyttet til å **vurdere** påvirkninger sine effekter på miljøtilstand. I stedet vises det generelt til sektormyndighetenes egne systemer og vurderingsmetoder, og til bruk av skjønn. Situasjonen er lignende både for å identifisere og vurdere aktuelle **tiltak** for å opprettholde eller forbedre miljøtilstanden i vannforekomster, og også når det skal **vurderes unntak for inngrep/tiltak etter §12** i vannforskriften. Begge deler kan være omfattende oppgaver om de skal gjøres ordentlig. Det er lite veiledning og i liten grad etablerte metoder for å kunne vurdere samfunnsmessig nytte eller kostnader opp mot endret miljøtilstand. Det vises igjen til faglig skjønn.

Når vi ser samlet på kunnskapsgrunnlag og vurderinger som er gjort om miljøpåvirkning på kystområder i akvakulturforvaltning, kystsoneplanlegging og vannforvaltning kommer det fram flere funn. For de forvaltningsregimene og stressorene vi har sett på er det ingen hvor vurderinger gjøres kun basert på standardiserte indikatorer. Det er også få tilfeller hvor det kun er standard metode for beslutning i forvaltningen knyttet til enkelt-stressorer. Det er altså rom for skjønn for alle stressorer og forvaltningsmyndigheter. Eventuelt kan det ses på som at det *må* utøves skjønn fordi man ikke har vært i stand til å lage et system med tilstrekkelig kunnskapsgrunnlag og klare nok kriterier for vurdering og beslutning.

Det er et omfattende **kunnskapsgrunnlag** som går inn i alle disse forvaltningsregimene. Mest kunnskap, og mest kvantitativ og systematisk innsamlet kunnskap, er det om miljøtilstand og om næringsaktiviteter. Det siste er imidlertid i mindre grad knyttet til stressorer enn til andre variabler. De største og viktigste kunnskapshullene later til å være for ***sammenhengen* mellom menneskelig aktivitet, stressorer og miljøpåvirkning**.

Tilsvarende er det begrenset med hjelp i retningslinjer og veiledere om hvordan **vurderinger** av den sammenhengen skal gjøres. Det er i begrenset grad bruk av standardiserte indikatorer i forvaltningen for å angi tilstand eller påvirkninger, men det kommer flere til hele tiden. Det å gjøre vurderinger av **samlede virkninger** (multi-stressor og kumulativ påvirkning) er det begrenset med metoder tilgjengelig for, og de som finnes krever i stor grad spesialkompetanse og mye ressurser. Gode metoder for å **sammenligne og vurdere miljøeffekter opp mot samfunnseffekter** (kostnad og nytte) er heller ikke tilgjengelig, selv om miljøregnskap og rammeverk for å analysere økosystemtjenester er under utvikling. Følgelig er det store behov for å utøve **faglig skjønn** på sentrale områder i flere av forvaltningsregimene. Det er delvis på grunn av kunnskapsmangel, og delvis fordi det er vanskelig å lage standardiserte vurderingsmetoder som kan håndtere lokal kompleksitet og en usikker framtidig utvikling godt nok. Bruk av lokalkunnskap og faglig skjønn kan riktignok åpne for gode lokale tilpasninger og innovative løsninger, men kan også innebære urimelig forskjellsbehandling mellom områder eller sektorer.

Der det er vanskelig å forutse effekter av nye tiltak eller annen utvikling er en adaptiv tilnærming fornuftig. Det er en rekke forhold som bidrar til **adaptiv forvaltning** i det vi har studert. Videre er det fortsatt flere hindringer til å få til en riktig **økosystembasert forvaltning**. Den største utfordringen er kanskje det å vurdere samlet påvirkning, på samme måte som det var pekt på som en sentral utfordring over, samt det å i det hele tatt vurdere sammenhengen mellom aktiviteter, påvirkning og miljøeffekt/-tilstand. Det har også vært pekt på behovet for en mer **helhetlig og integrert forvaltning** for å få til økosystembasert forvaltning. De tre forvaltningsregimene vi har studert her har mange kontaktpunkter og gjensidig avhengighet i forvaltningen av de stressorene for miljøpåvirkning vi har sett på. Det er et system av «checks and balances», hvor ulike hensyn, demokratisk makt og fagmyndigheter får påvirkning på det endelige resultatet. I tillegg til involvering av myndigheter er det også betydelige muligheter for interessenter til å spille inn og påvirke prosessene, ikke minst med kunnskap. Det er samtidig noen begrensninger for integrering og helhetstenkning. Det gjelder blant annet at ulike sektormyndigheter i stor grad bestemmer over egne tiltak og egen sektor. Av det vi har sett på her er det kanskje mest tydelig for identifisering, vurdering og gjennomføring av tiltak knyttet til vannforvaltningsplaner. Det vil imidlertid være komplekst og administrativt ressurskrevende med mye større grad av integrering på tvers av sektormyndigheter.

### Executive summary


The main purpose of this chapter has been to look at which knowledge base and which assessments are made in important regimes for managing environmental impact in the coastal zone. The analysis is centered on the management of environmental impacts from aquaculture in aquaculture management, and how environmental impacts from aquaculture is handled together with other types of similar environmental impacts in management regimes where these are to be assessed together. The latter is done for coastal zone planning and water management.

The chapter also provides an overview of management of the environment in the coastal zone and the connection between the various management regimes. For the management regimes we look at in particular, it presents the regulations that apply to environmental management, based on laws and regulations. Guidelines and guides for how case processing and assessments are to be carried out have also been reviewed, with an emphasis on knowledge base and assessment methods.

We have collected examples of cases and plans and reviewed these to see how this is done in practice, and also conducted interviews and in other ways received input and elaboration on this.

The management of environmental effects in the coastal zone from various types of impacts is complex and extensive and includes many management regimes and actors. There are no stressors that have only been assessed in one regime or only by one administrative authority. This is natural given the structure of the Norwegian management system for the coast, where different sector authorities and authorities at different administrative and democratic levels are involved.

For all management regimes, we find that there is a broad knowledge base for assessments and decisions. In **aquaculture management**, there is nevertheless a lack of knowledge about the environmental effect of dissolved nutrient salts, about particulate organic emissions on hard bottoms, about vulnerable species and habitats, about the possible effects of aquaculture on marine fish, and environmental risks from cod farming. For assessments that

are made, a significant degree of discretionary judgment is used. There is some use of standardized indicators to assess the condition of recipients or possible impact from aquaculture, but this is limited.

In **municipal coastal zone planning**, legally binding limitation are made for land use in the coastal zone, which in turn can have a major impact on environmental impact and environmental condition. They include that aquaculture locations must be placed in areas set aside for aquaculture in the municipalities' spatial plans. It is particularly in the impact assessment of alternative land disposals that the systematic collection of knowledge and assessment of the environmental effects of aquaculture come into play. For the plan we particularly studied, which we consider to be among "best practice" in Norway, there was one objection due to a lack of knowledge - about the effects of kelp cultivation. Assessments in the impact assessment include a number of quantitative criteria or ordinal qualitative criteria, but also discretionary criteria. It varies how clearly the discretionary assessments are described in the impact assessment for each proposed aquaculture area. There must also be a combined and holistic assessment of all the proposals in a coastal zone plan. It includes looking at effects on the water environment (including assessment according to §12 of the Water Regulations), as well as assessing overall risk. We find that the reviews have thorough descriptions of both status, risk factors and assessments. Since discretion has been used in most cases, and it is demanding to describe in detail, it can still be difficult to fully grasp trade-offs or what makes it considered justifiable in one case and not in another.

**Water management** must classify the environmental condition of water bodies and create water management plans where environmental targets are set to be achieved during the planning period, identify relevant measures to improve or prevent deterioration of the environmental status, and ensure monitoring. However, the prioritization and implementation of measures is up to the various sector authorities within their areas of responsibility, and not something that can be determined in the water management. For the assessment of **environmental status** of water bodies, there are clearly defined goals and assessment criteria, and there are established monitoring programs linked to this. To identify existing and possible **influences** on the water environment, clear guidance is provided, and databases, other sources of information and methods for doing this are available. The biggest challenges are for **assessing** the effects of influences on the state of the environment. Instead, reference is generally made to the sector authorities' own systems and assessment methods, and to the use of discretionary judgement. The situation is similar both for identifying and assessing possible **measures** to maintain or improve the environmental condition of water bodies, and also when **exceptions pursuant to §12** of the water regulations are to be assessed. Both parts can be extensive tasks if they are to be done properly. There is little guidance and to a small extent established methods for being able to assess social benefits or costs against a changed environmental condition. It is again referred to professional discretionary judgement.

When we look collectively at the knowledge base and assessments made about the environmental impact on coastal areas in aquaculture management, coastal zone planning and water management, several findings emerge. For the management regimes and stressors we have looked at, there are none where assessments are made only based on standardized indicators. There are also few cases where there are only standard methods for decision-making in management related to single stressors. There is therefore room for discretionary judgement for all stressors and administrative authorities. Alternatively, it can be seen that discretion must be exercised because one has not been able to create a system with a sufficient knowledge base and clear enough criteria for assessment and decision.

There is an extensive **knowledge base** that goes into all these management regimes. The most knowledge, and the most quantitative and systematically collected knowledge, is about the state of the environment and about industrial activities. The latter is, however, to a lesser extent linked to stressors than to other variables. The biggest and most important knowledge gaps seem to be for ***the connection*** **between human activity, stressors and environmental impact.**

Correspondingly, there is limited help in guidelines and guides on how **assessments** of that connection should be made. There is limited use of standardized indicators in administration to indicate environmental status or impacts, but more are being added all the time. There are limited methods available for making assessments of **overall effects** (multi-stressor and cumulative impact), and those that do exist require specialist expertise and a lot of resources. Good methods for **comparing and assessing environmental effects against social effects** (cost and benefit) are also not available, although environmental accounting and frameworks for analyzing ecosystem services are under development. Consequently, there is a great need to exercise **professional discretionary judgment** in key areas in several of the management regimes. This is partly due to lack of knowledge, and partly because it is difficult to create standardized assessment methods that can handle local complexity and an uncertain future development well enough.  The use of local knowledge and professional judgment can open up for good local adaptations and innovative solutions, but can also involve unreasonable differential treatment between areas or sectors.

Where it is difficult to predict the effects of new measures or other developments, an adaptive approach makes sense. There are a number of conditions that contribute to **adaptive management** in what we have studied. Furthermore, there are still several obstacles to achieving proper **ecosystem-based management**. The biggest challenge is perhaps assessing the overall impact, in the same way that it was pointed out as a central challenge above, as well as the overall assessment of the connection between activities, impact and environmental effect/condition. It has also been pointed out the need for a more **holistic and integrated management** to achieve ecosystem-based management. The three management regimes we have studied here have many points of contact and interdependence in the management of the environmental impact stressors we have looked at. It is a system of "checks and balances", where different considerations, democratic power and professional authorities influence the final result. In addition to the involvement of authorities, there are also significant opportunities for stakeholders to play a part in and influence the processes, not least with knowledge. At the same time, there are some limitations to integration and holistic thinking. This applies, among other things, to the fact that various sector authorities largely decide on their own measures and their own sector. Of what we have looked at here, it is perhaps most obvious for the identification, assessment and implementation of measures linked to water management plans. However, it will be complex and administratively resource-intensive with a much greater degree of integration across sector authorities.

## 5.1 Introduksjon

Formålet med dette kapitlet er for det første å se på hvordan ulike stressorer fra akvakultur som kan gi miljøeffekter i kystområdene er dekket og håndtert i akvakulturforvaltningen. For det andre er det å analysere på hvordan akvakultur og annen menneskelig påvirkning med lignende miljøeffekter på kysten dekkes og håndteres i mer helhetlig forvaltning av sjøområdene langs kysten. For begge analysene legges det særlig vekt på hvilket kunnskapsgrunnlag som brukes og hvordan vurderinger gjøres. Kapitlet blir dermed et bindeledd mellom analysene fra de to foregående kapitlene og neste kapittel, som handler om mulighetsrommet for forbedret forvaltning.

Miljøhensyn har vært sentralt i regelverket for akvakultur helt fra den første oppdrettsloven ble vedtatt i 1973 og er det fortsatt (Hersoug m.fl. 2019). Omfanget og detaljene i miljøreguleringene har vokst i tråd med at oppdrettsnæringen i Norge har vokst i omfang og utviklet seg på alle måter (Hovland 2021). Kunnskapen om naturmiljøet og ulike miljøeffekter, inkludert metoder og teknologi for å undersøke og overvåke dette har også utviklet seg og bidratt til dette. Annet og mer generelt regelverk har også kommet til eller utviklet seg og gitt ytterligere grunnlag for regulering av miljø og miljøeffekter fra menneskelig aktivitet i kystområdene i Norge. Det inkluderer blant annet kystsoneplanlegging etter plan og bygningsloven og vannforvaltning etter vannforskriften (Hauge 2021). I tillegg til miljøhensyn så dekker regelverket både for akvakultur og for disse andre forvaltningsregimene en hel del andre hensyn (Mikkelsen m.fl. 2018, Hauge 2021). Dette har ført til omfattende systemer med lover og forskrifter, hvor ulike hensyn kan oppleves å stå mot hverandre, og hvor avveininger mellom hensynene ofte blir nødvendige (Mikkelsen m.fl. 2022).

Negative effekter på naturmiljøet fra menneskelige aktiviteter er i utgangspunktet noe som det søkes å unngå. Men de menneskelige aktivitetene gir også positive effekter, så noe risiko eller degradering av naturmiljøet aksepteres. Begrepet bærekraft er brukt i formålsparagrafene til de tre forvaltningsregimene vi særlig ser på her, og inkluderer da hensyn til både naturmiljø, økonomi og samfunnsmessige forhold. Selv om disse hensynene ofte er avhengige av hverandre (Mikkelsen m.fl. 2021) kan de også oppleves som å stå i motsetningsforhold til hverandre, hvor «bruk eller vern» er en vanlig frase. Selv om denne rapporten og prosjektet den stammer fra særlig er rettet mot miljøeffekter av havbruk og andre aktiviteter i kystsonen er det ikke hensiktsmessig å bare se på forvaltning av miljøpåvirkning. Det må ses i den større sammenhengen som forvaltningen også skal operere innenfor. Her henger de tre forvaltningsregimene vi studerer tett sammen. Hvilket kunnskapsgrunnlag og hvordan avveininger foretas vil være avgjørende for hva som blir konklusjonen i slike avveininger.

Miljøeffekter fra menneskelige aktiviteter kan påvirke andre interessenter sin bruk og nytte av ressurser og områder i kystsonen. Sjøareal er en knapp ressurs selv i Norge, til tross for Norges lange kyst, store havområder og relativt lave befolkningstetthet. Kystområder er etterspurt for blant annet fiskeri, akvakultur, transport, annen infrastruktur, friluftsliv, turisme, vern og militære formål (Hersoug m.fl. 2021). Ulike interessenter har ulike behov som skal ivaretas og alternative anvendelser av areal skal vurderes. Arealplanlegging og arealforvaltning er derfor et viktig verktøy for å kunne balansere interesser og sikre effektiv bruk av kystområdene.

Det generelle regelverket for forvaltning av havbruksnæringen og praktisering av det har tidligere vært vurdert i flere arbeider (Robertsen m.fl. 2016, Hersoug m.fl. 2019, Robertsen m.fl. 2020, Dahl og Sørgård 2020, Hauge og Stokke (red.) 2021, Hersoug 2022). Her går vi særlig inn på krav og praksis for å vurdere miljøhensyn i akvakulturforvaltningen, inkludert kunnskapsgrunnlaget for å gjøre det. Vi ser også på forvaltningen av tilsvarende miljøutfordringer som fra akvakultur i kystsoneplanlegging og vannforvaltningen. Vi har gjennomgått og analysert hvordan miljøpåvirkningen fra havbruksnæringen forvaltes i dag, og hvordan kunnskap om miljøpåvirkning inngår, både i akvakulturforvaltningen, i vannforvaltning og i kystsoneplanlegging. Dette er interessant i seg selv, men er også grunnlag for analyse av om og hvordan annet kunnskapsgrunnlag enn dagens kan brukes i praktisk forvaltning.

**Forskningsspørsmål:** 1) Hvilke føringer legger det formelle akvakulturregelverket (lover og forskrifter) for forvaltningen av miljøpåvirkning fra havbruk? Hva sier veiledere fra direktoratet/fagetater om hvordan dette skal gjøres i praksis, og hvordan gjøres praktiske vurderinger av dette? Hvilke indikatorer og annet kunnskapsgrunnlag brukes for dette, og vurderes også andre hensyn, som samfunnsøkonomiske effekter?; 2) Tilsvarende som for (1), men for helhetlig forvaltning (vannforvaltning og kystsoneplanlegging), og rettet mot vurdering og forvaltning av miljøpåvirkning fra havbruk og andre næringer/aktiviteter. For det siste har vi særlig vært opptatt av hvordan det påvirker akvakultur.

**Gjennomgangen av forvaltningen her skulle legge et grunnlag for utforsking og analyser av mulighetsrommet for endret forvaltning, som kan være mer lokaltilpasset, treffsikker, og samfunnsøkonomisk effektiv.** Oppsummeringen fra dette delkapitlet har **siktet mot å gi en oversikt over følgende: 1) hvilke etater som har roller i forvaltningen av hvilke miljøstressorer; 2) hvordan vurderingen av stressorene foregår**. Disse er forsøkt framstilt i oversiktlige tabeller.

**Oversikt og leserveiledning:** I det neste del-kapitlet forklarer vi kort om metode, før vi gir et overblikk over sentrale lover og forvaltningsregimer relevante for forvaltning av miljøet i kystsonen, inkludert trekk og koblinger mellom de som bidrar til integrasjon i forvaltningen og til økosystembasert forvaltning. Deretter tar vi for oss henholdsvis akvakulturforvaltning, kystsoneplanlegging og vannforvaltning i separate delkapitler, før vi oppsummerer til slutt. For de som kjenner regelverket for akvakulturforvaltningen godt, og kun ønsker å lese om kunnskapsgrunnlaget brukt og vurderinger gjort i praksis, så kan man hoppe over delkapitlene fra **Error! Reference source not found.** til og med 5.4.4 Tilsvarende for kystsoneplanlegging kan de som allerede kjenner regelverket godt hoppe mer eller mindre rett til 5.5.7. For vannforvaltningen gjelder tilsvarende at man kan hoppe til 5.6.6.

## 5.2 Metode

I arbeidet med å besvare forskningsspørsmålene har vi basert oss på flere datakilder og metoder. Dokumentanalyse har vært sentralt, hvor vi har sett på lover og forskrifter, retningslinjer og veiledere fra myndighetene om forvaltning basert på lovverket, og dokumenter fra saksbehandling og kystsoneplaner og vannforvaltningsplaner. Vi har gjennomført intervjuer og på annen måte fått informasjon fra personer i ulike forvaltningsorganer og fra akvakulturnæringen, inkludert skriftlig på epost og gjennom møter og workshop. Vi har videre støttet oss på tidligere publisert forskning. Nøyaktig hvilke dokumenter og litteratur det er framgår i de ulike delkapitlene her.

Vi startet med å gjennomgå kravene som regelverket stiller for hvordan miljøhensyn skal vurderes, med en vektlegging av hva slags stressorer eller miljøeffekter som skal vurderes, hvilke krav er det til kunnskap og hvordan vurderinger skal gjennomføres. Dette ble støttet av gjennomgangen av retningslinjer og veiledere som ytterligere forklarer og utdyper hvordan det skal skje. Deretter samlet vi informasjon om praksis i forvaltningen, først slik det framkom gjennom dokumenter fra saksbehandling i akvakultur og fra planlegging og planer fra kystsoneplanlegging og vannforvaltning, og deretter gjennom intervjuer eller annen type kontakt med saksbehandlere. Saksdokumenter ble samlet inn fra de ulike forvaltningsorganene gjennom direkte kontakt med dem, nedlasting fra databaser på nett, eller fra postjournaler. Igjen var vi særlig opptatt av hvilke stressorer og miljøhensyn som ble vurdert, og kunnskapsgrunnlag og metoder brukt for vurderingene.

Praktisering av akvakulturregelverket ble gjennomgått ved hjelp av tabeller hvor elementer relevante for ulike forskningsspørsmål ble samlet for hvert dokument fra saksbehandling. Tabeller ble fylt ut for saksbehandling etter ulike forvaltningsorganer: Statsforvalteren (forurensingstillatelse), Fylkeskommunen, Fiskeridirektoratet, og Mattilsynet. Basert på tabellene ble det laget en verbal oppsummering. Tabellene er relativt omfattende, og er derfor plassert i et appendiks. Etter gjennomgangen basert på saksdokumenter, og delvis parallelt med denne, har vi samlet ytterligere informasjon og søkt avklaringer fra personer fra de ulike forvaltningsorganene, gjennom formelle intervjuer, diskusjoner på workshop i prosjektet, samtaler på andre møter/arenaer, og på epost. Noen intervjuer har blitt gjennomført for å dekke behovene både i arbeidspakke 3 (inneværende kapittel om forvaltning) og i arbeidspakke 4 (kapittel 6 som omhandler mulighetsrommet for endret forvaltning).

For kystsoneplaner og vannforvaltningsplaner ble det valgt ut et par case, og dokumenter fra disse ble gjennomgått for å identifisere tilsvarende elementer og besvare de samme typer forskningsspørsmål som for akvakulturforvaltningen. I tillegg har vi gjennomført intervjuer med sentrale personer i planleggingsarbeidet for avklaring og utdyping.

Utviklingen av tabeller for analyse inkludert identifisering av elementer å kartlegge i saksdokumenter og planer ble utviklet av forskerne i arbeidspakken gjennom flere møter. Gjennomgangen av saksdokumenter fra hvert forvaltningsorgan ble gjort av én forsker, og så framlagt og diskutert i forskergruppen. Ved behov ble saksdokumenter vurdert av flere forskere. Tema og spørsmål for intervjuer ble identifisert av enkeltforskere basert på gjennomgang av saksdokumenter og gjennom diskusjoner i forskergruppen.

Prosjektet har levert «Meldeskjema for personopplysninger i forskning» og prosjektet er funnet å oppfylle kravene som stilles om personvern i forskning (referansenummer 203176 hos sikt.no).

## 5.3 Forvaltning av miljøet i kystsonen

Før vi går inn i akvakulturforvaltning, kystsoneplanlegging og vannforvaltning skal vi gi en oversikt over forvaltning av miljøet i kystsonen mer overordnet, presentere noen begreper og prinsipper som er relevant for forvaltning og miljøforvaltning mer generelt, samt beskrive sammenhengen mellom noen sentrale forvaltningsregimer.

Det er en rekke lover og regimer som bidrar til forvaltningen av naturmiljøet langs kysten. Hauge (2021) gir en oversikt som inkluderer Grunnlovens §112 («miljøparagrafen»), plan og bygningsloven med både kommunal, regional og nasjonal planlegging, naturmangfoldloven, forurensingsloven, matloven og dyrevelferdsloven, og akvakulturloven. Også annet lovverk og forvaltningsregimer kunne vært inkludert. Hauge omtaler ikke vannforvaltning etter vannforskriften, selv om vannforvaltningsplaner formelt vedtas som regionale planer av fylkeskommunene. Vannforvaltning er en sentral del av miljøforvaltningen av sjøområdene på kysten. Selv om den gjelder bredt, har den imidlertid noen begrensninger opp mot akvakultur. Av andre spesifikke næringsaktiviteter som kan ha påvirkning på naturmiljøet i kystsonen og lover som regulerer det er det særlig fiskeri med havressursloven og energiloven som kan nevnes. Fiskeri fordi fiske og fangst åpenbart kan påvirke bestander, arter og økosystemer. Energiloven fordi arealmessig plassering av energirelatert infrastruktur ikke styres gjennom plan og bygningsloven, og slik infrastruktur kan påvirke både landskap og ville arter, og økosystemtjenester fra naturen. For utslipp til det ytre miljø, inkludert støy, dekker forurensingsloven alle typer virksomheter, inkludert landbruk, mineralutvinning, deponering og avløp. I det videre her konsentrerer vi oss uansett om akvakulturforvaltning, kystsoneplanlegging og vannforvaltning, i tråd med den overordnede innretningen på prosjektet og rapporten.

Miljøet forvaltes ikke direkte gjennom de ulike lovene og forvaltningsregimene, men indirekte gjennom at det settes grenser eller krav til menneskelige handlinger som på ulike vis kan påvirke miljøet. Noe av regelverket setter mål om hvordan tilstanden for naturmiljøet skal eller bør være, som naturmangfoldloven og vannforskriften. Noe av regelverket gir generelle forbud eller påbud, slik forurensingsloven gir mot å forurense. I tillegg til å bestemme hva som er tillatt eller forbudt bestemmes det også gjennom noe regelverk hvor og eventuelt når noe er tillatt eller forbudt. Dette gjelder eksempelvis kystsoneplanlegging etter plan og bygningsloven, men også naturvern etter naturmangfoldloven. Noe regelverk gir prinsipper for offentlig forvaltning og planlegging som angår naturmiljøet, slik naturmangfoldloven stiller krav til kunnskapsgrunnlag og vurderinger generelt, og konsekvensutredningsforskriften etter plan og bygningsloven stiller krav nettopp for konsekvensutredninger. Det stilles også krav til prosess for saksbehandling og planlegging som blant annet skal sikre at alle relevante aktører kan uttale seg, at kunnskapsgrunnlaget blir godt og at ulike hensyn vurderes før en beslutning tas. Eksemplene over har på ulikt vis alle sektorovergripende regelverk. Noe regelverk er imidlertid direkte rettet mot enkeltsektorer og forvaltningen av dem, som akvakulturloven og energiloven. **Error! Reference source not found.** illustrerer forenklet sammenhengen mellom de sektoroverordnede lovene og forvaltningsregimene og sektorlovene. Samlet sett er det et komplekst samspill mellom ulike typer regelverk, og vi kan ikke dekke alt her. Det har ikke vært rom for å vurdere spesifikt sektorregelverk og sektorforvaltning for andre næringer enn akvakultur. Men både kystsoneplanlegging og vannforvaltning som vi har studert står for helhetlig forvaltning på tvers av sektorer, selv om det er noen unntak, som vi kommer tilbake til. Før vi går inn i de enkelte forvaltningsregimene skal vi kort orientere om noen overordnede begreper og prinsipper som er relevante for forvaltningen vi skal se på.

### 5.3.1 Noen sentrale begreper, prinsipper og utfordringer

**Forskriftslover:** Det første vi vil kommentere er den vanlige strukturen på norsk lovverk, med lover og forskrifter. Regelverket på de fleste områder består av en lov, eksempelvis akvakulturloven (LOV-2005-06-17-79). Loven angir overordnede og sentrale regler og føringer. Loven har flere sentrale uttrykk og begrep som kan være åpne for tolkning, som kravet i §6 om at akvakulturtillatelse kan gis dersom det er «miljømessig forsvarlig». Loven har imidlertid også bestemmelser om at det kan gis mer detaljerte regler for hvordan de overordnede regler og føringer i loven skal tolkes gjennom at det lages forskrifter. Forskriftene kan normalt endres raskere enn loven kan endres, slik at dette gir en økt fleksibilitet til å endre forvaltningen, innenfor lovens rammer. Forskriftene skal enten vedtas av departementet eller av Kongen. «Kongen» betyr regjeringen i statsråd («Kongen i statsråd»). Departementer delegerer i noen tilfeller sin rett til å lage forskrifter (forskriftskompetanse) til direktorater. Når man skal se på regelverket for et tematisk område må man altså vurdere både lov og forskrifter. I tillegg til presiseringer i forskrifter så kan forarbeidene til utarbeidelsen av loven være en kilde for mer nøyaktig tolkning av begreper brukt i loven, og i tillegg kan også rettsavgjørelser være kilde til slike avklaringer. Her har vi imidlertid ikke kunnet gå så dypt inn i materien, og har i all hovedsak konsentrert oss om lover og forskrifter.

**Økosystembasert forvaltning** legges til grunn på stadig flere områder, etter særlig å ha blitt utviklet og vektlagt i tilknytning til FNs konvensjon om biologisk mangfold (Aas m.fl. 2022). Begrepet har ikke noen entydig definisjon, men det er allikevel økende enighet om hva som bør legges i det (Aas m.fl. 2022). Etableringen av de såkalte Malawi-prinsippene om økosystemtilnærming fra 1998 var viktig for å få på plass noen sentrale elementer (se tekstboks om Malawi-prinsippene). I norsk sammenheng kan man kjenne igjen flere av prinsippene i sentrale paragrafer i naturmangfoldloven (se tekstboks om naturmangfoldloven).

Prinsippene inkluderer (med henvisning til §§ i naturmangfoldloven):

- arter, naturtyper og økosystemer skal beskyttes slik at deres funksjon, struktur og produktivitet ivaretas «så langt det anses rimelig» (§§ 4 og 5 i naturmangfoldloven)
- at offentlig beslutningstaking «så langt det er rimelig» bygger på vitenskapelig kunnskap om økologiske forhold og effekten av påvirkninger, og også tradisjonell kunnskap, men at kravet til kunnskapsgrunnlag må stå i forhold til risikoen for skade på naturmangfoldet i den enkelte saken (§8)
- føre-var tilnærming: Når det er utilstrekkelig kunnskap om mulige virkninger på naturmiljøet av en beslutning «skal det tas sikte på å unngå mulig vesentlig skade på naturmangfoldet» (§9)
- det er samlet belastning på økosystemene som må vurderes (§10)
- tiltak etter naturmangfoldloven skal avveies mot andre viktige samfunnsinteresser (§14)

Sentrale barrierer for å kunne realisere mer økosystembasert forvaltning er sterk sektororganisering og fragmentert forvaltning, ifølge Aas m.fl. (2022) sin gjennomgang av internasjonal forskningslitteratur om dette. De konkluderer at det ikke vil være tilstrekkelig med ytterligere styrking av (det naturfaglige) kunnskapsgrunnlaget og produksjon av beslutningsstøtte-verktøy, men at det først og fremst kreves mer kunnskap om utfordringene med fragmentert forvaltning, sektorbarrierer, politikk og maktforhold.

**Integrert og helhetlig forvaltning** har vært trukket fram av mange som nødvendig for å få en bedre forvaltning av marine ressurser og områder (Underdal 1980, Sørdahl 2023). Det har også lenge vært promotert knyttet til begrepet «integrert kystsoneforvaltning» (Stokke og Hauge 2022). Et sentralt argument er at beslutninger som tas uten å vurdere helheten kan gi utilsiktede effekter som kan påvirke både effektivitet og fordeling (Underdal 1980). Hva «integrert og helhetlig» forvaltning bør innebære er det ulike beskrivelser av, men de tre elementene som Underdal (1980) trekker fram kan trolig mange støtte (Stokke 2021, Stokstad m.fl. 2020, Sørdahl 2023): 1) Alle relevante forhold må trekkes inn i vurderinger (comprehensiveness of input), over tid, over geografi, og med alle relevante aktører og hensyn. 2) forvaltningen må veie ulike interesser mot hverandre og gjøre prioriteringer mellom dem. 3) forvaltningen må være konsistent både vertikalt og horisontalt.

Vertikal konsistens innebærer at vedtak og policy fra ulike hierarkiske nivåer i forvaltningssystemet er i samsvar og ikke motarbeider hverandre (Underdal 1980, Stokstad m.fl. 2020). Horisontal konsistens gjelder da vedtak og policy fra ulike sektor-forvaltninger.

Det er ikke rom her for å gå særlig inn i hvordan integrasjon kan oppnås, men i norsk sammenheng har og er plan og bygningsloven instrument for samordning både vertikalt og horisontalt i forvaltningen (Winge 2017, Stokstad m.fl. 2020). Kommunal planlegging, inkludert kystsoneplanlegging, og også regionale planer er viktig i så måte. Imidlertid har flere har tatt til orde for at den juridiske statusen til regionale planer må styrkes for å få mer konsistens i forvaltningen av arealer og miljø i kystsonen (Stokstad m.fl. 2022, Stokke 2022).

Idealet eller ambisjonen om økosystembasert forvaltning, hvor funksjonelle økosystemer også blir den naturlige geografiske enheten for forvaltning og planlegging, er imidlertid ikke alltid i tråd med kommunal planlegging siden kommunegrenser ikke har blitt bestemt ut fra økosystemer i Norge. Mer utstrakt interkommunal kystsoneplanlegging har imidlertid motvirket dette (Kvalvik og Robertsen 2017, Mikkelsen m.fl. 2022). Vannforvaltningsplaner etter vannforskriften er også regionale planer etter plan og bygningsloven, og de er basert på økologisk definerte vannforekomster.

**Adaptiv forvaltning** er når forvaltningen er designet for å lære mer om det systemet som man forvalter samtidig som man forvalter det, og at man justerer forvaltningen i tråd med den nye kunnskapen (Williams 2011). Når det gjelder forvaltning av økosystemer og menneskelig påvirkning på det kan læringen både være overordnet og mer prinsipiell om sammenhenger, for eksempel hvordan påvirkning fra en menneskelig aktivitet fører til miljøeffekter, og helt spesifikk og konkret, som at en spesiell menneskelig aktivitet i et område gir en betydelig miljøeffekt. Ny kunnskap kan tilsvarende bidra til at man endrer det overordnede forvaltningssystemet, og til at man endrer den konkrete forvaltningen av den spesielle aktiviteten som gir betydelig miljøeffekt.

Det kan med andre ord være endringer både på kort og lang sikt, og lengden på syklusen for adaptiv forvaltning kan variere. På den ene siden er det noen ganger lange planleggingssykluser, slik det eksempelvis er for de helhetlige forvaltningsplanene for norske havområder (Sander 2018). Her er DPSIR-modellen for adaptiv forvaltning en nyttig konseptuell og praktisk modell (selv

**Tekstboks: The Malawi Principles on the Ecosystem Approach**

1.The objectives of management of land, water and living resources are a matter of societal choices.

2. Management should be decentralized to the lowest appropriate level.

3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context.

5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

6. Ecosystems must be managed within the limits of their functioning.

7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

9. Management must recognize that change is inevitable.

10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

(Hentet fra Aas m.fl. 2022)

om den siden har blitt sterkt videreutviklet (Elliott m.fl. 2017). På den andre siden kan det være en mer kortsiktig, nærmest løpende adaptiv forvaltning, slik som det er i norsk havbruk. Her er det overvåkning av flere stressorer og miljøforhold på ulike tidsskala, fra daglig (sykdom) til ukentlig (lus) til over lenger tid (B- og C-undersøkelser), og hvis resultater fra overvåkningen tilsier at tiltak må settes inn, enten fra oppdrettsselskapene selv eller av myndighetene, så kan man på kort varsel gjøre det. Hvordan man kan oppnå en hensiktsmessig **balanse mellom forutsigbarhet og fleksibilitet** i forvaltning er også et tilbakevendende tema i litteraturen (Schütz og Slater 2019).

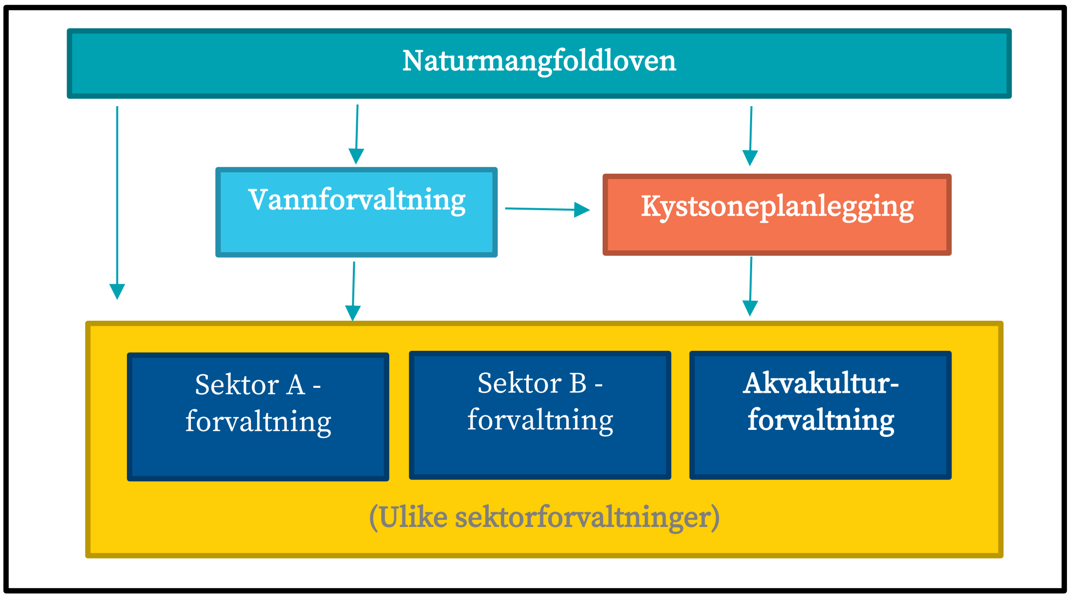
### 5.3.2 Sammenhengen mellom de ulike forvaltningsregimene

Når vi bruker begrepet forvaltningsregime så gjelder det regelverk og praksis som regulerer et område, og det området kan være avgrenset tematisk eller knyttet til en sektor med menneskelige aktiviteter. Dette kan relateres til Figur 5-1, hvor naturmangfoldloven utgjør ett forvaltningsregime, vannforvaltningen utgjør ett forvaltningsregime, og det samme gjelder kystsoneplanlegging, og akvakulturforvaltning. Denne framstillingen skjuler imidlertid at det vi akkurat har omtalt som separate forvaltningsregimer i realiteten ofte påvirker hverandre. Påvirkningen skjer på ulike måter. For det første utgjør lovene et hierarki, slik at bestemmelser i noen lover er førende på andre lover og dermed også forvaltning eller andre aktiviteter styrt av disse lovene. Eksempelvis gir naturmangfoldloven en del prinsipper som skal styre offentlig forvaltning som kan påvirke naturmiljøet, slik vi har omtalt nylig. For det andre kan det være bestemmelser om at forvaltningsvedtak etter et regelverk legger føringer på hvilke konkrete vedtak som kan gjøres etter et annet regelverk. Et eksempel er at arealplaner laget for kystsonen (som skjer etter plan og bygningsloven) legger føringer på hvor akvakulturanlegg kan etableres. Et annet eksempel er at vannforvaltningsplaner, inkludert bestemmelse av miljøkvalitetsmål for vannforekomster, kan begrense menneskelig aktivitet som kan påvirke vannmiljøet negativt.

Når vi i det videre tar for oss akvakulturforvaltning, kystsoneplanlegging og vannforvaltning så vil vi allikevel omtale disse som separate forvaltningsregimer og forsøke å avgrense analysen til det som vurderes og vedtas innenfor hvert av disse regimene. Eventuell påvirkning fra de andre forvaltningsregimene vil i hovedsak tas som gitt når vi analyserer hvert enkelt regime.

Detaljer om hvordan de ulike forvaltningsregimene faktisk påvirker og påvirkes av de andre regimene dekkes i delkapitlene om hvert regime. Her vil vi imidlertid kort omtale de overordnede sammenhengene, inkludert hvordan det gir rammer for akvakulturforvaltningen, men vi omtaler ikke akvakulturforvaltningen separat, da det kommer allerede i neste delkapittel.

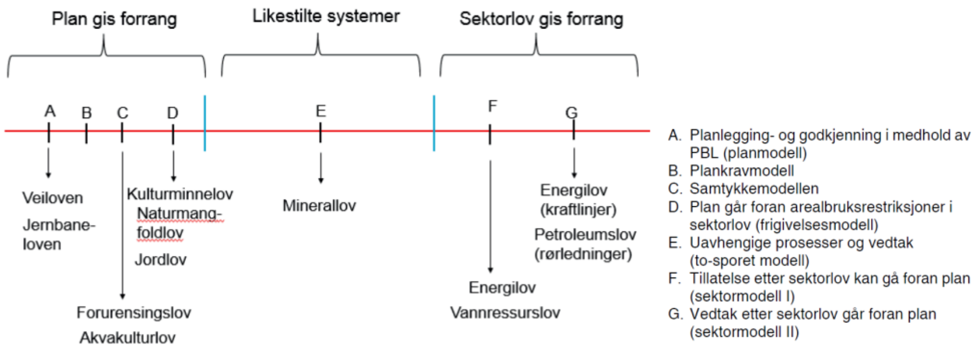
**Naturmangfoldloven** ble også omtalt over knyttet til økosystembasert forvaltning. Den er den mest generelle miljøloven og gjelder for all offentlig saksbehandling og prinsippene der skal legges til grunn der reglene er relevante, uavhengig av bransjer og sektorer. Loven inneholder viktige prinsipper som kunnskapsgrunnlag for vedtak og føre var-prinsippet i de saker der det mangler kunnskapsgrunnlag og det er fare for "alvorlig eller irreversibel skade" (se tekstboks). Vedtak om naturvern gjøres etter naturmangfoldloven, og vernetiltak legger betydelige begrensninger på menneskelig aktivitet og offentlige forvaltningsvedtak.




*Figur 5-1. Sammenhengen mellom de ulike forvaltningsregimene.*

**Vannforvaltning** etter vannforskriften sier at vannforekomster minst skal ha «god» økologisk og kjemisk status. Vannforekomster inkluderer kystvann i tillegg til elver og innsjøer og grunnvann. Tiltak og aktiviteter som kan forringe miljøkvaliteten i vannforekomster er i utgangspunktet ikke tillatt, og dersom tilstanden er dårligere enn «god» skal det gjøres tiltak for å forbedre den. Det lages sektorovergripende vannforvaltningsplaner, og disse vedtas som regionale planer av fylkeskommunene. Det betyr at de skal legges til grunn for all offentlig virksomhet, inkludert når det lages kommunale arealplaner eller gjøres forvaltningsvedtak, inkludert for søknader om akvakulturlokaliteter.

**Kystsoneplanlegging** er kommunal arealplanlegging etter plan og bygningsloven. Kystsoneplaner er juridisk bindende, i den forstand at den begrenser hvilke typer aktiviteter og utbygginger som kan skje i ulike områder. Spesifikt er det slik at akvakulturlokaliteter må plasseres i det som er definert som akvakulturområder i kystsoneplaner. Alternativt kan det søkes om dispensasjon fra kystsoneplanen, men da er saksbehandlingen av en lokalitetssøknad mer omfattende enn ellers, og kommunen kan velge å si nei. Dersom det søkes om å etablere en akvakulturlokalitet i det som er definert som et akvakulturområde i en kystsoneplan så er kommunen kun høringsinstans, og fylkeskommunen kan som ansvarlig myndighet for lokalitetssøknader velge å godkjenne søknaden selv om kommunen skulle være imot det. Bestemmelser i arealplaner etter plan og bygningsloven er i de fleste tilfeller førende for saksbehandling etter sektorlover (Figur 5-2), men det gjelder ikke alle vedtak etter energiloven, vannressursloven eller mineralloven (Winge 2017).




*Figur 5-2. Forholdet mellom planer etter plan og bygningsloven og noen sektorlover. Kilde: Winge (2017).*

## Tekstboks: Naturmangfoldsloven - utdrag

§ 4. ***(forvaltningsmål for naturtyper og økosystemer):*** Målet er at mangfoldet av naturtyper ivaretas innenfor deres naturlige utbredelsesområde og med det artsmangfoldet og de økologiske prosessene som kjennetegner den enkelte naturtype. Målet er også at økosystemers funksjoner, struktur og produktivitet ivaretas så langt det anses rimelig.

§ 5. ***(forvaltningsmål for arter):*** Målet er at artene og deres genetiske mangfold ivaretas på lang sikt og at artene forekommer i levedyktige bestander i sine naturlige utbredelsesområder. Så langt det er nødvendig for å nå dette målet ivaretas også artenes økologiske funksjonsområder og de øvrige økologiske betingelsene som de er avhengige av.

§ 6. ***(generell aktsomhetsplikt):*** Enhver skal opptre aktsomt og gjøre det som er rimelig for å unngå skade på naturmangfoldet i strid med målene i §§ 4 og 5. Utføres en aktivitet i henhold til en tillatelse av offentlig myndighet, anses aktsomhetsplikten oppfylt dersom forutsetningene for tillatelsen fremdeles er til stede.

§ 7. ***(prinsipper for offentlig beslutningstaking i §§ 8 til 12):*** Prinsippene i §§ 8 til 12 skal legges til grunn som retningslinjer ved utøving av offentlig myndighet, herunder når et forvaltningsorgan tildeler tilskudd, og ved forvaltning av fast eiendom. Vurderingen etter første punktum skal fremgå av beslutningen.

§ 8. ***(kunnskapsgrunnlaget):*** Offentlige beslutninger som berører naturmangfoldet skal så langt det er rimelig bygge på vitenskapelig kunnskap om arters bestandssituasjon, naturtypers utbredelse og økologiske tilstand, samt effekten av påvirkninger. Kravet til kunnskapsgrunnlaget skal stå i et rimelig forhold til sakens karakter og risiko for skade på naturmangfoldet. Myndighetene skal videre legge vekt på kunnskap som er basert på generasjoners erfaringer gjennom bruk av og samspill med naturen, herunder slik samisk bruk, og som kan bidra til bærekraftig bruk og vern av naturmangfoldet.

§ 9. ***(føre-var-prinsippet):*** Når det treffes en beslutning uten at det foreligger tilstrekkelig kunnskap om hvilke virkninger den kan ha for naturmiljøet, skal det tas sikte på å unngå mulig vesentlig skade på naturmangfoldet. Foreligger en risiko for alvorlig eller irreversibel skade på naturmangfoldet, skal ikke mangel på kunnskap brukes som begrunnelse for å utsette eller unnlate å treffe forvaltningstiltak.

§ 10. ***(økosystemtilnærming og samlet belastning):*** En påvirkning av et økosystem skal vurderes ut fra den samlede belastning som økosystemet er eller vil bli utsatt for.

§ 12. ***(miljøforsvarlige teknikker og driftsmetoder):*** For å unngå eller begrense skader på naturmangfoldet skal det tas utgangspunkt i slike driftsmetoder og slik teknikk og lokalisering som, ut fra en samlet vurdering av tidligere, nåværende og fremtidig bruk av mangfoldet og økonomiske forhold, gir de beste samfunnsmessige resultater.

§ 14. ***(vektlegging av andre viktige samfunnsinteresser og samiske interesser):*** Tiltak etter loven her skal avveies mot andre viktige samfunnsinteresser. Ved vedtak i medhold av denne loven som berører samiske interesser direkte, skal det innenfor rammen som gjelder for den enkelte bestemmelse legges tilbørlig vekt på hensynet til naturgrunnlaget for samisk kultur.

## 5.4 Akvakulturforvaltning

I gjennomgangen av akvakulturforvaltningen vil vi først ta for oss hvordan ulike miljøhensyn og påvirkningsfaktorer (stressorer) er dekket i regelverket. Deretter vil det bli studert hvordan de ulike forvaltningsorganer praktiserer miljøregelverket, med vekt på kunnskapsgrunnlaget og vurderingsmetoder de bruker.

### 5.4.1 Oversikt over akvakulturforvaltningen

Reguleringen av miljøpåvirkning i akvakulturforvaltningen er både knyttet til tildeling av selskapstillatelser og lokalitetstillatelser og regulering av driften av akvakulturaktivitet. Vi legger her mest vekt på saksbehandling knyttet til lokalitetssøknader, men omtaler også andre deler av akvakulturforvaltningen. Vi starter med en oversikt over de ulike delene av akvakulturforvaltningen.

For å kunne drive med akvakultur må man ha en **akvakulturtillatelse**. Den består av to deltillatelser. **Selskapstillatelsen**, noen ganger omtalt som produksjonstillatelsen, gir en generell rett til å drive akvakultur med en art i et bestemt omfang. **Lokalitetstillatelsen** gir rett til å drive akvakultur av en art i et bestemt omfang på et angitt område. For kommersielt matfiskoppdrett av laks og ørret gis det separat tilsagn om selskapstillatelse av Fiskeridirektoratet, mens Fylkeskommunen koordinerer saksbehandling og avgjør søknad om lokalitetstillatelse, og utsteder den komplette akvakulturtillatelsen. For andre arter og akvakulturformål (settefisk, stamfisk, forskningstillatelser osv, men ikke utviklingstillatelser) er det fylkeskommunen som behandler og avgjør begge deltillatelsene som inngår i en akvakulturtillatelse.

Omfanget som en tillatelse gis for er for matfiskoppdrett av laks og ørret *maksimal tillatt biomasse* (MTB). Denne oppgis vanligvis i tonn, og angir den maksimale samlede vekten som dyrene i oppdrett knyttet til en tillatelse kan veie på ett gitt tidspunkt. For andre arter og akvakulturformål kan tillatelser være angitt i antall, kg, eller areal (dekar eller $m^2$) eller volum ($m^3$). En selskapstillatelse for matfiskoppdrett av laks og ørret kan ha en annen MTB enn lokalitetstillatelsen(e) den er knyttet til. En selskapstillatelse kan normalt utnyttes på flere lokaliteter, og det er også mulig å knytte flere selskapstillatelser til én lokalitet.

For at fylkeskommunen skal kunne gi en lokalitetstillatelse kreves det først at det gis tillatelse fra Statsforvalteren etter forurensingsloven, fra Mattilsynet etter matloven og dyrevelferdsloven, fra Kystverket etter havne- og farvannsloven, og om det er relevant også fra NVE etter vannressursloven (Figur 5-3). Disse etatene kan sies å ha vetorett for lokalitetssøknader, innenfor sine kompetanseområder. I tillegg må plasseringen ikke være i strid med kystsoneplan eller naturvernområder eller vernede kulturminner (eller det må være gitt dispensasjon). Ut over disse «absolutte» kravene, så gjøres det skjønnsmessige vurderinger av om det vil være «miljømessig forsvarlig», og om arealkonflikter med andre interesser i kystsonen. Også vedtakene om å oppfylle de «absolutte kravene» kan inneholde skjønnsmessige vurderinger i betydelig grad. Dette kommer vil tilbake til.

Når det gjelder regulering av selskapstillatelser for oppdrett av laks og ørret, så gjøres det innenfor definerte produksjonsområder ved hjelp av trafikklyssystemet. Dette systemet har bidratt til at samlet miljøbelastning fra flere oppdrettsanlegg i større grad har blitt vurdert. Imidlertid inkluderer systemet nå kun én indikator, nemlig hvordan lakselus fra oppdrettsanleggene påvirker dødelighet for villaks i produksjonsområdet. Produksjonsområder som vurderes til å ha et akseptabelt nivå på denne dødeligheten over en to-årsperiode (grønne områder) gis mulighet til økt MTB, gule områder med noe større påvirkning på villaksen kan beholde den samlede MTB, mens røde områder med uakseptabel påvirkning må redusere MTB. Hvert andre år bestemmes det altså om produksjonskapasiteten i et produksjonsområde kan økes, må reduseres, eller beholdes slik det er.

Selskapstillatelser og økt produksjonskapasitet for andre arter og akvakulturformål enn kommersielt matfiskoppdrett av laks og ørret kan det normalt søkes om kontinuerlig, selv om det tidvis har vært innført begrensninger på å søke om dette, blant annet for settefisk av laks og ørret, og for utviklingstillatelser.

I tillegg til om selskapstillatelser og lokalitetstillatelser kan tildeles er det to ting som er sentrale for reguleringen av akvakultur. Det ene er vilkår for drift. Det andre er overvåkning og kontroll med virksomheten, og eventuell bruk av sanksjoner dersom vilkårene for drift er brutt eller forutsetningene for tildeling av akvakulturtillatelsen er endret. Mange krav er stilt gjennom akvakulturdriftforskriften (FOR-2008-06-17-822 Forskrift om drift av akvakulturanlegg). Dersom det blir alvorlige problemer knyttet til miljøforhold eller fiskevelferd kan Mattilsynet, Fiskeridirektoratet og Statsforvalteren alle enten pålegge tiltak (redusert biomasse, nedslakting, brakklegging av lokalitet), og i ytterste konsekvens kan en lokalitetstillatelse trekkes tilbake dersom viktige miljømessige eller samfunnsmessige forhold gjør det nødvendig.

**Miljøovervåkning**: Det skal være trendovervåkning av bunnforholdene under anlegget i henhold til Norsk Standard NS-9410 (Miljøovervåkning av marine matfiskanlegg) (eller lignende), og dette skal rapporteres til Fiskeridirektoratet. Dersom det er uakseptabel miljøtilstand kan det fattes vedtak om brakklegging.

**Lakselus og bruk av lusemidler**. Dette er styrt av lakselusforskriften (FOR-2012-12-05-1140 Forskrift om bekjempelse av lakselus i akvakulturanlegg). Telling og rapportering av lakselus i anlegget. Øvre grenser for antall lus per fisk. Det skal gjøres en risikovurdering for effekter på omkringliggende miljø før lusemidler brukes eller slippes ut etter bruk. Det er krav knyttet til avstand til rekefelt og eller gytefelt ved bruk.

**Forebygge og begrense rømming**: Generelle krav om særlig aktsomhet for å unngå rømming, samt gjøre risikovurdering for å minimalisere risikoen gjennom systematiske tiltak. Beredskapsplan for å håndtere og minimere og redusere antall rømt fisk om en rømmingshendelse skulle inntreffe. Krav om jevnlig inspeksjon av nøter.

**Sykdomssmitte**: Det er krav om en oppdatert beredskapsplan for å håndtere sykdomstilfeller. Fisken skal overvåkes og ved mistanke om sykdom er det rutiner for varsling og videre undersøkelse, samt opprettelse av soner for kontroll og bekjempelse av sykdom.

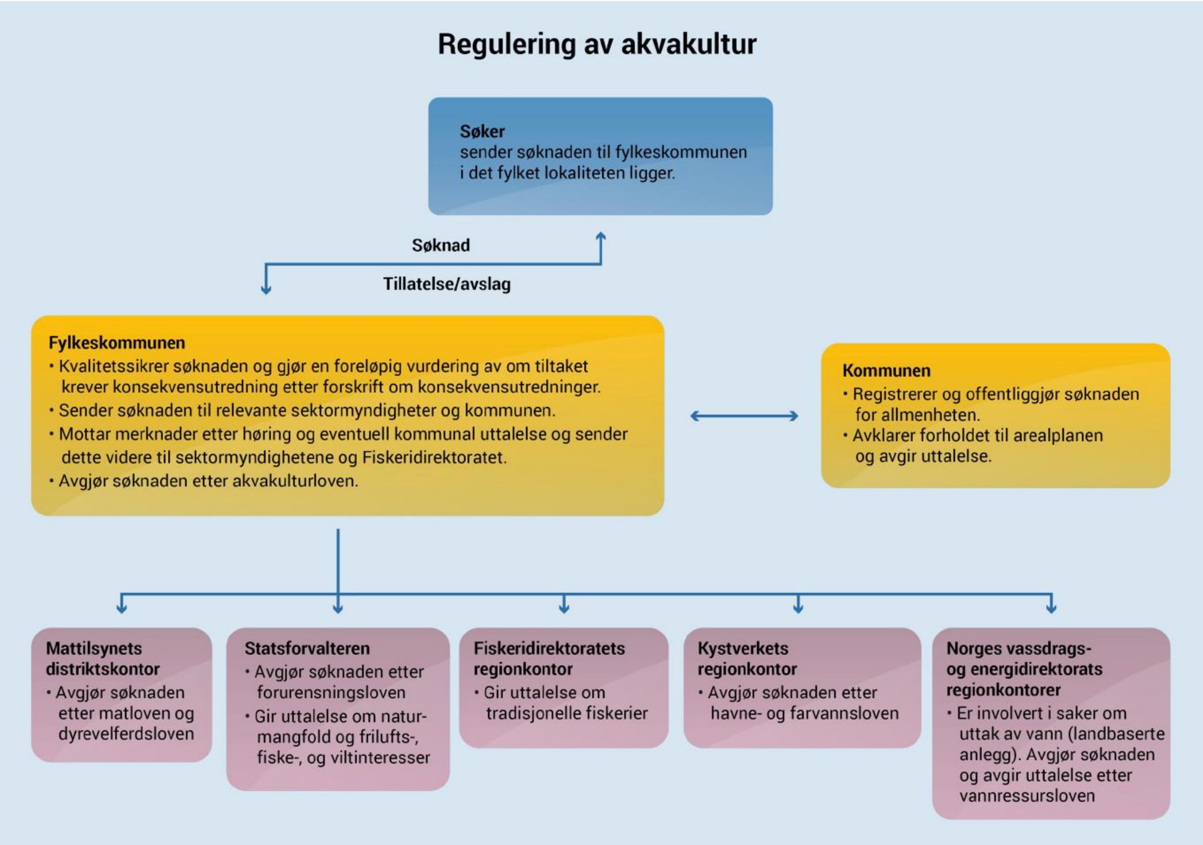
**Transport av dyr**. Styres av transportforskriften (FOR-2008-06-17-820 Forskrift om transport av akvakulturdyr). Tiltak for å forhindre smitte og rømming.

I neste delkapittel går vi dypere inn de ulike myndighetenes regelverk og praksis for å håndtere miljøeffekter ved behandling av lokalitetssøknader. Vi konsentrerer oss om lakseoppdrett, men noen av sakene vi har undersøkt er også for oppdrett av torsk eller tare.

### 5.4.2 Miljøregulering i behandling av lokalitetssøknader i sjø i kystsone

Tillatelser kan gis både for akvakultur på land, i elv og innsjø, i sjø i kystsonen (ut til én nm ut fra grunnlinjen), og til havs (utenfor kystsonen). Her ser vi mest på tillatelser i sjø i kystsonen for matfiskoppdrett av laks, ørret og regnbueørret, men vi vil også berøre akvakultur i kystsonen av andre arter enn laksefisk. Fylkeskommunen er ansvarlig myndighet for tildeling av alle disse tillatelsene som vi konsentrerer oss om for tillatelse til akvakultur av laks, ørret og regnbueørret (Figur 5-3).

Søknader om tillatelser til nye oppdrettslokaliteter og endringer i eksisterende lokaliteter behandles også av fylkeskommunene. Ved søknad om tillatelse, sender fylkeskommunen søknaden til kommuner og sektormyndighetene for behandling (Kystverket, Statsforvalteren, Mattilsynet, Fiskeridirektoratet). Fylkeskommunen mottar resultatene fra saksbehandlingen, foretar en samlet vurdering og fatter vedtak.




*Figur 5-3. Oversikt over søknadsprosessen knyttet til akvakulturtillatelse og lokalitet[4].*

I saksbehandling for tildeling, endring og opphør av tillatelse til akvakultur for laks, ørret og regnbueørret gjelder laksetildelingsforskriften (FOR-2022-11-07-1929), som er vedtatt med hjemmel i akvakulturloven. For tillatelser for akvakultur av andre arter gjelder forskriften om tillatelser for andre arter (FOR-2004-12-22-1799). De generelle vilkårene for klarering av lokalitet er nesten identiske i de to forskriftene. Tekstboksen under viser disse fra laksetildelingsforskriften. For tillatelse for andre arter er det et tillegg til punkt a): «Lokaliteter for torsk skal ikke etableres i gyteområder for vill torsk»

[4] Siden denne rapporten fokuserer på sjøfasen av akvakultur (havbruk), så inkluderes ikke NVE i videre omtale, selv om det kan tenkes at NVE involveres i sjeldne tilfeller, som ved uttak av ferskvann fra vassdrag til bruk i sjøbasert virksomhet.

**Tekstboks: Generelle vilkår for klarering av lokalitet**
**Laksetildelingsforskriften § 8-3 (utdrag)**

Lokalitet for akvakultur kan klareres dersom

a) det er miljømessig forsvarlig;

b) det er foretatt en avveining av arealinteresser med særlig vekt på
   1) søkers behov for areal til planlagt akvakultur,
   2) alternativ bruk av området til annen akvakultur,
   3) annen bruk av området, og
   4) verneinteresser som ikke omfattes av bokstav d, herunder vedtak om vern etter lov 29. mai 1981 nr. 38 om viltet;

c) det er gitt tillatelse som kreves etter
   1) lov 19. desember 2003 nr. 124 om matproduksjon og mattrygghet mv.,
   2) lov 13. mars 1981 nr. 6 om vern mot forurensinger og om avfall,
   3) lov 21. juni 2019 nr. 70 om havner og farvann,
   4) lov 24. november 2000 nr. 82 om vassdrag og grunnvann og
   5) lov 19. juni 2009 nr. 97 om dyrevelferd; og

d) det ikke er i strid med
   1) vedtatte arealplaner etter plan- og bygningsloven,
   2) vedtatte vernetiltak etter kapittel V i lov 19. juni 2009 nr. 100 om forvaltning av naturens mangfold, eller
   3) vedtatte vernetiltak etter lov 9. juni 1978 nr. 50 om kulturminner.

(...)
Forvaltningsmyndigheter for fiskeri-, vilt-, naturvern- og friluftsinteresser skal gis adgang til uttalelse før lokalitet klareres etter første ledd.

Figur 5-4 gir en skjematisk oversikt over hvordan miljøkrav er beskrevet i Akvakulturloven med forskrifter, mens Figur 5-5 gir minstekravene til søknad om akvakulturtillatelse i tildelingsforskriften. [5]

[5] Figurene gjelder for gammel utgave av laksetildelingsforskriften. I den nye forskriften (FOR-2022-11-07-1929) tilsvarer §36 nå §8-9.

**Akvakulturloven (miljømessige krav)**

**Tildeling:**

- Akvakulturtillatelse *«kan»* tildeles (krav på behandling av søknad, men ikke krav på tillatelse)
- Vilkår om *«miljømessig forsvarlig»* § 6 (1) a) – innholdet i kravet vil kunne endres over tid i takt med økt kunnskap og teknologisk utvikling, jf. forarbeidene
- Vilkår om tillatelse etter forurensningslov § 6 (1) d)

**Drift**:

- Generell miljønorm (rettslig standard): «miljømessig forsvarlig» § 10 (gjelder ved etablering, drift og avvikling – samme innhold i hele loven)
- Hjemmel til å gi vedtak / forskrifter om vilkår og annet for å sikre miljømessig akvakultur (§ 10) , krav til «miljøundersøkelser» (§ 11) etc.

**Tildelingsforskriftene (LTF / TFaa)**
(dokumentasjon pr søknadstidspunkt)

- Laksetildelingsforskriften (LTF)
- Tildelingsforskriften for andre arter (TFaa)

**Akvakulturdrifts-forskriften**
(dokumentasjon pr søknadstidspunkt)

**§ 8-9 / 10 Minstekrav til søknad**

*«Søknaden skal inneholde:*
*a. opplysninger om strømmålinger på lokaliteten,*
*b. kartdokumentasjon som angitt i NS-9410 – Miljøovervåking av marine matfiskanlegg – eller tilsvarende internasjonal standard/anerkjent norm, og*
*c. resultatene fra en miljøundersøkelse i form av en trendovervåking av bunnforholdene på lokaliteten (i NS-9410 kalt B-undersøkelse) gjort i henhold til NS-9410 eller tilsvarende internasjonal standard/anerkjent norm»*

- Kravet i a) og c) gjelder bare klarering av lokalitet i sjøvann, men Fylkeskommune kan i samråd med SF kreve miljøundersøkelser av lokaliteter i ferskvann

**§ 35 miljøovervåking**

- Krav til B-undersøkelse (under anlegget) i henhold til og etter intervaller i NS 9410
- Unntak: hvor B-undersøkelse *«vanskelig lar seg gjennomføre etter NS 9410 ... på grunn av dybdeforhold eller lokalitet med stein- eller fjellbunn» kan* Fdir i samråd med SF vedta alternativt overvåkingsprogram

**§ 35 Tiltak ved uakseptabel miljøtilstand**

- Der B-undersøkelsen viser uakseptabel miljøtilstand (tilstand 4) – krav til utvidede prøver
- Fdir i samråd med SF kan også i slike tilfeller kreve C-undersøkelser
- Hvis også slike undersøkelser viser uakseptabel miljøtilstand kan vedtak om brakklegging treffes.

*Figur 5-4. Miljøkrav etter Akvakulturloven med forskrifter (Laksetildelingsforskriften (§ 8-9) og Tildelingsforskriften for andre arter (§ 10), samt akvakulturdriftsforskriften (§ 35).*

**Tildelingsforskriftene § 8-9 / 10 Minstekrav til søknad**
*«Søknaden skal inneholde:*
*a. opplysninger om strømmålinger på lokaliteten,*
*b. kartdokumentasjon som angitt i NS-9410 – Miljøovervåking av marine matfiskanlegg – eller tilsvarende internasjonal standard/anerkjent norm, og*
*c. resultatene fra en miljøundersøkelse i form av en trendovervåking av bunnforholdene på lokaliteten (i NS-9410 kalt B-undersøkelse) gjort i henhold til NS-9410 eller tilsvarende internasjonal standard/anerkjent norm»*

- Kravet i a) og c) gjelder bare klarering av lokalitet i sjøvann, men Fylkeskommune kan i samråd med SF kreve miljøundersøkelser av lokaliteter i ferskvann

**Strømmålinger**
- Ikke utdypet i lov eller forskrift hvilke krav som gjelder

**Miljøundersøkelser**
- **Hovedregel:** B-undersøkelse (jf. § 8-9 første ledd c) og § 10 første ledd bokstav c)
- **Unntak 1:** hvor B-undersøkelse *«vanskelig lar seg gjennomføre etter NS 9410 … på grunn av dybdeforhold eller lokalitet med stein- eller fjellbunn»* kan Fylkeskommunen i samråd med SF vedta alternativt overvåkingsprogram (jf. § 8-9 fjerde ledd og § 10 femte ledd). Krav til **vedtak (begrunnelse, klagerett)**
- **Unntak 2:** *«Dersom anleggets størrelse, beliggenhet eller andre forurensningsmessige forhold tilsier det»* kan C-undersøkelse kreves (jf. § 8-9 femte ledd og § 10 sjette ledd)

**Fdirs. Merknader til tildelingsforskriften**

*«Forskriften setter ikke uttrykkelige krav til hvordan strømmålinger skal foretas. For nærmere opplysninger om dette vises til søknadsskjema med veileder.»*

**Søknadsskjema med veileder:**

- beskriver nærmere krav
- Måleenhet (cm/sek, m/sek), dybde, plasseringer, retning

**Fdirs. Merknader til tildelingsforskriften (andre arter)**

- Minstekrav til søknaden er minstekrav, ikke uttømmende. Det kan *«kreves opplysninger som ikke er nevnt ovenfor eller i § 10, men som er relevant for både særorganer og fiskerimyndighetene for å vurdere tildeling»* Søker skal gis mulighet til å rette/supplere ved tvil/ufullstendighet innen rimelig frist.

- **Miljøundersøkelser**. Formål: å kunne vurdere miljøpåvirkning på lokaliteten. Kravene tar sikte på å oppfylle også Statsforvalterens behov for undersøkelser iht. forurensningslov

- **Hovedregel:** B-undersøkelse

- **Unntak 1:** ment som et verktøy «i de situasjoner det vil være umulig» med B-undersøkelser.
  - minimum «gode faglige beskrivelser av sedimentering av utslipp fra anlegget»
  - «Kan være aktuelt å kreve strømmålinger utover kravet i nr. 1»
  - «i særlige tilfeller være aktuelt å kreve C-undersøkelser»

- **Unntak 2:**
  - **Størrelse**: Må dreie seg om «samlet produksjon på lokaliteten større enn 3120 tonn»
  - **Beliggenhet:** *«innenfor en terskel hvor resipienten kan avgrenses og faglige vurderinger tilsier at kapasiteten er utilstrekkelig»*
  - **Forurensningsmessige forhold**: *«når samlede utslipp av næringssalter .. til … lokalitetens fjernsone fra før anses å nærme seg tålegrensen til den totale resipienten»*
  - Ikke et enkeltvedtak, men inngår i forberedelsen av om det skal gis tillatelse. Det endelige vedtak kan påklages.

*Figur 5-5. Krav til søknad etter akvakulturloven med forskrifter (Laksetildelingsforskriften (§ 8-9) og Tildelingsforskriften for andre arter (§ 10).*

### 5.4.3 Statsforvalteren – forurensing

Formålet med forurensingsloven er «å verne det ytre miljø mot forurensning og å redusere eksisterende forurensning, å redusere mengden av avfall og å fremme en bedre behandling av avfall. Loven skal sikre en forsvarlig miljøkvalitet, slik at forurensninger og avfall ikke fører til helseskade, går ut over trivselen eller skader naturens evne til produksjon og selvfornyelse» (LOV-1981-03-13-6, §1).

Når Statsforvalteren vurderer om det kan gis forurensingstillatelse til en akvakultursøknad skal det «legges vekt på de forurensningsmessige ulemper ved tiltaket sammenholdt med de fordeler og ulemper som tiltaket for øvrig vil medføre» (forurensingsloven § 11). Det skal altså gjøres en helhetlig vurdering.

Det er et «fritt bredt skjønn» både om tillatelse skal gis og hvilke vilkår som skal settes (Mellbye 2018). Hvilken miljøkvalitet som skal oppnås/ bevares er et politisk spørsmål, ikke rettslig. Naturmangfoldlovens prinsipper skal legges til grunn ved saksbehandlingen. Kravene i vannforskriften skak vurderes for å se om de hindrer tillatelse. Det kan settes vilkår til en forurensingstillatelse (§16). Det er også mulig å endre eller trekke tilbake tillatelsen i ettertid om forurensningen blir vesentlig større enn forutsatt (§18).

Forurensningsforskriften (FOR-2004-06-01-931) kapittel 36 stiller krav til søknadens innhold i §36-2. Kravene til miljøundersøkelser som skal legges ved søknad om lokalitetsklarering skal dekke også Statsforvalterens behov for undersøkelser for å kunne behandle søknaden etter forurensingsloven. Det skal redegjøres for utslipp, miljøtilstand etc. (minstekrav). Videre heter det at Forurensningsmyndigheten kan gi utfyllende bestemmelser om søknadens form og innhold, og dersom det er nødvendig for behandlingen av saken, kreve ytterligere opplysninger» (enn de som er listet i punktliste).

I tillegg til å vurdere tillatelse etter forurensningsloven skal Statsforvalteren gi uttalelser om naturvern-, frilufts-, fiske- og viltinteresser. Disse uttalelsene vurderes av fylkeskommunen når de avgjør søknaden om lokalitetsklarering. Men til forskjell fra Statsforvalterens vedtak om forurensingstillatelse, som er en nødvendighet for at fylkeskommunen skal kunne klarere lokaliteten, så kan fylkeskommunen velge å klarere en lokalitet selv om Statsforvalteren ikke anbefaler det i sine uttalelser på de andre temaene.

#### 5.4.3.1 Forslag til revidering av forurensningsregelverket for akvakultur i sjø

Miljødirektoratet og Fiskeridirektoratet har på oppdrag fra Klima- og miljødepartementet og Nærings- og fiskeridepartementet sammen foreslått et nytt system for regulering av fiskeoppdrett i sjø etter forurensningsloven[6]. Akvakultur av fisk ut til en nautisk mil utenfor grunnlinjen blir som hovedregel tillatt uten enkelttillatelse etter forurensningsloven. Standardkrav i akvakulturdriftsforskriften for å forebygge og begrense forurensning og avfallsproblemer fra akvakultur, vil gjelde i stedet for vilkår i enkelttillatelser etter forurensningsloven.

Akvakulturdriftsforskriften, som er vedtatt med hjemmel i akvakulturloven, matloven og lov om dyrevelferd, vil også bli hjemlet i forurensningsloven, og fylkesmannen vil få tilsyns- og vedtaksmyndighet etter forskriften på forurensningsområdet.

[6] Revidering av forurensningsregelverket for akvakultur i sjø (miljodirektoratet.no)

I særlige tilfeller, der kravene i akvakulturdriftsforskriften ikke er tilstrekkelige for å ivareta forurensningsmessige hensyn, kan fylkesmannen bestemme at drift av bestemte akvakulturanlegg ikke kan skje uten tillatelse etter forurensningsloven.

Det foreslås endringer i en rekke forskrifter (bl.a. forurensningsforskriften, laksetildelingsforskriften, tildelingsforskrift om andre arter, akvakulturdriftsforskriften). De foreslåtte endringer kan oppsummeres som følgende:

- Forslag til nye minstekrav til søknad (samme minstekrav i laksetildelingsforskriften og andre arter forskriften)
- Foreslår krav til mer omfattende miljødokumentasjon per søknadstidspunkt
- Og fjerning av krav til utslippstillatelse som hovedregel, innenfor én nautisk mil fra grunnlinjen.
    - Forslaget tar inn krav som er vanlig å stille fra Statsforvalterens side
    - Ved søknad skal det bare vurderes om det er særlige forhold som tilsier at Statsforvalteren må inn i bildet å gi avslag eller utslippstillatelse
    - Blir det reell forenkling? Fortsatt et to-sporet system
- Hovedregelen er at driften ved anleggene reguleres gjennom standardiserte krav, som er samlet i akvakulturdriftsforskriften, i tillegg til driftskravene fra Fiskeridirektoratet og Mattilsynet
- Forskriftsendringene forventes å effektivisere søknadsbehandlingen og å øke forutsigbarheten for næringen.
    - Fortsatt spredt tilsynsmyndighet og behov for koordinering/samordning

### 5.4.4 Mattilsynet - Matloven og dyrevelferdsloven

Mattilsynet behandler tillatelser til akvakultur etter matloven og dyrevelferdsloven. Formålet med matloven er å sikre helsemessig trygge næringsmidler og fremme helse, kvalitet og forbrukerhensyn langs hele produksjonskjeden, samt ivareta miljøvennlig produksjon. Formålet med dyrevelferdsloven er å fremme god dyrevelferd og respekt for dyr.

Mattilsynet skal ved søknad om akvakulturtillatelse vurdere om anlegget og lokaliseringen vil være egnet med hensyn til fiskehelse og fiskevelferd. Det inkluderer å vurdere faren for smittespredning til og fra anlegget. Mattilsynet har også ansvar for kontroll og tilsyn knyttet til fiskehelse, sykdom og parasitter når anlegget er i drift. Dette gjelder for alle arter i oppdrett, også rensefisk som brukes i lakseoppdrettsanlegg for å redusere lakselus.

For MILJØREG-prosjektet, så er ikke fiskevelferden for oppdrettsfisken i seg selv i fokus, men miljørisiko ved akvakultur er klart påvirket av noen av de samme faktorer som påvirker fiskevelferd, spesielt smittsomme sykdommer og parasitter hos oppdrettsfisken. Mattilsynet skal både vurdere forhold for helse og velferd for oppdrettsfisken i anlegget, og fare for smitte til andre akvakulturanlegg samt til ville bestander. Gjennomgangen og analysen her er rettet mot Mattilsynet sin forvaltning ut fra hvordan det kan påvirke miljørisiko fra oppdrett.

Etableringsforskriftens §7 (FOR-2008-06-17-823) angir hva som skal vurderes ved søknad om ny lokalitet. For miljørisiko gjelder det særlig **spredning av smitte til omkringliggende miljø**, og da skal det **særlig legges vekt på avstand til vassdrag, art som produseres, driftsform og produksjonsomfang**.

Ved en søknad om utvidelse av en eksisterende lokalitet bør det ifølge Mattilsynets *Retningslinje for behandling av søknader om etablering og utvidelse av akvakulturanlegg* (Mattilsynet 2022) særlig vektlegges om driften på lokaliteten har vært forsvarlig, og relevant for miljørisiko spesielt, om hvordan varsling ved mistanke om smittsom sykdom og status for kontroll og bekjempelse av lakselus har vært.

Retningslinjen trekker også fram de krav som **Naturmangfoldloven** stiller til Mattilsynets behandling av akvakultursøknader gjennom naturmangfoldlovens prinsipper for saksbehandling (nml §§8-12).

Retningslinjen angir også at vedtakene som formidles til søker skal inneholde en «synliggjøring av hvordan vi vurderer og vektlegger det som det søkes om, opp mot prinsippene i naturmangfoldloven». Det trekkes fram at når lus eller andre miljøpåvirkninger utgjør en del av begrunnelse for et avslag så skal det vises til kravene i naturmangfoldloven.

Etableringsforskriften §6 angir hvilken informasjon en søknad til Mattilsynet om godkjenning av et akvakulturanlegg etter matloven skal inneholde. Det gjelder informasjon om art og utviklingsstadium, produksjonsform, driftsform og omfang, geografisk plassering av anlegget og dets vanninntak og avløp, beredskapsplan for å hindre og håndtere utbrudd av smittsom sykdom, massedød og andre kritiske situasjoner, og internkontrollsystem som sannsynliggjør at krav til smittehygiene mv. kan etterleves, samt dokumentasjon på lokalitetens egnethet til å sikre god velferd for dyrene i anlegget, herunder data på vannkvalitet, mengde vann og naturgitte forhold av vesentlig betydning for velferden.

I Retningslinjen slås det også fast at dokumentasjonen som kreves av søker skal være tilstrekkelig til å avgjøre en søknad, selv om det kan være vanskelig i en forhåndsvurdering å avgjøre om lokaliteten vil være egnet til å fylle de krav som regelverket stiller.

Opplysningene som kreves fra søker etter §6 inkluderer ikke informasjon om naturmangfold som kan påvirkes, men Mattilsynet skriver i Retningslinjen at «Søker må kunne synliggjøre hvordan regelverkskrav skal oppfylles i praksis ved ønsket lokalisering», og at «Dersom ytterligere opplysninger anses nødvendige for å kunne vurdere de hensyn Mattilsynet ved slike søknader er satt til å vurdere, skal søknaden ikke behandles før slike opplysninger foreligger».

Det kan stilles **vilkår** knyttet til en godkjenning av et anlegg, for at risiko skal bli håndtert på en tilfredsstillende måte. Retningslinjen sier også at hvis Mattilsynet er i tvil om tiltakene søker vil sette inn vil være tilfredsstillende, men allikevel konkluderer med at godkjenning kan gis, kan de informere søker om sitt syn i vedtaket, sånn at søker er forberedt på at de vil ha oppmerksomhet på dette ved tilsyn og at i ytterste konsekvens kan trekk tilbake godkjenning. Dette gir forutsigbarhet og veiledning for søker.

**Avstand** til andre akvakulturanlegg og til ville bestander er viktig for vurdering av hvordan et anlegg kan påvirke ville populasjoner. Mattilsynets retningslinje for saksbehandling oppgir avstandsanbefalinger, men er tydelige på at disse bare er et utgangspunkt for vurderinger. Det må også vurderes strømforhold, smittespredningsmodeller, lokale erfaringer med smitteforebygging og sykdomskontroll, og behandling av inntaks- og/eller avløpsvann utover det som følger av vanlige driftskrav. Det er ulike retningslinjer for ulike typer anlegg etter art og livsstadie, anleggsstørrelse, produksjonsform, og om de er del av en koordinert brakkleggingsgruppe eller ikke. Mattilsynet har også en anbefalt minsteavstand mellom koordinerte brakkleggingsgrupper.

Mattilsynet poengterer at det i utgangspunktet er oppdretterne som skal samordne driftsplaner og definere brakkleggingsgrupper. Men dersom oppdretterne ikke blir enige eller Mattilsynet mener at det oppdretterne er enige om ikke tar tilstrekkelig grad forebygger smittespredning så kan Mattilsynet bestemme hvilke anlegg som skal inngå i hvilke koordinerte brakkleggingsgrupper.

I tillegg til vurderinger av avstand mellom ulike anlegg og til ville populasjoner, så inneholder Retningslinjene et eget delkapittel om når omsøkte anlegg er nær grensen til et produksjonsområde. Som de skriver: «*Mattilsynet skal sikre at nyetablering eller utvidelse av anlegg med laksefisk ikke kommer i konflikt med de smittehensynene som ligger til grunn for etableringen av produksjonsområdene og bruken av lakselus som indikator for regulering av produksjonskapasiteten».* Hvis Mattilsynet vurderer å avslå en søknad på dette grunnlaget sier Retningslinjen at da skal det bestilles kunnskapsstøtte fra Havforskningsinstituttet, med kopi av bestillingen til Veterinærinstituttet.

Det er også særlig regler for etablering, flytting eller utviding av noen typer akvakulturanlegg i nasjonale laksefjorder og nasjonale laksevassdrag. For noen typer akvakulturanlegg er det forbud etter forskrift, mens for andre typer anlegg som ikke er forbudt skal vurderinger om anleggene vil «innebære uakseptabel risiko for spredning av smitte» skje etter strengere krav enn det som ellers ligger bak slike vurderinger.

Mattilsynet vurderer det slik at det ikke er hensiktsmessig å gi godkjenning på deler av et omsøkt MTB-volum, men at søker kan gis anledning til å endre søknaden. Unntaket er søknader for «store anlegg», større enn 3600 tonn MTB. De kan godkjennes under forutsetning av at driften viser seg å være forsvarlig i én produksjonssyklus for en mindre MTB enn omsøkt. Permanent godkjenning kan betinges av oppfyllelse av regelverket dokumenteres på konkrete punkt gjennom en produksjonssyklus.

Retningslinjens punkt 4.5 presiserer at utslipp og eventuell forurensning blir vurdert av fiskeri- og miljømyndighetene. Flere forhold som vurderes av Mattilsynet med hensyn på velferden for fisk i anlegget vil imidlertid også være relevant for miljøpåvirkning fra anlegget. Opphopning av bunnsedimenter under og nært merder kan påvirke vannkvaliteten i merden og også vannkvaliteten for viltlevende organismer i det samme området. Lokalitetens beliggenhet med strømforhold og bunntopografi er viktige faktorer for dette.

Retningslinjens kapittel 6 oppgir også relevante kunnskapskilder og forholdet til Statsforvalteren (tidligere fylkesmann): Det vises til Villaksportalen, Miljødirektoratets nettsider og risikovurderinger om lus fra Havforskningsinstituttet. Det anbefales å hente uttalelser fra fiskeri- eller miljømyndighetene der smittefare til bestander av villfisk er relevant for helhetsvurderingen Mattilsynet skal gjøre, og eventuelt kan gi grunnlag for avslag på søknad. Akvakulturanlegg bør ikke etableres i kjente vandringsruter for villfisk.

Retningslinjen presiserer også rollefordelingen mellom Fylkesmannen (Statsforvalteren) og Mattilsynet: «Fylkesmannen vil ofte komme med synspunkter og uttalelser om mulige effekter av en etablering/utvidelse på vill laksefisk. Mattilsynet skal imidlertid være tydelig på at slike uttalelser er av rådgivende karakter, og at mulige effekter av smittsomme agens på vill fisk er vårt forvaltningsområde. Det er hensiktsmessig å opplyse i vedtaket at eventuell uttalelse fra Fylkesmannen om villfisk inngår i faktagrunnlaget vi har vurdert. På den måten kan vi unngå at Fylkeskommunen er usikker på hvilken etat som tar endelig beslutning om hvilken betydning søknaden vil ha på villfisk».

Et nytt regelverk for dyrehelse ble innført i Norge i april 2022[7]. Gjennom det ble en rekke forskrifter opphevet og erstattet av nye. Ifølge Mattilsynet er det meste som før for akvakultur, men det er noen endringer. Selv trekker Mattilsynet fram det følgende[8]. Alle anlegg skal ha en biosikkerhetsplan. Et oppdrettsanlegg kan ikke få godkjenning av Mattilsynet kun basert på hva som beskrives i søknaden, men anlegget må inspiseres når det er kommet i drift. Det er også noen nye krav til hva søknaden skal ha av opplysninger. Mattilsynets overvåkning skal bli risikobasert, som da innebærer at de må risikoklassifisere anleggene med hensyn til fiskehelse. Det er også noen endringer knyttet til krav under transport av akvakulturdyr, og for sykdomshåndtering.

Når vi har sett på praksis i saksbehandling hos de ulike etatene, så har det for Mattilsynet vært basert på det gamle regelverket for dyrehelse, men dette betyr trolig lite for konklusjoner for det vi ser på, med vekt på kunnskapsgrunnlag brukt og vurderinger gjort.

### 5.4.5 Praksis i forvaltning av miljøhensyn i akvakulturforvaltningen

Som det er vist over så er det flere myndigheter som har en rolle å spille ved forvaltning av miljøhensyn knyttet til akvakulturtillatelser. Her fokuserer vi som sagt på lokalitetstillatelser og på lokale og regionale miljøeffekter, og mest på oppdrett av laksefisk. Vi har gått gjennom saksdokumenter og også fått innspill om praksis gjennom formelle intervjuer, samtaler, innspill på epost og gjennom workshop. I det følgende er det oppsummeringer fra dette for hhv Statsforvalteren, Fiskeridirektoratet, Fylkeskommunen og Mattilsynet. Etter gjennomgangen knyttet til akvakulturforvaltningen går vi også gjennom kystsoneplanlegging og vannforvaltning. Det er forvaltningsregimer som også påvirker akvakulturforvaltningen.

### 5.4.6 Statsforvalteren

Vi har gått gjennom 20 vedtak fra Statsforvalteren om utslippstillatelse til oppdrettsnæringen, og også uttalelse om naturmangfold. Vedtakene er hentet fra nettsiden *www.norskeutlipp.no*, hvor vedtak fra alle fylker skal legges ut etter hvert som de er ferdig behandlet. Vi har prøvd å finne fram til de nyeste vedtakene fra hvert fylke, samtidig som vi har valgt ut litt forskjellige vedtakstyper (utvidelse, ny lokalitet, avslag, osv).

Tabell 5-1 - Tabell 5-3 oppsummerer kunnskapsgrunnlag, vurderinger og krav til overvåkning fra Statsforvalteren i forbindelse med søknader om akvakulturtillatelse, basert på vår gjennomgang av saker (Tabell 8-1 i appendiks viser detaljer for hver sak vi har vurdert).

Oppsummert så ser vi følgende:

**Kunnskapsgrunnlaget** som brukes av Statsforvalteren er obligatorisk dokumentasjon fra søknaden, som strømmålinger, miljøundersøkelser (B- og C-undersøkelser), og bunnkartlegging med hardhetsmodul. I tillegg vurderes konsekvensutredning der dette finnes, info fra Vann-nett portalen, trafikklyssystemet, informasjon fra Legemiddelverket om lusemidler, informasjon fra Naturbase-portalen, Havforskningsinstituttets risikorapporter for fiskeoppdrett. I tillegg kan annen dokumentasjon som legges ved søknad/saksgang brukes. Anbefalingene/konklusjonene som gis i rapporter fra tredjeparter brukes sitatrett.

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[7] Se https://www.mattilsynet.no/dyr_og_dyrehold/dyrehelse/nytt_dyrehelseregelverk_2021/, sist besøkt 18/4-2023.

[8] Se https://www.mattilsynet.no/fisk-og-akvakultur/fiskesykdommer/hva-betyr-nytt-dyrehelseregelverk-for-akvakultur, sist besøkt 18/4-2023.

For **vurderingene** så bruker Statsforvalteren i alle fylkene samme vedtaksmal og dermed samme vedtaksskriv som gis. Lovhjemmel som brukes er i hovedsak forurensningsloven, ofte refereres det til §11, 16 og 18. Samtidig er det i mange vedtak gjort vurderinger etter vannforskriften, hvor særlig miljøkvalitetsklasse på vannforekomsten kan være viktig. For løste næringssalter bemerkes det i noen tilfeller om kunnskapsmangel, men også at det referes til det HI skriver om dette i sin risikorapport. Det vises også til prinsippene i naturmangfoldloven. Det er et fast sett med kriterier som belyses, og dette følges jevnt over av alle fylkene. For naturmangfold vises det til nærhet til vassdrag med anadrome laksefisk, med støtte fra rapporter fra Vitenskapelig råd for lakseforvaltning og HI. Det er oppmerksomhet på sårbare/verdifulle habitater som kan påvirkes, men det er ingen klare kriterier for å vurdere dette. Det ble ikke funnet noen saker som vurderte mulig effekt på vill torsk.

Akvaplan-niva er kjent med andre typer vedtak som ennå ikke finnes i Norskeutslipp-registeret, der det eksempelvis er vedtatt at tillatelser trekkes tilbake på grunn av at ny kunnskap viser at tiltaket (oppdrett) påvirker miljøet negativt og i irreversibel retning. Det er kjent at et nytt viktig tema for Statsforvalter er påvirkning av sårbare arter (svamper og koraller). Disse artene oppdages og kartlegges i større grad nå siden bruken av ROV i oppdrettsnæringen har økt betydelig de siste årene. Disse artene er beskyttet av både nasjonale og internasjonale regelverk/avtaler, samtidig som kunnskapsgrunnlaget om hvor sårbare disse er for menneskeskapt påvirkning er lavt. Dermed – etter hvert som disse artene også påvises i områder der det har vært oppdrettsaktivitet i flere år, viser Statsforvalteren til føre-var prinsippet og vurderer å trekke tilbake tillatelser med hjemmel i forurensningsloven.

**Krav om miljøovervåkning**: Basert på utslippstillatelsene gitt av Statsforvalter i flere fylker, virker det tydelig at C-undersøkelse er den viktigste parameteren som Statsforvalter styrer etter for å overvåke påvirkning av miljøet rundt en oppdrettslokalitet. Samtlige utslippstillatelser er gitt pålegg om slik undersøkelse, også der gamle utslippstillatelser revideres etter tilsyn av Statsforvalter. Det er tydelig at dette er gjeldende forvaltningspraksis, og er til forskjell fra kravet som opprinnelig stilles i tildelingsforskriften, der metodikken nevnes som et unntak eller ekstratiltak ved særlige tilfeller. Dette kommer i tillegg til B-undersøkelser under/tett ved anlegg som også er obligatorisk. Det pålegges å undersøke for kobber der dette er brukt i impregnering av nøter. I noen tilfeller er det også krav om makroalge-overvåkning eller undersøkelse med ROV for å se på mulig effekt av løste næringssalter. Det har også vært krav om ROV undersøkelse for å vurdere koraller ved anlegg.

*Tabell 5-1. Oppsummering av kunnskapsgrunnlag Statsforvalter brukt i akvakultursaker.*

| Kunnskapsgrunnlag brukt | Stressor/miljørisiko | Kvantifiserte kriterier |
|---|---|---|
| C-undersøkelse, B-undersøkelse, resipient-undersøkelse | Partikulære organiske utslipp, tungmetaller (Cu, Cd), bunnfauna (=Resipient tilstand) | Ja |
| HIs risikovurdering, strandsoneundersøkelser | Løste næringssalter | Nei |
| Produksjonsområde trafikklys-farge/vurdering | Lakselus | Ja |
| Legemiddelverket | Lusebehandling | Nei |
| Sedimentanalyse ifm C-undersøkelse | Tungmetaller | Ja |
| Reguleringsplan | naturmangfold – vill laksefisk | Nei |
| ROV-undersøkelser, makroalge-undersøkelse, avstand fra anlegget | naturmangfold – sårbare arter/habitat | Nei |
| Intet funnet | naturmangfold – vill torsk | - |

*Tabell 5-2.Oppsummering av vurderinger Statsforvalter gjort i akvakultursaker.*

| Stressor/miljørisiko | Vurderinger gjort |
|---|---|
| Partikulære organiske utslipp | Vannforekomst-kvalitet: Tilstand 2 eller bedre.<br><br>Resultater fra B- og/eller C-prøver (forundersøkelse, drift, prøveperiode). |
| Løste næringssalter | Vurderer kunnskap som mangelfull, men referer ofte til HIs årlige rapport |
| Lakselus | Trafikklys brukes som vurderingsgrunnlag, spesielt i områder med "rødt" lys. |
| Lusebehandling | Det er en generell uttalelse i de fleste tillatelsene om at godkjent legemiddel er tillatt brukt, og at tiltakshaver skal gjøre en risikovurdering ved bruk. |
| Tungmetaller | Miljødirektoratet Veileder 02:2018 Klassifisering miljøtilstand vann |
| Skade på naturmangfold – vill laksefisk | Nærhet til anadrome vassdrag, med støtteliteratur fra VRL, HI. Viser også til reguleringsplan i gjeldende kommune, der slike er laget. |
| Skade på naturmangfold – sårbare arter/habitat | De fleste har et fokus på dette, med pålegg om kartlegging av dette ved bruk av ROV. Det finnes dog ingen grenseverdier som vurderes. |
| Skade på naturmangfold - torsk | Intet funnet. |

*Tabell 5-3. Oppsummering krav til overvåkning fra Statsforvalter i akvakultursaker*

| Krav om overvåkning | Stressor/miljørisiko |
|---|---|
| B- og C-undersøkelser | Partikulære organiske utslipp, tungmetaller |
| Makroalge overvåkning | Løste næringssalter |
| Enkel (fiskehelsepersonell) eller utvidet risikovurdering. | Lusebehandling |
| ROV-kartlegging for å dokumentere tilstedeværelse av sårbare arter eller ikke. Fortsatt ikke tydelig overvåkingsprogram da man ikke har grenseverdier. | Skade på naturmangfold – sårbare arter/habitat |

### 5.4.7 Fiskeridirektoratet

Fiskeridirektoratet er forvaltningsmyndighet for fiskeri og akvakultur og har et særskilt ansvar for marine ressurser og marint miljø. Direktoratet vurderer konfliktpotensialet opp mot annen bruk av området. Fiskeridirektoratets oppgave er å tilrettelegge for fiskeri og akvakultur, og samtidig påse at dette skjer uten at det medfører vesentlige negative konsekvenser for marine ressurser og miljø.

Vi har analysert 16 uttalelser fra Fiskeridirektoratet angående søknader om etablering av akvakultur på nye lokaliteter og utvidelse av MTB der vi har kartlagt kunnskapskilder som var brukt og avveiningsmetoder (Tabell 5-4).

Fra de sakene vi har undersøkt så finner vi at Fiskeridirektoratet følger et standardisert oppsett i sine uttalelser, der kunnskapsgrunnlaget er ganske likt i alle sakene. Det refereres alltid til arealplaner, kartlagte fiskeriinteresser, sporing og sluttseddeldata og registrert biologisk mangfold (vanligvis HI data). Der det er tilgjengelig, brukes det kunnskap fra tidligere undersøkelser (B- og C). Offentlige databaser og kartløsninger (Naturbase, Vann-Nett) er brukt hvis slike undersøkelser var ikke gjort. Ofte foreligger det innspill fra ulike aktører gjennom kommunal behandling. Disse oppsummeres i dokumentet og tas hensyn til. Fiskarlaget blir som regel kontaktet og uttalelsene fra dem legges til i samlet vurdering.

Som det framgår av tabellen så er de fleste kunnskapskilder som Fiskeridirektoratet oppgir å bruke ikke direkte knyttet til en stressor, men tar for seg enten resipienten (bunnsedimenter/miljøforhold bunn), den naturkvaliteten man er bekymret for (biologisk mangfold), eller menneskelig aktivitet som kan påvirkes (fiskeri). Selv om flertallet av antallet kunnskapskilder ikke handler om stressorer er det imidlertid flere av kunnskapskildene som er oppgitt som bredt håndterer stressorer fra akvakultur og deres risiko og påvirkning på miljøet (HI risikorapport, Vann-Nett, konsekvensutredninger). I tillegg til disse er spesifikt studier om miljørisiko ved lusemidler oppgitt å brukes. Dette betyr at samlet sett dekkes alle relevante stressorer som er identifisert og omtalt i HI sin etablerte risikorapport, de som knyttes til vannkvalitet gjennom vannforvaltningen, og konsekvensutredninger som skal være gjennomført for å dekke alle relevante konsekvenser både for miljø og samfunn. Så har Fiskeridirektoratet altså i tillegg særlig brukt kunnskapskilder som sier noe om miljørisiko ved avslusningsmidler, og dette skyldes da trolig at det har kommet en del ny kunnskap de siste par-tre årene, samt at Fiskeridirektoratet da spesifikt finner disse relevante og en nyttig kilde.

Vurderingene som er gjort av Fiskeridirektoratet er primært jo knyttet til mulig påvirkning på ville marine arter, siden disse bestandene er grunnlag for de kommersielle fiskeriene. Her er det særlig avstand til og mulig påvirkning på gyte-, oppvekst- og leveområder som vektlegges. Det pekes i flere saker på utilstrekkelig kunnskap og usikkerhet knyttet til dette. I ett tilfelle foreslo Fiskeridirektoratet at Fylkeskommunen vurderer påvirkningen nærmere.

I tillegg er fiskeridirektoratet opptatt av hvor selve fiskeriaktiviteten foregår og om det kan være konflikt knyttet til dette. Igjen er avstand et viktig forhold som vurderes. Det pekes på at informasjon om fiskeriaktivitet kan være mangelfull.

Vi finner i vårt materiale at det er vanlig med en positiv uttalelse til akvakultursøknaden selv om etableringen kommer i en visst konflikt med fiskeriinteressene. Prinsippet som ofte brukes av Fiskeridirektoratet er å vurdere omfang og viktighet av fiskeriene og se på muligheter for å minimere konflikter. Det oppfordres til samarbeid og dialog mellom aktørene, og særlige vilkår for plassering og fortøyninger foreslås.

*Tabell 5-4. Oppsummering av kunnskapsgrunnlag vist til av Fiskeridirektoratet ved behandling av søknader om akvakulturtillatelse*

| **Kunnskapsgrunnlag** | **Stressor/ miljøhensyn (annet)** |
|---|---|
| Fiskeridirektoratets kartlagte fiskeriinteresser, inkl tradisjonelle fiskeriinteresser, AIS og VMS sporing, sluttseddeldata, og i form av registrerte kaste- og låssettingsplasser og bruk av aktive og passive redskap i området | (fiskeriaktivitet) |
| HI data om registrerte gyteområder | x/ Biologisk mangfold – kommersielle fiskearter |
| Kartlagt biologisk mangfold (HI) | x/ Biologisk mangfold |
| Naturbase, inkl brukt for kunnskap om tareskogsforekomster. | x/ Biologisk mangfold |
| ROV-undersøkelser med korallkartlegging ved lokaliteten | x/ Biologisk mangfold |
| Kystsoneplan / reguleringsplan | Flere* |
| B og C-undersøkelse / forundersøkelse | x/ Miljøforhold bunn/bunnsedimenter |
| HI risikorapport | Flere* |
| Studier om påvirkning av lusemidler, inkl på reker spesifikt | Avlusningsmidler / biologisk mangfold |
| Vann-Nett. | Flere* |
| Konsekvensutredning | Flere* |
| Uttalelser fra Fiskarlaget | x/ (fiskeri) |

x= gjelder ikke for en spesifikk stressor.
*) omtales andre steder i rapporten

*Tabell 5-5. Oppsummering av vurderinger i uttalelse fra Fiskeridirektoratet ved behandling av søknader om akvakulturtillatelse*

| Stressor / miljøhensyn /(annet) | Vurdering |
|---|---|
| Naturmangfold / vill marin fisk og andre arter | Avstand til gyte, oppvekstområder.<br><br>Har ikke kunnskap om hvilke effekter et anlegg for oppdrett av laks eventuelt vil kunne få for gyteområdet for lyr.<br><br>Mener at kunnskap ikke er tilstrekkelig, og det er ingen forvaltningsråd om vurdering av påvirkning på vill torsk.<br><br>HI risikorapport usikkerhet og kunnskapshull om påvirkning på vill torsk.<br><br>Etterspør ytterligere undersøkelser og/eller en stegvis økning i MTB og miljøundersøkelser over tid på lokaliteten i en del tilfeller. |
| (Fiskeriaktivitet) | Implisitt kobling naturmangfold vill marin fisk og fiskeri-interesser.<br><br>Sporing- og sluttseddeldata er brukt for å kartlegge aktivitet, men det er ikke usannsynlig at det er mer fiskeriaktivitet i området.<br><br>Avstand/nærhet til fiskeområder. |

### 5.4.8 Mattilsynet

Vi har samlet inn saksdokumenter for 8 saker fra Mattilsynet og analysert disse for å få fram hvilket kunnskapsgrunnlag og hvilke vurderinger som gjøres. Det ser ut til å være et standard oppsett for godkjenningsbrev, med faste vurderingspunkter, og standard formuleringer, for eksempel om vurdering opp mot naturmangfoldloven. I og med at Mattilsynet har en omfattende Retningslinje for behandling av søknader, slik vi har gått gjennom over, så er dette ikke overraskende.

En oversikt over sakene vi har vurdert er gitt i appendiks. Kunnskapsgrunnlaget det vises til i saksbehandlingen og vurderingene beskrevet er oppsummert i (Tabell 5-6 og Tabell 5-7).
Vi ser at kunnskapsgrunnlaget som er brukt knytter seg til stressorene sykdomssmitte, parasitter, og utslipp av næringsstoffer, tungmetaller og avlusningsmidler. Videre dreier det seg om forhold som påvirker spredning av stressorene (avstand og strømforhold), og det dreier seg om resipientene (vill laksefisk, naturmangfold generelt og i bunnfauna). I tillegg til disse er også konsekvensutredning inkludert, som kan inneholde flere stressorer og andre forhold relevant for miljøpåvirkning og miljørisiko.

I vurderingene som er gjort/uttrykt i saksdokumentene kommer det fram at mange søknader er avslått ut fra fare for smitte til andre anlegg for fiskeoppdrett. Der Mattilsynet tidlig i saksbehandlingen har konkludert at de vil avslå på grunn av dette har de latt være å gjøre en nøye vurdering av faren for smitte til ville bestander. Smitte til andre oppdrettsanlegg vil jo for øvrig også bety økt risiko for smitte til ville bestander.

Det heter i forskriften at godkjenning kan gis dersom det «ikke innebærer en uakseptabel risiko for spredning av smitte». Noen formuleringer av vurderinger bak vedtak gir oss inntrykk av at det er utfordrende å definere eller operasjonalisere hva som er «uakseptabel risiko». Eksempel: «Velger å avslå fordi vi ikke kan si at risikoen er ikkeeksisterende. Vi kan ikke garantere at ikke naboanleggene vi bli berørt […]. Sannsynligheten vil trolig være svært liten, men konsekvensen potensielt svært alvorlig». Risiko er jo produktet av sannsynlighet for at noe skjer og konsekvensen hvis det skjer, så det kan være høy risiko selv om noe har lav sannsynlighet. Fra formuleringene her synes det som om den eneste akseptable smitterisiko er en som er vurdert til å være null, og det vil den ikke være så lenge det drives akvakultur. Når det allikevel gis tillatelser så skjønner vi at vurderingene kan ikke være så strenge i praksis som det her synes å være.

Søknader om torskeoppdrett har gitt Mattilsynet en del utfordringer. Det ble uttrykt usikkerhet om smittefaren fra anlegg for matfiskoppdrett av torsk til vill torsk. Det ble vist til at Mattilsynets retningslinje for behandling av søknader ikke er oppdatert med anbefalinger om avstander fra anlegg til gyteområder til vill torsk. Det er imidlertid tatt i bruk spredningsmodeller fra HI for å vurdere mulig spredning av smitte. Det var også uttrykt usikkerhet og manglende kunnskap og retningslinjer for vurdering av smitterisiko fra torskeoppdrett til villaks-bestander og til anlegg for lakseoppdrett. Hvordan det å få anlegg for torskeoppdrett inn i en sone med lakseoppdrettsanlegg ville påvirke effekten av koordinert brakklegging og generasjonsskiller blant lakseanleggene var også noe det ble uttrykt usikkerhet om.

Det var en søknad om taredyrking i de sakene vi vurderte. Mattilsynet påpekte at vurdering opp mot fiskehelse og fiskevelferd kun var relevant der fisk kunne påvirkes. Da ble det vurdert avstand til nærmeste fiskeoppdrettsanlegg, og konkludert at risiko var ubetydelig.

Samlet sett var det generelt vanskelig å se hvilke konkrete vurderinger som var gjort når Mattilsynet konkluderte om smittefare og miljørisiko. Det ble vist til avstander fra anlegg til ulike typer resipienter, og i en del tilfeller at det har vært gjort analyser med strøm-/spredningsmodeller, men det er i liten grad klart hvordan man har kommet fram til konklusjonen. Det framstår altså som skjønnsbasert i relativt stor grad.

*Tabell 5-6. Kunnskapsgrunnlag vist til i Mattilsynets saksbehandling av akvakultursaker*

| Kunnskapsgrunnlag | Stressor/ miljøhensyn / (annet) |
|---|---|
| Avstand andre akvakulturanlegg. Brakkleggingssoner for ulike anlegg. | Sykdomssmitte og parasitter |
| Avstand annet produksjonsområde. | Lakselus |
| Avstand lakseførende vassdrag. Avstand til nasjonale laksevassdrag og laksefjorder. Tilstand villfisk-stammer der. Laksesmolt-rute. | x/ naturmangfold vill laksefisk |
| Naturmangfold i området og tilstand. | x/ naturmangfold generelt |
| Vurdering av påvirkning på villtorsk. Tidligere strøm-modellering ifht gyteområder for villtorsk. | x/ naturmangfold vill torsk |
| Beredskapsplanverk. Biosikkerhetsplan. Skisserte tiltak desinfeksjon. Matrise for smittehygienetiltak. | Sykdomssmitte |
| B-undersøkelser. C-Undersøkelse, Forundersøkelser. Miljøundersøkelser. Strømmålinger, oksygen og omkringliggende geografi. Bunnkartlegging. Dybde under anlegg. | Partikulært organisk utslipp, tungmetall/ naturmangfold bunnfauna, forurensing |
| Havstrømmer. HI Strømkatalogen. Ekstern analyse spredning avløpsvann. | Smittespredning |
| Fargelegging område i trafikklyssystemet. Lusesituasjonen i området (luserapporter fra anlegg i området, samt lusebehandlinger). | Lakselus, avlusningsmidler |
| Fiskeridirektoratet sin uttalelse til søknad, inkludert om fiskeplasser og låssettingsplasser, usikkerhet om etableringen av lokaliteten vil kunne påvirke vill torsk, nærliggende gyteområder, samt eventuelle oppvekst- og beiteområder. | Naturmangfold villfisk / (fiskeri) |
| KU-vurdering. Vurdering av behovet for konsekvensutredning. | Flere* |
| Anbefalte minsteavstander i retningslinjer for behandling av etableringssøknader. | Smittespredning |
| Plassering i forhold til utredningsområde for marint vern. | x/ naturmangfold |

x) Ikke om spesifikk stressor; *) Omtalt annet sted i rapporten.

*Tabell 5-7. Vurderinger uttrykt i brev fra Mattilsynets saksbehandling av akvakultursaker.*

| Stressor/ miljøhensyn /(annet) | Vurderinger |
|---|---|
| Sykdomssmitte / naturmangfold vill laksefisk | Avstand elver med laksefisk (laks, røye), nasjonale laksefjorder og nasjonale laksevassdrag. Tilstand bestander (vill laks, sjøørret, røye). Vandringsrute smolt.<br><br>Også vurdert for torskeoppdrett.<br><br>Avslag grunnet i smittefare til andre anlegg er noen ganger gjort før påvirkning på naturmiljø er vurdert. |
| Lakselus / naturmangfold vill laksefisk | Samme som over |
| Lusemidler/ naturmangfold | Ingen |
| Torskeoppdrett / naturmangfold | Utfordring koordinert brakklegging ved torskeoppdrett i område med lakseoppdrett |
| Skottelus fra oppdrettstorsk / naturmangfold | Vurdering om spredning av skottelus til vill fisk, inkludert vill laks. |
| Gyting oppdrettstorsk / naturmangfold vill torsk | Avstand gytefelt torsk. Strømforhold. Dersom torsken på lokaliteten skulle rømme eller gyte i merdene vil den kunne påvirke bestanden av villtorsk i området negativt. Oppdrettstorsken er nå 6. generasjon i avlsprogrammet og aktørene mener man har fått kontroll på både kjønnsmodning og rømningsadferd gjennom avlen. I tillegg utsettes kjønnsmodningen gjennom lysstyring. |
| Spredning sykdom og parasitter / (andre akvakulturanlegg) | Anbefalt avstand i retningslinjene. Gruppering av anlegg, strømforhold, koordinert brakklegging. Ikke klart hva som er vurderingskriterier når avstand er mindre enn anbefalt avstand i retningslinjer, og det legges opp til ulike tiltak for å redusere smitterisiko.<br><br>Etablering av nye anlegg ved grensen mellom to produksjonsområder innebærer en uakseptabel risiko for spredning av smitte dersom etableringen fører til økt utveksling av lakselus mellom produksjonsområdene. |
| Partikulært organisk utslipp/ Bunnforhold under eller ved merd | Vurderes for fiskevelferd/-helse for fisk i merden vha informasjon om vannstrøm, bunnforhold, dybde under merden, og b-undersøkelse, C-undersøkelse, miljøundersøkelse.<br><br>Ikke nevnt eksplisitt som vurdert opp mot naturmangfold i det vi har sett. |
| Tareoppdrett | Avstand akvakulturanlegg med fisk. Vurdert at påvirkning på akvakulturanlegg med fisk mer enn 10 km fra lokalitet vil være «ubetydelig». Ingen merknader ellers (inkludert ingen om naturmangfold). |

### 5.4.9 Fylkeskommunen

Ved søknad om tillatelser sender fylkeskommunen som tidligere opplyst søknader til kommuner og sektormyndighetene (Kystverket, Statsforvalteren, Mattilsynet, Fiskeridirektoratet). Fylkeskommunen mottar så resultatene fra kommunal og sektormyndighetenes saksbehandling og foretar en samlet vurdering og fatter vedtak. Der sektormyndigheter med «vetorett» ikke vil godkjenne eller gi tillatelse er det bare for fylkeskommunen å avslå søknaden. Der slike tillatelser er gitt, men andre forhold kanskje taler mot at fylkeskommunen bør gi akvakulturtillatelse, så innebærer det at fylkeskommunen må gjøre vurdering og avveining mellom ulike interesser.

Vi ba fylkeskommuner om å sende oss nylige saker om lokalitetstillatelse, fikk 18 stykker fra ulike deler av landet og gikk gjennom disse. Dette opprinnelige settet med saker hadde ikke søknader om klarering av ny lokalitet. Det var saker om konvertering av utviklingstillatelse, økt MTB på produksjonstillatelse uten at eksisterende lokalitets-MTB ville bli overskredet og tilsvarende. Dette var med andre ord saker som på ulikt vis handlet om endring av en eksisterende tillatelse. Da var mange vurderinger allerede gjort tidligere, og søknadsbehandlingen ble forenklet både mhp kunnskapsgrunnlag og avveininger. Vi hentet inn to saker til, men fikk allikevel et litt begrenset sett med saker. Funnene må derfor tolkes med noe forsiktighet. Tabell med oversikt over sakene er i appendiks. Vi viser her til tabellene under med oppsummering om kunnskapsgrunnlag og vurderinger fra sakene.

Når det gjelder kunnskapsgrunnlaget som fylkeskommunen viser til i sin saksbehandling så varierer det hvor grundig det er beskrevet i vedtakene. Ny kunnskap blir sjeldent hentet av fylkeskommunene og det refereres vanligvis til opplysninger fra sektormyndighetene eller tidligere vurderinger. Disse er ikke gjengitt i vedtaket, men behandlingsdokumenter fra kommunene tyder på at det stort sett er offentlig tilgjengelige kilder som er brukt for å vurdere miljøpåvirkning. Eksempler på slike informasjonskilder er Artsbanken, vannportalen og Fiskeridirektoratet sin kartløsning. I ett av vedtakene ble lokal kunnskap om gyteområder for torsk omtalt.

Kunnskapsgrunnlaget med relevans for miljøforhold som det vises til er av forskjellig type. Det er det som er fra selve søknaden (miljøundersøkelse, strømmålinger, mv.). For søknader om tillatelse for lukket anlegg i sjø og grønne tillatelser kom kunnskapen om hvordan teknologien reduserer miljøpåvirkning i søknadene. Videre er kunnskapsgrunnlaget vurderinger og opplysninger fra andre myndigheter som enten har behandlet denne søknaden (Statsforvalter, Fiskeridirektorat, osv) eller tidligere har vurdert akvakultur på det aktuelle området (kommunal kystsoneplan). Videre er det opplysninger om eksisterende miljøtilstand eller miljørisiko fra Vann-nett eller trafikklyssystemet. Disse kunnskapskildene dekker i ulik grad stressorer, resipient, påvirkningsmekanisme eller andre interesser. Det er også i noen tilfeller oppgitt noen kunnskapskilder som det ikke er mulig å bestemme nærmere hva de omhandler. Det er da brukt generiske beskrivelser som offentlige databaser eller åpne databaser eller lokal kunnskap.

I vedtakene var usikkerheten i kunnskapsgrunnlag i liten grad beskrevet. Konklusjoner var ofte formulert uten forbehold om eventuell kunnskapsmangel eller mulige endringer i miljø («risikoen vurderes som liten», «samlet belastning på miljø blir uendret»). For nye tillatelser var avveining av positive og negative virkninger (og risiko) mer tydelig i vedtakene. Viktige risikofaktorer som er lagt vekt på er mulighet for smitte og rømming fra anlegget, havari og arealkonflikter med fiskere. Særlige forhold, som nasjonal laksefjord-status eller høy tetthet av akvakulturanlegg (Hardangerfjord) gjelder i enkelte området.

Risikoen for negativ påvirkning veies opp mot økonomiske fordeler, økt næringsaktivitet lokalt og bærekraftig utvikling. For eksempel, fylkeskommunen kan være positiv til en ny lukket teknologi selv om den skaper arealkonflikt. Når slike motstridende interesser avdekkes i vurderinger, kan fylkeskommunen gi anbefalinger om hvordan negative effekter skal minimeres. Vedtak kan inneholde en «oppfordring» fra fylkeskommunen til å ta hensyn til naturverdier og andre bruksinteresser. Etter hva som framkom i sakspapirene ble det ikke brukt formelle metoder for avveining av fylkeskommunen, som nytte-kostnadsanalyse eller multikriterieanalyse.

Når det gjelder vedtak om økning av biomasse i grønne produksjonsområder ser det ut til at Fylkeskommunen bruker en standardbegrunnelse knyttet til miljøeffekter: «Det er fastsatt at det skal tillates en økning av tillatelsesbiomassen i de grønne produksjonsområdene. Hensyn knyttet til naturmangfoldloven og miljømessig bærekraft er ivaretatt, jf. Meld. St. 16 (2014-2015)».

Vurdering av konflikter, fordeler, ulemper og fordelingseffekter er avhengig av kontekst og kan være subjektiv. Derfor er det viktig at valgene og prioriteringene er godt beskrevet i saksdokumentene.

*Tabell 5-8. Kunnskapsgrunnlag vist til i fylkeskommunene sin saksbehandling av akvakultursaker.*

| **Kunnskapsgrunnlag** | **Stressor/ miljøhensyn / (annet)** |
|---|---|
| Statsforvalters vurdering om miljø | Forurensing, naturmangfold |
| Fiskeridirektoratet sin vurdering om miljø | Naturmangfold /(fiskeri/areal) |
| Miljøtilstand iflg vann-nett | x/ økologisk vann-tilstand |
| Kystsoneplan | Flere* |
| Fiskeridirektoratet om fiskeri i området | (arealkonflikter fiskeri) |
| B-undersøkelse, strømmålinger, miljøundersøkelse, «registreringer i området» | Forurensing/ naturmangfold |
| Trafikklyssystemet | Lakselus/naturmangfold |
| Kystverkets vurderinger | (arealkonflikter) |
| Søkers beskrivelse av behov for lokalitet (også ved endring areal/lokalitet) | Miljøpåvirkning / (arealbehov og driftsforhold/økonomi) |
| «Offentlige databaser», «åpne databaser», «lokal kunnskap» | ? |

*Tabell 5-9. Vurderinger uttrykt i fylkeskommunene sin saksbehandling av akvakultursaker.*

| **Stressor/ miljøhensyn /(annet)** | **Vurderinger** |
|---|---|
| «Miljømessig forsvarlig» | Basert på informasjon og vurderinger fra Statsforvalter og Fiskeridirektorat.<br><br>Viser til nml krav om økosystemtilnærming og samlet belastning, og hensyn til «biologisk mangfold, økologiske effekter eller naturmiljøet for øvrig».<br><br>Kunnskapsgrunnlag og behov for føre-var tilnærming.<br><br>Vannforekomst miljøtilstand og fare for forringelse, også jf. §12 vannforskrift.<br><br>Verneinteresser. |
| (Areal-interesser) | Søkers behov, andre interesser, verneinteresser |

### 5.4.10 Oppsummert om akvakulturforvaltningen

Her oppsummerer vi funn om praksis for kunnskapsgrunnlag og vurderinger som gjøres av de ulike sektormyndighetene innen akvakulturforvaltningen for vurdering av miljøeffekter.

For **kunnskapsgrunnlag** så er obligatorisk informasjon som skal følge en lokalitetssøknad viktig for alle myndighetene vi har sett på. Dette inkluderer strømmålinger, miljøundersøkelser, og beskrivelse av lokaliteten, inkludert bunnforhold, omsøkt produksjonsvolum og art, og planlagt drift.

Kunnskap om miljøtilstand og miljørisiko for det aktuelle geografiske området mer generelt brukes også av alle myndighetene. Av kunnskap og utførte vurderinger som gjøres og samles inn systematisk inkluderer det klassifiseringer i trafikklyssystemet om lus og villaks, og også luserapporter fra oppdrettsanlegg i det aktuelle området, miljøtilstand og miljømål for vannforekomsten basert på vannforskriften, om naturmangfold fra Naturbase, og geografisk baserte kunnskap og vurderinger fra Havforskningsinstituttets risikorapport for fiskeoppdrett. Videre er det kunnskap om anadrome vassdrag og bestander (avstand og tilstand), inkludert om vandringsruter for smolt i fjordene. I tillegg kommer kartlagte/registrerte gyte-, oppvekst og fiskeområder for marin fisk.

Risikorapporten er også blant kildene som brukes for mer generell kunnskap om sammenhenger mellom stressorer og miljøeffekter. I samme kategori finner vi legemiddelverkets informasjon om miljørisikoer med lusemidler, uavhengige studier om det samme, og kunnskap om mulig påvirkning fra akvakultur på villaks og andre anadrome laksefisk fra Vitenskapelig råd for lakseforvaltning og Havforskningsinstituttet.

Manglende kunnskapsgrunnlag som påpekes er om miljøeffekten av løste næringssalter, om partikulært organisk utslipp på hardbunn, om sårbare arter og habitater, om mulig effekt fra akvakultur på marin fisk, og miljørisiko fra torskeoppdrett.

I økende grad etterspørres kartlegging av sårbare arter og habitater ved lokalitet med ROV i tilknytning til lokalitetssøknader. Det stilles også i en del tilfeller krav om overvåkning på lokaliteten ut over standard-kravene for B- og C-undersøkelser. Dette er da for å styrke kunnskapsgrunnlaget for forvaltningsbeslutninger i driftsperioden. Eksempler vi har sett er makroalge-overvåkning, som er relevant for effekter fra løste næringssalter, spesifikt om overvåkning av kobber i sedimenter der det brukes kobber som antibegroingsmiddel på nett (selv om kobber også er del av C-undersøkelse).

For **vurderinger** som gjøres i akvakulturforvaltningen så er det for de fleste stressorer og myndigheter en betydelig grad av skjønn som legges til grunn. Det er en del bruk av standardiserte indikatorer for å vurdere tilstand på resipienter eller mulig påvirkning fra akvakultur, men dette er begrenset. Statsforvalteren i alle fylkene har en mal for vedtak og vedtaksskriv, og et fast sett med kriterier som belyses, som det ser ut til at alle fylkene jevnt over følger. Mattilsynet har en retningslinje for behandling av lokalitetssøknader som også bidrar til lik behandling på tvers av regioner og søknader. I retningslinjene til Mattilsynet er det anbefalte minsteavstander knyttet til risiko for spredning av sykdom og parasitter, men det presiseres at det må gjøres konkrete vurderinger i hvert enkelt tilfelle. Fiskeridirektoratet forholder seg i stor grad til nærhet/avstand fra lokalitet til gyte-, oppvekst- og leveområder for marin fisk (inkludert reker). Fiskeridirektoratet etterspør i en del tilfeller ekstra undersøkelser. De foreslår også noen ganger stegvis økning i MTB opp til omsøkt biomasse eller mer hyppige miljøundersøkelser enn det som er standard. Også Statsforvalteren kan legge opp til at man opererer med en mindre MTB enn omsøkt for én første generasjon i produksjon. Fylkeskommunen tar nødvendige tillatelser for lokalitetsklarering fra andre myndigheter til orientering, men gjør selvstendige vurderinger for andre forhold. Miljøtilstand i vannforekomsten er viktig i noen tilfeller, særlig der kvaliteten ikke er god. Alle myndighetene gjør sine vurderinger etter de krav som naturmangfoldloven stiller. Disse er i all hovedsak skjønnsbaserte.

## 5.5 Kystsoneplanlegging

### 5.5.1 Kommunal arealplan

Kommunene har etter plan- og bygningsloven (PBL) (LOV-2008-06-27-71) ansvaret for å utarbeide kommunale arealplaner på land og ut til 1 nautisk mil fra grunnlinjen. Disse arealplanene er juridisk bindende for akvakultur, i den forstand at lokaliteter til akvakultur i utgangspunktet må være i områder som er satt av til akvakultur i slike planer, og dersom det er ønske om å etablere en akvakulturlokalitet utenfor slike såkalte A-områder (akvakulturområder) må kommunene gi dispensasjon fra planen. Dette gir kommunene en viktig rolle i fremtidig utvikling av havbrukssektoren. Alle havbruksanlegg ligger i dag innenfor 1 nautisk mil fra kysten, men det er søkt om én lokalitet til havs[9], og et regelverk for havbruk til havs er under utvikling[10].

Kommunen er forpliktet til å ha en kommuneplan som er oppdatert og i samsvar med behovet for planavklaringer. I sjøområdene kan både miljøforhold, aktiviteter og behov endres raskt, og kommunene bør da vurdere endringer i planene. Alle kystkommuner bør derfor ha en arealdel til kommuneplanen der det er gjort en konkret vurdering av arealbruken i kystnære farvann, og foretatt en avveining mellom ulike interesser og hensyn (KMD 2020).

Nesten alle norske kommuner har nå en gjeldende arealplan som dekker sjøarealet, enten i form av en egen kommunedelplan eller som en del av den kommunale arealplanen.

[9] https://www.fiskeridir.no/Akvakultur/Tema/Havbruk-til-havs/klarering-av-lokalitet-for-akvakultur-i-norskehavet, besøkt 30/4-2023

[10] https://www.fiskeridir.no/Akvakultur/Tema/Havbruk-til-havs, besøkt 30/4-2023.

Interkommunale planer har blitt en vanlig praksis og sikrer i større grad en helhetlig og økosystembasert forvaltning, samt bedre tilgang til ressurser og kompetanse for planleggere.

Plan og bygningsloven skal fremme bærekraftig utvikling, samordning, helhetstenkning og medvirkning. Den har som definert formål (§1) å «*fremme bærekraftig utvikling til beste for den enkelte, samfunnet og framtidige generasjoner. Planlegging etter loven skal bidra til å samordne statlige, regionale og kommunale oppgaver og gi grunnlag for vedtak om bruk og vern av ressurser. Planlegging og vedtak skal sikre åpenhet, forutsigbarhet og medvirkning for alle berørte interesser og myndigheter. Det skal legges vekt på langsiktige løsninger, og konsekvenser for miljø og samfunn skal beskrives»*.

PBL har bestemmelser for både statlig, regional og kommunal planlegging, og forholdet mellom dem. Vannforvaltningsplaner, som omtales i neste delkapittel skal vedtas som regionale planer etter PBL. Regionale planer gir føringer for kommunal planlegging og saksbehandling, og kan også gi grunnlag for innsigelser fra fylkeskommunen om forslag til kommunale arealplaner. I tillegg gir særlig «Nasjonale forventinger til regional og kommunal planlegging» føringer. Disse legges fram hvert fjerde år av regjeringen, og skal følges opp i fylkeskommunenes og kommunenes planarbeid, og legges til grunn for statlige myndigheters medvirkning i planleggingen. For akvakultur er det en forventning om at "Fylkeskommunene og kommunene sikrer nok areal til fiskeri- og havbruksnæringen i kystsoneplanleggingen og avveier dette opp mot miljøhensyn og andre samfunnsinteresser" (KMD 2019).

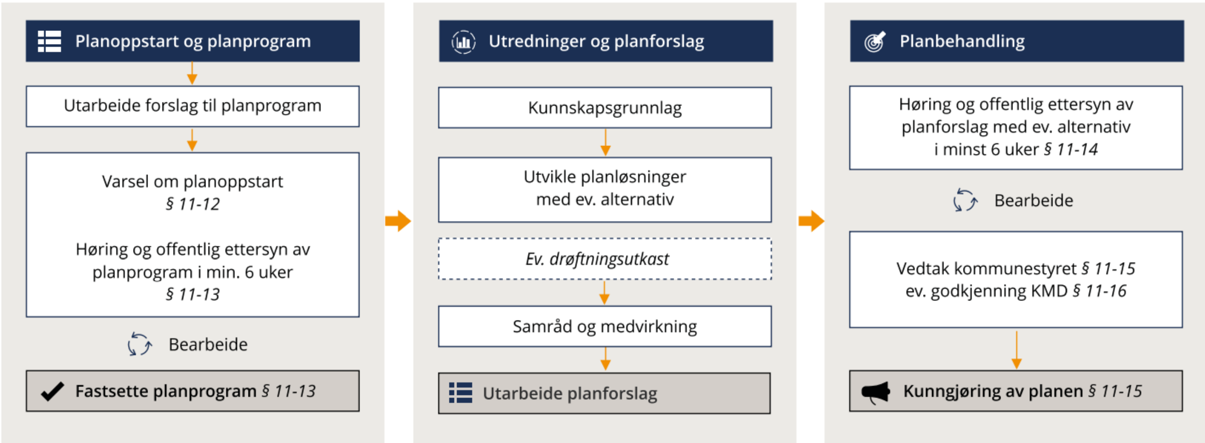
Det er imidlertid en demokratisk prosess og kommunene bestemmer om de vil avsette akvakulturareal i kystsoneplan. Men statlige og andre myndigheter med innsigelsesrett kan varsle eller komme med innsigelser til planforslaget. Innsigelser må løses før planen kan tre i kraft, eventuelt kan planen utenom delene som er berørt av innsigelser tre i kraft. Mer om innsigelser står lenger ned.

Veilederen *Planlegging i sjøområdene* (KMD 2020) gir råd om forvaltningen av kystnære sjøområder ved bruk av plan- og bygningsloven. Den utfyller Rundskriv H-6/18 «Lover og retningslinjer for planlegging og ressursutnytting i kystnære sjøområder» (KMD 2018). Veilederen slår fast at «Plan- og bygningsloven er det viktigste virkemiddelet for å sikre sektorovergripende samfunnsplanlegging med helhetlige løsninger». Veilederen fremmer interkommunal planlegging for å sikre helhetlig vurdering, spesielt når det gjelder areal til akvakultur. Det understrekes at regionale og interkommunale planer vil kunne bidra til tidligere avklaring og avveining i konflikter. Interkommunal samordning kan også gi bedre kystsoneplanlegging, hvor også sjøfartsinteresser, fiskeri- og havbruksinteresser og miljøhensyn kommer sterkt inn, ifølge veilederen.

### 5.5.2 Planprosess og konsekvensutredning

Planprosessen for å lage kystsoneplaner er illustrert i Tabell 5-10.

*Tabell 5-10. Oversikt over den samlede planprosessen for kommuneplan. Kilde: KMD 2022*




Selv om beslutningene er politiske, har krav til planprogram, utredninger, kunnskapsgrunnlag og medvirkning alle som mål å sikre en åpen, kunnskapsbasert og forutsigbar planprosess der alle relevante fakta og interesser er tatt i betraktning. Her står krav til utredning sentralt.

Når det skal lages kommunale arealplaner starter prosessen med å utvikle forslag til *planprogram*. Planprogrammet skal gjøre rede for formålet med planarbeidet, planprosessen med frister og deltakere, opplegget for medvirkning, hvilke alternativer som vil bli vurdert og behovet for utredninger (PBL §4-1). Forslag til planprogram skal ut på høring samtidig med varsling av planoppstart, og vedtas deretter av kommunen. Her beskrives normalt også opplegget for konsekvensutredning, men noen ganger redegjøres det mer i detalj for metode for KU på et senere tidspunkt.

Miljødirektoratet understreker at det er viktig å ha god konsekvensutredning på plass i planprosessen selv for tiltak som videre behandles etter sektorlover. Dette bidrar til å forebygge konflikter tidlig. Dette gjelder for akvakultursaker der den påfølgende behandlingen etter akvakulturloven gir ytterlige avklaringer om mulige miljøpåvirkninger. Konsekvensutredning bør utrede miljøpåvirkningen samt samfunnsmessige konsekvenser av å sette av areal til akvakultur og prinsipielle spørsmål bør da avklares før behandling av eventuelle tillatelser.

For å gjennomføre gode konsekvensutredninger der miljøkonsekvenser er en viktig del, kreves det et solid kunnskapsgrunnlag. Overordnede krav til kunnskap og metoder for konsekvensutredning er gitt i KU-forskriften (FOR-2017-06-21-854), og flere veiledere og retningslinjer er også laget. I det følgende ser vi nærmere på disse kravene og veilederne som gjelder miljøpåvirkning fra havbruk, andre næringer og samlet miljøpåvirkning.

Vurdering og forvaltning av miljøpåvirkning i kystsoneplanlegging er regulert på ulike nivåer (planer og enkelttiltak) og på tvers av flere virkeområder. Plan og bygningsloven setter overordnede prinsipper for prosessen av areal planlegging. Disse prinsippene sikrer åpenhet, forutsigbarhet, samarbeid mellom alle involverte og vurdering av konsekvenser for miljø og samfunn. Ved dispensasjon fra loven og forskriften til loven skal det legges særlig vekt på dispensasjonens konsekvenser for helse, miljø, jordvern, sikkerhet og tilgjengelighet.

Loven inneholder en liste av ulike hensyn i planprosessen, herunder miljømessige, økonomiske og andre ressursrelaterte forutsetninger for gjennomføring. I tillegg skal planleggingen fremme helhet, bygge på økonomiske og andre ressursmessige forutsetninger for gjennomføring, samt ikke være mer omfattende enn nødvendig. Planer skal også bidra til å gjennomføre internasjonale konvensjoner og avtaler innenfor lovens virkeområde. Sistnevnte kan ha betydning for utredning av akvakultursaker siden miljøpåvirkning kan berøre felles økosystemer og bestander (e.g., villaks som er beskyttet gjennom NASCO).

### 5.5.3 Konsekvensutredning

PBL inneholder et krav om utredning av planer og tiltak som har vesentlige virkninger for miljø og samfunn (Kap. 14). Utdypende krav i tråd med EU-direktiv om konsekvensutredning for tiltak er gitt i **KU-forskriften** (FOR-2017-06-21-854). Denne forskriften er det fremste regelverket for hvordan man skal utrede og synliggjære konsekvenser av ny arealbruk og utbyggingstiltak. Formålet med forskriften er å sikre at hensynet til miljø og samfunn blir tatt i betraktning under forberedelsen av planer og tiltak, og når det tas stilling til om og på hvilke vilkår planer eller tiltak kan gjennomføres.

Konsekvensutredning er en systematisk prosess for å utrede (samle inn, fortolke og kommunisere) konsekvensene av beslutninger om arealdisponeringer som kan få vesentlige virkninger for miljø og samfunn (tiltak.no). Forskriften presiserer 18 miljø- og samfunnsmessige forhold som skal vurderes og avveies (§21) (Tabell 5-11). De aller fleste av disse kan være relevante for miljøpåvirkning fra akvakultur eller lignende miljørisiko fra andre menneskelige aktiviteter.

I vurdering av hvordan en plan eller et tiltak kan påvirke miljø eller samfunn, skal det også utredes hvorvidt lokalisering og påvirkning på omgivelsene kan medføre eller komme i konflikt med en rekke andre hensyn, jf. §10 i KU-forskriften. Herunder verneområder, truede arter, forurensning og økt belastning på allerede påvirkede områder. **Samlede virkninger** av planen eller tiltaket sett i lys av allerede gjennomførte, vedtatte eller godkjente planer eller tiltak i et område, samt virkninger over landegrensene skal også vurderes. Naturmangfoldloven prinsipper om økosystembasert forvaltning er også styrende for planlegging og saksbehandling etter PBL, inkludert om økosystemtilnærming og vurdering av samlet belastning.

Ansvarlige myndigheter har en viss fleksibilitet i bruk av kunnskapsgrunnlag, uten at konkrete retningslinjer er gitt: «Ansvarlig myndighet skal, på bakgrunn av høringen og egne vurderinger, ta stilling til om konsekvensutredningen tilfredsstiller kravene i kapittel 5, eller om det er behov for tilleggsutredninger eller ytterligere dokumentasjon.» Planleggere skal også vurdere om det er aktuelt med å inkludere overvåkningskrav i planen «der det er nødvendig».

En konsekvensutrednings innhold og omfang skal etter forskriftens bestemmelser tilpasses den aktuelle planen eller tiltaket. Konsekvensutredningen skal ta utgangspunkt i relevant og tilgjengelig informasjon. Hvis det mangler informasjon om viktige forhold, skal slik informasjon innhentes. Utredninger og feltundersøkelser skal følge anerkjent metodikk og utføres av personer med relevant faglig kompetanse. Ansvarlig myndighet skal også ha tilstrekkelig kompetanse og opptre objektivt. Forskriften konkretiserer ikke hvilke metoder som er ansett å være anerkjente, men metodene og data som er brukt skal beskrives i konsekvensutredning. En konsekvensutredning skal også ha beskrivelse av den nåværende miljøtilstanden og null-alternativet som er bygget på «tilgjengelig informasjon». Usikkerheten i data og metodene skal også formidles.

*Tabell 5-11. Utredningstemaer i KU-forskriftens §21*

| # | Utredningstema |
|---|---|
| 1 | ***naturmangfold, jf. naturmangfoldloven*** |
| 2 | ***økosystemtjenester*** |
| 3 | ***nasjonalt og internasjonalt fastsatte miljømål*** |
| 4 | kulturminner og kulturmiljø |
| 5 | friluftsliv |
| 6 | ***landskap*** |
| 7 | ***forurensning (utslipp til luft, herunder klimagassutslipp, forurensning av vann og grunn, samt støy)*** |
| 8 | ***vannmiljø, jf. vannforskriften*** |
| 9 | jordressurser (jordvern) og viktige mineralressurser |
| 10 | samisk natur- og kulturgrunnlag |
| 11 | transportbehov, energiforbruk og energiløsninger |
| 12 | beredskap og ulykkesrisiko |
| 13 | virkninger som følge av klimaendringer, herunder risiko ved havnivåstigning, stormflo, flom og skred |
| 14 | befolkningens helse og helsens fordeling i befolkningen |
| 15 | tilgjengelighet for alle til uteområder og gang- og sykkelveinett |
| 16 | barn og unges oppvekstvilkår |
| 17 | kriminalitetsforebygging |
| 18 | arkitektonisk og estetisk utforming, uttrykk og kvalitet. |

I tillegg kan nevnes utredningsplikten i Utredningsinstruksen (kapittel 2) – for arealbruk som vedtas av regjeringen eller Stortinget (e.g., overordnet beslutning om større utbygginger). Der kreves det en utredning i form av nytte-kostnadsanalyse (NKA). I en NKA kan også noen økosystemtjenester bli prissatt og brukes som supplerende informasjon i utredningen. Nytte-kostnadsanalyser er ikke pålagt som del av konsekvensutredninger i kommunale plansaker, men NKA fra andre utredninger kan være en del av beslutningsgrunnlaget også for kystsoneplanlegging.

### 5.5.4 Praktisk konsekvensutredning og avveininger

Det finnes flere relevante veiledere for konsekvensutredning på ulike plannivå og for ulike sektorer. ***Veileder om konsekvensutredninger for planer etter PBL*** (KMD 2021) gir veiledning til KU-forskriften.

***Veilederen Konsekvensutredning av arealdelen*** (KMD 2022) redegjør nærmere for hva de enkelte elementene i planprogrammet kan omfatte for å oppfylle kravene til konsekvensutredning. Den legger særlig vekt på kunnskapsgrunnlaget og viser til ulike kilder til informasjon. Den fremmer systematisk arbeid med data og inneholder anbefalinger for hvordan denne jobben kan organiseres: «Et kontrollspørsmål kan være: «Hva må vi vite for å kunne ta stilling til forslag om ny eller endret arealbruk?» For å besvare dette bør man gå gjennom listen over temaer i forskrift om konsekvensutredning § 21 og vurdere hvilke av disse som er relevante, og hvor detaljert temaet må utredes og omtales». Veilederen konkretiserer ikke metoder for avveininger.

**Veilederen *Planlegging i sjøområdene*** (KMD 2020) trekker fram interkommunal planlegging som noe som gir kommunene større kapasitet både økonomisk og personellmessig til å innhente og bearbeide kunnskap ved å gå sammen om en felles planprosess. I likhet med andre veiledere, finnes det ikke noen konkrete regler for avveining av miljøeffektene. Veilederen understrekker at det vil være stor forskjell på hvilke temaer som skal utredes i ulike planer for sjøområder. Det anbefales å gjøre «en bevisst vurdering og prioritering av relevante tema, slik at det ikke brukes unødvendige ressurser på analyser som ikke er beslutningsrelevante.»

Hensyn til villaks, og forebygging av sykdom i oppdrettsnæringen gjennom trafikklyssystemet for lakselus, er eksempler på tema som bør vurderes i en regional og interkommunal sammenheng, ifølge veilederen. Samtidig, anbefales det en lokaltilpasset planlegging i områder med stort arealpress.

Når det gjelder **kunnskapsgrunnlaget**, inneholder veilederen en liste av relevante kilder og refererer til **Miljødirektoratets veileder *Konsekvensutredninger for klima og miljø*** (MDir 2022). Denne er et forsøk å systematisere tidligere retningslinjer og samordne veiledning mellom de ulike sektorene innenfor temaer miljø- og klima. Bl. a., pågår det arbeid med å samordne med Vegvesenets *Håndbok om Konsekvensanalyser V712*, som til tross for å være sektorspesifikk for vegbygning, er mye brukt som veileder også for konsekvensutredning knyttet til kystsoneplanlegging (Sørdahl et al. 2017). Veilederen tar med seg mange av temaene fra *Veilederen Konsekvensutredning av arealdelen* (MD 2012).

Miljødirektoratets nye veileder anses som anerkjent metodikk for utredning av klima- og miljøtemaer. Denne metodikken skal i utgangspunktet brukes for alle planer og tiltak som skal utredes. Øvrige fagtemaer som ikke er dekket av veilederen utredes ved hjelp av andre tilgjengelige veiledere av fagdirektorater.

Veilederen beskriver konsekvensutredningsprosess innenfor hvert tema i flere steg: inndeling i delområder, sette verdi i hvert område (i fysiske enheter, f.eks. mengde utslipp), vurdere påvirkning og konsekvens i delområder og samlet sett, og til slutt, sammenstille vurderinger av ulike typer påvirkninger.

Veilederen gir konkrete kvantitative kriterier når det gjelder vurdering av påvirkning på naturmangfold, landskap, kulturmiljø, friluftsliv, forurensing, klimagassutslipp og vannmiljø. Vurdering av økosystemtjenester er beskrevet (Figur 5-6). I veilederen er det gjort grep for en mer helhetlig vurdering av vann. Vann og vannmiljø inkluderer både naturmangfold og forurensing. Arter i vann og funksjonsområder ligger under tema Naturmangfold. Det er større fokus på forurensing av vann sammenliknet med det man finner i andre veiledere (V712). Vannmiljø bør inngå i supplerende vurdering knyttet til §12 i Vannforskriften og avbøtende tiltak.


*Figur 5-6. Temaer for konsekvensutredning innen miljø- og klima. Kilde: https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/arealplanlegging/konsekvensutredninger/vurdere-miljokonsekvensene-av-planen-eller-tiltaket/*

Når det fastsettes konsekvensgrad for forurensing og andre påvirkninger, gjøres det i forhold til grenseverdier som er gitt i lover, forskrifter og retningslinjer. Det er ikke gitt en veldig streng inndeling av hvordan konsekvens skal vurderes, men det er gitt noen kriterier for hvordan man kan fastsette konsekvens ut ifra hvor omfattende påvirkningen er (for eksempel, hvor mange mennesker som blir berørt eller hvor mye grenseverdier overskrides). Disse kriteriene er gitt i en tabell. Utreder bør bruke faglig skjønn og begrunne valget og konsekvensgraden. Tabell 5-12 viser et eksempel på metodikken for temaet «forurensing av vann».

*Tabell 5-12. Skala og veiledning for konsekvensgrad for vannmiljø jfr. vannforskriften. Kilde: www.miljodirektoratet.no*

| Skala | Konsekvensgrad | Forklaring |
|---|---|---|
| ---- | Svært alvorlig miljøskade | Stor risiko for vesentlig, irreversibel vann-forurensning og forringet tilstand etter vannforskriften |
| --- | Alvorlig miljøskade | Stor risiko for vann-forurensning og forringet tilstand etter vannforskriften |
| -- | Betydelig miljøskade | Risiko for vann-forurensning og forringet tilstand etter vannforskriften |
| - | Noe miljøskade | Noe risiko for vann-forurensning, lite fare for forringelse etter vannforskriften |
| 0 | Ubetydelig miljøskade | Ingen risiko for vannforurensning eller forringelse etter vannforskriften |
| +/++ | Noe miljøforbedring. Betydelig miljøforbedring | Noe forbedring (+) eller betydelig forbedring (++) av vannkvaliteten/tilstand etter vannforskriften |
| +++/++++ | Stor miljøforbedring. Svært stor miljøforbedring | Stor (+++) eller svært stor (++++) forbedring av vannkvaliteten i vassdrag der vannkvaliteten i dag er dårlig/tilstanden i vannforekomstene er moderat eller dårlig jf, vannforskriften |

§ 12 etter vannforskriften er en absolutt skranke, og forringelse tillates i utgangspunktet ikke. Ingen eller liten fare for forringelse er akseptabelt jamfør § 12. Dersom kjemisk tilstand er dårlig, tillates ikke forringelse.

Veilederen anbefaler å gjøre en grundig klargjøring av behovet for utredninger. Utredningskravene bør være konkrete og tilpasset den enkelte plan eller tiltak. Hvis man ikke har vært presis nok, risikerer man å ikke få den kunnskapen man trenger. Den gir anbefalinger om når ulike temaer kan være aktuelt å utrede. For eksempel er naturmangfold og økosystemtjenester aktuelle problemstillinger om hele eller deler av området er naturpreget. Temaene har beslutningsrelevans dersom naturmangfold eller økosystemtjenester av nasjonal eller vesentlig regional interesse i området kan bli negativt påvirket.

Når det gjelder krav til kunnskap, anbefaler veilederen å sjekke at utredningen dekker alle krav til kunnskapsinnhenting og utredninger i plan- eller utredningsprogrammet og kapittel 5 i forskriften. Det skal ikke være et mål å innhente mest mulig kunnskap. Kunnskapen som innhentes skal være fokusert på, tilstrekkelig for og relevant for beslutningen som skal fattes. Kravet til kunnskapsgrunnlaget skal være tilpasset sakens karakter, og risiko for skade på miljøverdiene som berøres. Utredningsmyndighet bør ta utgangspunkt i relevant eksisterende kunnskap i kunnskapsinnhenting, samtidig som det ikke bør brukes utdatert kunnskap.

Andre anbefalinger angående kunnskap og metode i veilederen:

- Konsekvensutredning må beskrive hva som er gjort og hva som ikke er gjort. En god konsekvensutredning skal gjøre det mulig for høringsinstansene å vurdere kvaliteten.

- Konsekvensutredning må beskrive hvor kunnskapen kommer fra, og kvaliteten på datamaterialet. Årstall for siste kartlegging og kilden til registreringene er eksempel på informasjon som kan belyse kvaliteten på datamaterialet.
- Utredningen skal inneholde en liste med opplysninger om de kildene som er brukt i beskrivelser og vurderinger i rapporten.
- Utredningen skal si noe om hvordan man har funnet opplysningene, altså hvilken metode som er brukt. Der det er brukt anerkjent metodikk, skal det henvises til dette. Der det er gjennomført feltarbeid, vil værforhold og lengde på feltarbeid være eksempler på relevante opplysninger. Med lengde på feltarbeid menes både tid og befaringsrute.
- Det må også gå fram hvordan opplysningene er satt sammen og hvordan de eventuelt er vektet eller avveid.
- Hvilke vurderinger som er lagt til grunn for verdisetting, påvirkning og konsekvens skal synliggjøres, sånn at det er tydelig hvordan man kom fram til resultatet. Se forskriften § 22.
- Det er viktig at plan- eller utredningsprogrammet er tydelig på at usikkerhet knyttet til kunnskapsgrunnlag og vurderinger skal komme fram i en konsekvensutredning.
- Konsekvensutredningsrapporten skal utarbeides av personer med relevante og tilstrekkelige faglige kvalifikasjoner på det aktuelle fagfelt. Dette inkluderer undersøkelser i felt, og tolkning og vurdering av foreliggende materiale.
- Ved innhenting av ny kunnskap bør metodene av sentrale myndigheter følges
- Ansvarlig myndighet må stille krav om kompetanse når de leier inn konsulenter til å gjennomføre utredninger; forsikre seg om at den som utfører utredningene har relevant faglig kompetanse;
- Det er ofte en fordel om utredningene gjennomføres av et tverrfaglig miljø.
- Felles steg i metodikken er samlet vurdering og sammenstilling av resultater, og her skal avveining på tvers av ulike typer påvirkninger vurderes. Veilederen presenterer metode for sammenstilling i en tabell (Tabell 5-13).

*Tabell 5-13. Kilde: www.miljodirektoratet.no*

Tabell: Sammenstille konsekvenser for alle klima- og miljøtema

| | Alternativer | Nullalternativet | Et eller flere alternativer | | |
|---|---|---|---|---|---|
| Vurderinger av konsekvens | | | Alternativ A | Alternativ B | Alternativ C |
| Klima- og miljøtema | Naturmangfold | 0 | Svært stor negativ konsekvens | Stor positiv konsekvens | |
| | Friluftsliv | 0 | Svært stor negativ konsekvens | Positiv konsekvens | |
| | Landskap | 0 | Stor negativ konsekvens | Ubetydelig konsekvens | |
| | Kulturmiljø | 0 | Middels negativ konsekvens | Noe negativ konsekvens | |
| | Forurensning | 0 | Noe negativ konsekvens | Stor negativ konsekvens | |
| | Klimagassutslipp | 0 | | | |
| Supplerende vurderinger | Begrunne vektlegging av temaene | | | | |
| | Andre avveininger | | | | |
| | Vannmiljø | | | | |
| Evt Rangering | Rangering | | | | |
| | Begrunnelse for rangering | | | | |

Det understrekes at selv om metoden er den samme for alle, styrer faglig skjønn vesentlig del av sammenstillingsarbeid. Veilederen er avgrenset med klima- og miljøtema og bør suppleres med utredninger av andre relevante temaer. Samlet konsekvensgrad for hvert alternativ skal settes, men det finnes i dag ingen konkret veiledning på det.

**Det gis ingen konkrete retningslinjer om hvordan prioriteringer mellom ulike hensyn skal gjøres og hvilken kunnskap som skal innhentes for å begrunne den**. Loven legger mest vekt på å beskrive organisering av planprosess og ansvarsområder, og av forvaltningsorganer og andre involverte aktører. Derfor krever loven at det skal fremgå av saksframlegget eller begrunnelsen for vedtak hvordan virkningene av planforslag eller søknad og innkomne uttalelser har vært vurdert, og hvilken betydning disse er tillagt ved vedtaket, særlig når det gjelder valg av alternativer.

### 5.5.5 Innsigelser og deltagelse fra andre myndigheter i planleggingen

Kommunene er de som vedtar kystsoneplaner for sine sjøområder, men flere andre myndigheter spiller viktige roller i kystsoneplanleggingen. Statlige myndigheter har rett og plikt til å delta i planleggingen. Statlige og andre myndigheter med innsigelsesrett kan varsle og levere *innsigelse* til et forslag til kommunal arealplan (som en kystsoneplan er), knyttet til områder de har ansvar for.

Berørt statlig fagmyndighet/sektormyndighet, som Statsforvalter, NVE, fiskeridirektoratet, og fylkeskommune kan fremme innsigelse i spørsmål som er av «nasjonal eller vesentlig regional betydning, eller som av andre grunner er av vesentlig betydning for vedkommende organs saksområde» (KMD 2014). Andre kommuner kan fremme innsigelse når det er av «vesentlig betydning for kommunens innbyggere, for næringslivet eller natur- eller kulturmiljøet i kommunen, eller for kommunens egen virksomhet eller planlegging». Sametinget kan fremme innsigelse for saker av vesentlig betydning for samisk kultur eller næringsutøvelse. Vi ser at flere av disse klart kan være knyttet til miljøpåvirkning fra akvakultur. Retningslinjer for innsigelse i plansaker etter PBL (KMD 2014) inneholder også et vedlegg som nærmere klargjør hvilke myndigheter som har innsigelsesrett for hvilke temaer. På nettsiden for retningslinjene er vedlegget oppdatert per januar 2021. Tekstboks under viser et utdrag av myndigheter med innsigelsesrett for tema som særlig kan være relevante for havbruk etter vår vurdering.

**Tekstboks: Oversikt over myndigheter med innsigelseskompetanse i plansaker etter plan- og bygningsloven** (utdrag av de særlig relevant for havbruk etter vår vurdering)

(KMD 2014, fra vedlegg oppdatert per januar 2021)

**Andre kommuner**: Saker av vesentlig betydning for kommunen.

**Statsforvalterne**: Forurensning herunder støy, lokalluft og klima, vannmiljøkvalitet, naturmangfold, landskap, friluftsliv, strandsone, samordnet areal- og transportplanlegging (..). Folkehelse herunder miljørettet helsevern.

**Fylkeskommunene**: Kulturmiljø, friluftsliv, samordnet areal- og transportplanlegging, regional plan eller planstrategi. Havbruksinteresser, akvakultur.

**Fiskeridirektoratet**: Fiskeri, tang- og tarehøsting (NFD)

**Forsvarsbygg**: Forsvarets interesser.

**Kystverket**: Havne- og farvannsforvalting, havner, kaianlegg, utnyttelse av sjøområder, sjøtransport.

**Mattilsynet**: Fiskehelse og fiskevelferd.

**Riksantikvaren**: Kulturmiljø.

**Sametinget:** Samiske kulturmiljøer. Samisk kultur og næringsutøvelse.

Før det eventuelt kan komme til en innsigelse må myndighetene ha vært involvert i planprosessen. Forslag til *planprogram* skal ha vært sendt på offentlig høring, og er normalt oppe i *regionalt planforum*. Gjennom møter i regionalt planforum skal statlige, regionale og kommunale interesser klarlegges og forsøkes samordnet i forbindelse med utarbeidelse av regionale og kommunale planer. Planprogrammet skal presentere formål med planen, samt opplegg for planprosess og utredninger. Også konsekvensutredninger og forslag til arealplan presenteres og diskuteres normalt i regionalt planforum. Alt dette betyr at den samlede kunnskap og de vurderinger som relevante statlige og regionale myndigheter har kan bli spilt inn til og bli inkludert i arbeidet med en kommunal kystsoneplan.

Når en innsigelse først varsles må kommunen som har laget planforslaget og det organet som har levert innsigelse møtes for å se om de kan komme til enighet. Kan planforslaget justeres, eller er noen på en eller annen måte villige til å gi seg. Dersom ingen vil gi seg går innsigelsen til ansvarlig departement for plan- og bygningsloven (kommunal og regionaldepartementet) for avgjørelse. Selv om kommunen skulle vedta planforslaget, vil ikke delen det er levert innsigelse på være gyldig før departementet har behandlet innsigelsen og gitt kommunen medhold. Dersom departementet støtter innsigelsen, vil den aktuelle delen av planen ikke være gyldig.

### 5.5.6 Miljøkrav til akvakultur i kystsoneplaner

Plan og bygningsloven (§11-9) åpner for at kommunene kan stille krav om miljøkvalitet knyttet til bruk av arealene det planlegges for. Om og hvilke spesifikke miljøkrav som eventuelt kan stilles til akvakultur i kystsoneplaner er imidlertid ikke fullt ut avklart (Myklebust 2018a). Noen kommuner har i forslag til kystsoneplaner stilt særlige miljøkrav til akvakultur i kystsoneplanen, og/eller hatt at reguleringsplan skal være nødvendig for nye akvakulturlokaliteter (Stokke 2017, Myklebust 2018a, Hovland 2021).

Osterøy kommune stilte i kystsoneplan krav om at oppdrettsanlegg i en spesifikk fjord i kommunen måtte være tilnærmet utslippsfrie (Stokke 2017). Fylkeskommunen varslet innsigelse på dette, men trakk etter hvert kravet. Akkurat denne spesifikke fjorden hadde dårlig miljøforhold med lavt oksygennivå. I og med at fylkeskommunen ikke sto på innsigelsen fikk vi ikke en mer prinsipiell avgjørelse i departementet. I saker hvor det er levert innsigelse og kommunen og innsigelsesmyndigheten ikke klarer å løse den gjennom forhandlinger går jo saken til Kommunal og regionaldepartementet for endelig avgjørelse (som ansvarlig departement for plan og bygningsloven).

Alta, Skjervøy, Karlsøy og Tromsø kommuner har også på ulike vis forsøkt å stille miljørelaterte krav til akvakultur (Stokke 2017, iLaks[11]). Men som det er redegjort for tidligere i dette del-kapitlet så er det anbefalt i veileder for planlegging i sjø at slike miljøkrav ikke stilles i kommunal kystsoneplanlegging, men at det overlates til sektormyndighetene for akvakultur å vurdere dette.

Veilederen Planlegging i sjøområdene (KMD 2020) presiserer når det bør utarbeides reguleringsplaner, som for havneområder, moloer, utbedring av farleder, deponier og utfyllinger i sjø og andre tiltak som har stor påvirkning på omgivelsene. Det kan også brukes reguleringsplan for å ivareta særlige hensyn til naturmiljø, friluftsliv og kulturminner. Det vises imidlertid til rundskriv H-6/18 som sier at kommunene bør være tilbakeholdne med å benytte reguleringsplaner for akvakultur i sine arealplaner, fordi kommuneplanen og påfølgende behandling etter akvakulturloven gir nødvendige avklaringer. Fylkeskommunen samordner og behandler akvakultursøknadene etter sektorregelverket der det vil stilles krav til miljøkvalitet, drift og teknologi.

[11] «Droppet kravet om lukkede anlegg i Tromsø», iLaks, 1/4-2019, https://ilaks.no/droppet-kravet-om-lukkede-anlegg-i-tromso-vi-har-ikke-snudd-sier-aps-gruppeleder/, besøkt 30/4-2019

I forslag til Kystsoneplan for Tromsø-regionen som ble sendt på høring i desember 2021 var det lagt inn både nullutslipp som krav for flere foreslåtte akvakulturområder, og krav om reguleringsplan før lokalitet kunne tildeles. Et krav om reguleringsplan gjør at kommunen får en annen rolle for vurdering av konsekvenser av en konkret lokalitetssøknad, og også en tilnærmet veto-rett over avgjørelsen om faktisk bruk av området til akvakultur. Der det i kystsoneplanen er avsatt akvakulturareal og en lokalitetssøknad gjelder et slikt området så er kommunen kun høringsinstans på lokalitetssøknaden. Da kan fylkeskommunen vedta på tvers av kommunens høringsuttalelse til lokalitetssøknaden.

Gjennom planprosessen for kystsoneplanen kom det innspill og innsigelser knyttet til disse forslagene om akvakulturområder. Til slutt ble kravet om reguleringsplan for akvakultur fjernet av kommunen, men de valgte å beholde nullutslippskravet for akvakulturområder, og utfordrer dermed Statsforvalterens innsigelser. Imidlertid ble antall akvakulturområder redusert fra de foreslåtte 25 i høringsutkastet til 14 i endelig forslag fremmet til kommunestyre-behandlinger. Reduksjonen var begrunnet i at de var i konflikt med andre næringer, naturmangfold, miljø, bolyst og friluftsliv. Det var altså ikke bare rene miljøhensyn, selv om miljøeffekter fra akvakultur også indirekte kan gi konflikter med f.eks. andre næringer og bolyst.

#### 5.5.7 Kunnskapsgrunnlag og vurderinger om akvakultur og miljø i kystsoneplanlegging

I kystsoneplanleggingen er det særlig knyttet til konsekvensutredning av foreslåtte akvakulturområder at et systematisk kunnskapsgrunnlag om mulige miljøeffekter av akvakultur frambringes og brukes. Vurderinger og avveininger skjer imidlertid på flere punkter i arbeidet med å lage en kystsoneplan (Mikkelsen m.fl. 2022). Selve konsekvensutredningen skal være en faglig utredning, og administrasjonen (eller den de har satt på oppgaven) skal gi sin anbefaling som en del av konsekvensutredningen. Når det så lages et endelig planforslag og saksframlegg til kommunestyret som skal vedta planen hender det noen ganger at det gjøres andre vurderinger enn det som lå direkte i KU-en. Dette kan da være basert på innsigelser og andre innspill. Til slutt er det de vurderinger som kommunestyrets medlemmer gjør, og som samlet blir uttrykt gjennom avstemning over vedtak om planen.

Kunnskapsgrunnlag og vurderinger for to interkommunale kystsoneplaner i Troms som ble fullført i 2015 ble undersøkt av Mikkelsen m.fl. (2022). Disse to planprosessene ble ansett som tilnærmet beste praksis for metode og kunnskapsgrunnlag for konsekvensutredning. Den ene KU-prosessen var drevet av et konsulentselskap som har bistått mange kommuner med kystsoneplanlegging. Den andre var støttet av fylkeskommunen både med midler og kompetanse, og hadde en grundig prosess med å utvikle KU-metodikken og for å forsøke å samkjøre hvordan saksbehandlere fra de ulike kommunene gjorde sine konkrete vurderinger av de foreslåtte akvakulturområdene.

Gjennomgangen viste at det var et bredt **kunnskapsgrunnlag** som var brukt i begge prosessene, og at det var ganske likt (Mikkelsen m.fl. 2022). Nasjonale databaser/registre var det som var nevnt flest ganger i metodebeskrivelsene for konsekvensutredningene for de to planprosessene. Deretter kom tekniske rapporter og innspill fra eksperter, samt folkemøter eller innspill fra spesifikke interessent-grupper. En svakhet var imidlertid at oversikten bare viste navnet på datakilden, og ikke nøyaktig hvilke data som er brukt. Flere ganger ble større databaser med svært mange datasett nevnt, men det ble ikke angitt hvilke(t) datasett som var brukt i konkrete vurderinger. Det samme gjaldt i mange tilfeller når folkemøter og informasjon fra interessenter eller fra eksperter var oppgitt som kunnskapskilde. KU-ene var ofte lite klare på nøyaktig hva slags kunnskap dette ga, og heller ikke på hvordan kunnskapen hadde inngått i vurderinger.

Mikkelsen m.fl. (2022) har for de ulike kunnskapskildene vurdert i detalj hva slags type kilde det er, om det er nasjonalt verifiserte data, om det er kvantitative data, om det representerer lokal kunnskap, og om det er produsert i planprosessen eller uavhengig av den. Poenget med det siste er at kunnskap produsert direkte knyttet til planprosessen potensielt kan være framstilt strategisk for å påvirke utfallet av konsekvensutredning og vurderinger i planprosessen. Det betyr ikke nødvendigvis at kunnskapen ikke er troverdig, for det avhenger av hvordan den er produsert, men det kan innebære et skjevt utvalg av kunnskap. På den andre siden kan det være helt nødvendig å samle inn kunnskap gjennom planprosessen for å kunne få et riktig bilde.

I prosjektet her har vi studert prosessen for **ny kystsoneplan for Tromsø-regionen**. Denne planprosessen startet opp i 2018, og planen ble vedtatt sent i 2022. Planen gjelder for 2023-2033. Tabell 5-15 gir en tidslinje over planprosessen. Tabellen viser også at det er mange punkter i prosessen hvor det spilles inn faktisk kunnskap eller om kunnskapsgrunnlaget (se «kunnskapsgrunnlag» i kommentar-kolonnen). Det er også flere punkter hvor kunnskapen brukes til å vurdere virkninger av planen og avveie mellom ulike interesser (se «vurdering» i kommentar-kolonnen.
Metodikk for konsekvensutredning og planprosess for Kystplan for Tromsø-regionen har mange likhetstrekk med de planene som Mikkelsen m.fl. (2022) så på, særlig kystsoneplanen for Midt- og Sør-Troms. Kunnskapsgrunnlaget er svært likt. Oversikt over kunnskapskildene for Tromsø-regionen slik de var presentert i et eget notat om metode for konsekvensutredning er i Tabell 5-14. Originaldokumentet inneholder også hyperlenker til flere av kildene.

Det er som sagt et omfattende kunnskapsgrunnlag som er brukt. **Etter naturmangfoldloven skal det gjøres en egen vurdering av kunnskapsgrunnlaget** som del av planleggingen og konsekvensutredningen. Dette er gjort i planbeskrivelsen, og konklusjonen er at ««*er tilstrekkelig som kunnskapsgrunnlaget i forhold til sakens karakter og risiko for skade på naturmangfoldet», og å «være god nok for kommuneplannivået*». Det konkluderes at «*saken er tilstrekkelig opplyst, jf. naturmangfoldsloven § 8. Føre-var-prinsippet kommer derfor ikke til anvendelse, jf. naturmangfoldsloven § 9*».

For ett område ble det allikevel levert innsigelser fra Statsforvalteren knyttet til manglende kunnskapsgrunnlag, og det var for konsekvensutredningene for foreslåtte akvakulturområder for taredyrking. Anlegg for taredyrking ble vurdert å kunne komme i konflikt med nasjonale eller vesentlige regionale miljøverdier, og det ble stilt krav om kartlegging av naturtyper før lokaliteter kan avsettes.

*Tabell 5-14. Kunnskapskilder for konsekvensutredning for Kystsoneplan for Tromsø-regionen 2023-2032. Kilde: Tromsø-områdets Regionråd (2021).*

| **TEMA** | **KUNNSKAPSKILDER** |
|---|---|
| SÅRBARE VERDIER | |
| Naturvernområder, eksisterende og planlagte | Miljødirektoratet Naturbase, Miljøstatus, Nordatlas.no og Yggdrasil, Fiskeridirektoratets karttjeneste |
| Naturmangfold, som viktige naturtyper, prioriterte, freda-, og trua arter | Miljødirektoratet Naturbase, Kartlegging av marine naturtyper, Norsk Rødliste for naturtyper 2018, Norsk Rødliste for arter 2015, Artsdatabanken.no, MAREANO, Forsvarsbygg.no, lokale fiskere, Havforskningsinstituttet https://dugnadforhavet.no/ |
| Anadrom laksefisk | Lakseregisteret, fylkesmannen + lokalkunnskap, vitenskapelige råd for lakseforvaltning, stroms.no stromkatalogen.hi.no |
| Gyte- og oppvekstområder for marin fisk | Yggdrasil, Fiskeridirektoratets database, lokale fiskerlag, m.m. |
| Forurensning, vannmiljø | Vann-nett.no, Miljøstatus.no, lokal kunnskap. Vannmiljø (Miljødirektoratet), B- og C-undersøkelser. |
| Støy- og lysforurensning | Lokal kunnskap, veileder til retningslinje for behandling av støy i planlegging (M-128), Retningslinjer for støy i arealplanlegging (T-1442, FHI) |
| Kulturminner og kulturmiljø, samisk kulturgrunnlag | Riksantikvaren, Askeladden.ra.no, Nordatlas.no, kulturminnesok.no, innspill fra folkemøter og andre lokale innspill, kulturminneplaner, kommunens reguleringsplaner.<br>Marine kulturminner: Tromsø museum og Troms fylkeskommune. Nasjonalt viktige kulturlandskap (KULA) |
| Friluft og friluftsliv. Strandsone | Kommunal plan, innspill fra folkemøter, Ishavkysten friluftsråd, FNF i Troms og Finnmark, Nordatlas.no, Naturbase.no, mfl |
| Reindrift | Reindrift.no, NIBIO Kilden, lokal kunnskap |
| NÆRINGSAKTVITET OG OFFENTLIGE INTERESSER | |
| Fiskeri | Yggdrasil, Fiskeridirektoratets database, lokalkunnskap |
| Lokalt og samisk naturgrunnlag/sjølaksefiske/ fritidsfiske/turistfiske | Yggdrasil, Fiskeridirektoratets database, Lakseregistret, lokalkunnskap, appen: fiskher, Havforskningsinstituttet https://dugnadforhavet.no/ |
| Havbruk | Yggdrasil, Fiskeridirektoratets databaser, Stroms.no, Mattilsynets retningslinjer |
| Reiseliv | NHO reiseliv, Visit Tromsø, lokalkunnskap |
| Næringsliv og sysselsetting, konkurranseforhold | Lokal kunnskap, næringsplaner. Grus- pukk og Mineralressurser (NGI) |
| Teknisk infrastruktur, transportbehov | Lokal kunnskap, kommunale planer |
| Havner, farled, hvit sektor | Kystinfo.no, Havbase.no, Kystdatahuset.no |
| Forsvaret | Nordatlas.no, forsvarsbygg.no |
| Forholdet til kommuneplanen/annen utviklingsstrategi | Egne planer: kommuneplan, næringsplan osv. |
| En bærekraftig Tromsø-region | Kommunenes samfunnsplan definerer bærekraft for den enkelte kommune |

*Tabell 5-15. Tidslinje for Kystplan for Tromsø-området 2018->, med kommentarer*

| Tidspunkt | Hva | Kommentar |
|---|---|---|
| 2018-09 | Kommunene enige om å gjøre rullering | |
| 2019-03 – 2019-06 | Formelle vedtak i kommunene om rullering | |
| 2019-07 | Søknad om prosjektmidler sendt fylkeskommunen | |
| 2020-01 | Prosjektleder ansatt | |
| 2020-04 | Møte Regionalt planforum | Kunnskapsgrunnlag, vurdering. Samordning mot planer, nasjonale føringer mv. |
| 2020-06-05 | Forslag planprogram lagt ut til offentlig ettersyn, og planoppstart varslet og vedtatt i kommunene | Kunnskapsgrunnlag |
| 2020-06 | Digitalt folkemøte | Kunnskapsgrunnlag |
| 2020-08-31 | Forslag Planprogram høringsfrist | Kunnskapsgrunnlag |
| 2020-09 | Merknadsbehandling Planprogram-forslag | Kunnskapsgrunnlag |
| 2020-09 | Planfase oppstart | |
| 2020-11 | 17/11: Åpent møte om Kunnskapsstatus<br>18/11: Innspillsmøte for strukturert lokaliseringsprosess | Kunnskapsgrunnlag |
| 2021-01-28 | Møte ressursgruppe sjømat | Kunnskapsgrunnlag |
| 2021-02-02 | Møte ressursgruppe reiseliv, friluftsliv, strandsone | Kunnskapsgrunnlag |
| 2021-02-09 | Særmøte Fiskeri – Ressursgruppe sjømat | Kunnskapsgrunnlag |
| 2021-02-09 | Særmøte marine arter og fangstbasert akvakultur – Ressursgruppe sjømat | Kunnskapsgrunnlag |
| 2021-03-01 | Særmøte Reiseliv | Kunnskapsgrunnlag |
| 2021-03-03 | Møte ressursgruppe reiseliv, friluftsliv, strandsone | Kunnskapsgrunnlag |
| 2021-03-04 | Særmøte fiskeri Karlsøy | Kunnskapsgrunnlag |
| 2021-05 | Notat med oversikt innspill fra utviklingslag, grunneierlag mv, etter dialogmøter, innspills- og medvirkningsrunde i perioden november 2020 – mai 2021 | Kunnskapsgrunnlag |
| 2021-09-02 | Planprogram i endelig versjon etter vedtak i kommunene | |
| 2021-09-09 | Notat KU metode | Kunnskapsgrunnlag, vurderingsmetode |
| 2021-11-11 | Møte i Regionalt planforum | Kunnskapsgrunnlag, vurdering. Samordning mot planer, nasjonale føringer mv. |
| 2021-11-12 | Planbeskrivelse utkast | |
| 2021-12-08 | Konsekvensutredning ferdig | Kunnskapsgrunnlag, vurdering |
| 2021-12-10 | Planforslag høring startet | Kunnskapsgrunnlag |
| 2022-01 | Folkemøter med presentasjon av planforslaget i kommunene | Kunnskapsgrunnlag |
| 2022-02-18 | Planforslag høringsfrist (fra 2021-12-10). Kom inn 109 innspill | Kunnskapsgrunnlag |
| 2022-03-09 | Møte fylkeskommunen om innsigelser | Kunnskapsgrunnlag |
| 2022-04-07 | Møte Avinor om innsigelser | Kunnskapsgrunnlag |
| 2022-04-20 | Møte Mattilsynet om uttalelse fra dem | Kunnskapsgrunnlag |
| 2022-05-09 | Møte Fiskeridirektoratet og Sametinget om innsigelser | Kunnskapsgrunnlag |
| 2022-05 /06 | Informasjonsmøte og formell konsultasjon med samiske parter: BIVSU – organisasjon for fiskere i sjøsamisk område | Kunnskapsgrunnlag |
| 2022-06/08 | Informasjonsmøte og formell konsultasjon med samiske parter: Reinøy reinbeitedistrikt | Kunnskapsgrunnlag |
| 2022-08-23 | Tilleggshøring og offentlig ettersyn – innspill nye lokaliteter akvakultur tare. Frist høring 4/10-2022 | Kunnskapsgrunnlag |

| | | |
|---|---|---|
| 2022-10 | Endelig forslag til kystsoneplan fra administrasjon/ prosjektleder klart for politisk behandling i kommunene | Vurdering |
| 2022-11-23 – 2022-12-11 | Kystsoneplan vedtas i kommunene (behandling i komiteer før endelig vedtak i kommunestyrene) | Kunnskapsgrunnlag, vurdering |
| 2022-12-09 | Kystsoneplan i siste versjon | |
| Etter kommunestyre-behandling | Det er knyttet uløste innsigelser til deler av planen. Gjelder fire akvakulturområder. Plan ikke gyldig for disse områdene. Avventer vedtak om innsigelsene fra KMD. | |

**Oppsettet for konsekvensutredningen** for hvert foreslått akvakulturområde i KU for Tromsø-området er også ganske likt med det som var brukt i kystsoneplanen for Midt- og Sør-Troms som Mikkelsen m.fl. (2022) studerte. For hvert tema for utredning vurderes «verdi» på det som kan bli påvirket av etablering og drift av akvakultur på en ordinal skala, deretter vurderes «omfang» - altså mulig påvirkning fra akvakultur, og så ses verdi og omfang i sammenheng for å konkludere om «konsekvens». Se eksempel i Figur 5-7.

I tillegg til den ordinale tall-vurderingen for *Verdi*, *Omfang* og *Konsekvens* gis det en kort verbal beskrivelse av *Nåværende status*, og *Vurdering av konsekvenser* for hvert tema. I eksempelet i Figur 5-7 under framgår det ikke klart hvilke vurderinger som er gjort for å lande på en tallverdi i vurderingene, og det samme gjelder for andre foreslåtte akvakulturområder og temaer i konsekvensutredningen.

Det ble imidlertid laget et eget metode-notat om hvordan verdi, omfang og konsekvens skal settes/vurderes for hvert tema i konsekvensutredningen (Tromsø-områdets Regionråd 2021). Her er det kvantitative eller klare kvalitative kriterier for noen av dem, men også skjønnsmessige kriterier for flere av dem, slik oversikten i Tabell 5-16 viser. For noen vurderinger kan det være noen klare kriterier, gitt at spesielle forhold er oppfylt, men ellers behov for skjønn. Disse er i tabellen markert enten med K/S eller S/K, ut fra hva som ser ut til å dominere av skjønn eller klare kriterier. Vi ser at det er mest klare kriterier for det å sette Verdi, mens når Omfang skal bestemmes så er det skjønn som dominerer, og for vurdering av Konsekvens er det kun ett eneste tema som har klare kriterier, og det er Havbruk. For den hovedgruppen av tema som er mest relevant for miljøeffekter (*SÅRBARE VERDIER*), så finner vi at klare kriterier dominerer over skjønn, mens det er motsatt for hovedgruppen *NÆRINGSAKTIVITET OG OFFENTLIGE INTERESSER*.

Det varierer hvor klart de skjønnsmessige vurderingene er beskrevet i KU for hvert akvakulturområde. Skjønnsmessige vurderinger vil være vanskelige å unngå. For at både politikere, interessenter og befolkningen ellers skal kunne forstå og ha tillit til vurderingene er det viktig at de beskrives godt nok, slik Mikkelsen m.fl. (2022) påpeker. De skjønnsmessige vurderingene bør beskrives så utfyllende at det er mulig å se at like tilfeller vurderes likt. Det er en forventning om at like tilfeller skal behandles likt – at det skal være konsistens i vurderinger. Da bør det også være mulig å se i størst mulig grad hvordan vurderinger er gjort.

Det er tidligere funnet tilfeller av svak sammenheng mellom faktiske vurderinger (score) i konsekvensutredningen for ulike temaer for noen akvakulturområder og den verbale oppsummeringen av KU for akvakulturområder, og også at det har vært systematisk skjevheter i oppsummeringene (Mikkelsen m.fl. 2022). De verbale oppsummeringene er trolig spesielt viktige for kommunepolitikerenes beslutninger og publikums oppfatning om konsekvensene av å etablere akvakultur, siden de vanligvis vil kjenne de individuelle tilfellene dårligere enn de som har gjennomført konsekvensutredningene. Derfor bør det prioriteres høyt å kvalitetssikre oppsummeringene. Vi har ikke kunnet gå gjennom oppsummeringene for Tromsø-områdets KU systematisk og sammenligne med score på hvert tema, men stikkprøver indikerer bra sammenheng.

Når det gjelder de samlede vurderingene for alle tema og konklusjonene som gjøres som del av konsekvensutredningene for de enkelte foreslåtte akvakulturområder, så er det tidligere funnet at konsistensen i vurderinger mellom ulike A-områder og mellom kommuner kan variere mye (Mikkelsen m.fl. 2022). Dette har vi ikke kunnet undersøke systematisk for kystplan for Tromsø-området innenfor dette prosjektet.

Gjennom planprosessen har **antallet akvakulturområder** som har vært vurdert og anbefalt blitt færre, slik en kunne forvente. I en oversikt fra januar 2021 er det 42 områder som havbruksaktørene har foreslått skal tas inn i planen. Etter videre prosess blir det 41 som går til konsekvensutredning: 26 nye lokaliteter for laksefisk, 9 for fangstbasert akvakultur eller oppdrett av marine arter, og endring av 6 eksisterende akvakulturområder.

Når planutkast går til høring i november 2021 har det blitt 18 nye områder til «alle arter», 5 nye områder til arter utenom anadrom laksefisk, ett område til ikke-intensivt oppdrett (ikke fôring eller medisinering), og ett til fangstbasert oppdrett. For å ta hensyn til ny teknologi og nye typer produksjonssystemer så settes det også av tre områder til havbruk i eksponert farvann utenfor kysten, to områder med bestemmelser om at det skal være nullutslipp av organiske partikler, og fire områder med bestemmelse om tilnærmet nullutslipp av organiske partikler. For sju eksisterende lokaliteter foreslås det å åpne for utvidelser, justeringer eller endret lokalisering. Med argumentasjon om at nye lokaliteter vil kunne få vesentlige virkninger for miljø og samfunn foreslås det å stilles krav om reguleringsplan for alle nye lokaliteter.

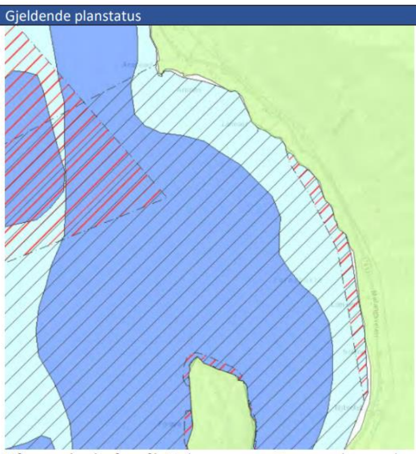
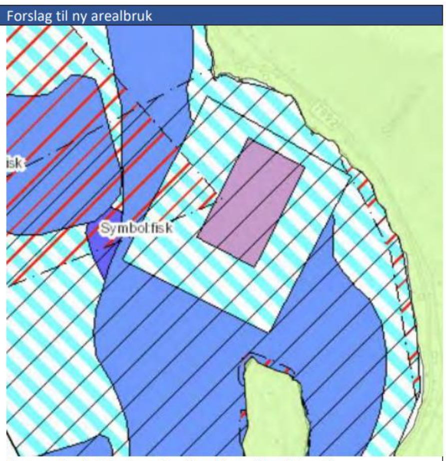
Etter møte i Regionalt planforum og annen dialog med sektormyndigheter valgte kommunen å ta ut kravet om reguleringsplan, noe som også er i tråd med retningslinjer og veileder for kystsoneplanlegging fra Kommunal og regionaldepartementet. Det tas også ut flere av de tidligere foreslåtte akvakulturområdene i arbeidet mot endelig planforslag. Det kommer også inn et forslag om å sette av lokaliteter til taredyrking, og siden dette ikke var del av den første høringsrunden må det en egen høringsrunde på det.

I den endelige planbeskrivelsen, etter kommunestyrenes behandling, er det totalt avsatt 7 nye områder til akvakultur i sjø, bestående av tre områder til alle arter, tre for tang og tare og ett til fangstbasert akvakultur (FBA). I tillegg er det avsatt areal til ett landbasert anlegg for alle arter. Det settes også av to områder til havbruk i eksponert farvann, med miljøkvalitetsmål om at nye anlegg skal være rømningssikre og ikke slippe ut frittsvømmende stadier av lakselus, og med minimum rensegrad på 70-80% av finpartikulært materiale (slam). Det skal videre gjennomføres naturtypekartlegging og kartlegging av rødlistearter ved alle nye akvakulturlokaliteter, og gjennomføres resipientovervåkning av nærliggende svært viktige naturtyper for å dokumentere at disse ikke påvirkes negativt av utslipp. Alle nye områder skal gis tidsbegrensede konsesjoner for maks 25 år. Det er videre gjort utvidelser eller justeringer av arealet for tre eksisterende lokaliteter.

| | |
|---|---|
| **Kommune** | **Balsfjord** |
| **Nummer** | **5422-VA1** |
| **Navn** | **Forøybukt** |
| **Forslagsstiller** | **Wilsgård** |

**Områdebeskrivelse**

Arealet ligger i Forøybukt på Malangshalvøya i sørenden av vannforekomst Indre Malangen. Fra Tennskjær-Arsnes er Malangen en regulær fjord innover Troms fastland. Betydelig vannføring fra Målselva gjør at fjorden i perioder er ferskvannspåvirket. Ikke terskelfjord. Spredt boligbebyggelse/fritidsboliger. Landbruk.

| Gjeldende planstatus | Forslag til ny arealbruk |
|---|---|
|  |   |
| **Nåværende planformål**: Bruk og vern av sjø og vassdrag med tilhørende strandsone, Fiskeri, Forsvarets skytefelt. LNFR på land. | **Ny arealbruk**: Marine arter (torsk) med tradisjonell merdeteknologi. |

| Konsekvensutredning | Nåværende status | Verdi | Omf. | Kons | Vurdering av konsekvenser |
|---|---|---|---|---|---|
| **SÅRBARE VERDIER** | | | | | |
| Naturvernområder, eksisterende og planlagte | Forøya naturreservat 0,9 km (bevare middels stor øy med tilhørende plante- og dyreliv), Spilderøya naturreservat 6km S. Begge med verneplan for sjøfugl. Rossfjordstraumen marine verneområde 6,4km SV. Målselvutløpet naturreservat 16km. Nasjonal laksefjord. | 2 | -1 | -1 | Avstanden er stor nok til at man kan anta liten påvirkning. |
| Naturmangfold som viktige naturtyper, prioriterte, Freda og trua arter | Verneplan for sjøfugl, jf ovenfor. Gytefelt for uer (EN) 0,6 km V. Alke (EN), lunde (VU) observert i området. Viktig bløtbunnsområder fra 4 km S (v Spildran). | 3 | -2 | -2 | Det er ikke dokumentert hvordan gyte- og oppvekstområder for uer vil bli påvirket av et anlegg. Oppdrettsanlegg kan fysisk, eller ved at utslipp fra anlegg forhindrer marin fisk fra å oppsøke gyteområdene, gjøre området utilgjengelig. Avstanden til naturreservat er stor nok til at man kan anta liten påvirkning. Det antas ingen påvirkning på bløtbunnsområder, jf stor avstand samt hovedstrømretning ut fjorden. |
| Anadrom laksefisk | Nasjonal laksefjord. Rossfjordstraumen 14km, Målselva 23 km. | 3 | 0 | 0 | Ingen konsekvens, jf genetisk påvirkning. Ingen kjente effekter av lus fra torsk. |
| Gyte- og oppvekstområder for marin fisk | Overlapper med oppvekstområde for torsk og sei som går fra sør av Spilderøya langs land nord til Strausmfj. Gyteområde for uer (EN) 600m V av VA-område. Lokalt viktig gytefelt for torsk med lav eggtetthet og medium retensjon fra >7km km SØ. | 1 | -3 | -1 | Oppdrett og levendelagring av torsk kan påvirke villtorsken genetisk (rømming, gyting også i merd), økologisk (adferd, fysiologi, vandringsmønster, konkurranse om beiteområder, predasjon) og spredning av sykdom. Hovedstrømretning ved lokaliteten er ut fjorden. Det vurderes derfor som mindre sannsynlig med negativ effekt på lokalt viktig gytefelt for torsk. Det er usikkert hvordan gyte- og oppvekstområder for andre marin fisk vil bli påvirket av et akvakulturanlegg. Effekt på gyte- og oppvekstområder kan ikke utelukkes. |
| Forurensning, vannmiljø | Vannforekomst Malangen Indre. God økologisk og kjemisk tilstand (2017, delprogrammet Norskehavet Nord). Påvirkes (liten grad) fra diffus avrenning fra spredt bebyggelse og diffus avrenning og utslipp fra ett oppdrettsanlegg etablert i 2017. Trolig liten påvirkningsgrad. | 3 | -1 | -1 | Produksjon av fisk i konvensjonelt anlegg vil gi økte utslipp av næringssalter, organiske partikler og miljøfarlige stoffer som kan forurense miljøet rundt anlegget og over tid akkumuleres i næringskjeden. Økte CO2 utslipp, støy- (også under vann) og lysforurensning. Hovedstrømretning er ut fjorden mot N. Det er sannsynligvis gode strømforhold og vannutskifting på lokalitet. Det forventes derfor at utslipp fra anlegget vil spres og brytes ned, uten at det oppstår uakseptabel forurensning. Vannforekomsten er en stor resipient med gode strømforhold. Det er derfor liten risiko for at tiltaket vil medføre redusert mulighet for å oppnå mål om god kjemisk og økologisk tilstand. Landstrøm vil redusere CO2-utslipp og støy. |

| | | | | | |
|---|---|---|---|---|---|
| Støy- og lysforurensning | Spredt boligbebyggelse/landbruk, fritidsboliger. | 3 | -2 | -2 | Støy- og lysforurensning vil kunne påvirke spredt boligbebyggelse/landbruk/hytter i Forøybukt. Landstrøm vil redusere støy. |
| Kulturminner, kulturmiljø, samisk kulturgrunnlag | Automatisk fredet kulturminne (steinøks) 0,6 km, et par uavklarte funn. Flere SEFRAK-bygg. | 2 | -2 | -1 | Liten konsekvens for kulturminner. Vil i liten grad svekke den historiske opplevelsen av kulturminnene. |
| Landskap og estetikk, geologiske områder | Landskapsregion 32 Fjordbygdene i Nordland og Troms underregion Malangen. Ikke inngrepsfri natur. Malangen åpner seg her noe opp og deles i Straumsfjorden (til V) og Malangen. Relativt åpent med utsyn mot Senja og Kvaløya sør. Landbruk og spredt bebyggelse/hytter langs sjøen. | 1 | -1 | 0 | VA-området vil være eksponert for bebyggelsen langs sjøen og i et større landskapsrom i Malangen. Tiltaket vil synes, men ikke dominere i landskapet. |
| Friluft og friluftsliv. Strandsone | Større, svært viktig friluftsområde som omfatter hele Malangen i Balsfjorden (revidert kartlegging 2021). Registrert friluftsområde i fjellet ovenfor. | 3 | -1 | 0 | Tiltaket vil ikke hindre utøvelsen av friluftsliv. Påvirkningen vil i hovedsak være redusert friluftsopplevelse gjennom opplevd visuell-, støy- og lysforurensning. Påvirker ikke tilgjengelig strandsone. |
| Reindrift | Reinbeitedistrikt Meavki / Mauken. | 0 | 0 | 0 | Ingen konsekvens. |
| NÆRINGSAKTIVITET OG OFFENTLIGE INTERESSER | | | | | |
| Fiskeri | Tiltaket ligger utenfor rekefelt. Overlapper med middels stort felt for passivt fiske etter torsk og sei. Ingen registrerte stående bruk i området. | 2 | -2 | -1 | Rekefeltet er et aktivt helårsfelt. Foreslått areal ligger utenfor feltet. Tråling av feltet vil kreve et visst manøvreringsrom, da redskap og fartøy ikke kan befinne seg på nøyaktig samme sted når tråling foregår. Lokalitet Forøybukt ligger innenfor det som betraktes som nødvendig manøvreringsrom ved tråling på feltet. Tiltaket vil måtte tilpasses rekefeltet. Fiskere: Ansnesfeltet (lite felt ytterst i Malangen) er mye brukt. Båten går helt inn i foreslått areal når det tråles på dette feltet, for å få trålen til å kunne utnytte hele trålfeltet. Et registrert faststående bruk (garn) innenfor fortøyningsområdet. Ingen registrerte faststående bruk/garn. Liten effekt på passivt fiske. |
| Lokalt og samisk naturgrunnlag/sjølaksefiske/fritidsfiske/turistfiske | Flere registrert laksefiskeplasser i Forøybukt. Område for fritidsfiske etter sei rett innenfor VAO-området. | 2 | -2 | 0 | Tiltaket overlapper delvis med registrerte områder for fritidsfiske, men vil i liten grad hindre bruk av disse områdene, jf det kan fiskes fra 100m fra VA-området.. |

| | | | | | |
|---|---|---|---|---|---|
| Havbruk | 17027 Trettevik 5,9km (Senja) | 1 | 0 | 0 | Ingen konflikt. |
| Reiseliv | Buvika | 1 | 0 | 0 | Ingen konsekvens. |
| Næringsliv og sysselsetting, konkurranseforhold | Arealer til havbruk overlapper med viktige arealer for fiskeri. | 2 | -1 | -1 | Tiltaket vil kunne bidra til nye arbeidsplasser innen havbruk, men ligger innenfor manøvreringsrommet for tråling av Ansnesfeltet. |
| Teknisk infrastruktur, transportbehov | Mobildekning. Mulighet for landstrøm. Småbåthavn på Forøy. Fv. 7892 | 2 | -1 | -1 | Oppdrett generer trafikk hovedsakelig på sjø: utstyr, for og brønntransport av yngel og slakteferdig fisk. Transport av personell, evt. noe utstyr vil generere landtrafikk til landbase på annet sted. Ved økt behov for landtransport bør fylkesveg utbedres. Landstrøm som vil kunne redusere støyforurensning og CO2. Anlegget vil ha behov for data og telekommunikasjon. |
| Havner, farled, hvit sektor | Ikke i konflikt med biled inn Malangen. Ikke i hvit sektor. Småbåthavn på Forøy. | 3 | 0 | 0 | Tiltaket anses å ikke være til hinder for trafikk i bileden eller ut fra småbåthavn. |
| Forsvar | VA-området ligger akkurat utenfor enden av Forsvarets skytefelt i indre malangen. En liten del av fortøyningsområdet ligger innenfor. | 3 | -1 | -1 | Kun fortøyningsområdet (installasjoner under – 20 ligger innenfor skytefeltet). Liten/ingen konsekvens. |
| Forholdet til kommuneplanen/annen utviklingsstrategi | Kommunal planstrategi Balsfjord kommune 2016 – 2019. Strategisk næringsplan for Balsfjord kommune 2016 - 2025 | 3 | 1 | 1 | Med en bestemmelse om tilnærmet null utslipp av organisk materiale og næringssalter, samt landstrøm, anses arealbruken å være i tråd med samfunnsplanens mål og strategi for miljø og klima; Balsfjorden vil opprettholde sitt gode miljø. Delvis i tråd med tiltak 7 i næringsplanen om å avsette nok næringsarealer i arealplanen i forbindelse med revisjon av planen, havbruk vs fiskeri. |
| En bærekraftig Tromsøregion | Balsfjord kommune har i gjeldende planer ikke fastsatt spesifikke bærekraftsmål. Tiltakets bærekraft anses vurdert gjennom KU. | 3 | 1 | 1 | Bestemmelse om tilnærmet null utslipp av organisk materiale og næringssalter, samt landstrøm, anses å i stor grad kunne redusere påvirkning på gytefelt for uer og torsk, samt redusere CO2 utslipp og støy. Tiltaket ligger utenfor aktivt helårsfelt for reker men i manøvreringsrommet og vil måtte tilpasses dette. |

| RISIKO OG SÅRBARHETSANALYSE | | | | | |
|---|---|---|---|---|---|
| HENDELSE | AKTUELLE HENDELSER | Sans. | Kons. | Risiko | Vurdering |
| NATURRISIKO | | | | | |
| Stormflo, havnivåstigning | Forventet stormflonivå i 2100 er 255cm over NN2000 | 3 | 1 | 3 | Lav sårbarhet. Anlegget må dimensjoneres og tilpasses forholdene. Det bør være beredskapsplaner knyttet til anlegget både for folk og fisk. |
| Vær, vind, bølger, nedising, isdrift | Noe utsatt ift bølgeeksponering og vind ut Malangen. Ising kan forekomme f.eks. ved fralandsvind fra S-SØ og lav temperatur. | 2 | 2 | 4 | Lav sårbarhet. Merder og annet må bygges robust for bølgepåvirkning, ising og vind. Det bør være beredskapsplaner knyttet til anlegget både for folk og fisk. |
| Skredfare og grunnforhold | Aktsomhetsområde for stein og snøskred i hele fjellområdet innenfor Forøybukt. Går ikke ut i sjø. En skredhendelse sørøst i 2016, stort stein/jordskred som endret bukt til nes. 500 m til VA-område | 1 | 2 | 2 | God avstand til aktsomhetsområder. |
| VIRKSOMHETSRISIKO | | | | | |
| Industri og næringsliv | Ingen næring/industri som vil gi økt risiko eller sårbarhet ift uønskede hendelser. | 1 | 1 | 1 | Ingen tiltak nødvendig. |
| Kritiske samfunnsfunksjoner og kritisk infrastruktur | Biled inn Malangen. VA-området ligger utenfor farledaareal. 2,7 km til senter av led. | 1 | 1 | 1 | Anlegget må merkes slik at det er godt synlig både i mørke og lys. |
| Forhold ved utbyggingsformålet | Økt risiko for genetisk forurensning og annen påvirkning på lokalt viktig gytefelt for torsk. Økt risiko for utslipp av næringssalter, organiske partikler og miljøfarlige stoffer som kan forurense miljøet rundt anlegget og akkumuleres i næringskjeden. CO2-utslipp, støy- og lysforurensning. | 3 | 1 | 3 | Krav om landsstrøm for å redusere støypåvirkning over og under vann. Nødvendige tiltak for å hindre øvrige utslipp og rømming av torsk reguleres gjennom tillatelser. Avstand til gyteområder for torsk anses som tilstrekkelig. |
| Akutt forurensning, transport av farlig gods | Biled inn Malangen og noe båttrafikk/fiske. | 1 | 3 | 3 | Anlegget må merkes slik at det er godt synlig både i mørke og lys. |

| |
|---|
| **ROS-vurdering:** Bestemmelse om å redusere utslipp av organisk materiale og næringssalter til et minimum, samt landstrøm vil i stor grad redusere potensiell negativ påvirkning på gytefelt for uer og torsk. Bestemmelse om landstrøm vil redusere støypåvirkning og CO2-utslipp. Avstand til lokalt viktig gytefelt for torsk, samt hovedstrømretning, reduserer faren for genetisk forurensning av gytefelt. |
| **Samlet vurdering og eventuelle alternativer/avbøtende tiltak:** |
| Bestemmelse om tilnærmet null utslipp av organisk materiale og næringssalter, samt landstrøm, anses å i stor grad kunne redusere påvirkning på gytefelt for uer og torsk, samt redusere CO2 utslipp og støy. Tiltaket vil ikke hindre utøvelsen av friluftsliv. Påvirkningen vil i hovedsak være redusert friluftsopplevelse gjennom opplevd visuell-, støy- og lysforurensning. Tiltaket ligger utenfor aktivt helårsfelt for reker, men i manøvreringsrommet og vil måtte tilpasses dette. Lokaliteten anbefales. |
| **Forslag til vedtak:** |
| Foreslått lokalitet 5422-VA1 Forøybukt tas med i planen som lokalitet for oppdrett av alle arter unntatt laksefisk. Bestemmelse om tilnærmet null utslipp av organiske partikler til resipienten. Bestemmelse om landstrøm. |
| **Vurdering i forhold til naturmangfoldloven:** |
| Det som vises til av vitenskapelige publikasjoner, naturfaglige undersøkelser og erfaringsbasert kunnskap i planbeskrivelse og konsekvensutredning er tilstrekkelig som kunnskapsgrunnlag i forhold til sakens karakter og risiko for skade på naturmangfoldet. Saken er tilstrekkelig opplyst, jf § 8 Kunnskapsgrunnlaget. Det antas at et konvensjonelt anlegg med åpen merdeteknologi for torsk vil kunne påvirke gyteområde for uer og gytefelt/oppvekstområde for torsk. Det foreslås derfor en bestemmelse om tilnærmet null utslipp av organiske partikler til resipienten. Føre-var-prinsippet-kommer derfor til anvendelse, jf. bestemmelser om reduserte utslipp. For vurdering ift. NML §§ 10 – 12 se planbeskrivelsen. |
| **Vurdering i forhold til vannmiljø (vannforskriften § 4):** |
| Det er liten risiko for at tiltaket vil medføre redusert mulighet for vannforekomsten til å oppnå mål om god kjemisk eller økologisk tilstand. |

*Figur 5-7. Eksempel konsekvensutredning av ett foreslått akvakulturområde i KU for Kystsoneplan for Tromsø-regionen 2023-2032.*

*Tabell 5-16. Kvantitative eller klare kvalitative kriterier (**K**) eller skjønnsmessig (**S**) fastsettelse av score i KU for Tromsø-områdets kystsoneplan. Kilde: Egen analyse av metodenotat om KU (Tromsø-områdets Regionråd 2021).*

| TEMA | Verdi | Omfang | Konse-kvens |
|---|---|---|---|
| *SÅRBARE VERDIER* | | | |
| Naturvernområder, eksisterende og planlagte | K | S | S/K |
| Naturmangfold, som viktige naturtyper, prioriterte-, freda-, og trua arter | K | S/K | S/K |
| Anadrom laksefisk | K/S | K | K/S |
| Gyte- og oppvekstområder for marin fisk | K | K | K/S |
| Forurensning, vannmiljø | K | S | K/S |
| Støy- og lysforurensning | K | S | S |
| Kulturminner og kulturmiljø, samisk kulturgrunnlag | S | S | K/S |
| Friluft og friluftsliv. Strandsone | K | S | K/S |
| Reindrift | K | S | K/S |
| NÆRINGSAKTVITET OG OFFENTLIGE INTERESSER | | | |
| Fiskeri | S/K | K/S | S/K |
| Lokalt og samisk naturgrunnlag/sjølaksefiske/ fritidsfiske/turistfiske | S | K/S | S/K |
| Havbruk | K | K | K |
| Reiseliv | K | K | ? |
| Næringsliv og sysselsetting, konkurranseforhold | S | K | S |
| Teknisk infrastruktur, transportbehov | S | S | S |
| Havner, farled, hvit sektor | K | S | S |
| Forsvaret | K | S | S |
| Forholdet til kommuneplanen/annen utviklingsstrategi | K | S | S |
| En bærekraftig Tromsø-region | K | S | S |

? = Ikke mulig å fastsette om vurdering er (mest) K eller S fra omtale i metodenotat om KU.

Det skal også gjøres **samlet og helhetlig vurdering av alle forslagene i en kystsoneplan**. For Kystplan for Tromsø-området ble det gjort for akvakultur sin virkning på miljøet ved å se på *virkninger for vannmiljø* (inkludert vurdering etter vannforskriftens §12), *virkninger for klima*, og *virkninger for marine naturtyper*, samt å vurdere *samlet risiko*. Dette gjennomgås og diskuteres relativt omfattende, over 6-7 sider i endelig planbeskrivelse.

For vurderingen mot vannmiljø og vannforskriften ble det gått gjennom følgende del-tema:

- Miljøeffekter på bunn som følge av partikulære organisk utslipp fra fiskeoppdrett
- Tilførsel av organisk løste næringsstoffer – eutrofiering
- Miljøeffekter som følge av utslipp av kopper fra fiskeoppdrett
- Miljøeffekter på non-target arter (arter som ikke er mål for behandlingen) ved bruk av legemidler
- Miljøeffekter som følge av ferskvannsuttak fra landbasert akvakultur

Etter vannforskriftens §12 skal det vurderes om inngrepet/aktiviteten negativt kan påvirke vannmiljøet i tilknyttede vannforekomster. Tiltaket skal også avveies i forhold til grad av påvirkning og konsekvenser for allmenne interesser. Vurderingen må begrunne at inngrepene i vannforekomsten er nødvendige i en slik grad at de negative miljøkonsekvensene mer enn oppveies av nytteverdien for samfunnet. Ansvarlig myndighet skal demonstrere at de løsningene som foreslås er de samfunnsmessig minst skadelige.

I Kystsoneplanen for Tromsøregion integreres beskrivelsen av vannforekomstene og deres relevante kvalitetselementer, hvordan og i hvilken grad de vil påvirkes av tiltaket, samt skadebegrensende tiltak. For hver ny oppdrettslokalitet som er tatt inn i planen, vurderes både risiko for at tiltaket vil redusere muligheten for at vannforekomsten oppnår mål om god kjemisk eller økologisk tilstand, og avbøtende tiltak som krav til begrensninger på utslipp og/eller krav til overvåking.

Begrunnelse er basert på eksisterende kunnskap:

- Avstand fra oppdrett av anadrome arter til anadrome vassdrag: forskrifter om anadrome arter og kvalitetsnormen som suppleres med lokale hensyn.
- Nåværende tilstand i vannforekomsten opp mot miljømål.
- Konsekvens av tiltaket for tilstand/funksjon, herunder potensiell fare for påvirkning på sårbare naturtyper. Det er vurdert i hvilken grad effektene er reversible.
- Innvirkning på den samlende belastning i produksjonsområdet.
- Ulempe for allmenne interesser, herunder støy og lys, rekreasjon og reindrift.
- Alternative løsninger som er vurdert.
- Samfunnsnytten. Her nevnes det ofte nye arbeidsplasser innen havbruk, bidrag til innovasjon og ny kunnskap. Denne nytten vurderes opp mot andre formål som areal kan benyttes til, men er ikke eksplisitt.

I gjennomgangene ble det beskrevet hvordan det for nye akvakulturtiltak for alle arter er satt bestemmelser om at nye anlegg skal være rømningssikre og ikke slippe ut frittsvømmende stadier av lakselus, og at de minimum skal ha en rensegrad på 70-80% av finpartikulært materiale (slam). Videre skal det gjennomføres kartlegging av naturtype og rødlistearter ved alle nye akvakulturlokaliteter, og være resipientovervåkning av svært viktige naturtyper som ligger nært anleggende for å sikre at disse ikke påvirkes negativt av utslipp. Gitt disse tiltakene vurderes det som svært lite sannsynlig at akvakulturtiltak skal påvirke tilstand eller potensiale for å oppnå vannmiljømål. I gjennomgangene vises det til både overvåkningsdata, strømmålinger, kartlegginger av naturmangfold, og annen vitenskapelig kunnskap, inkludert om mulige effekter av medikamenter.

Det ble også gjort samlede vurderinger av effektene for fiskerinæringen og reiselivet, hvor også miljøkvaliteter og hvordan akvakultur kan påvirke de vektlegges. Det var i planen ikke satt av nye oppdrettslokaliteter i viktige fiskeri- eller gyteområder. Det er tatt hensyn til både kysttorsk og reker, og gytefelt for alle arter ble markert slik at fiskeri skulle prioriteres. I sum ble det dermed vurdert å ikke bli effekter på fiskerinæringen fra nye oppdrettslokaliteter slik at det er til skade for næringen. Av hensyn til reiseliv og friluftsliv ble det også «satt av større sammenhengende områder av særlig høy kvalitet» hvor det ikke blir akvakultur-arealer.

**Samlet sett** finner vi at gjennomgangene har grundige beskrivelser av både status, risikofaktorer og vurderinger. Siden det er brukt skjønn i de fleste tilfeller, og det er krevende å beskrive utfyllende, kan det allikevel være vanskelig å fullt ut få grep om avveininger eller hva som gjør at det vurderes som forsvarlig i ett tilfelle og ikke i et annet.

Selv om det i planbeskrivelsen konkluderes med at det ikke er fare for negativ påvirkning fra nye akvakulturtiltak i det omfang og med de bestemmelser om tiltak det er lagt opp til, så pekes det i saksframlegg til kommunestyrebehandling fra november 2022 på en annen utfordring med samlede virkninger. Der skriver man:

- *Flere anlegg og økt produksjon vil på sikt gjøre det nødvendig å se på de samvirkende miljø- og smitteeffektene fra flere anlegg i et område, og ikke bare på lokale effekter fra enkeltanlegg. Aktørene ønsket ikke fokus i denne prosessen på hvordan det kan oppnås en struktur som sikrer best mulig kontroll på fiskehelsesituasjonen i området. Det ligger heller ikke innenfor kommunens ansvarsområde å kunne stille krav om det. Økt* *avsetning av arealer til akvakultur i denne planen medfører imidlertid ytterligere fortetning også i Tromsøregionen, med økt risiko for sykdomsutbrudd og at trafikklyset går fra grønt til gult også her. Kommunene har derfor en forventning om at et slikt struktureringsarbeid er gjennomført før neste revisjon av kystsoneplanen.*

Kommunen peker altså selv på behovet for en vurdering av annen type «samlede virkninger» fra akvakultur enn det de har gjort gjennom kystsoneplanprosessen. De mener spørsmålet om geografisk struktur av akvakultur ikke ligger til kommunens ansvarsområde. I en nylig uttalelse fra Sivilombudet (Sivilombudet 2022) pekes det imidlertid på at nettopp i arbeidet med kystsoneplaner kan det tas mer overordnede vurderinger og avveininger om hvor nye akvakulturanlegg kan og bør komme. Det peker mot at kommunen kunne og burde vurdere også smittehensyn mellom anlegg i kystsoneplanarbeidet.

Det kan hende oppdrettsaktørene og kommunen har tenkt at en mer omfattende omstrukturering vil være den beste måten å redusere smitterisiko på. Analyser av omstrukturering i PO3 har jo pekt mot at det kan oppnås store reduksjoner i smitterisiko ved omstrukturering, uten at det trenger å gå ut over samlet produksjon av laks (Huserbråten m.fl. 2020). En slik større omstrukturering vil kreve et mer omfattende samarbeid og koordinering mellom både flere sektormyndigheter for akvakultur, kommunen og aktører fra havbruksnæringen. Å få til slike omstruktureringer er imidlertid vanskelig, slik vi har lært gjennom intervjuer og workshop i prosjektet. Antallet havbruksaktører som må involveres, fordelingen av lokaliteter mellom dem, hvor omfattende endringer som vil være nødvendige, men også samarbeidskulturen og -klimaet blant aktørene.

## 5.6 Vannforvaltning

Det tredje forvaltningsregimet vi særlig har sett på er vannforvaltning etter vannforskriften (FOR-2006-12-15-1446). I vannforskriften står det at den skal sikre "en mest mulig helhetlig beskyttelse og bærekraftig bruk av vannforekomstene» (§1), og dermed oppnå en mer helhetlig og økosystembasert vannforvaltning i Norge (Vannportalen 2023). Forskriften gir rammer for hvordan miljømål for vannforekomstene fastsettes, og skal også sikre at det lages vannforvaltningsplaner i tråd med planperiodene på seks år, og stiller krav til innholdet i planene og hvordan de utarbeides. Det er laget detaljerte kriterier for å måle økologisk og kjemisk tilstand i vannforekomstene, og det er et hovedmål at vannforekomster minst skal ha «god» tilstand etter begge kriteriesettene. Det finnes allikevel unntak til kravet om god økologisk og kjemisk tilstand.

Vannforskriften gjelder både for grunnvann og overflatevann, hvor overflatevann inkluderer ferskvann, brakkvann og kystvann. For denne rapporten her er kystvann særlig relevant. Det er definert som overflatevann fra land eller fra brakkvannsområde og ut til én nautisk mil utenfor grunnlinjen. Det vil si det samme området som det skal lages kystsoneplaner for etter plan- og bygningsloven. For bestemmelser om kjemisk tilstand er imidlertid kystvann definert som ut til den ytre grensen for territorialfarvannet, altså 12 nautiske mil utenfor grunnlinjen.

### 5.6.1 Miljømål

Tilstanden i vannforekomstene skal «beskyttes mot forringelse, forbedres og gjenopprettes med sikte på at vannforekomstene skal ha minst god økologisk og god kjemisk tilstand», i samsvar med klassifiseringen for økologisk tilstand (Vedlegg V i forskriften) og miljøkvalitetsstandardene for forurensende stoffer (vedlegg VIII).

For kystvann omfatter miljømålet både økologisk og kjemisk tilstand. Økologisk tilstand er tilstanden for vannlevende planter og dyr og leveområdene deres. Leveområdene omfatter både vannkvalitet og fysiske forhold (f.eks. strømningsforhold, tilgjengelige vandringsveier og bunnforhold). Kjemisk tilstand er et mål på mengden av miljøgifter med særlig negativ effekt på helse og miljø. Vannforekomster som er i dårlig tilstand vurderes etter et eget system for «økologisk potensial». I tillegg til å vurdere tilstand eller potensial langs skalaene indikert under, så kan noen vannforekomster få «udefinert tilstand» dersom det ikke er tilgjengelig informasjon for å gjøre vurdering. Det kan også angis om kunnskapen om miljøtilstand for enkelt-vannforekomster gjør vurdering mulig med høy, middels eller lav presisjon.


*Figur 5-8. Miljømål i vannforvaltningen. Kilde: Vannportalen.*

Klassifiseringen for økologisk tilstand for kystvann tar utgangspunkt i hva slags type område det er, og vurderer så en rekke «biologiske kvalitetselementer» for bunnfauna, planteplankton, og fastsittende alger (makroalger) basert på «økologiske kvalitetskvotienter», og også mengde klorofyll a for planteplankton. Kriteriene er ulike ut fra slags type kystvannområde det er, forenklet sagt kan det eksempelvis være terskelfjorder, åpne områder, og dype fjorder. For kjemisk tilstand angir miljøkvalitetsstandardene grenser for konsentrasjoner av en lang rekke forurensende stoffer både i vannet, i sedimenter og i organismer som lever i området.

Miljøkvalitetsmålene brukes slik at det kriteriet med dårligst skår er det som bestemmer miljøkvaliteten for vannforekomsten. Eksempelvis, hvis det er fem biologiske kvalitetselementer som vurderes for økologisk tilstand for en vannforekomst, og fire av de angir svært god tilstand og én god tilstand, så vurderes økologisk tilstand som god.

Lenge var det uavklart hvordan forringelse av tilstanden skulle tolkes (Lodding Gabrielsen 2021:8). Hvis vurderingen for én av de fire kvalitetselementene med svært god tilstand i eksempelet falt til god, skulle det regnes som en forringelse, når økologisk tilstand overordnet fortsatt var god og dermed i samme tilstandsklasse? Gjennom en dom i EU-domstolen ble det imidlertid avklart at også dette skulle regnes som en forringelse. I samme dom ble det også avklart hvor langt kravet om å hindre forringelse går; med mindre unntaksreglene slår inn, så er myndighetene forpliktet til å avslå tillatelser til aktiviteter som *kan* føre til forringelse av miljøtilstanden. Et viktig spørsmål blir da hvordan myndighetene kan vurdere om en aktivitet kan føre til forringelse av miljøtilstanden.

### 5.6.2 Planlegging

Norge er delt i vannregioner, og for hver av disse er en fylkeskommune ansvarlig **vannregionmyndighet** (også benevnt vannregionkoordinator i en del sammenhenger). De skal koordinere arbeidet i hver seks-årige planperiode med å revurdere og om nødvendig oppdatere vannforvaltningsplaner og tilhørende tiltaksprogram. Første planperiode var 2016-2021, og andre planperiode som vi er inne i nå går 2022-2027. **Vannregionutvalget** skal ha representanter fra vannregionmyndigheten og eventuelle andre fylkeskommuner, og fra statsforvaltere og andre berørte sektormyndigheter og kommuner. Berørte rettighetshavere og private og allmenne brukerinteresser skal være representert gjennom en **referansegruppe** for vannregionutvalget. I tillegg skal det være **offentlige høringer** på flere steder i prosessen med å lage vannforvaltningsplanene. Dette bidrar til demokrati og legitimitet, og gjør også at relevant kunnskap lettere kan komme fram.

Vannforvaltningsplanene skal inkludere elementene som er listet under (fra §26), men kan suppleres med mer detaljerte planer for deler av vannregionen, sektorer, påvirkningstyper, vanntyper eller vannforekomster:

a. angi miljømål for vannforekomstene,
b. sammenfatte karakteristika i vannregionen,
c. gi en analyse av menneskeskapte påvirkninger i vannregionen,
d. gi en oversikt over beskyttede områder,
e. gjøre rede for overvåkning og resultatene av denne,
f. sammenfatte tiltaksprogrammet.

I tillegg til kravene i vannforskriften så gis det regler og føringer fra staten (Vannportalen 2023). Sentralt er «Nasjonale føringer» og «Statlige retningslinjer og føringer», og det er også gitt en rekke «presiseringer» fra statlig side.

Vannforvaltningsplanene skal vedtas som **regionale planer** av fylkestinget i de aktuelle fylkeskommunene, i tråd med plan- og bygningslovens bestemmelser om regionale planer. Vedtatt plan sendes til Miljødirektoratet som i samråd med NVE og andre berørte direktorater skal sikre at nasjonale føringer er fulgt opp. Deretter sender Miljødirektoratet oppdatert plan med sin tilrådning til Klima- og miljødepartementet. Eventuell uenighet mellom direktoratene skal gjengis i tilrådingen, og skal avklares når Klima- og miljødepartementet godkjenner planen i samråd med Olje- og energidepartementet, eventuelt med endringer som de finner nødvendig ut fra rikspolitiske interesser. Godkjente vannforvaltningsplaner skal legges til grunn for regionale organers virksomhet og for kommunal og statlig planlegging og virksomhet i vannregionen. Det betyr blant annet at myndigheter kan fremmes innsigelser til arealplaner basert på vannforvaltningsplanene, og at offentlige myndigheter skal ta hensyn til føringer i planen i sin saksbehandling.

### 5.6.3 Kunnskapsgrunnlaget for planene

Kunnskapsgrunnlaget for vannforvaltningsplanene må inkludere:

- i) informasjon om vannforekomstenes egenskaper i tråd med miljøkvalitetsmålene og krav om overvåkning;
- ii) en vurdering av miljøeffekten av menneskeskapt påvirkning;
- iii) en økonomisk analyse av vannbruken.

Kunnskapsgrunnlaget skal oppdateres og foreligge på nettstedet Vann-Nett (https://vann-nett.no), og det er Statsforvalteren som er ansvarlig for dette, basert på bidrag fra alle deltagerne i arbeidet.

En veileder er laget for å utarbeide kunnskapsgrunnlaget (Direktoratsgruppen 2018). Her konsentrerer vi oss om hva den sier om kunnskapsgrunnlag for menneskeskapt påvirkning og miljøeffekten av det.

Påvirkninger som kan endre miljøtilstanden skal identifiseres og det skal vurderes hvor stor betydning de kan ha på miljøtilstanden. Den analysen blir så grunnlag for overvåkingsprogram, analyser av mulige tiltak, og vurdering av om miljømålene kan nås for vannforekomstene. Målet er å identifisere «vesentlige påvirkninger», som kan hindre at miljømålene nås. Det skal samles inn informasjon om type og omfang av alle påvirkninger som kan tenkes å ha betydning på miljøtilstanden. Det skal beskrives hvilken type påvirkning det er, effekt på miljøforholdene og drivkrefter i samfunnet som er opphav til påvirkningen. Det er de enkelte myndighet som er ansvarlig for få fram informasjon om egen sektor, og sikre at det tas med i karakteriseringen.

Veilederen gir informasjon om hvordan en kan identifisere påvirkninger, og peker på offentlige registre, den enkelte sektormyndighet og Vann-nett. For akvakultur nevnes spesielt oversikt fra Fiskeridirektoratet.

Grad av påvirkning på miljøtilstand vil avhenge av omfanget av påvirkningen og hvor sårbar vannforekomsten er for denne. Veilederen peker på at vurderingen av dette kan skje på tre hovedmåter, basert på «**data om tilstand, modellering, eller faglig vurdering**». Det siste er da gjennom lokalkunnskap og fagkunnskap, som også omtales som **skjønn** i veilederen.

**Graden av påvirkning** skal angis på skalaen *liten – middels – stor*. Disse er nærmere beskrevet i veilederen, knyttet til om påvirkningen er for ett eller flere kvalitetselementer for miljøtilstanden og hvordan endringer det gir for tilstandsklasse på miljøtilstanden.
En påvirkning anses som vesentlig hvis den fører til en forverring av miljøtilstanden med minst en tilstandsklasse, og det inkluderer både *stor* og *middels* påvirkning. Der det ikke er grunnlag for å foreta en vurdering av påvirkningen kan man unntaksvis bruke klassifiseringen «Ukjent grad av påvirkning». Det skal også gjøres en **samlet vurdering av påvirkning på vannforekomsten**.

Veilederen inkluderer oversikter over en del mulige **verktøy for å analysere påvirkning**, inkludert overvåkningsdata fra klassifisering, data for representative vannforekomster, og kvantitative modeller. For akvakultur er det kun modellering av tilførsel av nitrogen og fosfor som angis eksplisitt som metode. Der ingen av metodene over kan brukes pekes det på å samle all tilgjengelig kunnskap og gjøre en faglig vurdering, altså bruke skjønn.

I tillegg til å vurdere dagens tilstand i vannforekomsten og påvirkning skal det også vurderes hvordan påvirkning vil kunne utvikle seg framover, og hvordan det kan påvirke miljøtilstanden og muligheten for å nå miljømålene. Dette skal inkludere samfunnsendringer, gjennom å vurdere hva som ligger i planer og gitte eller søkte tillatelser til aktiviteter som kan påvirke stressorer og vannkvalitet. Analyser av drivkreftene bak dagens eller mulige påvirkninger skal også ses på. I tillegg skal klimaendringer og mulige klimatilpasninger som kan ha betydning for vannforekomster vurderes.

For vannforekomster med fysiske inngrep er det i tabell i vedlegg gitt «Retningsgivende fysiske kriterier for å gradere fysiske påvirkninger i kystvann». Det er imidlertid ikke tilsvarende hjelp til å vurdere påvirkning fra forurensende aktiviteter.

**Akvakultur** er ikke nevnt spesifikt i vannforskriften som en av de påvirkningene som skal registreres. De nasjonale føringene har imidlertid tatt inn at påvirkning fra lakselus og rømt oppdrettsfisk skal være med.

Det er også verdt å merke seg at for **kystvann** så er ikke tilstanden for fisk eller andre høyere trofiske nivåer, som sjøfugl, en del av klassifiseringen av miljøkvalitet (Sander 2023). For vannforvaltningsplanen for Troms og Finnmark poengterer Sander (2023) at heller ikke situasjonen for tareskogen i fylket er vurdert, til tross for at denne har vært sterkt nedbeitet i flere tiår.

**Oppsummert** er det et omfattende kunnskapsgrunnlag som skal lages. For vurdering av eksisterende **miljøtilstand** er det relativt klart definerte mål og vurderingskriterier, det er etablerte overvåkningsprogram knyttet til dette, og innsamlede data samles systematisk i lett tilgjengelige databaser. Når det gjelder å **identifisere** eksisterende og mulige **påvirkninger** gis det også klar veiledning, og databaser, andre informasjonskilder og metoder for å gjøre dette er tilgjengelig. De **største utfordringene** er knyttet til å **vurdere påvirkninger sine effekter på miljøtilstand**. For påvirkninger som er fysiske inngrep i vannforekomster gis det en del «retningsgivende kriterier» i veiledere, men for forurensende påvirkninger er det lite hjelp i regelverk og veiledere spesifikt for vannforvaltningen. I stedet vises det generelt til sektormyndighetenes egne systemer og vurderingsmetoder, og til bruk av skjønn.

### 5.6.4 Unntak fra miljømålene

I utgangspunktet skal det minst være god økologisk og kjemisk tilstand i vannforekomstene, og dersom det ikke er tilfellet skal vannforvaltningsplanen skissere tiltak for at det skal oppnås innen utgangen av planperioden. Det er imidlertid noen unntak. Dersom overskridelse av kriterier for god kjemisk tilstand skyldes langtransportert forurensing så kan det ses bort fra dette kriteriet, og det kan også gjelde dersom det er høye bakgrunnskonsentrasjoner av metaller.

Hvis «vesentlige kostnader eller andre tungtveiende hensyn» gjør det vanskelig å nå miljømålene i planperioden, kan det utsettes til neste planperiode (§8).

Det kan også stilles mindre strenge miljømål enn «god» dersom (§10) «en vannforekomst er så påvirket av menneskelig virksomhet at det er umulig eller uforholdsmessig kostnadskrevende å nå målene», og en del vilkår er oppfylt – blant dem at tilstanden ikke ytterligere forverres fra dagens tilstand.

Det kan også i noen tilfeller gis **unntak**, og aksepteres å starte opp ny menneskelig virksomhet eller inngrep i en vannforekomst selv om det betyr at miljømålene for vannforekomsten ikke nås eller at tilstanden forringes (**vannforskriftens §12**). Dette gjelder dersom det er (§12a) inngrep som endrer de «fysiske egenskapene til en overflatevannforekomst eller endret nivå i en grunnvannsforekomst», eller (§12b) en «**ny bærekraftig aktivitet**» og det er snakk om

**endring fra svært god til god tilstand**, samt at «**alle praktisk gjennomførbare tiltak settes inn for å begrense negativ utvikling i vannforekomstens tilstand**, **samfunnsnytten av ny aktivitet er større enn tapet av miljøkvalitet**», og at det man oppnår med den nye aktiviteten kan ikke «med rimelighet» oppnås med andre midler som er vesentlig miljømessig bedre på grunn av manglende teknisk gjennomførbarhet eller uforholdsmessig store kostnader.

**Hvordan unntak etter §12 rent praktisk skal vurderes har imidlertid vært en utfordring som myndighetene på noen områder fortsatt strever med å håndtere.** Det kom en veiledning i bruken av §12 i 2015, og denne ble oppdatert i 2021 med noen presiseringer (KLD 2021).

Om ny aktivitet kan startes opp med **unntak etter §12 skal ikke vurderes i arbeidet med vannforvaltningsplan** i forkant av sektormyndigheters vedtak. **Det er de enkelte sektormyndigheter som er ansvarlige for å avgjøre om tiltak kan eller skal gjennomføres som skal gjøre vurderinger etter §12**. Det inkluderer også å gjøre slike vurderinger knyttet til overordnede planer (som eksempelvis kystsoneplan og regional plan).

I veiledningen er det klargjort at vurderinger skal gjøres i to trinn. Først skal det vurderes om §12 vil komme til anvendelse fordi ny aktivitet eller nye inngrep i en vannforekomst kan medføre at miljømålene ikke nås eller at tilstanden forringes. Deretter skal det gjøres vurderinger for å sikre at de nødvendige vilkårene etter §12 er oppfylt (at alle praktiske gjennomførbare tiltak er satt inn for å unngå negativ effekt på vannforekomsten, at netto samfunnsnytte er positiv, osv) før endelig vedtak treffes eller tillatelse gis.

Det er sektormyndighetene som skal gjøre vurdering etter §12 som er ansvarlige for å få fram et **kunnskapsgrunnlag** for å gjøre slike vurderinger. Mye av informasjonen i vann-nett vil imidlertid være nyttig, bl.a. om dagens miljøtilstand for vannforekomster. Langt fra alle vannforekomster har imidlertid slik informasjon basert på overvåkningsdata. Da må sektormyndighet også vurdere hvor omfattende undersøkelser tiltakshaver skal pålegges (KLD 2021). Det vil avhenge av flere ting, som spesielle forhold ved tiltaket («tiltakets art») og hvor sannsynlig det er at det vil forringe miljøtilstanden. Informasjon trenger bare å innhentes om de vannkvalitetselementer som det kan forventes påvirkning på, og bare de antatt mest følsomme.

Veiledningen presiser hva som skal regnes som nye aktiviteter etter hhv. §12a (de som gir **endringer i de fysiske egenskapene**) og §12b («**nye bærekraftige aktiviteter**»). Det første gjelder inngrep som påvirker vannstand, vannføring, strømningsforhold mv., som eksempelvis vannkraftverk og drift av dem, demninger, fyllinger og deponering av masser. Det andre er forurensende eller andre aktiviteter som ikke endrer de fysiske egenskapene som nevnt foran. Eksempler som er gitt er **akvakultur**, avløp, industri og mineralvirksomhet. Begrepet **«bærekraftig»** i §12b innebærer i praksis kun at de vilkår som i utgangspunktet stilles om bærekraftig etter sektorregelverket som vurderinger skal gjøres etter vil være tilstrekkelig (KLD 2021). Det stilles altså ikke noen nye krav til aktiviteten av dette begrepet i §12b ut over de som allerede følger av gjeldende regelverk.

Merk at for nye aktiviteter etter §12b («nye bærekraftige aktiviteter») så kan de kun tillates om miljøtilstanden ikke blir dårligere enn «god», mens for aktiviteter etter §12a så er det ikke en slik nedre grense for forringelse.

For vurderingene om miljøforringelse pekes på at det må være **større presisjon i vurderingsmetodene** om man forventes å **nærme seg grensene** for miljøtilstand som er relevante. Negative effekter må være av en **viss varighet** for at det skal anses som en forringelse etter forskriften. Negativ påvirkning som går over av seg selv innenfor den perioden som overvåkningsprogrammer etter vannforskriften skal ha prøvetaking kan være eksempler på kortvarige effekter som ikke innebærer forringelse etter vannforskriften (KLD 2021).

Når det gjelder de **konkrete vurderingene** for å få fram hvilken **miljøforringelse** som tiltaket kan medføre, så **gir veiledningen ingen støtte til hvordan det skal gjøres**. I praksis må det selvsagt utredes/vurderes hvordan tiltaket kan påvirke de kvalitetselementene som ligger bak klassifiseringen for økologisk og kjemisk tilstand etter vannforskriften. Her vil ulike veiledere for konsekvensutredning av miljøeffekter fra tiltak være relevante, men veiledningen fra KLD (2021) for vurderinger etter §12 peker ikke mot noen slike.

Veiledningen tar opp vurderingene som skal gjøres etter §12 andre ledd om avbøtende tiltak, samfunnsnytte og andre midler for å oppnå samme formål. **For avbøtende tiltak** pekes det på at et bredt spekter av tiltak kan være aktuelle. I tillegg til å vurdere hvordan mulige avbøtende tiltak kan redusere miljøforringelse, skal det også vurderes om tiltakene er «praktisk gjennomførbare» (teknisk gjennomførbare, forenlige med driften av tiltaket og ikke uforholdsmessig kostnadskrevende). Det er altså en potensiel svært stor oppgave å gjøre slike vurderinger, og heller ikke her gir veiledningen fra KLD noe hjelp for hvordan effekt på miljøtilstanden i vannforekomsten skal vurderes. **For vurderingen om samfunnsnytte** må det vurderes hvilke samfunnsmessige behov tiltaket kan bidra til å dekke (f.eks. produksjon av mat eller kraft), og hvor stort bidraget kan være fra akkurat dette tiltaket. I tillegg må tapet av miljøkvalitet vurderes. Veilederen fra KLD er her tydelig på at «Det foreligger ikke i dag en omforent metode for verdsetting av økosystemtjenester og kostnader ved tap av slike, ei heller for verdsetting av miljøulemper, og vurderingen vil derfor i stor grad bero på **skjønn**» (vår utheving). **Det tredje vurderingspunktet, om andre måter å oppnå samme formål på som er «miljømessig vesentlig bedre»**, er også potensielt krevende å gjennomføre. Det går for det første på en annen mulig utforming av det aktuelle tiltaket, og kan også innebære å vurdere om andre prosjekter kan oppfylle samme formål og behov.

**Samlet sett** er det en rekke **vurderinger** som skal gjøres når §12 i vannforskriften skal anvendes som både kan være **omfattende**, hvor det er **begrenset med veiledning eller etablerte metoder for hvordan konkrete vurderinger av effekter skal gjøres**, og det er også **lite veiledning om hvordan negative og positive effekter av et mulig tiltak skal vurderes opp mot hverandre. Dermed overlates mye til den enkelte saksbehandler sitt skjønn**.

### 5.6.5 Tiltaksprogram

I tillegg til å sette miljømål for alle vannforekomstene skal vannregionmyndigheten i samarbeid med vannregionutvalget lage et tiltaksprogram til vannforvaltningsplanen som viser hvordan miljømålene kan nås, eller skal forhindre at tilstanden forverres (§25). Tiltaksprogrammet skal være sektorovergripende og på et overordnet nivå, og skal oppsummere alle tiltakene som er foreslått av sektormyndighetene. Kostnader skal anslås og det rettslige grunnlaget for å gjennomføre tiltakene angis, men det **skal kun være forslag til tiltak**, og ikke foregripe sektormyndighetenes saksbehandling. **Vedtak om gjennomføring av enkelttiltak gjøres av ansvarlig myndighet** etter det relevante lovverket som gjelder for den myndigheten (Miljødirektoratet 2015).

Tiltakene skal i utgangspunktet være operative senest tre år etter at tiltaksprogrammet er fastsatt. Det er mulig å fravike planene, men da skal det begrunnes ved rullering av planen hvorfor tiltak ikke er iverksatt. **Vannregionmyndigheten kan altså ikke pålegge noen å gjennomføre tiltak, og de har heller ikke penger som kan fordeles til tiltak. De som er ansvarlige må finansiere tiltakene over egne budsjetter. Sektormyndigheter og kommuner**

**får dermed i praksis kontroll over hvilke tiltak som blir ført opp og gjennomført.** Miljødirektoratet (2023) presiserte dette tydelig ved å påpeke at vannregionutvalgene er samarbeidsforum som ikke har fått overført myndighet fra andre instanser, og avgjørelser som ligger til den enkelte sektormyndighet kan ikke være gjenstand for avstemning/vedtak i vannregionutvalget. Staten kan imidlertid selv påvirke gjennom sin politikk for de ulike sektorene, enten gjennom finansiering eller direkte bestemmelser, slik Sander (2023) påpeker.

Det er laget en **veileder med oversikt over aktuelle tiltak** innenfor ulike sektorer for å oppnå eller sikre miljøkvalitet i vannforekomster (Direktoratsgruppen 2022). For akvakultur lister den opp de grunnleggende og supplerende tiltak som er gjengitt i Tabell 5-17. Veilederen beskriver tiltakene nærmere, inkludert ansvarlig sektormyndighet og virkemiddel (lov eller forskrift eller andre virkemidler). Veilederen fra Direktoratsgruppen **tar ikke for seg hvordan det skal vurderes om eller hvilke tiltak som bør vurderes** i forbindelse med utarbeiding av tiltaksprogram. Den tar heller ikke for seg hvordan den mulige effekten av tiltakene kan vurderes. I stor grad er det trolig tenkt at på samme måte som uttrykt i veilederen for §12 om unntak skal sektormyndighetene bruke metoder og skjønn slik de ellers gjør innenfor sin sektorforvaltning.

*Tabell 5-17. Tiltakstyper for akvakultur (med kode) fra Veileder fra Direktoratsgruppen (2022).*

| **Grunnleggende tiltak** |
|---|
| **MT136** Alternativ overvåkning av organisk påvirkning ved lokaliteter og resipienter der det er behov for det |
| **MT163** Overvåkning av strandsone og øvre vannlag |
| **MT169** Stopp i nye lokalitetsklareringer og utvidelser |
| **MT171** Midlertidig reduksjon/stans av produksjon på oppdrettslokalitet |
| **MT179** Permanent reduksjon/opphør av produksjon på oppdrettslokalitet |
| **MT325** Stille krav om rensing av utslipp for nye, ombygde og evt. eksisterende landbaserte oppdrettsanlegg |
| **MT148** Overvåkning av andre miljøpåvirkninger fra akvakultur |
| **MT189** Overvåking/ kartlegging av genetisk innkryssing i laksebestander |
| **MT186** Uttak av rømt oppdrettsfisk i sjø og elver |
| **MT193** Kontroll av lusenivå, reaksjoner og pålegg |
| **MT118** Utslippsreduserende tiltak i akvakulturnæringen |
| **Supplerende tiltak** |
| **MT182** Overvåkning av innslag av rømt oppdrettsfisk i vassdrag |
| **MT125** Frivillige utslippsreduserende tiltak i akvakulturnæringen |

### 5.6.6 Vannforvaltningsplan for Troms og Finnmark plan

Vi har studert vannforvaltningsplanen for Troms og Finnmark 2022-2027, med særlig oppmerksomhet på hvordan akvakultur har vært vurdert og håndtert. Sander (2023) har studert samme plan på et bredere og mer overordnet nivå. Formålet med vår gjennomgang er å bruke planen for Troms og Finnmark som et eksempel på hvordan miljømål og miljøtilstand, påvirkningskilder og tiltak vurderes og fremstilles i vannforvaltningsplaner. Planen følger nasjonale maler for innhold (Sander 2023), slik det er omtalt foran her. Den består av selve vannforvaltningsplanen, Tiltaksprogram, og Handlingsprogram.

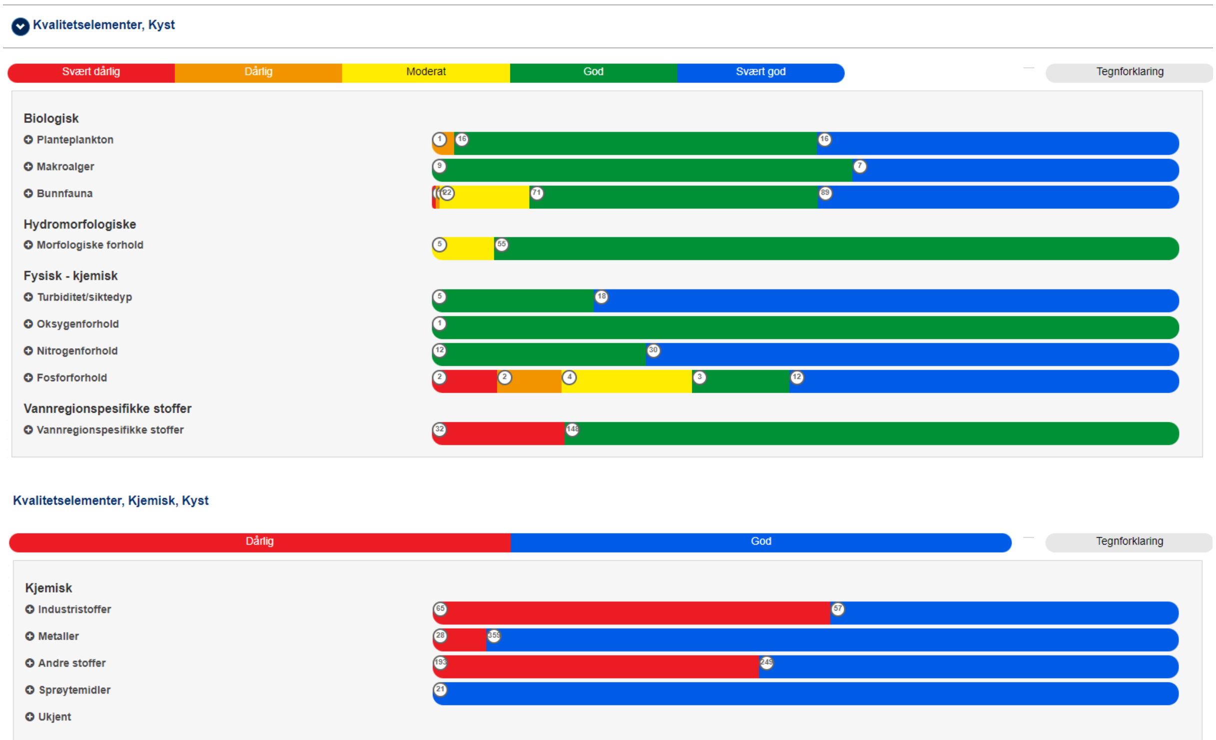
Planen trekker selv fram at **kunnskapsgrunnlaget** har blitt bedre siden forrige planperiode. For **miljøtilstand** så er det brukbar oversikt over **økologisk tilstand** for fylkets vannforekomster, både generelt og for kystvann spesielt (Tabell 5-18). Bare noen svært få vannforekomster har ikke definert økologisk tilstand. Det er imidlertid 15 % av vurderingene for økologisk tilstand i kystvann som har lav presisjon. Dette er dobbelt så stor andel med lav presisjon som det er for alle vannforekomster i Troms og Finnmark totalt. For vurdering av **kjemisk tilstand** er det hele 69 % av kystvann-forekomstene som ikke har definert tilstand, og 10 % av de vurderinger som er gjort er med lav presisjon. For alle vannforekomstene samlet er det imidlertid 94 % som det ikke er definert kjemisk tilstand for. Til gjengjeld er bare 2 % av de vurderingene som er gjort med lav presisjon.

*Tabell 5-18. Miljømål og miljøtilstand for Kystvann i Troms og Finnmark vannregion. Kilde: vann-nett.no*, 9/5-2023.*

| | **Antall vann-forekomster** | **Andeler** | | | **Antall** | | |
|---|---|---|---|---|---|---|---|
| | | Udefinert tilstand | Lav pres-isjon | Høy pres-isjon | Udefinert tilstand | Lav pres-isjon | Høy pres-isjon |
| **Kystvann** | 402 | | | | | | |
| Økologisk tilstand | 394 | 0,3 % | 15 % | 37 % | 1 | 60 | 146 |
| Økologisk potensial | 8 | | 50 % | 38 % | - | 4 | 3 |
| Kjemisk tilstand | 402 | 69 % | 10 % | 0,0 % | 277 | 42 | 0 |
| **Alle vannforekomster** | 4561 | | | | | | |
| Økologisk tilstand | 4192 | 0,0 % | 8 % | 10 % | 2 | 354 | 409 |
| Økologisk potensial | 204 | | 65 % | 8 % | - | 132 | 17 |
| Kjemisk tilstand | 4396 | 94 % | 2 % | 0,0 % | 4122 | 94 | 0 |

*) https://vann-nett.no/portal/#/area/1109/RiverBasinDistrictID

Vurderingene av økologisk og kjemisk tilstand baseres på en rekke kvalitetselementer, og det er i vann-nett mulig å få informasjon om hver enkelt av disse, både statistikk for alle vannforekomster eller kategorier av vannforekomster, og også data for enkelt-vannforekomster. Figur 5-9 gir statistikk for tilstanden for alle kvalitetselementene for kystvann. For hvert kvalitetselement kan man også dykke inn i de enkelte kvalitetselementene og få informasjon om underelementene som ligger der. For kvalitetselementet Makroalger er det f.eks. fem underelementer som til sammen avgjør klassifiseringen. For Bunnfauna er det 11 underelementer, og for Vannregionspesifikke stoffer hele 14 underelementer. Blant de siste er «kobber og kobberforbindelser», som ett slikt element som særlig kan være relevant for akvakultur. Også for de kjemiske kvalitetselementene er det flere underelementer til hver av de.




*Figur 5-9. Vurdering av kvalitetselementer for kystvann i Troms og Finnmark vannregion. Kilde: vann-nett.no, 9/5-2023.*

Vann-nett har også data og statistikk for de **vurderte påvirkninger** på vannforekomstene. I Figur 5-10 er dette vist for kystvann for Troms og Finnmark. Her er det angitt hvilken grad av påvirkning som er vurdert for enkelt-vannforekomster for de ulike påvirkningskategoriene. For skjermdumpen som er i figuren har vi utvidet visningen slik at mer detaljerte påvirkningskilder kommer fram innenfor hver hovedkategori av påvirkning.

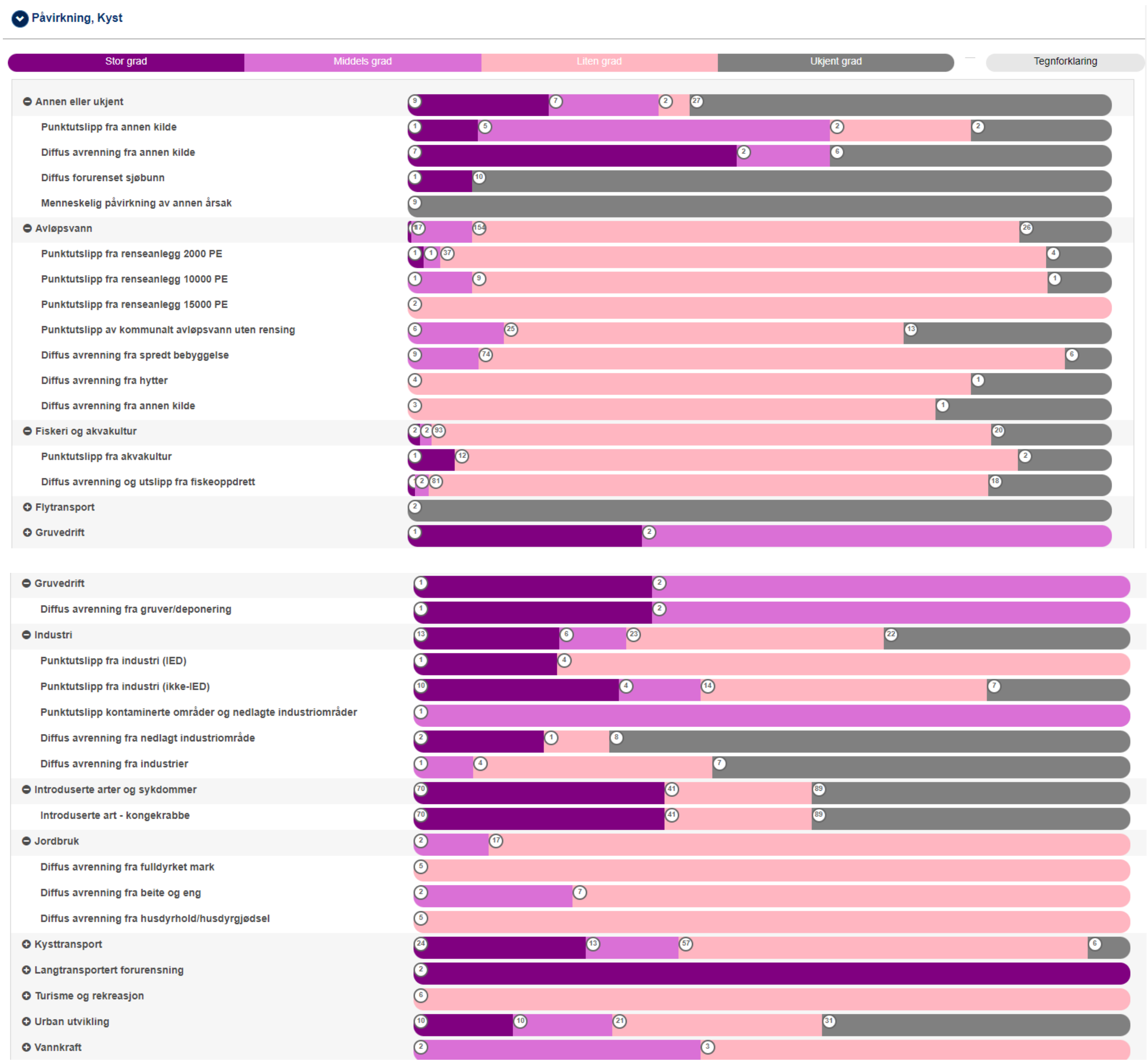
Vi ser kategoriene **Punktutslipp fra akvakultur** og **Diffus avrenning og utslipp fra fiskeoppdrett.** For den første er det identifisert 15 vannforekomster hvor det er angitt påvirkning fra dette, én i Stor grad, 12 i Liten grad, og 2 i Ukjent grad. For den andre er det til sammen 102 vannforekomster hvor den påvirkningen er identifisert, med én i Stor grad, to i Middels grad, 81 i Liten grad og 18 i Ukjent grad. Det at noen er angitt som **Ukjent grad** av påvirkning innebærer da **mangelfull kunnskap**.

Der de definerte kategoriene for påvirkning ikke passer brukes det «Annen eller ukjent» kategorien. Denne er i planen brukt for flere typer **påvirkning fra akvakultur**. Innkryssing av gener fra rømt laks og påvirkning på vill laks fra lakselus i oppdrettsanlegg er i teksten ført opp som de største påvirkningene innen fiskeri og akvakultur. I tillegg nevnes **utslipp av næringssalter og partikler**, **kobber** og **legemidler**, **oppdrett av torsk**, **levendelagring av fisk** og **taredyrking** som mulige kilder til endret miljøtilstand. HI sin risikorapport trekkes fram som kunnskapkilde.

Det trekkes i planen også fram **ambisjoner og potensial for vekst innen akvakultur** i Troms og Finnmark, som da har betydning for framtidig påvirkning fra akvakultur.

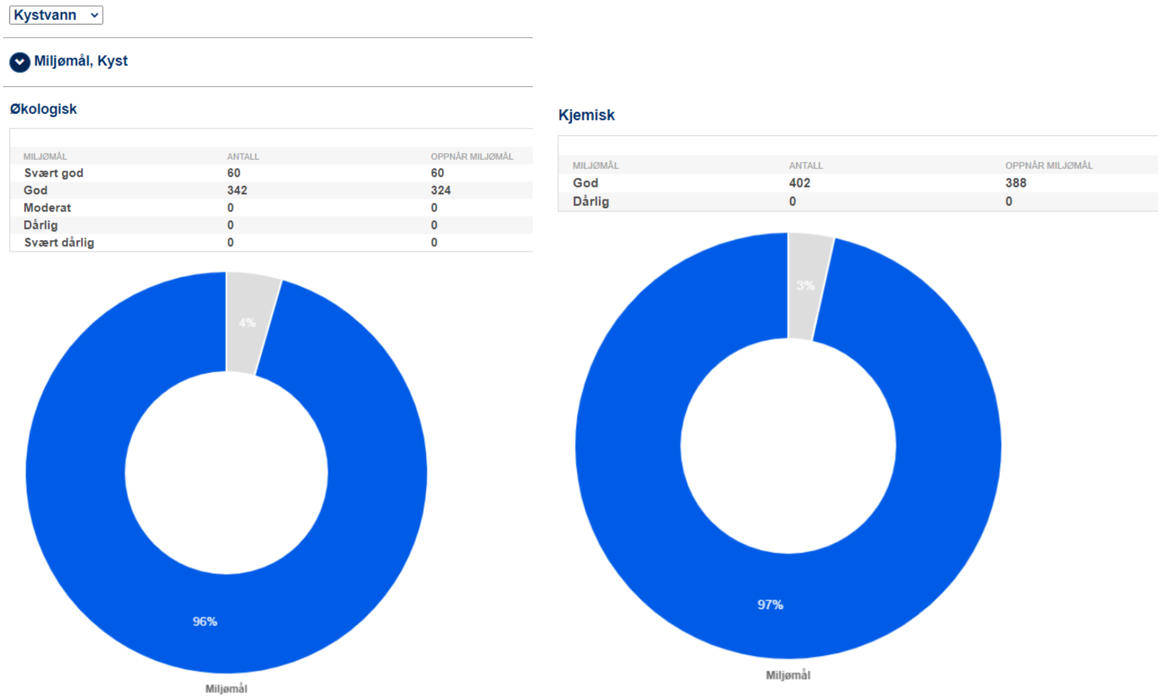
For å forbedre kunnskapsgrunnlaget for planen har det vært arrangert seks **temamøter** (inkludert ett om **akvakultur**), gitt ut en rapport om plastforurensing, og arrangert en konferanse om «drikkevann, avløp og folkehelse». Temamøtene trekkes from som viktige for «en felles oppfatning av påvirkninger på vannforekomstene, dialog om nødvendige tiltak for å nå miljømålene, og evt. behov for unntak fra miljømålet».

Miljømålene som er satt for miljøtilstand for kystvann i Troms og Finnmark vannregion framgår av Figur 5-11. For de som det er forventet ikke når miljømålet om økologisk tilstand i inneværende planperiode, og dermed har utsatt frist til å nå målet, så sier vannforvaltningsplane at det i all hovedsak er på grunn av vannforekomster som har dårlig genetisk integritet på grunn av rømt oppdrettsfisk.




*Figur 5-10. Påvirkninger for Kystvann i Troms og Finnmark vannregion. Kilde: vann-nett.no, 9/5-2023.*

Planen og tiltaksprogrammet har 315 ulike **tiltak** i alt, hvorav 180 er knyttet til kystvann (Figur 5-11). Av alle tiltakene er ca. halvparten om **forskning/kunnskap**, noe som peker mot at man synes **kunnskapsgrunnlaget** bør bli bedre. Videre er de mest vanlige tiltakene innen avløp, **akvakultur** og vannkraft. Det bemerkes i vannforvaltningsplanen at en del planlagte tiltak er det utfordrende å knytte til de kategoriene som er i Vann-Nett, og flere tiltak er derfor bare beskrevet i tekstform og vises ikke figurer og tabeller med statistikk.

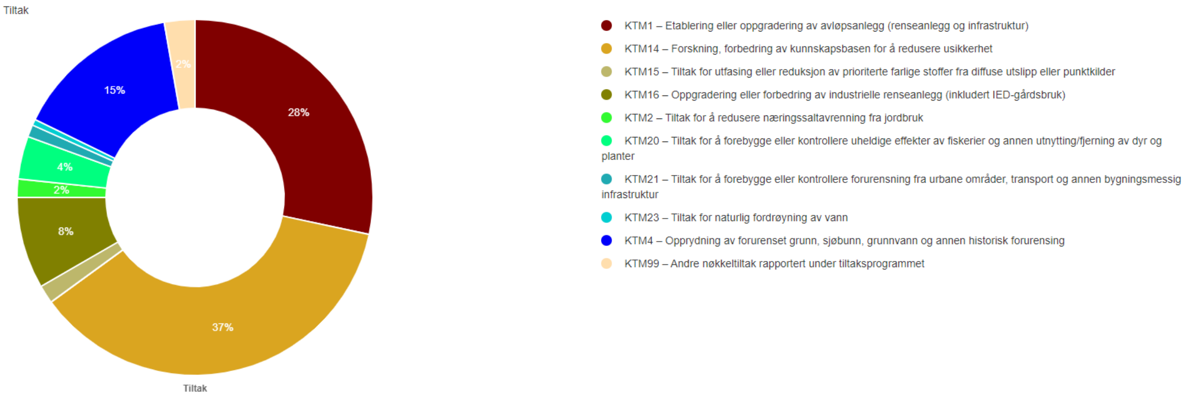



*Figur 5-11. Miljømål for Kystvann i Troms og Finnmark vannregion. Kilde: vann-nett.no, 9/5-2023.*

**Tiltakene knyttet til akvakultur** er hovedsakelig om rømming og lakselus. Tiltakene på rømming inkluderer overvåkning av rømt oppdrettslaks i noen vassdrag, oppfisking av rømt fisk i noen vassdrag. Siden det tar lang tid å få ut genetisk forurensing er miljømålene knyttet til dette utsatt oppnåelse på til 2033. Videre er tiltak (mulig) inndragning av én forurensningstillatelse (og dermed akvakulturtillatelse) på grunn av diffus forurensing, miljøovervåkning, og inspeksjon av et settefiskanlegg med punktutslipp. Tiltak mot lakselus er om informasjon og kunnskapsbygging, men er mange i antall med 30 tiltak.

**Nøkkeltiltak**

| TILTAK | ANTALL | VANNFOREKOMSTER | FORESLÅTT | PLANLAGT | PÅBEGYNT | UTSATT | AVVIST | GJENNOMFØRT |
|---|---|---|---|---|---|---|---|---|
| KTM1 – Etablering eller oppgradering av avløpsanlegg (renseanlegg og infrastruktur) | 51 | 81 | 28 | 6 | 12 | 1 | 4 | 0 |
| KTM14 – Forskning, forbedring av kunnskapsbasen for å redusere usikkerhet | 66 | 70 | 29 | 3 | 4 | 7 | 4 | 19 |
| KTM15 – Tiltak for utfasing eller reduksjon av prioriterte farlige stoffer fra diffuse utslipp eller punktkilder | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| KTM16 – Oppgradering eller forbedring av industrielle renseanlegg (inkludert IED-gårdsbruk) | 15 | 16 | 3 | 2 | 2 | 0 | 3 | 5 |
| KTM2 – Tiltak for å redusere næringssaltavrenning fra jordbruk | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| KTM20 – Tiltak for å forebygge eller kontrollere uheldige effekter av fiskerier og annen utnytting/fjerning av dyr og planter | 7 | 7 | 1 | 0 | 2 | 0 | 3 | 1 |
| KTM21 – Tiltak for å forebygge eller kontrollere forurensning fra urbane områder, transport og annen bygningsmessig infrastruktur | 2 | 5 | 1 | 0 | 0 | 0 | 0 | 1 |
| KTM23 – Tiltak for naturlig fordrøyning av vann | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| KTM4 – Opprydning av forurenset grunn, sjøbunn, grunnvann og annen historisk forurensing | 27 | 27 | 8 | 0 | 4 | 0 | 1 | 14 |
| KTM99 – Andre nøkkeltiltak rapportert under tiltaksprogrammet | 5 | 6 | 1 | 0 | 4 | 0 | 0 | 0 |
| Alle | 180 | 219 | 77 | 11 | 28 | 8 | 16 | 40 |




*Figur 5-12. Tiltak for Kystvann i Troms og Finnmark vannregion. Kilde: vann-nett.no, 9/5-2023.*

Når det gjelder videre **vurdering og prioritering av tiltak** anbefales det i vannforvaltningsplanen at tiltak prioriteres innenfor hver sektor og ikke mellom sektorene, slik at sektorene ikke stilles opp mot hverandre ved gjennomføringen av vannforvaltningsplanen. De peker på at **kost-effekt vurderinger** bør legges til grunn for å prioritere tiltak innen enkeltsektorer, men også at det mangler kostnadsberegninger for noen tiltak.

Videre pekes det på at **noen typer vannforekomster** med særlige kvaliteter eller utfordringer bør prioriteres høyt for tiltak, og flere av disse er eller kan være særlig relevante for akvakultur:

- Vannforekomster med verdifulle og trua arter
- Vannforekomster med utvalgte og sårbare naturtyper
- Vannforekomster med viktige brukerinteresser for allmenheten (eksempelvis fritidsfiske, friluftsliv og nærmiljøområder)
- Vannforekomster som krever særskilt beskyttelse (eksempelvis drikkevannskilder og nasjonale laksevassdrag og fjorder)

Planen trekker videre fram betydningen av at sektormyndighetene prioriterer avbøtende og forebyggende tiltak for å **opprettholde miljøtilstanden** i vannforekomstene, og at dette vil være **samfunnsøkonomisk fornuftig**, siden det da vil bli mindre behov for ressurser til reversering av negative påvirkninger senere. Vannforvaltningsplane understreker også viktigheten av **samarbeid** mellom regionale og lokale myndigheter, og virksomheter som påvirker vannforekomstene, for å nå miljømålene.

Vannforvaltningsplanen for 2022-2027 for Troms og Finnmark har utarbeidet egne **regionale planretningslinjer for kommunal arealplanlegging**. Tanken oppgis å være at ved å vurdere vannmiljø og fastsatte miljømål tidlig i planleggingsarbeidet kan man lettere få til en «samfunnsøkonomisk og bærekraftig forvaltning av vannmiljøet». De sier imidlertid at «Retningslinjene følger krav som allerede er gitt i lovverket. Derfor innebærer retningslinjene i **liten grad noe nytt** i forhold til utredningskrav, men bidrar til å tydeliggjøre behovet for å utrede og vurdere hvordan ny aktivitet og inngrep kan påvirke vannmiljøet».

## 5.7 Oppsummering

Hovedformålet med dette kapitlet har vært å se på hvilket kunnskapsgrunnlag og hvilke vurderinger som gjøres i viktige regimer for forvaltning av miljøpåvirkning i kystsonen. Analysen er sentrert om forvaltningen av miljøpåvirkning fra akvakultur i akvakulturforvaltningen, og hvordan miljøpåvirkning fra akvakultur er håndtert sammen med andre typer lignende miljøpåvirkning i forvaltningsregimer hvor disse skal vurderes samlet. Dette siste er da gjort for kystsoneplanlegging og vannforvaltning.

Kapitlet gir også en oversikt over forvaltning av miljøet i kystsonen og sammenhengen mellom de ulike forvaltningsregimene. For de forvaltningsregimene vi særlig ser på presenterer det regelverket som gjelder for miljøforvaltning, basert på lover og forskrifter. Retningslinjer og veiledere for hvordan saksbehandling og vurderinger skal gjøres er også gjennomgått, med vekt på å få fram kunnskapsgrunnlag og vurderingsmetoder.

Vi har samlet eksempler på saker og planer og gjennomgått disse for å se på hvordan dette gjøres i praksis, og også gjort intervjuer og på andre måter fått innspill og utdypinger om dette.

Forvaltningen av miljøeffekter i kystsonen fra ulike typer påvirkninger er kompleks og omfattende og inkluderer mange forvaltningsregimer og -aktører. Tabell 5-19 gir en oversikt over hvilke av de stressorene som denne rapporten konsentrer seg om som de ulike forvaltningsregimene og -myndighetene er involvert i. Vi ser at det er ingen stressorer som bare er vurdert i ett regime eller bare av én forvaltningsmyndighet. Dette er naturlig gitt oppbyggingen av det norske forvaltningssystemet for kysten, hvor ulike sektormyndigheter og myndigheter på ulikt administrativt og demokratisk nivå er involvert.

*Tabell 5-19. Forvaltningsregimer, forvaltningsmyndigheter og miljøstressorer/hensyn fra havbruk.*

| **Stressor/effekt**<br>**Forvaltningsregime**/ forvaltningsmyndighet | **Partikulære organiske utslipp** | **Løste nærings-salter** | **Medikament-bruk** | **Lys-/ støy-forurensing** | **Annen forurensing** | **Sykdom** | **Lus / parasitter** | **Rømming** | **Natur-mangfold** |
|---|---|---|---|---|---|---|---|---|---|
| **Akvakultur-sektorforvaltning** | | | | | | | | | |
| Statsforvalter | X | x | | x | x | | | | X |
| Mattilsynet | | | x | | | x | x | | x |
| Fylkeskommune | X | x | X | X | X | X | X | X | X |
| Fiskeridirektoratet | X | | x | | | | | | x |
| | | | | | | | | | |
| **Kystsoneplanlegging** | | | | | | | | | |
| Kommune | X | x | x | x | x | | x | x | X |
| Statsforvalter | X | x | | x | x | | x | x | X |
| Mattilsynet | | | X | | | x | X | | |
| Fiskeridirektoratet | | | | | | | | | X |
| | | | | | | | | | |
| **Vannforvaltning** | | | | | | | | | |
| Statsforvalter | X | x | X | | x | | x | X | x |
| Fylkeskommune | X | x | x | | x | | X | x | X |

For akvakulturforvaltningen finner vår gjennomgang av praksis følgende om kunnskapsgrunnlag og vurderinger som gjøres av de ulike sektormyndighetene for vurdering av miljøeffekter. Dette gjelder da både for avgjørelse av søknader om akvakulturtillatelse og overvåkning og kontroll med drift. For **kunnskapsgrunnlag** så er obligatorisk informasjon som skal følge en lokalitetssøknad viktig for alle myndighetene vi har sett på. Dette inkluderer strømmålinger, miljøundersøkelser, og beskrivelse av lokaliteten, inkludert bunnforhold, omsøkt produksjonsvolum og art, og planlagt drift.

Kunnskap om miljøtilstand og miljørisiko for det aktuelle geografiske området mer generelt brukes også av alle myndighetene. Av kunnskap og utførte vurderinger som gjøres og samles inn systematisk inkluderer det klassifiseringer i trafikklyssystemet om lus og villaks, og også luserapporter fra oppdrettsanlegg i det aktuelle området, miljøtilstand og miljømål for vannforekomsten basert på vannforskriften, om naturmangfold fra Naturbase, og geografisk baserte kunnskap og vurderinger fra Havforskningsinstituttets risikorapport for fiskeoppdrett. Videre er det kunnskap om anadrome vassdrag og bestander (avstand og tilstand), inkludert om vandringsruter for smolt i fjordene. I tillegg kommer kartlagte/registrerte gyte-, oppvekst og fiskeområder for marin fisk.

Risikorapporten er også blant kildene som brukes for mer generell kunnskap om sammenhenger mellom stressorer og miljøeffekter. I samme kategori finner vi legemiddelverkets informasjon om miljørisikoer med lusemidler, uavhengige studier om det samme, og kunnskap om mulig påvirkning fra akvakultur på villaks og andre anadrome laksefisk fra Vitenskapelig råd for lakseforvaltning og Havforskningsinstituttet.

**Manglende kunnskapsgrunnlag** som påpekes er om miljøeffekten av løste næringssalter, om partikulært organisk utslipp på hardbunn, om sårbare arter og habitater, om mulig effekt fra akvakultur på marin fisk, og miljørisiko fra torskeoppdrett.

I økende grad etterspørres kartlegging av sårbare arter og habitater ved lokalitet med ROV i tilknytning til lokalitetssøknader. Det stilles også i en del tilfeller krav om overvåkning på lokaliteten ut over standard-kravene for B- og C-undersøkelser. Dette er da for å styrke kunnskapsgrunnlaget for forvaltningsbeslutninger i driftsperioden. Eksempler vi har sett er makroalge-overvåkning, som er relevant for effekter fra løste næringssalter, spesifikt om overvåkning av kobber i sedimenter der det brukes kobber som antibegroingsmiddel på nett (selv om kobber også er del av C-undersøkelse).

For **vurderinger** som gjøres i akvakulturforvaltningen så er det for de fleste stressorer og myndigheter en betydelig grad av **skjønn** som legges til grunn. Det er en del bruk av standardiserte indikatorer for å vurdere tilstand på resipienter eller mulig påvirkning fra akvakultur, men dette er begrenset. Statsforvalteren i alle fylkene har en mal for vedtak og vedtaksskriv, og et fast sett med kriterier som belyses, som det ser ut til at alle fylkene jevnt over følger. Mattilsynet har en retningslinje for behandling av lokalitetssøknader som også bidrar til lik behandling på tvers av regioner og søknader. I retningslinjene til Mattilsynet er det anbefalte minsteavstander knyttet til risiko for spredning av sykdom og parasitter, men det presiseres at det må gjøres konkrete vurderinger i hvert enkelt tilfelle. Fiskeridirektoratet forholder seg i stor grad til nærhet/avstand fra lokalitet til gyte-, oppvekst- og leveområder for marin fisk (inkludert reker). Fiskeridirektoratet etterspør i en del tilfeller ekstra undersøkelser. De foreslår også noen ganger stegvis økning i MTB opp til omsøkt biomasse eller mer hyppige miljøundersøkelser enn det som er standard. Også Statsforvalteren kan legge opp til at man opererer med en mindre MTB enn omsøkt for én første generasjon i produksjon. Fylkeskommunen tar nødvendige tillatelser for lokalitetsklarering fra andre myndigheter til orientering, men gjør selvstendige vurderinger for andre forhold. Miljøtilstand i vannforekomsten er viktig i noen tilfeller, særlig der kvaliteten ikke er god. Alle myndighetene gjør sine vurderinger etter de krav som naturmangfoldloven stiller. Disse er i all hovedsak skjønnsbaserte.

I kommunal **kystsoneplanlegging** legges det juridiske føringer for arealbruken i kystsonen, som igjen kan ha stor betydning for miljøpåvirkning og miljøtilstand. De juridiske føringene inkluderer at akvakulturlokaliteter skal plasseres i arealer satt av til akvakultur i kommunenes arealplaner. Det er riktignok mulig å søke om dispensasjon fra arealplaner, men dette skal ikke være vanlig. Endret arealdisponering som kan få vesentlige effekter for samfunn eller miljø skal konsekvensutredes som del av planprosessen, og det er særlig der systematisk innsamling av kunnskap og vurdering av miljøeffekter av akvakultur kommer inn i kystsoneplanleggingen. Systemet med innsigelser supplerer dette med hensyn og fagkompetanse fra sektormyndighetene. Kommunestyrets endelige behandling og beslutning for kystsoneplanen innebærer også en vurdering, men ikke så systematisk som de andre delene av prosessen.

Konsekvensutredningen i forbindelse med utarbeidelse av en kystsoneplan skal være mer overordnet enn konsekvensutredninger av konkrete tiltak. Omfang og detaljgrad skal tilpasses de aktuelle tiltakene og hvilke potensielle effekter det kan gi for samfunn og miljø. Det er en egen forskrift om konsekvensutredning og flere veiledere og retningslinjer som er relevante, men allikevel betydelig frihet til kommunene å bestemme hvordan de vil gjennomføre en konsekvensutredning. Vår analyse av kunnskapsgrunnlag og vurderinger bygger på en gjennomgang av kystsoneplan for Tromsø-området, samt tidligere studier på feltet. Denne kystsoneplanen ble vedtatt sent i 2022, og vi anser den som tilnærmet best practise for kystsoneplanlegging i Norge.

For **konsekvensutredningen av foreslåtte akvakulturarealer** var det et bredt **kunnskapsgrunnlag** som ble brukt. Det inkluderte også mange møter og innspill fra interessenter og publikum, gjennom både særmøter med ulike etater og interessentgrupper, folkemøter og egne ressursgrupper for hhv. Sjømat og «Reiseliv, friluftsliv og strandsone» med interessenter som deltagere.

Vurderingen etter naturmangfoldloven i planprosessen fant at kunnskapsgrunnlaget var tilstrekkelig «for kommuneplannivået». Det ble allikevel levert innsigelse fra Statsforvalteren for ett område, og det var for foreslåtte områder for taredyrking. Det ble det stilt krav om kartlegging av naturtyper før lokaliteter kan avsettes, av frykt for at taredyrking kunne komme i konflikt med nasjonale eller vesentlige regionale miljøverdier.

For å gjennomføre konsekvensutredningen ble det laget et eget metodenotat som beskrev og definerte hvordan **vurderinger** om *verdi, omfang* og *konsekvens* skulle gjøres for hvert tema i konsekvensutredningen. Her inngår det en rekke kvantitative kriterier eller ordinale kvalitative kriterier for en del tema, men også skjønnsmessige kriterier for flere temaer. Det er mest klare kriterier for det å sette Verdi, mens når Omfang skal bestemmes så er det skjønn som dominerer, og for vurdering av Konsekvens er det kun ett eneste tema som har klare kriterier, og det er for temaet Havbruk.

Det varierer hvor klart de skjønnsmessige vurderingene er beskrevet i konsekvensutredningen for hvert akvakulturområde. Skjønnsmessige vurderinger vil være vanskelige å unngå. For at både politikere, interessenter og befolkningen ellers skal kunne forstå og ha tillit til vurderingene er det viktig at de beskrives godt nok, slik Mikkelsen m.fl. (2022) påpeker. De skjønnsmessige vurderingene bør beskrives så utfyllende at det er mulig å se at like tilfeller vurderes likt. Det er en forventning om at like tilfeller skal behandles likt – at det skal være konsistens i vurderinger. Da bør det også være mulig å se i størst mulig grad hvordan vurderinger er gjort.

Det skal også gjøres **samlet og helhetlig vurdering av alle forslagene i en kystsoneplan**. For Kystplan for Tromsø-området ble det gjort for akvakultur sin virkning på miljøet ved å se på ***virkninger for vannmiljø*** (inkludert vurdering etter vannforskriftens **§12**), *virkninger for klima*, og *virkninger for marine naturtyper*, samt å vurdere *samlet risiko*. Dette gjennomgås og diskuteres relativt omfattende, over 6-7 sider i endelig planbeskrivelse. Samlet sett finner vi at gjennomgangene har grundige beskrivelser av både status, risikofaktorer og vurderinger. Siden det er brukt skjønn i de fleste tilfeller, og det er krevende å beskrive utfyllende, kan det allikevel være vanskelig å fullt ut få grep om avveininger eller hva som gjør at det vurderes som forsvarlig i ett tilfelle og ikke i et annet.

**Vannforvaltningen** skal klassifisere miljøtilstand for vannforekomster etter et gitt system (inkludert «kystvann»), og lage seks-årige vannforvaltningsplaner hvor det settes miljømål som skal nås i planperioden, identifiseres aktuelle tiltak for å forhindre forverring av miljøtilstanden eller for å forbedre den, og sørge for overvåkning. Prioritering og gjennomføring av tiltak er imidlertid opp til ulike sektormyndigheter innenfor sine ansvarsområder, og ikke noe som kan bestemmes i vannforvaltningen.

I vannforvaltningen er det et omfattende **kunnskapsgrunnlag** som skal lages. For vurdering av eksisterende **miljøtilstand** er det relativt klart definerte mål og vurderingskriterier, det er etablerte overvåkningsprogram knyttet til dette, og innsamlede data samles systematisk i lett tilgjengelige databaser. Når det gjelder å identifisere eksisterende og mulige **påvirkninger** gis det også klar veiledning, og databaser, andre informasjonskilder og metoder for å gjøre dette er tilgjengelig. De største utfordringene er knyttet til å **vurdere** påvirkninger sine effekter på miljøtilstand. For påvirkninger som er fysiske inngrep i vannforekomster gis det en del «retningsgivende kriterier» i veiledere, men for forurensende påvirkninger er det lite hjelp i regelverk og veiledere spesifikt for vannforvaltningen. I stedet vises det generelt til sektormyndighetenes egne systemer og vurderingsmetoder, og til bruk av skjønn. Situasjonen er lignende både for å identifisere og vurdere aktuelle **tiltak** for å opprettholde eller forbedre miljøtilstanden i vannforekomster, og også når det skal **vurderes unntak for inngrep/tiltak etter §12** i vannforskriften. Begge deler kan være omfattende oppgaver om de skal gjøres ordentlig. Det er lite veiledning og i liten grad etablerte metoder for å kunne vurdere samfunnsmessig nytte eller kostnader opp mot endret miljøtilstand. Det vises igjen til faglig skjønn.

Tabell 5-20 er et forsøk på å gi en **oversikt over hvordan de ulike forvaltningsorganene/-regimene gjør vurderinger knyttet til hver stressor**. Det er i en del tilfeller utfordrende å identifisere og definere hva som er «én vurdering» som de ulike forvaltningsmyndighetene har gjort, så tabellen bør ses på som en indikasjon på situasjonen heller enn å tolkes helt bokstavelig.

For den første kolonnen («*Brukes standardiserte indikatorer for vurdering av miljøtilstand og mulig påvirkning i forvaltningen?»)* så er det krysset av for *Ja* dersom det for alle de vurderinger som skal gjøres av en forvaltningsmyndighet for den aktuelle stressoren er standardiserte indikatorer som de skal bruke. Det er da for indikatorer som brukes i forvaltningen, og ikke «standardiserte indikatorer» som finnes i den vitenskapelige litteraturen, men ikke nødvendigvis skal brukes i forvaltningen. Dersom det både er standardiserte indikatorer for noen forhold som skal vurderes i forvaltningen, OG behov for å gjøre andre vurderinger for noen forhold, så er det krysset av for *Både og*.

Dersom det er forhold som kunne vært vurdert i forvaltningen knyttet til en stressor, men som ikke tas i betraktning nå, så er dette ikke vist i tabellen her. Tabell 6-1 Kunnskapsstatus og indikatorer i kapittel 6 gir en oversikt over om det finnes etablerte grenseverdier/indikatorer for stressorene i den vitenskapelige litteraturen. Dette er da til forskjell fra tabellen som vises her, hvor det er det som faktisk brukes i forvaltningen i Norge i dag som presenteres.

Vi ser at **det er ingen stressorer hvor det kun gjøres vurdering i forvaltningen basert på standardiserte indikatorer** (ingen markeringer i den første *Ja*-kolonnen). Det er en del hvor standardiserte indikatorer brukes for noen vurderinger (13 markeringer i *Både og*-kolonnen), mens det er flest markeringer i *Nei*-kolonnen (20 stk.).

I den andre kolonnen («*Er det standard metoder for beslutning i forvaltningen*») har vi markert *Ja* dersom det enten skal brukes en bestemt beslutningsregel eller at det er en gitt prosedyre for hvordan man skal komme til en beslutning i forvaltningen. Det inkluderer eksempelvis hvordan situasjonen med lus vurdert i trafikklyssystemet gir en klar beslutningsregel for økt produksjonskapasitet i lakseoppdrett, og der det er laget retningslinjer for hvordan beslutninger skal tas, slik eksempelvis Mattilsynet har for behandling av lokalitetssøknader.

Her kommer vi fram til at **det er få tilfeller hvor det kun er standard metoder for beslutning i forvaltningen** (to markeringer i *Ja*-kolonnen). For noen myndigheter sin behandling av en stressor brukes både standard beslutningsmetoder og andre metoder (12 markeringer av *Både og*). Det er flest tilfeller av at det ikke brukes standard metoder for beslutning (*Nei*-markeringer).

Den siste kolonnen («Er det mulig å gjøre avveininger i forvaltningen?») indikerer om det er rom for å utøve skjønn, og at de hensynene som forvaltningsmyndigheten er satt til å forvalte knyttet til å en stressor kan avveies mot andre hensyn. Det kan eksempelvis være miljøeffekter opp mot samfunnshensyn, mot fiskevelferd, eller kostnader for gjennomføring. Her ser vi at det rom for **skjønn** for alle stressorer og forvaltningsmyndigheter. Eventuelt kan det ses på som at det må utøves skjønn fordi man ikke har vært i stand til å lage et system med tilstrekkelig kunnskapsgrunnlag og klare nok kriterier for vurdering og beslutning.

*Tabell 5-20. Miljøstressorer fra havbruk og vurdering i ulike forvaltningsregimer/ forvaltningsorganer.*

| | **Brukes standardiserte indikatorer for vurdering av miljøtilstand og mulig påvirkning i forvaltningen?** | | | **Er det standard metoder for beslutning i forvaltningen?** | | | **Er det mulig å gjøre avveininger i forvaltningen?** | |
|---|---|---|---|---|---|---|---|---|
| **Stressor** | **Ja** | **Både og** | **Nei** | **Ja** | **Både og** | **Nei** | **Ja** | **Nei** |
| Partikulære organiske utslipp | | SF, MT, FD VF | KSP | | SF, MT, FD, VF | KSP | SF, MT, FD, VF, KSP | |
| Løste næringssalter | | VF | SF, KSP | | VF | SF, KSP | VF, KSP | |
| Medikamentbruk | | SF, MT, VF | KSP | | | SF, MT, KSP | MT, SF, KSP | |
| Lys-/ støy-forurensing | | | SF, KSP | | | SF, KSP | SF, KSP | |
| Annen forurensing | | SF, VF | KSP | | SF, VF | KSP | VF, KSP | |
| Sykdom | | MT | FK, KSP | MT | | FK, KSP | MT, FK, KSP | |
| Lus / parasitter | | MT | FK, KSP | FD | FK, MT | KSP | MT, FK, KSP | |
| Rømming | | | SF, VF, FK, KSP | | VF | FK, KSP | VF, FK, KSP | |
| Naturmangfold | | VF | SF, FD, MT, FK, KSP | | MT, VF | SF, FK, KSP | SF, MT, VF, FK, KSP | |

**VF**=Vannforvaltning, **KSP**=Kystsoneplanlegging. For akvakulturforvaltning: **SF**=Statsforvalter, **MT**=Mattilsynet, , **FD**=Fiskeridirektoratet, **FK**=Fylkeskommune (For fylkeskommunene gjelder dette egne selvstendige vurderinger i akvakulturforvaltningen, og ikke de hensyn/miljøstressorer hvor andre etater må gi egen tillatelse, men som også legges til grunn for saksbehandling hos fylkeskommunene).

Når vi ser samlet på kunnskapsgrunnlag og vurderinger som er gjort om miljøpåvirkning på kystområder i akvakulturforvaltning, kystsoneplanlegging og vannforvaltning kommer det fram flere funn.

Det er et omfattende **kunnskapsgrunnlag** som går inn i alle disse forvaltningsregimene. Mest kunnskap, og mest kvantitativ og systematisk innsamlet kunnskap, er det om miljøtilstand og om næringsaktiviteter. Det siste er imidlertid i mindre grad knyttet til stressorer enn til andre variabler. De største og viktigste kunnskapshullene later til å være for ***sammenhengen*** **mellom menneskelig aktivitet, stressorer og miljøpåvirkning**.

Tilsvarende er det begrenset med hjelp i retningslinjer og veiledere om hvordan **vurderinger** av denne sammenhengen skal gjøres. Bruken av standardiserte indikatorer i forvaltningen for å angi tilstand eller påvirkninger er begrenset, men det kommer flere til hele tiden.

Det er begrenset med metoder tilgjengelig for å gjøre vurderinger av **samlede virkninger** (multi-stressor og kumulativ påvirkning), og de som finnes krever i stor grad spesialkompetanse og mye ressurser.

Gode metoder for å **sammenligne og vurdere miljøeffekter opp mot samfunnseffekter** (kostnad og nytte) er heller ikke tilgjengelig, selv om miljøregnskap og rammeverk for å analysere økosystemtjenester er under utvikling.Følgelig er det store behov for å utøve **faglig skjønn** på sentrale områder i flere av forvaltningsregimene. Det er delvis på grunn av kunnskapsmangel, og delvis fordi det er vanskelig å lage standardiserte vurderingsmetoder som kan håndtere lokal kompleksitet og en usikker framtidig utvikling godt nok. Bruk av lokalkunnskap og faglig skjønn kan riktignok åpne for gode lokale tilpasninger og innovative løsninger, men kan også innebære (urimelig) forskjellsbehandling mellom områder eller sektorer.

Der det er vanskelig å forutse effekter av nye tiltak eller annen utvikling er en adaptiv tilnærming fornuftig. Det er en rekke forhold som bidrar til **adaptiv forvaltning** i det vi har studert. Både vannforvaltningsplaner og kystsoneplaner skal revideres og oppdateres jevnlig. Trafikklyssystemet for regulering av produksjonskapasiteten i lakseoppdrett gjør også faste oppdateringer av kunnskap om miljøtilstand og miljørisiko. Fast overvåkning av stressorer og miljøtilstand relatert til akvakultur gir også forvaltningen mulighet til å tilpasse drift av anleggene over tid til miljømessige utfordringer og utvikling ellers. Praksisen med at man i en del tilfeller gir midlertidig tillatelse for produksjon av én generasjon og deretter vurderer før man eventuelt gir endelig tillatelse bidrar også til dette. I tillegg til en adaptiv forvaltning over tid så gir det også muligheter for mer lokaltilpasset forvaltning.

Det er fortsatt flere hindringer for å få til en riktig **økosystembasert forvaltning**. Det ene er å ha funksjonelle økosystem som forvaltningsenhet. I vannforvaltningen har man langt på vei det. Ved at interkommunal kystsoneplanlegging har blitt mer og mer vanlig er det også lettere å forvalte etter økosystem i kystsoneplanleggingen, selv om kommunegrenser ikke alltid passer med økosystemgrenser. Den største utfordringen er kanskje å vurdere samlet påvirkning, samt å i det hele tatt vurdere sammenhengen mellom aktiviteter, påvirkning og miljøeffekt/-tilstand.

Det har også vært pekt på behovet for en mer **helhetlig og integrert forvaltning** for å få til økosystembasert forvaltning (Aas m.fl. 2022). De tre forvaltningsregimene vi har studert her har mange kontaktpunkter og gjensidig avhengighet i forvaltningen av de stressorene for miljøpåvirkning vi har sett på, som den første tabellen i oppsummeringen indikerer. Det er et system av «checks and balances», hvor ulike hensyn, demokratisk makt og fagmyndigheter får påvirkning på det endelige resultatet. I tillegg til involvering av myndigheter er det også betydelige muligheter for interessenter til å spille inn og påvirke prosessene, ikke minst med kunnskap. Det er samtidig noen begrensninger for integrering og helhetstenkning. Det gjelder blant annet at ulike sektormyndigheter i stor grad bestemmer over egne tiltak og egen sektor. Av det vi har sett på her er det kanskje mest tydelig for identifisering, vurdering og gjennomføring av tiltak knyttet til vannforvaltningsplaner. Det vil imidlertid være komplekst og administrativt ressurskrevende med mye større grad av integrering på tvers av sektormyndigheter. En viss grad av spesialisering – eller «differensiert integrering» som Sørdahl (2023) skriver om – er kanskje et greit kompromiss mellom en ideell «full integrering» og en grad av integrering som er administrativt håndterbar.

# 6 Utforsking av mulighetsrommet for mer presis regulering av miljøpåvirkning

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## Sammendrag

Det blir i mange sammenhenger pekt på mulighetene for en betydelig økning av produksjonen i oppdrett, og en mangedobling av verdiskapningen, frem mot 2050. Økende bekymringer knyttet til både fiskevelferd og miljøpåvirkning har imidlertid ført til reguleringer som har bremset veksten i produksjonen. Det ligger dermed en åpenbar motsetning i ønsket om vekst og bekymringene for miljøpåvirkningen fra oppdrett.

Hvordan balanseres disse motstridende hensynene i dagens reguleringer? Har vireguleringer som godt nok regulerer miljøpåvirkningene fra næringen? Og har vi regulereringer som er unødig strenge?

En mer lokaltilpasset og presis regulering, samt en mer helhetlig forvaltning av oppdrett og annen virksomhet, stiller store krav til kunnskapen om viktige miljøpåvirkninger. Det kreves kunnskap om påvirkningsmekanismer, det kreves oversikt over forekomst og omfang av ulike miljøpåvirkninger, det kreves kunnskap om opprinnelse der hvor det er flere kilder, og det kreves vitenskapelig baserte og aksepterte mål og grenseverdier for ulike stressorer.

Prosjektet har identifisert flere stressorer som vi mener i større grad kan bør inkluderes i forvaltningen: partikulært organisk avfall på hardbunn, rømt rensefisk, antibegroingsmidler (kobber), lus (godt dekket, men fortsatt ikke godt nok) og avlusningsmidler.

Det finnes potensial for å utnytte bedre den kunnskap som samles inn, både i sertifiseringsprosesser og gjennom løpende drift, av oppdrettsbedrifter og helsepersonell. Sanntidsdata på ulike miljø- og vannkvalitetsparameterer i stort omfang har også et potensial for gi bedre forvaltning.

Nye arter møter regulering som i ofte er utformet for laks, noe som kan hemme utviklingen. Vi har sett på reguleringer for torsk, tare (som et eksempel på lavtrofiske arter) og steinbit. Nye arter bør delvis reguleres med eget regelverk, på egne premisser, og som en del av en helhetlig forvaltning, hvor man tilpasser eksisterende regelverk for de ulike artene. For å kunne oppnå en helhetlig forvaltning hvor man tenker både oppdrett, gjensidig nytte mellom ulike arter og forbedring av økosystemer i ubalanse, må forvaltningen ha bredere kunnskap.

Nye oppdrettskonsepter, hvor fisken skjermes for stressorer, og som har mindre påvirkning på økosystemet enn det tradisjonelle (innaskjærs notbaserte), kan legge til rette for mindre miljøpåvirkning (eller mer vekst med samme miljøpåvirkning). Ny teknologi vil også kunne nyte godt av mer direkte reguleringer på målbare miljøparametre. I områder hvor lus og sykdom i dag er vekstbegrensende, kunne for eksempel lukkede anlegg i sjø tillates, gitt at andre stressorer, som organiske utslipp, er innenfor tålegrensene.

Kunnskapsstatus og de verktøy myndighetene bruker for innsamling, analyse og formidling av data i dag trekker i retning av at forvaltning baseres på virkninger for spesifikke arter og naturtyper snarere enn for økosystemene. For en mer helhetlig og økosystembasert forvaltning vil det være viktig å styrke kunnskapsgrunnlaget og videreutvikle

beslutningsstøtteverktøy for forvaltningen, med bedre data om økosystemer og all menneskelig aktivitet som har påvirkning på samme resipient i økosystemet og på hverandr. Det vil imidlertid ikke være tilstrekkelig med ytterligere styrking av (det naturfaglige) kunnskapsgrunnlaget og bedrebeslutningsstøtteverktøy, det kreves også godt koordinert forvaltning og god håndtering av sektorbarrierer, politikk og maktforhold for å kunne oppnå målet med helhetlig og økosystembasert forvaltning.

En mer treffsikker helhetlig regulering kan gi rom for vekst uten større miljøpåvirkning, men det krever kunnskap om både helhetlig miljøpåvirkning, men også kunnskap om utfordringene i forvaltningen med sektorbarrierer, politikk og maktforhold.

## Executive summary

A significant increase in aquaculture production towards 2050 is expected by many, including a strong increase in value creation. However, growing concerns related to both fish welfare and environmental impact have led to regulations that have slowed down growth in production. There is thus an obvious contradiction in the desire for growth and the concerns about the environmental impact of farming.

It is also possible that the current regulations does not sufficiently balance these conflicting considerations. This raises two types of questions: Do we currently have regulations that adequately regulate the environmental impacts from the industry? And do we have regulations that unnecessarily limit growth?

A more locally adapted and precise regulation, as well as a more comprehensive management of aquaculture and other activities, place great demands on the knowledge about environmental impacts. Knowledge of impact mechanisms is required, as well as an overview of the occurrence and extent of various environmental impacts. Knowledge of origins is also required where multiple sources are present, and scientifically based and accepted targets and limits for various stressors are required. The project has identified several stressors that should be included in the management to a greater extent: effects of effluents on hardbottom habitats, escaped cleaner fish, anti-fouling agents (copper), lice (well covered, but still not good enough) and de-lice agents.

There is potential for better use of knowledge collected by aquaculture companies, both through certification processes and through ongoing operations. Real-time data on a large scale can also provide better management, as assessments of carrying capacity and load in a fjord system can be made, both to monitor ongoing operations and when assessing expansions, new capacity, etc.

New species face regulations that are often designed for salmon, which can inhibit development. We have looked at regulations for cod, kelp (as an example of low-trophic species) and wolffish. New species should be partially regulated with their own regulations, on their own terms, and as part of an overall management, where existing regulations are adapted for the various species. In order to achieve a holistic management where one considers both farming, mutual benefit between different species and the improvement of ecosystems in imbalance, the management must have broader knowledge.

New farming concepts, where the fish are shielded from stressors, and which have less impact on the ecosystem than the traditional (inshore, net-based) concept, can facilitate less environmental impact (or more growth with the same environmental impact). New technology may also benefit from more direct regulations on measurable environmental

parameters. In areas where lice and disease are currently limiting growth, for example, closed facilities in the sea could be permitted, given that other stressors are within tolerance limits.

The state of knowledge and the tools the authorities are using for collecting, analyzing and disseminating data today point in the direction that strategic decisions are being based on effects for specific species and habitat types rather than for ecosystems. For a more comprehensive and ecosystem-based management, it will be important to strengthen the knowledge base and further develop decision support tools for management, with better data on ecosystems and all human activity that has an impact on the same recipient in the ecosystem and on each other. However, it will not be sufficient to further strengthen the (natural science) knowledge base and produce decision support tools, but also to achieve a less fragmented management and to handle sector barriers, politics and power dynamics in order to be able to achieve the goal of ecosystem-based comprehensive management. A more accurate overall regulation can provide room for growth without major environmental impact, but it requires knowledge of both overall environmental impact and efficient management.

## 6.1 Innledning

Det blir i mange sammenhenger pekt på mulighetene for en betydelig økning av produksjonen i oppdrett, og en mangedobling av verdiskapningen, frem mot 2050. Økende bekymringer knyttet til både fiskevelferd og miljøpåvirkning har imidlertid ført til reguleringer som har bremset veksten i produksjonen. Det ligger dermed en åpenbar motsetning i ønsket om vekst og bekymringene for miljøpåvirkningen fra oppdrett.

Det har samtidig vokst frem en forståelse av, eller iallfall mistanke om, at dagens regulering ikke godt nok balanserer disse motstridende hensynene. På den ene siden kritiseres forvaltningen for manglende kontroll på miljøpåvirkningene. På den annen side for at deler av miljøforvaltningen av havbruksnæringen skjer gjennom reguleringer som i liten grad tar hensyn til variasjon i tilstand og sårbarhet i de aktuelle områdene, og dermed gir både unødig streng og lite effektiv regulering, som bremser veksten i næringen.

Disse to ulike utgangspunktene gir opphav til to typer spørsmål i dette prosjektet. Har vi i dag reguleringer som godt nok regulerer miljøpåvirkningene fra næringen? Og har vi regulereringer som er unødig strenge?

Mye av veksten i næringen reguleres i dag gjennom trafikklyssystemet, som fortsatt baseres på én miljøindikator, nemlig lakselus. Hele produksjonsområder reguleres i utgangspunktet under ett, og lokale forhold kan i mindre grad påvirke mulighetene for vekst. Veksten begrenses også av tilgangen til lokaliteter, og av viljen til å avsette areal, en vilje som både speiler konkurranse om sjøarealene og næringens samfunnsaksept.

Prosjektet[12] er utformet etter en utlysning fra FHF, som nok i stor grad har bakgrunn i næringens ønsker om reguleringer som er mer tilpasset faktisk miljøpåvirkning, som uttrykt i Sjømat Norges strategidokument «Et blått taktskifte»[13] (som for øvrig også handler om andre

[12] https://www.fhf.no/prosjekter/prosjektbasen/901738/
[13] https://sjomatnorge.no/blatt-taktskifte/

viktige forutsetninger for vekst, som markedsadgang, skatteregime osv.). I deres fremtidsvisjon heter det:

> *«I motsetning til dagens ordning skal matproduksjonen på lokaliteter i sin helhet reguleres ut fra faktisk påvirkning, og ikke forventet påvirkning. Vitenskapelig kunnskapsbaserte grenser for faktisk påvirkning på miljøet langs kysten skal optimalisere matproduksjonen. Prøvetaking og analyser skal dokumentere matproduksjonens effekt på det marine miljøet opp mot relevante miljøparametere og grenseverdier. Forslaget vil sikre optimalisert matproduksjon med en bærekraftig drift tilpasset lokal bæreevne. Samtidig vil reguleringen gi havbruksbedriftene sterke incentiver til kontinuerlig reduksjon av miljøavtrykk, fordi de bare kan øke sin matproduksjon basert på dokumenterte miljøavtrykk innenfor bærekraftige grenser.*

Med reguleringer basert på lokalitetens bæreevne kan det legges til rette for høyere produksjon i områder hvor en økning i produksjonen er bærekraftig. Tilsvarende, om produksjonen ikke er bærekraftig ved en lokalitet, bør risikoreduserende tiltak iverksettes. Samtidig må påvirkningen fra større produksjon på de beste lokalitetene også vurderes som en del av påvirkningen på større kystområder. For stressorer som påvirker større «resipienter», må det vurderes hvilken kapasitet området har som resipient for påvirkning fra både havbruk og fra andre næringer og kilder til miljøpåvirkning.

Næringen og forvaltningen ønsker at veksten skal være miljømessig bærekraftig gjennom en helhetlig og økosystembasert forvalting. En helhetlig økosystembasert forvaltning krever en forståelse av økosystemenes funksjon og struktur og samlede effekter av ulike typer menneskelig påvirkning. I Norge finnes det i dag ulike regimer som baserer seg på helhetlig og økosystembasert forvaltning, for eksempel vannregionforvaltning gjennom vannforskriften, helhetlige forvaltningsplaner, kystsoneplanlegging, og villaks-forvaltningen.

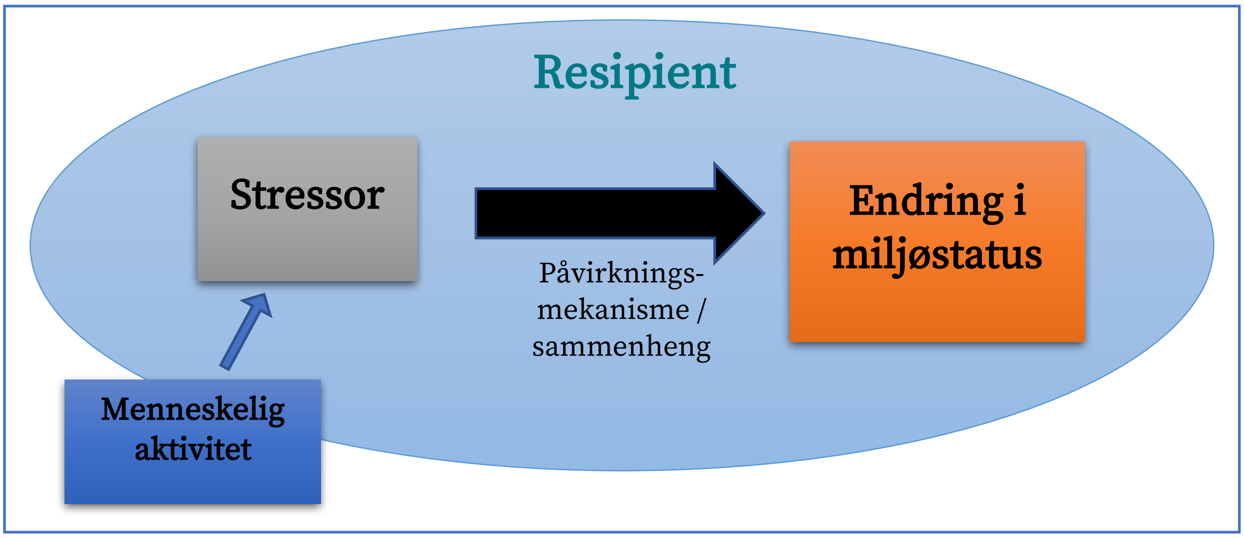
**Økt kunnskapsbehov**

Både en mer lokaltilpasset og presis miljøregulering og en mer helhetlig forvaltning høres forlokkende ut. Men begge tilnærminger stiller store krav til kunnskapen om viktige miljøpåvirkninger. Det kreves kunnskap om påvirkningsmekanismer, det kreves oversikt over forekomst og omfang av ulike miljøpåvirkninger, det kreves kunnskap om opprinnelse der hvor det er flere kilder, og det kreves vitenskapelig baserte og aksepterte mål og grenseverdier for ulike stressorer.

Det vitenskapelige kunnskapsgrunnlaget for havbruksnæringens miljøpåvirkninger er oppsummert i kapittel 1 og 2, etter systematiske litteratursøk og gjennomgang (QSR) av kunnskapen. Gjennomgangen av den vitenskapelige litteraturen om miljøpåvirkning er gjort for en rekke påvirkningsfaktorer, heretter omtalt som stressorer. Gjennomgangen viser at det er betydelig forskjell på det vitenskapelige kunnskapsgrunnlaget for ulike stressorer, både den etablerte kunnskapen og forskningsfronten. Det kan også være forskjeller i hvilken grad kunnskap om enkeltstressorer når frem til og tas i bruk i forvaltningen. I kapittel 3 undersøkte vi hvilke kilder til kunnskap som brukes i forvaltningen, og presenterer oversikt over kunnskapsgrunnlag og vurderingskriterier som brukes i dag.

For å kunne gjøre gode vurderinger av om hvordan en stressor vil gi miljørisiko/miljøeffekt trenger man kunnskap om flere ulike forhold. Det mest elementære er at man forstår sammenhengen mellom stressor og resipient, altså den miljørisiko og -påvirkning som stressoren representerer for den aktuelle resipient.

For å bruke kunnskap aktivt i praktisk forvaltning kreves det at det finnes kunnskap om årsakssammenhenger mellom stressorer og resipienter, og det må finnes indikatorer eller mål som kan belyse årsakssammenhengen. Finnes det for eksempel etablerte kvantitative modeller som kan beregne økt miljøpåvirkning eller -risiko ved en endring i en stressor? Eller for en gitt tilstand eller gitte egenskaper ved en resipient? Videre er det et viktig spørsmål om det finnes data som kan mates inn i modellene, og slik vise tilstand og påvirkning over tid. Dette er illustrert i Figur 6-1.




*Figur 6-1. Nødvendig kunnskap for å gjøre gode vurderinger av miljøpåvirkning fra stressorer.*

I denne arbeidspakken integreres resultater fra de øvrige arbeidspakker for å utforske og vurdere mulighetsrommet for en mer direkte og differensiert regulering av miljøpåvirkningen fra havbruk. Vi skal også vurdere mulighetene for en mer helhetlig og samfunnsøkonomisk effektiv forvaltning av miljøpåvirkning fra både havbruksnæringen og annen miljøpåvirkning fra menneskelig aktivitet.

Vi har tilnærmet oss målsetningene ved å søke svar på følgende forskningsspørsmål:

1) Er det viktige miljøpåvirkninger fra havbruk identifisert i AP1 som i liten grad er dekket i dagens forvaltning?

2) Kan man med det kunnskapsgrunnlag og de metoder for vurdering av miljørisiko **som brukes i forvaltningen i dag** få til en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning av havbruksnæringen og samlet miljøpåvirkning?

3) Kan bruk av indikatorer, kunnskapsgrunnlag og metoder **som ikke brukes i forvaltningen** i dag, brukes til forbedret forvaltning?

4) Hvilke miljøeffekter kan oppdrett av nye arter gi og hva betyr det for forvaltningen av miljøeffekter?

5) Hvordan kan/bør nye produksjonskonsepter for lakseoppdrett reguleres for å gi mulighet for vekst uten økt miljøpåvirkning?

6) Hvilke muligheter kan en mer differensiert (mellom områder) og direkte (på målbare miljøparametere) miljøforvaltning av akvakulturnæringen gi for miljømessig bærekraftig vekst i næringen?

## 6.2 Metode

I arbeidet med å besvare forskningsspørsmålene skissert i innledningen (se kapittel 6.1) har vi basert oss på flere ulike metoder avhengig av forskningsspørsmål. Spørsmål 1 og 2 har blitt adressert gjennom workshoper både internt i prosjektgruppa og med forvalting og næring. I disse workshopene ble det foretatt en systematisk gjennomgang, analyse og diskusjon av kunnskapen om de ulike typene miljøpåvirkning fra akvakultur (diskutert i kapittel 3), påvirkning av andre næringer på akvakultur (diskutert i kapittel 4), dagens forvaltning av disse og forvaltningens kunnskapsgrunnlag (diskutert i kapittel 5).

For å besvare spørsmål 3 har vi identifisert miljødata og annen dokumentasjon som registreres og brukes i næringen, og pekt på potensielle kilder til data som kan brukes i ulike deler av forvaltningen. KPIer (Key Performance Indicators) relevante for vurdering av miljøpåvirkning og sosioøkonomi er tilgjengelige hos akvakulturselskapene. Lerøy Seafood Group og Holmøy Maritime vil brukes som eksempler og grunnlag for casestudier.

For å besvare spørsmål 4 og 5 ble det gjort en litteraturgjennomgang av miljøpåvirkning fra de mest aktuelle nye arter og nye produksjonskonsepter for Norge. For å besvare spørsmål 5 ble det også gjennomført en kvantitativ scenario-analyse av mulig produksjonsvolum i lakseoppdrett med endret utnyttelse av sjøarealene i kystsonen med lukkede/semi-lukkede lakseoppdrettsanlegg og endret lokalitetsstruktur for åpne merder. Dette ble brukt som grunnlag for ytterligere kunnskapsinnhenting og analyser i en workshop med forvaltning og akvakulturnæring. For å besvare spørsmål 6 ble det også brukt kvantitativ scenario-analyse, samt workshops, for å analysere muligheter for produksjonsvekst med mer presis miljøregulering på enten en avgrenset geografisk case eller for hele den norske kystsonen.

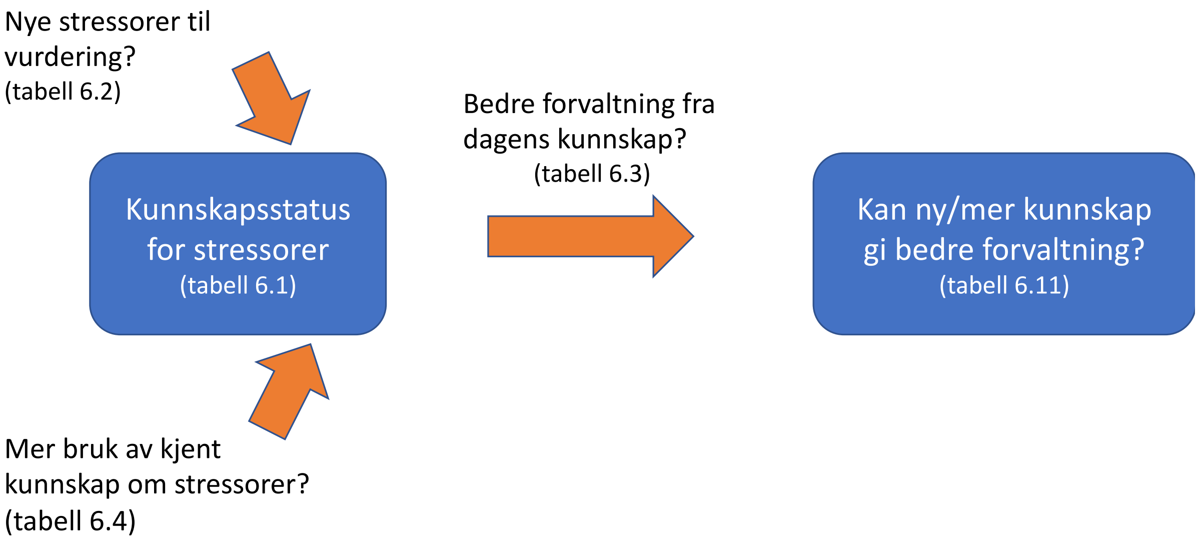
Både kunnskapsstatus, manglende kunnskap og bruk av kunnskap i forvaltningen er for oversiktens skyld oppsummert i form av tabeller. Disse tabellene, og spesielt scoren som er gitt på ulike stressorer, **er skjønnsbaserte oppsummeringer og må tolkes med litt forsiktighet**. Bakgrunnen for vurderingene vil finnes i kapittel 3 og 4.

## 6.3 Resultater

En mer lokaltilpasset og treffsikker regulering av miljøpåvirkning krever omfattende kunnskap om ulike typer miljøpåvirkning, fra ulike stressorer, på ulike resipienter og i ulik skala i tid og rom. I de neste avsnittene diskuterer vi i hvilken grad denne kunnskapen finnes og brukes i forvaltningen.

I Figur 6-2 har vi skissert sammenhengen mellom forskingsspørsmålene og gangen i dette kapitlet. For hver stressor har vi vurdert kunnskapsstatus og i hvilken grad det finnes gode indikatorer og aksepterte grenseverdier Tabell 6-1 (forskningsspørsmål 1).

Vi har så pekt på tre nye kilder til bedre kunnskap, gjennom at vi har identifisert viktige miljøpåvirkninger som ikke er tilstrekkelig dekket i dagens forvaltning (Tabell 6-1 og Tabell 6-2), vi har diskutert i hvilken grad dagens kunnskapsgrunnlag kan gi bedre forvaltning dersom det brukes mer eller bedre (Tabell 6-5) og sist hvorvidt det finnes uutnyttet kunnskap om kjente stressorer som i større grad kan tas i bruk (Tabell 6-6). Basert på disse oversiktene vil vi diskutere hvilket potensial ny kunnskap har for å forbedre forvaltningen. Her peker vi på mulighetene for å gjøre forvaltningen mer treffsikker, mer tilpasset lokale forhold og den geografiske skala hvor stressoren best kan reguleres.




*Figur 6-2. Oppsummering av kunnskap for mulighetsrommet.*

Forståelsen av lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning som vi har lagt til grunn i denne rapporten er her denne:

*Lokaltilpasset forvaltning*: En forvaltning som vurderer de lokale miljømessige forhold, som eksisterende lokal miljøtilstand og faktorer som påvirker hvordan miljøtilstanden vil kunne påvirkes av stressoren. Forhold og kvaliteter som påvirker resipienten sin sårbarhet for negative miljøeffekter kan blant annet være volum på resipienten, strømforhold, vannutskiftning med mer. Videre vurderes om stressoren påvirker lokalt eller over et større område (avhenger bl.a. av hvor stort utslipp det er snakk om, fysiokjemiske egenskaper eller andre relevante kvaliteter med stressoren som kan påvirke miljøeffekten. Lokaltilpasset forvaltning kan også være å inkludere andre kilder for den samme stressoren, slik at man vurderer samlet belastning.

*Treffsikker forvaltning*: Når forvaltningen i høy grad retter seg mot, og treffer, den miljøpåvirkning og miljørisiko man er opptatt av, og i liten grad påvirker andre forhold negativt. Dette kan være både lokalt, regionalt og på større geografisk nivå.

*Samfunnsøkonomisk effektiv forvaltning*: Forvaltningen kan være samfunnsøkonomisk effektiv på to ulike måter. For det første kan det være en forvaltning hvor prioriteringer og interesseavveininger innenfor et politikkområde og mellom politikk-områder gjøres slik at den samlede effekten som oppnås (f.eks. miljøforbedring, menneskelig nytte) blir størst mulig til en gitt kostnad, eller til lavest kostnad for en gitt samlet effekt. Et relevant spørsmål er om forbedringer i miljøkvaliteter eller redusert miljørisiko som er oppnådd etter tiltak i én sektor kunne vært oppnådd til en lavere kostnad hvis man alternativt hadde gjort tiltak i en annen sektor. Kostnadene hos næringsaktører kan både være direkte kostnader ved tiltak for å redusere miljøpåvirkningen, men det kan også være indirekte tap i form av redusert vekst i produksjon med tilsvarende redusert verdiskapning. Den andre tolkningen av samfunnsøkonomisk effektiv forvaltning er om kostnadene for selve forvaltningsprosessene står i et rimelig forhold til den reduserte miljøpåvirkning som oppnås. Lønner det seg å skaffe til veie mer kunnskap? Det er et spørsmål som både dreier seg om samfunnsøkonomisk effektivitet, og et spørsmål om hvilket kunnskapsgrunnlag som kreves for å kunne avveie miljømessige og samfunnsmessige hensyn.

Kostnader til datainnsamling varierer selvsagt mye. Noen data kan man samle uten betydelig kostnad (en vannprøve fra lokalitet, som oppdrettere selv kan gjøre). Mye registreres allerede, og kan samles inn med moderate kostnader. Oppdretterne bruker allerede en del tid på å rapportere på mange parametere, og ny teknologi gjør at det stadig blir flere parametere som kan overvåkes for relativt lave kostnader. Omfattende forskningsprosjekter og utvikling av modeller og verktøy samt oppdateringer har som regel store kostnader.

Det blir da et spørsmål om kostnadene for generering, innsamling og analyse av nødvendige data, samt for å ta en beslutning i forvaltningen, er mindre enn gevinstene med redusert miljøpåvirkning. Samfunnsøkonomisk effektivitet drøftes videre i slutten av rapporten der alle resultatene settes i sammenheng. Vi vil i diskusjonene legge mest vekt på første type effektivitet, altså forvaltningens påvirkning på effektiviteten.

### 6.3.1 Miljøpåvirkninger fra havbruk lite dekket i dagens forvaltning

I dette avsnittet diskuterer vi første forskningsspørsmål, om det finnes **viktige miljøpåvirkninger** fra havbruk (identifisert i AP1) som **i liten grad er dekket i dagens forvaltning**. For å svare på dette har vi oppsummert kunnskapsstatus for miljøpåvirkning i havbruk, og vurdert i hvilken grad det finnes gode indikatorer og aksepterte grenseverdier i bruk for hver stressor i dag (Tabell 6-1).

Vi har i de følgende oversikter over stressorer tatt utgangspunkt i litteraturanalysen vi har gjennomført tidligere i prosjektet (AP1 og 2). Her begrenset vi oss ikke til den kunnskap som brukes i ulike deler av forvaltningen i dag, men gikk bredt ut og søkte kunnskap om alle former for miljøpåvirkning, for så å systematisere denne.

Vi identifiserte deretter viktige miljøpåvirkninger som ikke er dekket i dagens forvaltning (Tabell 6-2).

Både kunnskapsstatus, manglende kunnskap og bruk av kunnskap i forvaltningen er for oversiktens skyld oppsummert i form av tabeller. Disse tabellene, og spesielt scoren som er gitt på ulike stressorer, er skjønnsbaserte oppsummeringer og må tolkes med litt forsiktighet. Bakgrunnen for vurderingene vil finnes i mer utfyllende form i kapittel 3 og 4 en systematisk gjennomgang, analyse og diskusjon av kunnskapen om de ulike typene miljøpåvirkning fra akvakultur.

#### *Oppsummert kunnskapsgrunnlag om miljøpåvirkning av havbruk*

I tabellen under har vi oppsummert kunnskapsstatus for hver stressor og tilsvarende resipient, inkludert kunnskap om påvirkningsmekanismer, tilgjengelige data, eksisterende modeller/analyseverktøy og etablerte grenseverdier. Oppsummeringen gir grunnlag for Tabell 6-2 og videre diskusjon av muligheter til å regulere mer presist i kommende delkapitler.

*Tabell 6-1. Kunnskapsstatus og indikatorer.*

| Stressor | Kunnskap om påvirknings-mekanismer<br>1=lite/dårlig<br>5=Mye/god | Data og modeller på stressor mengde<br>1=lite/dårlig<br>5=Mye/god | Data og modeller på resipientens tilstand (baseline) og endring relatert til stressoren<br>1=lite/dårlig<br>5=Mye/god | Etablerte grense-verdier for stressor mengde<br>(ja/nei) | Etablerte grense-verdier for endring hos resipient<br>(ja/nei) | Kunnskaps-status oppsummert<br>1=lite/dårlig kunnskap<br>5=mye/god |
|---|---|---|---|---|---|---|
| **Partikulære organiske utslipp:**<br><br>**Bløtbunn** | 5<br><br>God kunnskap om effekter på bløtbunn fauna og kjemi samt virkningsmekanismer | 5<br><br>Etablerte estimater for utslippsmengde utfra biomassen | 5<br><br>Det finnes flere indikatorer som kombineres for å evaluere påvirkning lokalt | Nei | Ja<br><br>Metoder, indikatorer og grenseverdier er etablert (NS 9410:2016) | 5 |
| **Partikulære organiske utslipp:**<br><br>**Hardbunn** | 2<br><br>Begrenset kunnskap om effekter på hardbunn | 5<br><br>Etablerte estimater for utslippsmengde ut fra biomasse | 1<br><br>Det finnes ikke tilsvarende indikatorer for hardbunn | Nei | Nei | 2 |
| **Løste nærings-salter** | 5/4<br><br>Direkte effekter er kjent, men risiko er svært avhengig av hydrodynamiske forhold. Vet mindre om indirekte effekter | 4<br><br>Ulike modeller kan brukes for å estimere mengde utslipp basert på mengde produsert fisk | 4<br><br>Gode data fra overvåkning i vannforekomster dekket av nasjonale overvåkningsprogra m. Foreløpig relativt dårlig geografisk dekning. Finnes modeller som predikerer risiko for eutrofiering | Nei | Ja<br><br>Det finnes grenseverdier for klassifisering i henhold til Vanndirektivet for effekter på lavere trofiske nivåer. | 4 |
| **Rømming** | 3 | 4 | 4 | Ja | Ja | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | God kunnskap om genetisk påvirkning, mindre om smitte og evt. bestandseffekter. Lite kunnskap om effekter fra rømt rensefisk | Rapporterte rømmingstall er usikre, også for rensefisk. Gode data fra overvåkningsprogrammet i laksevassdragene. | Det finnes data og modeller for vurdering av påvirkning i laksevassdragene | Nullvisjon i utgangspunktet | Kvalitetsnorm utarbeidet av VRL | |
| **Sykdom** | 3<br><br>Først og fremst et fiskehelseproblem, blir et miljøproblem ved spredning til vill fisk. | 3<br><br>Rapporterte utbrudd på lokaliteter for flere viktige patogener. Utslipp av patogener ikke kjent | 2<br><br>Lite data om sykdomsutbrudd hos villfisk og vanskelig å knytte til kilde. Mye usikkerhet rundt ev. påvirkning siden normalt sykdomsnivå hos villfisk er ukjent. Sykdomsstatus i oppdrett brukes som proxy for smitterisiko | Ja<br><br>Rutiner for rapportering og tiltak ved sykdom er etablert for ulike patogener | Nei<br><br>Vanskelig å vite hva normalt smittenivå er i økosystemet og relatere utbrudd til smitte fra oppdrett | 3 |
| **Parasitter (lus)** | 4<br><br>God kunnskap om påvirkning av lus på overlevelse av laksesmolt | 5<br><br>Ukentlig lusetelling, spredningsmodeller, overvåkning av villaks og ørret | 3<br><br>Bestandsregulerende effekt av lus er usikker siden den er vanskelig å isolere fra andre miljøfaktorer. Modeller er utviklet for trafikklyssystemet, men fortsatt flere kunnskaps-hull. | Ja<br><br>Kritiske lusenivåer er etablert for ulike typer tillatelser.<br><br>Ingen grenseverdi for utslipp i en fjord/område | Ja<br><br>Etablerte grenseverdier i TS på produksjonsområdenivå | 4 |
| **Kunstige strukturer (stepping stone,** | 2 | 2 | 1<br><br>Lite data om lyd- og lyseffekter og | Nei | Nei | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **artificial ; lys og lyd** | Har ikke vært forsket på systematisk, fragmentert kunnskap | Ingen systematisk datainnsamling | strukturer fra oppdrett | Ikke med hensyn til marint miljø | | |
| **Medisiner og andre fremmedstoffer** | | | | | | |
| a) Antifoulants (kobber) | 3<br><br>Noe manglende kunnskap om hvor toksisk kobber er for ulike arter | 5<br><br>Gode data for samlet bruk, utslipp og på konsentrasjon under lokalitet | 2<br><br>Kun data fra feltstudier | Ja<br><br>Det finnes grenseverdier for klassifisering av vannkvalitet | Nei | 2 |
| b) Plast | 3<br><br>Vet at mikroplast tas opp av marine organismer, men effekt av dette er ukjent | 4<br><br>Finnes noen estimater av gjennomsnittlig utslipp fra et anlegg | 1<br><br>Ingen data om påvirkning som kan kobles direkte til oppdrett | Nei | Nei | 2 |
| c) Uønskede stoffer i fôr | 3<br><br>Systematisk overvåkning av fôr. Lite forskning på temaet i miljøet. Men god kunnskap om toksisitet av ulike stoffer. | 2<br><br>Ingen systematisk datainnsamling, finnes gode modeller som kan brukes til spredning av fôr/stoffer. | 1<br><br>Gjøres ikke målinger i dag. | Ja<br><br>Innhold i fôr er regulert for enkelte stoffer, men ikke med hensyn til miljø. | Nei | 2 |
| d) Antibiotika | 3<br><br>Effekt er avhengig av flere faktorer og vanskelig å predikere | 5<br><br>Finnes statistikk på forbruk.<br><br>Lavt forbruk per kilo produsert i Norge, effektive | 2<br><br>Få vitenskapelige publikasjoner om miljøeffekter | Nei | Nei | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | vaksiner siden 1990-tallet | | | | |
| e) Desinfiserings midler | 1<br><br>Få studier som dokumenterer effekt på andre arter enn oppdrettsfisk. Toksisitetsdata finnes via datablad. | 2<br><br>Finnes statistikk på salg/forbruk av enkelte stoffer (formaldehyd), men ikke data om mengde utslipp til marin resipient. | 1<br><br>Kun data om fortynningsegenskaper for enkelte stoffer | Nei | Nei | 1 |
| f) Nanopartikler | 1<br><br>Begrenset kunnskap om NP effekter relatert til bruk i akvakultur | 1<br><br>Ingen statistikk på forbruk og utslipp | 1<br><br>Finnes ikke målinger av effekt på fisk som følge av NP transfer gjennom trofiske nivåer | Nei | Nei | 1 |
| | | | | | | |
| g) Lusemidler | 4/5<br><br>Gode kunnskaper fra lab- og feltstudier om effekter av ulike midler på ulike marine arter under varierende forhold (konsentrasjon, tid) | 4/5<br><br>Lusebehandlinger rapporteres til Mattilsynet | 4/5<br><br>Gode Det finnes noe data fra B- eller C-undersøkelser, men disse data finnes for eksempel ikke i vannmiljø, gode modeller utviklet for å predikere effekt | Nei<br><br>Etablert forbudssoner | I Norge er grenseverdier etablert i nær- og fjernsone kun for flubenzoroner, ellers ikke. Internasjonale grenseverdier finnes for andre stoffer, som kan bli brukt i Norge med dagens kunnskap. | 4 |

Vurdering av score i siste kolonne er gjort individuelt for hver stressor.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

Tabell 6-1 viser at kunnskapsstatusen for ulike stressorer identifisert i AP1 varierer mye. Dette kan ha sammenheng med hvor viktig de ulike stressorene oppfattes å være både i forvaltningen og i befolkningen generelt. Mye forskning igangsettes og finansieres nettopp med bakgrunn i forvaltningens behov, og den vekt stressorene har hatt i forvaltningen kan derfor reflektere den kunnskap man har opparbeidet seg til nå.

Noen stressorer har vært tungt vektlagt i forvaltningen. Dette gjelder for eksempel lus og partikulære organiske utslipp og næringsstoffer, disse har god kunnskapsstatus og høy score i tabellen (score 4 og 5). Når det gjelder partikulære organiske utslipp har vi for eksempel mye mindre kunnskap og verktøy tilgjengelig for hardbunn (score 2) enn for bløtbunn (score 5). På hardbunn satte vi scoren til 2, da vi vet at der er en påvirkning, men at påvirkningen både i utstrekning og i tid er uklar. Videre mangler både terskler/grenseverdier og effektive overvåkingsverktøy. Selv om vi vet mengden utslipp, kan vi ikke nødvendigvis tallfeste påvirkningen av det aktuelle utslippet.

Videre har man i både forvaltningen og befolkningen vært opptatt av bruk av lusemiddel og antibiotika som viktige miljøpåvirkninger. Dette gjenspeiles også i dagens gode kunnskapsgrunnlag om disse stressorene (score 4).

Vi har for veldig mange stressorer imidlertid gitt en lav score. Det betyr at kunnskapen foreløpig er vurdert som begrenset. Dette gjelder for stressorer som sykdom (score 3), kunstige strukturer, lyd og lys (score 1), antibegroingsmiddel (score 2), plast (score 2), uønskede stoffer i for (score 1), desinfiseringsmiddel (score 1) og nanopartikler (score 1).

Betyr dette at man har for lite kunnskap i forhold til dagens behov? Eller for liten kunnskap til å kunne bidra til mer presis forvaltning? Dette kommer vi tilbake til Tabell 6-2 i neste seksjon og i de følgende delspørsmål.

### *Forvaltningens håndtering av miljøpåvirkning fra havbruk*

Havbruksforvaltningen bruker i dag kunnskap om mange typer miljøpåvirkning. Noen av miljøpåvirkningene er åpenbart viktige, og gjenstand for grundige vurderinger og reguleringer, slik som lus, rømming og utslipp av partikulært organisk materiale. Samtidig kan det være at man i for liten grad tar hensyn til en del typer miljøpåvirkning. Behovet for å ta flere typer miljøpåvirkning inn i forvaltningens vurderinger kan skyldes flere ting:

- økende produksjon (vekst i næringen) og økende mangfold av produksjonssystemer og arter kan gjøre at miljøpåvirkning som tidligere ikke har vært ansett som vesentlig kan komme opp i en størrelse/over en terskel som gjør den viktig
- kunnskap om nye stressorer, eller ny kunnskap om kjente stressorers miljøpåvirkning, kan endre vurderingene av hva som bør inn i forvaltningens vurdering
- økning i en stressor kan forsterke effekten av en annen, for eksempel vil økning i lusepåslaget også kunne føre til økt behandling og økte utslipp av lusemidler.
- Utslipp fra andre næringer, og flere typer utslipp fra næringen selv, gjør at behovet for å vurdere kumulative effekter øker.

Dette betyr at forvaltningen ikke bare må vurdere dagens situasjon (og dagens miljøpåvirkning), men også må evne å se konsekvensene av mulig vekst i akvakulturnæringen, og hvordan miljøpåvirkningen vil kunne bli i fremtiden. Det betyr også at man må evne å identifisere ny kunnskap, og vurdere relevansen av denne.

For å kunne svare på om det finnes viktige miljøpåvirkninger som ikke er dekket i dagens forvaltning har vi derfor gjort tre vurderinger:

1) Miljøpåvirkning fra stressoren i dag, gitt dagens produksjonsnivå og -teknologi.
2) Forventet miljøpåvirkning ved en tenkt vekst i produksjonen. Vi tar da utgangspunkt i stressorens miljøpåvirkning ved doblet produksjonsvolum
3) Eventuelt behov for å håndtere stressoren bedre enten gjennom bedre forvaltning eller ny teknologi.

I tabellen nedenfor identifiserer vi viktige miljøpåvirkninger som etter vår oppfatning ikke er dekket godt nok i dagens forvaltning basert på de tre vurderingene. I kommentarene under vil det også komme frem om vi anser at forvaltningen av stressoren også er egnet til å håndtere vekst. Et moment i vurderingen av viktighet bør være om miljøpåvirkningen er langvarig eller irreversibel, eller om det er en påvirkning som raskt reduseres, eller forsvinner ved redusert påvirkning fra den aktuelle stressor.

For noen stressorer finnes det lite kunnskap som identifisert over; vi kan derfor ikke med sikkerhet si at det er behov for å vurdere stressoren i forvaltningen. Andre stressorer kan ha lite betydning i dag, men mulig større betydning i fremtiden, avhengig av blant annet vekst i havbruksnæringen og andre faktorer diskutert under. Tilfredsstillende dekning i tabellen betyr at man har gode indikatorer som overvåkes på riktig romlig og tidsmessig skala. Om stressoren er viktig, men godt dekket, representerer den i denne sammenhengen ikke noe problem. Om den er viktig, men dårlig dekket, betyr det at vi har identifisert en stressor som krever større oppmerksomhet fremover.

*Tabell 6-2. Betydning av dagens og fremtidig miljøpåvirkning fra havbruk (stressorer) og hvor godt de er dekket i dagens forvaltning*

| **Miljøpåvirkning/stressor** | **Miljøpåvirkning fra stressoren i dag, med dagens produksjons-metoder og -volum og forvaltning**<br><br>**1(liten) – 5(stor)** | **Forventet miljøpåvirkning fra stressor ved dobling av produksjonen, med dagens produksjons-metoder og forvaltning.**<br><br>**1(liten) – 5(stor)** | **Behovet for å forbedre forvaltning og/eller produksjons-metoder med dagens produksjons-metoder og volum**<br><br>**1(lite) – 5(stort)** | **Korte kommentarer (utfyllende kommentarer på utvalgte stressorer under tabellen)** |
|---|---|---|---|---|
| **Partikulære organiske utslipp**: Bløtbunn | 2 | 3 | 3 | Dekker lokalt, men mangler helhetlig geografisk regional og nasjonal vurdering.<br><br>Manglende kunnskap om hardbunn, noe som hindrer klarering av nye lokaliteter. Mangler geografisk vurdering regionalt, nasjonalt og globalt. |
| **Partikulære organiske utslipp**: Hardbunn | Uklart | Uklart | 5* | |
| Løste næringssalter | 2 | 3 | 3 | Romlig dekning ikke god nok på grunn av begrenset antall stasjoner. Mangler helhetlig regional, vurdering. Lite kunnskap om indirekte effekter, og effekter på høyere trofisk nivå. |
| **Rømming**: Laks/ørret | 4 | 4 | 3 | Godt definert og godt overvåket for laks. Genetisk påvirkning har blitt vist på nasjonalt plan, men pga. mulig lang vandring av fisk bør denne vurderes globalt.<br><br>Dårlig overvåket for rensefisk. Genetisk påvirkning bør vurderes på globalt plan siden rensefisken distribueres internasjonalt. |
| **Rømming**: Rensefisk | uklart | 4 | 4 | |
| Sykdom | 2 | 3 | 3 | Viktighet og dekning varierer for ulike sykdommer, men følges generelt godt opp i forvaltningen. |
| Parasitter | 4 | 5 | 5 | Gode løsninger mangler fortsatt for å kunne kontrollere lusenivåer. |

| | | | | |
|---|---|---|---|---|
| Kunstige strukturer (inkl. anlegg, lys, lyd) | 2 | 4 | 5* | Lite kunnskap om effekten av lys, lyd og plassering av anlegg for å vurdere effekten, men sannsynlig betydning for miljø. Mangler helhetlig regional vurdering. |
| **Medisiner og andre fremmedstoffer** | | | | |
| a) Antibegroingsmidler | 4 | 5 | 5 | Mulig å inkludere mer i forvaltningen (målbar effekt). Mangler helhetlig regional vurdering |
| b) Plast | Uklart | Uklart | 5* | Lite informasjon om miljøpåvirkning fra akvakultur, ikke dekket i forvaltningen av akvakultur. |
| c) Fôringredienser | Uklart | Uklart | 5* | Overvåkning av fôrinnhold, men lite kunnskap om stressoren i miljøet. |
| d) Antibiotika | 1 | Uklart | 1 | Begrenset bruk i norsk oppdrett. Usikkert behov ved økt produksjon. |
| e) Desinfiseringsmidler | Uklart | Uklart | 5* | Få vitenskapelige studier om dette, men sannsynlig av noe betydning for miljø. Mangler helhetlig regional vurdering. |
| f) Nanopartikler | Uklart | Uklart | 5* | Lite kunnskap om stressoren. |
| g) Avlusningsmidler | 3 | 5 | 5 | Store miljøutfordringer ved dagens produksjon. Finnes både behov og mulighet til bedre regulering. Dekkes lokalt, mangler helhetlig geografisk regional og nasjonal vurdering. |

Forklaring av skala brukt i tabellen: 1 – ikke viktig/godt dekket/ingen behov; 2 – noe viktig/ganske godt dekket/lite behov; 3 – ganske viktig/manglede dekning/begrenset behov (for enkelte områder eller brukere); 4 – viktig/dårlig dekket/ ganske stort behov; 5 – meget viktig/ikke dekket/stort behov. Score og fargen i kolonne «behov for å inkludere stressoren» er definert etter følgende prinsipp: +1 til score på dekning hvis viktighet er på nivå 5 eller 4; +0 hvis viktighet er 3, 2 eller uklart; -1 hvis viktighet er 1. Det gjøres ingen endring i score på «behov for å inkludere stressoren i forvaltning» hvis resultat er utenfor skala 1-5. * behov for utredning av miljøpåvirkning/inkludering i forvaltning.

| 1 | 2 | 3 | 4 | 5 | -uklart |
|---|---|---|---|---|---|

Vi har gjennom denne tabellen identifisert og oppsummert en rekke stressorer, med stor spredning i vurderingene. Basert på en vurdering av om stressorene er viktige, status på kunnskapsgrunnlaget og i hvor stor grad stressoren er dekket i forvaltningen, har vi funnet at vi kan snakke om fire hovedgrupper av stressorer:

**Stressorer som er viktige, har et godt kunnskapsgrunnlag og er godt dekket i forvaltning:**

- *partikulære organiske utslipp (bløtbunn)*
- *løste næringssalter*
- *rømming (laks/ørret)*
- *sykdom*
- *antibiotika.*

**Stressorer som er viktige, med et godt kunnskapsgrunnlag, men er dårlig dekket av forvaltning i dag. Dette betyr at vi har identifisert en stressor som krever større oppmerksomhet av forvaltningen fremover:**

- *rømming(rensefisk)*
- *parasitter*
- *antibegroingsmidler*
- *avlusingsmidler*

**Stressorer som det finnes for lite kunnskap om miljøpåvirkning i dag, men hvor det er behov for å avdekke hvilken betydning de kan ha for forvaltning og næringen:**

- *partikulære organiske utslipp (hardbunn)*
- *kunstige strukturer (inkl. anlegg, lys, lyd)*
- *plast*
- *uønskede fôringredienser*
- *nanopartikler*
- *desinfiseringsmidler.*

**Stressorer som har betydning i dag, men potensielt større betydning i fremtiden, avhengig av blant annet vekst i havbruksnæringen:**

- *Alle unntatt én er vurdert til å ha større betydning i fremtiden*

Under kommenterer vi de ulike kategoriene og gir litt mer utfyllende vurderinger av stressorene.

Det er viktig å påpeke at vi i denne delen ikke har sett på sammenheng mellom stressorene. Stressorer har her vært diskutert enkeltvis, men det er viktig for forvaltningen å vurdere dem i sammenheng. Lusebekjempelse er et eksempel der arbeidet med å holde en stressor (lus) nede kan skape eller øke alvorlighet av en annen stressor (for eksempel rømming av rensefisk, utslipp av lusemidler). Muligheter til å håndtere flere stressorer samtidig bør også vurderes (for eksempel, både parasitter og andre sykdommer og rømming kan håndteres ved avstandssoner, forebygges ved bruk av lukkede anlegg osv.). Det er også viktig å vurdere disse stressorene i forhold til andre næringer og klimaforandringer.

**Stressorer som er viktige, har et godt kunnskapsgrunnlag og er godt dekket i forvaltning.**

I denne kategorien har vi stressorer som har scoret tre eller mindre i tabellen. Dette gjelder stressorene partikulære organiske utslipp: bløtbunn, løste næringssalter og rømming: laks/ørret, sykdom, og antibiotika. Dette betyr ikke at det er uttømmende kunnskapsgrunnlag for disse stressorene eller ikke rom til forbedringer og mere presis forvaltning for disse stressorene. Men at det er et relativt godt kunnskapsgrunnlag og de er godt dekket i forvaltningen. For desinfeksjonsmidler er kunnskapsgrunnlaget manglende, men er scoret relativt lavt siden man vurderer at dette er en mindre viktig miljøpåvirkning. Men det er anbefalt at kunnskapsgrunnlaget for miljøpåvirkning av desinfeksjonsmiddel økes.

**Stressorer som er viktige, med godt kunnskapsgrunnlag, men er dårlig dekket av forvaltning i dag, dette betyr det at vi har identifisert en stressorer som krever større oppmerksomhet av forvaltningen fremover.**

Vi har i denne kategorien identifisert stressorer vi mener har et godt kunnskapsgrunnlag, men som er dårlig dekket av forvaltning, dette er stressorer som scorer 4-5 i tabellen (ikke de med Asterix). Om stressoren viktig, men dårlig dekket, betyr det at vi har identifisert en stressor som krever større oppmerksomhet fremover og det er et behov for å inkludere stressorene i forvaltningen på en bedre måte. Disse stressorene er rømming(rensefisk), parasitter, antibegroingsmidler og avlusningsmidler.

Det mangler en oversikt over antall *rømte rensefisk*. Rømming kan være en risikofaktor for overføring av sykdom og genetisk påvirkning på lokale bestander, i tillegg til et fiskevelferdsproblem. Rensefiskbruk er i liten grad forvaltet, og det er utrykt behov for reguleringer fra ulike interessentgrupper i samfunnet.

*Parasitter* som lus er godt dekket i dagens forvaltning, men ikke godt nok, gitt at det er den viktigste begrensningen for vekst. Til tross for omfattende regulering er ikke lusesituasjon under kontroll per i dag. Trafikklyssystemet er mye kritisert, blant annet for at man selv med stor inngripen oppnår lite påvirkning på bestanden av lus på villaks (Larsen og Vormedal, 2021), og bør utvikles videre. For fremtidig vekst kreves dermed enten mer kunnskap, bedre forvaltning eller teknologi som løser eller i det minste reduserer problemet til et akseptabelt nivå.

Kobber som brukes til i *antibegroingsmidler* vurderes å utgjøre en viktig miljøpåvirkning. Så vidt vi vet finnes det ingen regulering eller standardisert overvåking, men bruken av kobber måles i sertifiseringssystemet ASC (derav score 4). De norske grenseverdiene for kobber fremkommer av veilederne 02:2018 og M-608 (Direktoratsgruppen, 2018; Miljødirektoratet, 2016). Overvåking etterspørres sporadisk av Statsforvalter, og det gjøres også sporadisk vurdering av tilstandsklasse, men det er usikkert hva konsekvensen av å overskride tilstandsklasse god vil være.

*Avlusningsmidler* vurderes å utgjøre en viktig miljøpåvirkning. I gitte konsentrasjoner representere fare for miljøet, for eksempel rekefelt. Krepsdyr er svært følsomme for midlene, og de dør av konsentrasjoner som er langt lavere enn det som slippes ut i miljøet etter endt behandling. Det finnes reguleringer angående avstand, man kan for eksempel ikke bruke bademidler eller flubenzuroner nærme rekefelt (ingen dumping fra badbehandlinger nærmere enn 500 m unna rekefelt, og ingen bruk av flubenzuroner nærmere enn 1000 m til rekefelt). I tilfeller der det ikke finnes rekefelt er det ingen regulering. Risikovurdering har vist at stoffer kan spres over store avstander (mange kilometer), dvs. betydelig lengre enn de geografiske grensene som er angitt for rekefelt. Internasjonale grenseverdier for områder tilsvarende nær-/fjernsone eksisterer. Det finnes også modeller for spredning og for halveringstid i sediment. Det finnes dermed et relativt godt kunnskapsgrunnlag som kan danne grunnlag for bedre reguleringer og standardiseringer. En viktig årsak til at dette ikke er bedre regulert, er at disse stoffene ikke tas med i utslippstillatelsen. De er i utgangspunktet ikke planlagt brukt. Bruk av lusemidler er definert som "hendelse" hvor veterinærer må gjøre vurderinger og skissere tiltak for å fjerne lus. Det er i det siste tatt i bruk metoder for medikamentell behandling i lukkede systemer. Dette er kostbart, og det er foreløpig usikkert hvor mye av fremtidig medikamentbasert behandling som vil foregå i lukkede systemer. Det er derfor mulig at økt produksjon også vil gi økt bruk av medikamenter.

**Stressorer som det finnes for lite kunnskap om miljøpåvirkning i dag, men det er behov for å avdekke hvilken betydning de kan ha for forvaltning og næringen.**

For noen stressorer finnes det lite kunnskap; vi kan derfor ikke si med sikkerhet eksakt hvilken miljøpåvirkning disse stressorene har i dag eller vil ha med dobbel produksjon (derfor er disse definert som uklare i tabellen). For noen er også bruk ikke godt nok utredet. Men ut fra kunnskapsgrunnlaget som eksisterer om virkning og toksisitet av disse stressorene mener vi at det er presserende behov for bedre kunnskapsgrunnlag og forvaltningspraksis, regulatorer har for øyeblikket ingen retningslinjer for hvordan de skal håndtere disse stressorene som f.eks. hardbunns påvirkninger. Disse stressorene er kategorisert som 5*, og er partikulære organiske utslipp(hardbunn), kunstige strukturer (inkl. anlegg, lys, lyd), plast, uønskede fôringredienser, nanopartikler og desinfiseringsmidler.

Det er utviklet standardmetoder og grenseverdier for å evaluere påvirkning av *organisk materiale* på sediment og bunnfauna for bløtbunn. Rapportering av tilstand under og nært anlegg gjennom pålagte miljøundersøkelser danner godt grunnlag for iverksettelse av tiltak ved uakseptabel påvirkning. Det finnes derimot ikke standardiserte metoder og grenseverdier for *hardbunnshabitater* og effekten av utslipp fra akvakultur er uklar. Regulatorer har ingen retningslinjer for hvordan de skal håndtere hardbunnspåvirkninger for øyeblikket, derfor er det et klart behov for å utvikle slike metoder og inkludere dem forvaltningen. Det finnes begrenset kunnskap om påvirkningen på hardbunnshabitater. Det er ofte dominans av sårbare habitater og sensitive arter på hardbunn (korallrev, svamp osv.). Skulle disse være til stede, kan påvirkningen være alvorlig over tid da de har en viktig økologisk rolle (hotspots for biologisk mangfold osv.). Sjeldenhet er en nøkkelparameter i rødlistevurderingen og dermed er alle romlige skalaer av betydning for sensitive arter. Selv om antall av en sensitiv art i en regional kontekst ser sunne ut, kan populasjonen være begrenset til det spesifikke området, dvs. forekomst ingen andre steder i verden, noe som da gjør den svært verdifull. Dette er spesifikt for habitater med hardbunn. Det vil da også være behov for en geografisk vurdering regionalt, nasjonalt og globalt.

Betydningen av *plastforurensing* i havet har vært økende, og fokuset på dette vil sannsynligvis øke fremover. Det finnes anslag på mengde utslipp av plastpartikler av ulike størrelser fra oppdrett, men det er lite kvantitativ kunnskap om effekter på ulike resipienter. Omfanget av påvirkninger i tid og rom fra det enkelte anlegg er også uklart. Det er behov for både kunnskap og overvåking, og muligens tiltak på dette området.

Det er behov for en vurdering av eventuell miljøpåvirkning i det marine miljø av *uønskede stoffer i fôr*. Det er god kunnskap om både mengde i for av de ulike stoffene og virkning av de uønskede stoffene på miljøet. Det finnes også gode modellverktøy som skulle kunne brukes til å predikere spredning av fôr og dermed stoffene, etter dette vil man kunne gjøre en miljørisikovurdering. Det trengs også å opparbeide bedre kunnskap om miljøpåvirkning av kunstige strukturer (inkl. anlegg, lys, lyd), nanopartikler og desinfiseringsmidler for å kunne forbedre operasjonelle beslutninger og forvaltning av dette.

**Stressorer som kan ha lite betydning i dag, men potensielt kan ha større betydning i fremtiden, avhengig av blant annet vekst i havbruksnæringen.**

Stressorer kan ha betydning i dag, men potensielt ha større betydning for miljøpåvirkning i fremtiden, avhengig av blant annet vekst i havbruksnæringen, vekst i belastning fra annen menneskelig aktivitet eller endret sårbarhet i resipienter, for eksempel på grunn av klimaendringer. Nesten alle stressorene scoret høyere på vurderingen av forventet miljøpåvirkning fra stressor ved dobling av produksjonen. Det er av strategisk viktig betydning når man vurderer mulig vekst.

For eksempel er eutrofiering (på grunn av løste næringsstoffer) en mulig konsekvens og endepunkt av for mye løste næringsstoffer, og kan utgjøre en svært viktig negativ påvirkning på økosystemnivå. Løste næringsstoffer er derfor et viktig element i norsk og internasjonal marin miljøforvaltning, og en viktig del av nasjonal overvåkning i henhold til vanndirektivet. Løste næringsstoffer har potensielt stor betydning, og kan bli en større utfordring ved vekst, men er i prinsippet tatt hensyn til i forvaltningen, for eksempel gjennom vanndirektivet, selv om romlig dekning fortsatt er lav (score 2). Klimaendringer kan føre til større utfordringer i enkelte områder i fremtiden.

Et annet eksempel er antibiotika. Dette brukes ikke lenger mye i norsk oppdrett, og har samlet sett ikke stor påvirkning. Antibiotika reguleres ut fra reseptsystemet som forvaltes av fiskehelsepersonell og veterinærer. Det finnes ingen miljøindikator eller systematisk overvåkning av denne stressoren. Men selv om det gjennomsnittlig er snakk om veldig få gram per produsert kilo fisk, så kan bruk på enkelte lokaliteter, hvor flere tusen tonn laks skal behandles, likevel representere et punktutslipp som kan være stort nok til å bli ansett som en utfordring. Om denne bruken går opp ved vekst kan det også være viktig. Aktuelle miljøeffekter av en slik forurensing er resistensutvikling hos bakterier i sedimentet.

### 6.3.2 Kan eksisterende kunnskapsgrunnlag brukes bedre?

I dette avsnittet vil vi diskutere om eksisterende kunnskapsgrunnlag kan brukes bedre i forvaltningen, slik at man kan få til en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning av havbruksnæringen, og samlet miljøpåvirkning. Dette har vi valgt å undersøke som et todelt spørsmål. For det første spør vi om det kunnskapsgrunnlag og de metoder for vurdering av miljørisiko **som brukes i forvaltningen i dag** kan brukes bedre (forskningsspørsmål 2, se kapittel 6.1), før vi spør om eksisterende indikatorer, kunnskapsgrunnlag og metoder **som ikke brukes i forvaltningen i dag**, kan brukes til forbedret forvaltning (dette svarer til første del av forskningsspørsmål 3 i kapittel 6.1, resten av dette forskningsspørsmålet behandles i kapittel 6.3.3).

#### 6.3.2.1 Kan kunnskapsgrunnlag og metoder som forvaltningen bruker i dag brukes bedre?

I dette avsnittet vil vi diskutere om man med det **kunnskapsgrunnlag og de metoder** for vurdering av miljørisiko **som brukes i forvaltningen i dag** kan få til en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning av havbruksnæringen og samlet miljøpåvirkning.

Er det med andre ord mulig å bruke data, kunnskap og vurderingsmetoder som allerede er kjent eller finnes til å få en bedre forvaltning? Det kan eksempelvis innebære enten at man bruker data eller kunnskap i andre deler av forvaltningen enn der de brukes i dag, eller at man bruker eksisterende kunnskapsgrunnlag på en ny måte. Det siste kan være å bruke data til andre vurderinger, eller kombinere flere datasett for å gjøre vurderinger.

For å få til en lokaltilpasset forvaltning kreves det kunnskap om lokale forhold og egenskaper ved resipienten som påvirker graden av negativ påvirkning en gitt stressor forventes å ha. For det andre krever det kunnskap om mengde av den enkelte stressor som tilføres resipienten. I tillegg kreves verktøy som er egnet for å analysere risikoen for miljøpåvirkning som er tilpasset skala i tid og rom.

En grov oversikt over hvilket geografisk nivå vi vurderer miljøeffekter fra de ulike stressorene å være relevante for er gitt i Tabell 6-3.

*Tabell 6-3. Stressorer sin relevans for effekter på miljø på ulike geografiske nivåer*

| | Lokalitet | Rundt lokalitet/ i fjord | PO | Generelle |
|---|---|---|---|---|
| Partikulært organisk utslipp | x | x | | |
| Løste nærings-salter | | x | | |
| Medikament-bruk | x | x | | |
| Lys-/ støy-forurensing | x | x | x | |
| Annen forurensing | x | x | x | x |
| Sykdom | | x | x | |
| Lus / parasitter | | x | x | |
| Rømming | | x | x | |
| Naturmangfold | | x | x | x |

I kapittel 5 er det kartlagt hvilket kunnskapsgrunnlag forvaltningen bruker i dag. En oppsummering av dette er oppgitt i Tabell 6-4 hvor vi også har gjort en grov angivelse av hvilket geografisk nivå dette kunnskapsgrunnlaget er relevant for når miljøeffekter skal vurderes, slik vi ser det. Sammen med tabellen over er dette informasjon som setter rammer for å vurdere om dagens kunnskapsgrunnlag kan brukes bedre.

*Tabell 6-4. Geografisk dekning av kunnskapsgrunnlaget som blir brukt (relevant for miljøtilstand/miljøpåvirkning).*

| Geografi-nivå-> Kunnskapsgrunnlag | Lokalitet | Rundt lokalitet / i fjord | PO | Større / generell |
|---|---|---|---|---|
| B-undersøkelse | x | | | |
| C-undersøkelse | | x | | |
| HI risikovurdering, strandsoneundersøkelser (jf løste næringssalter) | | x | | |
| Trafikklys-vurdering produksjonsområde | | | x | |
| Legemiddelverket om medikamenter | x | x | | x |
| Fiskeområder mv. i kart | x | x | | |
| Gyteområder i kart | x | x | | |
| Avstand og tilstand anadrome lakseelver | | x | x | x |
| Kartlagt naturmangfold, Naturbase | x | x | x | x |
| Vannforekomst-vannkvalitetsmål | x | x | | |
| Studier om lusemidler | x | x | | x |
| Avstand annet produksjonsområde | | | x | |
| Laksesmolt-rute i sjø | x | x | x | |
| Risikovurdering påvirkning villtorsk | x | x | | |
| Strømmålinger og -modelleringer | x | x | x | |
| Geografi og topografi ved lokalitet | x | x | | |
| Oksygen-målinger | x | x | | |
| Luserapporter | x | x | x | |
| Verneområder | x | x | | |
| Oversikt viktige naturtyper, prioriterte, freda og truede arter | | | | x |

I Tabell 6-5 har vi på en skala fra 1-5 vurdert de ulike stressorenes potensiale for å forvaltes mer lokaltilpasset, treffsikkert og samfunnsøkonomisk effektivt med dagens kunnskapsnivå. Vurderingene må leses som indikasjoner hvor de relative forskjellene mellom stressorene er det viktigste. Som beskrevet tidligere i rapporten er forvaltningen kompleks og de ulike stressorene inngår i vurderinger knyttet både til arealplanlegging, produksjonstillatelser, lokalitetsgodkjenning og drift.

*Tabell 6-5. Kan man med det kunnskapsgrunnlag og de metoder for vurdering av miljørisiko* ***som brukes i forvaltningen i dag*** *få til en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning av havbruksnæringen og samlet miljøpåvirkning?*

| | **Kan forvaltning bli mer lokaltilpasset enn dagens?** *1(neppe) – 5(klart)* | **Kan forvaltning bli mer treffsikker enn dagens?** *1(neppe) – 5(klart)* | **Kan forvaltning bli mer samfunnsøkonomisk effektiv enn dagens?** *1(neppe) – 5(klart)* |
|---|---|---|---|
| Partikulære organiske utslipp | 2 | 2 | 2 |
| Løste næringssalter | 2 | 2 | 3 |
| Rømming | 2 | 2 | 2 |
| Sykdom | 3 | 2 | 3 |
| Parasitter | 3 | 4 | 4 |
| Kunstige strukturer (lys, lyd osv.) | 1 | 1 | 1 |
| **Medisiner og andre fremmedstoffer** | | | |
| Antibegroingsmidler | 2 | 3 | 3 |
| Plast | 1 | 2 | 2 |
| Fôringredienser | 1 | 1 | 1 |
| Antibiotika | 1 | 1 | 1 |
| Desinfiseringsmidler | 1 | 1 | 1 |
| Nanopartikler | 1 | 1 | 1 |
| Andre farmasøytika | 1 | 1 | 1 |
| Lusemidler | 4 | 4 | 4 |

I det følgende beskriver vi hvilke betraktninger som ligger til grunn for de vurderingene av hver stressor som er presentert i Tabell 6-3.

**Partikulære organiske utslipp**: Overvåkning av påvirkning på bløtbunn gjøres gjennom B- og C-undersøkelsene. Overvåkningen er risikobasert, hvor store anlegg har flere prøvepunkter enn små, og hvor resultatet av en undersøkelse avgjør når neste undersøkelse skal gjøres. Det kommer pålegg om tilpasninger av drift dersom resultatene viser dårlig miljøtilstand ved lokaliteten over tid. Forvaltningen av drift er i stor grad lokaltilpasset og treffsikker allerede. Rapportering av resultater fra B-undersøkelsene gikk fra april 2023 over til å bli helt digitalisert, dette gjør at disse dataene blir lett tilgjengelige og kan kobles med andre data forvaltningen har tilgjengelig. Et mulig område for forbedring er om fastsettelse av MTB kan bli mer lokaltilpasset og treffsikker. Her kan man eksempelvis tenke seg å kombinere modellering med data som likevel samles inn (data fra forundersøkelse, strømmålinger, topografi og bunntype). Hydrodynamiske spredningsmodeller blir stadig bedre og mer treffsikre og såkalte forecast-modeller er under utvikling. Per nå vurderes dagens løsning (å gi midlertidig tillatelse og så vurdere tillatelse og MTB på nytt etter en gjennomført produksjonssyklus og prøvetaking) å være en fornuftig løsning og kompromiss. For hardbunn er det kommet forslag til kartlegging/undersøkelse, men disse har en betydelig kostnad. For sårbare hardbunnshabitater praktiseres i dag føre var prinsippet.

**Løste næringssalter**: Utslippsmengde kan beregnes basert på MTB-grense på lokalitet eller fôrforbruk, og det tas hensyn til økologisk og kjemisk tilstand i en vannforekomst når det skal vurderes hvorvidt en lokalitet blir klarert i en vannforekomst. I dag er det stort sett total belastning ved utslipp av løste næringssalter som vurderes, og ikke om eller hvordan ulike lokaliteter i et område bidrar til risiko for overgjødsling, og heller ikke om allerede godkjente lokaliteter i et område burde fått endret MTB for å tilpasse produksjon til miljørisiko, når det søkes om en ny lokalitet. Overvåkning som settes i gang og tiltak som iverksettes i vannforvaltningen skal også inkludere kost-nytte analyser. Men i praksis later det til å være begrenset med faktiske kost-nytte analyser som gjennomføres. Løste næringssalter tilføres miljøet fra flere kilder, og flere næringer pålegges krav om overvåkning i tillegg til de nasjonale overvåkningsprogrammene. En større grad av samkjøring mellom overvåknings programmer vil kunne gjøre forvaltningen av denne stressoren mer samfunnsøkonomisk effektiv.

**Rømming**: Det tas hensyn til bestander av anadrome laksefisk ved klarering av en lokalitet, og også i kystsoneplanlegging, herunder tilstanden for bestandene i området, avstand til elver, og vandringsruter for smolt i fjorder. Men det er stort sett skjønnsmessige vurderinger, også der det legges inn kvantitative kriterier. I løpende drift tas det normalt ikke hensyn til tilstanden for bestander av anadrome laksefisk. Eksempelvis er lusegrenser for en lokalitet ikke påvirket av dette. Unntaksvis kan det tas hensyn til dette, men det er ikke vanlig. Risikoen for en rømmingshendelse fra en konkret lokalitet vil uansett være vanskelig å forutsi, med mindre man gjør større endringer i anlegg/teknologi, som for eksempel å gå fra åpne merder til lukkede anlegg. Det gjøres i liten grad eksplisitte samfunnsøkonomiske analyser av kostnader/verdsetting av negative effekter av rømming eller beregning av direkte og indirekte kostnader ved å gjennomføre tiltak for å redusere rømming. Unntaket er kostnadene knyttet til utfisking i elver ved rømmingshendelser. Ettersom det er usikre sammenhenger mellom mange tiltak for å hindre rømming og faktiske rømminger, og også mellom rømminger og tilstanden for ville bestander, kan det være vanskelig å identifisere lokaltilpassede og samfunnsøkonomisk funderte forvaltningstiltak. Det som kanskje kunne være mulig med dagens data og kunnskap er å tillate vekst kun med lukkede og tilnærmet rømningssikre anlegg i enkelte områder.

**Sykdom**: Forvaltningen ved sykdomsutbrudd er rettet mot både enkeltanlegg og områder med flere anlegg, og er slik både lokaltilpasset og relativt treffsikker. Sykdom er noe man klart ønsker å unngå og har valgt å slå hardt ned på dersom det blir utbrudd. Samtidig er sykdomsutbrudd vanskelige å forutse, med mindre det er risiko for smitte fra nærliggende anlegg. Det gjør det vanskelig med ytterligere treffsikker og mer samfunnsøkonomisk forvaltning. Et eksempel på en mer lokaltilpasset regulering er muligheten til å redusere avstand mellom lokalitetene ved koordinering av driftsplaner, og det er mulig at det her ligger potensiale for effektivisering. Hovedregel er at avstand mellom anlegg skal være minst fem km, men innenfor en brakkleggingsgruppe kan den være kortere enn 2,5 km dersom alle praktiserer fire uker samtidig brakklegging. Mattilsynet oppfordrer til forebyggende koordinering som i dag skjer på frivillig basis. Hydrodynamiske modeller og spredningsmodeller som brukes i trafikklyssystemet kan mulig være nyttig for å evaluere risiko for sykdomsspredning.

**Parasitter**: Den viktigste parasitten i dag er lakselus. Trafikklyssystemet har relativt store produksjonsområder som gis samme trafikklysfarge. Her kan det være store forskjeller i risiko knyttet til lakselus i oppdrettsanleggene mellom ulike områder innenfor ett produksjonsområde. Det er relativt stor grad av lokaltilpasset forvaltning ved arealplanlegging og lokalitetssøknad, samt ved unntakssøknader i trafikklyssystemet. Andre elementer i forvaltningen av lakselus er imidlertid lite lokaltilpasset. Det er samme lakselusgrense for alle anlegg, og der kan tenkes mer lokaltilpasset og treffsikker forvaltning. Siden lusebehandlinger har stor betydning for dødelighet og vekst og dermed produktivitet, ville endringer i lakselusforvaltningen på lokalitetsnivå være noe som kunne ha betydelig samfunnsøkonomisk effekt. Her kunne man trolig hatt en forvaltning som var mer lokaltilpasset og også treffsikker, selv om unntaksreglene i trafikklyssystemet for MTB-vekst på lokalitetsnivå avhjelper dette noe.

**Kunstige strukturer, inkludert lyd og lys**: Forvaltningen av akvakultur har i liten grad eksplisitt vurdert og hatt bestemmelser knyttet til hvordan oppdrettsanlegg som kunstige strukturer påvirker ansamling av ville arter, og det samme gjelder for hvordan lys og lyd fra anlegg påvirker ville arter. Det finnes imidlertid ikke kunnskap og data om disse forholdene i forvaltningen i dag som kan utnyttes til kunnskapsbasert regulering.

**Antibegroingsmidler**: Dette har frem til i dag primært vært kobber-impregnering av nøter, men det er også kommet ulike biocider på markedet. Noen lokaliteter har fått krav fra Statsforvalter om utvidet overvåkning av kobber i sedimenter gjennom C-undersøkelser. Det er forbudt med utslipp av miljøskadelige kjemikalier fra rengjøring, for eksempel kobber, men §25 i forurensningsforskriften gir unntak for rengjøring av not på oppdrettslokaliteten. Dette er imidlertid reaktive krav for en type forurensing (tungmetaller) som har lang varighet i miljøet. Mer systematisk prøvetaking ved B- og C-undersøkelser vil kunne gi et grunnlag for mer lokaltilpasset forvaltning. Mengdene som brukes og slippes ut er trolig høye i forhold til andre utslipp av dette i Norge. Det er uklart om det er gjort noen samfunnsøkonomiske betraktninger rundt å tillate så høye utslipp av kobber.

**Plast**: Dette dreier seg både om marin forsøpling og mikroplast. Marin forsøpling med større plastbiter kan være en risiko for dyreliv, og negativt for landskap, friluftsliv og rekreasjon. Det er i liten grad klart hvor stor risiko mikroplast utgjør for miljø og natur. Det er et generelt forbud mot forsøpling og påbud om å minimere forurensing. Det er imidlertid begrenset med data både om lokale og samlede utslipp, og forvaltningen av akvakultur har i liten grad eksplisitt vurdert og hatt bestemmelser knyttet til plast. Begrenset kunnskap om miljøpåvirkning gir dermed i liten grad mulighet for en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning med dagens kunnskapsgrunnlag.

**Fôringredienser**: De fôringrediensene som det vises til i litteraturgjennomgangen (Kapittel 3) er immunostimulanter, plantebaserte råvarer og PAH. Det er lite kunnskap i forvaltningen om faktiske råvarer og innhold som brukes på ulike lokaliteter, men det er regler om stoffer som er forbudt i fôr. Det antas å være liten kunnskap om hvordan stoffer som er tillatt i fôr kan påvirke miljøet rundt lokaliteter, og dermed i liten grad mulig å få en bedre forvaltning med dagens tilgjengelige kunnskap.

**Antibiotika**: Det brukes svært lite antibiotika i oppdrett i Norge i dag, slik at det neppe utgjør en miljørisiko av betydning. Det må videre foreskrives av kompetent fiskehelsepersonell. Det er lite trolig at forvaltningen av dette kan forbedres på en samfunnsøkonomisk fornuftig måte.

**Desinfiseringsmidler**: Det er lite kunnskap om miljørisiko ved å bruke desinfiseringsmidler. Begrenset kunnskap om miljøpåvirkning gir dermed i liten grad mulighet for en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning med dagens kunnskapsgrunnlag.

**Nanopartikler**: Det er lite kunnskap om miljørisiko knyttet til nanopartikler og ingen data om det for norsk akvakultur. Nanopartikler er ikke aktivt forvaltet i norsk akvakultur i dag. Begrenset kunnskap om miljøpåvirkning gir dermed i liten grad mulighet for en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning med dagens kunnskapsgrunnlag.

**Andre farmasøytika**: I litteraturgjennomgangen (kapittel 3) ble det indentifisert to to antimikrobielle biocider i denne kategorien, men det finnes ikke kunnskap om diss for norsk akvakultur. Begrenset kunnskap om miljøpåvirkning gir dermed i liten grad mulighet for en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning med dagens kunnskapsgrunnlag.

**Lusemidler**: Før lusemidler brukes på et anlegg skal det gjøres en risikovurdering om miljøeffekter. Denne gjøres av fiskehelsepersonell/veterinær. Litteraturgjennomgangen i kapittel 3 indikerer at det finnes data om giftighet, konsentrasjoner i miljøet (modellert og målt i noen tilfeller) og miljørisiko. De eksisterende data og modellverktøy kan brukes mer aktivt for å oppnå en mer treffsikker forvaltning.

#### 6.3.2.2 Finnes kunnskapsgrunnlag som ikke brukes i forvaltningen i dag?

I dette avsnittet diskuterer vi hvorvidt det eksisterer indikatorer, kunnskapsgrunnlag, data eller metoder som **ikke brukes i forvaltningen i dag**, og om denne kunnskapen eventuelt kan bidra til bedre forvaltning.

I dette avsnittet diskuterer vi hvordan det vitenskapelige kunnskapsgrunnlaget om miljøpåvirkning samlet inn gjennom litteraturgjennomgangen, både kunnskap, data og metoder, kan brukes til en bedre mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning av havbruksnæringen.

Tabell 6-6 viser kunnskap som ikke, eller i liten grad, brukes i forvaltningen i dag.

*Tabell 6-6. Kan mer bruk av eksisterende kunnskap og data gi bedre forvaltning?*

| | **Finnes det data/ indikatorer om stressor, ikke brukt i forvaltningen i dag**<br><br>***1(Neppe) – 5(Klart)*** | **Finnes det data/ indikatorer om resipient ikke brukt i forvaltningen i dag**<br><br>***1(Neppe) – 5(Klart)*** | **Finnes det metoder for miljø-risikovurdering ikke brukt i dag? (f.eks. modeller for geografisk spredning, metode for å vurdere faktisk miljørisiko)**<br><br>***1(Neppe) – 5(Klart)*** | **Kommentar** |
|---|---|---|---|---|
| **Partikulære organiske utslipp** | 2 | 1 | 2 | Miljørisiko-vurderinger brukes i svært variabel grad av sektormyndigheter, mer som et unntak enn regel. Ikke godt dekket for hardbunn. |
| **Løste næringssalter** | 1 | 1 | 2 | Miljørisiko-vurderinger brukes i svært variabel grad av sektormyndigheter, mer som et unntak enn regel. |
| **Rømming** | 2 | 2 | 2 | En rekke tiltak er pålagt og følges opp av forvaltning. Forskes videre på rømnings-tematikk. |
| **Sykdom** | 2 | 2 | 2 | |
| **Parasitter** | 3 | 3 | 3 | Regionale kunnskapsaktører sitter på data som ikke brukes av forvaltning. |
| **Kunstige strukturer (lys, lyd osv.)** | 1 | 2 | 2 | Svært dårlig datagrunnlag og empiri i Norge. |
| **Medisiner og andre fremmedstoffer** | | | | |
| **a) Antifoulants** | 4 | 1 | 4 | Finnes kunnskap som ikke brukes. Kjenner omfang, men ikke effekter. Måles ved sertifisering. |
| **b) Plast** | 1 | 1 | 1 | Svært dårlig datagrunnlag og empiri i Norge. |
| **c) Fôringredienser** | 2 | 2 | 4 | Godt dekket av HI. |
| **d) Antibiotika** | 1 | 1 | 1 | Lite brukt og lite fokus. |
| **e) Desinfiserings-midler** | 2 | 2 | 4 | Svært usikkert datagrunnlag. |
| **f) Nanopartikler** | 1 | 1 | 1 | Lite kunnskap. |
| **g) Lusemidler** | 5 | 3 | 4 | Mangler norske akseptkriterier, men internasjonale grenseverdier finnes. |

I denne tabellen er det gjennomgående lav score, det vil si at for de fleste stressorer er det slik at (det meste av) tilgjengelig kunnskap tas i bruk. De eneste stressorene med høy score er antibegroingsmidler og avlusningsmidler, hvor det finnes kunnskap som i større grad kan tas i bruk. Vi kommenterer kort nedenfor hvilke vurderinger som ligger til grunn for score gitt i

Tabell 6-6 og hva slags kunnskap om de ulike stressorene som i dag ikke tas i bruk.

**Antibegroingsmidler (kobber):** Det finnes en god del kunnskap om kobber i sedimenter ved og nært oppdrettsanlegg (C-undersøkelser + ASC-krav om måling). Man mangler kunnskap om ulike former av kobber i sedimenter, og toksisitetsdata for andre arter enn de som er i sedimentene (HI 2022). Vanndirektivet kategoriserer kobber i tilstandsklasser (se Veileder M-608 og 02:2018). Statsforvalteren har en viss oppmerksomhet mot kobber-forurensing fra fiskeoppdrett og ber sporadisk om overvåkning av dette på lokaliteter. Det er store forskjeller mellom fylker. På Vestlandet har det i lengre tid vært stort fokus på kobberforurensing, mens i andre fylker har ikke problemet og temaet vært like viktig.

**Lusemidler:** Det finnes risikovurderingsmetoder som inkluderer grenseverdier for midlene som brukes i Norge i dag, men det er ikke etablert tilstandsklasser for lusemidler. Modelleringsverktøy for spredning av midlene er utviklet for norske forhold, og kan brukes til å vurdere risiko lokalt. Det finnes internasjonale grenseverdier, og for enkelte stoffer (flubenzuroner) også anbefalte verdier for Norge. Kort oppsummert så det finnes godt nok datagrunnlag for å definere akseptkriterier for de ulike stoffene i nærsone og fjernsone. Om grenseverdiene overstiges i nær/fjernsone bør oppdretter iverksette tiltak for å redusere miljørisikoen. Kjemikalier som gis via pellets kan overvåkes ved prøvetaking av ekstra sediment i B/C-undersøkelser. For lusemidler har man kunnskap og verktøy til å gjøre nøyaktige, lokaltilpassede risikovurderinger, som tar høyde for produksjonsspesifikke forhold, strøm på stedet, økotoks-/kjemikalietype osv.

**Lus:** Bestandsstørrelsen av laks og dens sosio-økonomiske betydning vil også variere, der noen vassdrag har stor betydning for rekreasjonsfiske og verdiskapning lokalt. Data om status på villaksbestander og kvalitetsindikatorer fra vitenskapelig råd for lakseforvaltning (VRL) (e.g., Thorstad et al. 2022; Forseth & Fiske, 2022; Forseth & Fiske 2022a; Forseth et al. 2018), samt ringvirkningsanalyser av laksefiske (e.g., Andersen et al. 2019) kan også brukes for å tilpasse tiltak lokalt.

Inndeling av produksjonsområder er gjort ved hjelp av spredningsmodellering, der naturlige klynger er identifisert, og hvor produksjonsområdene er antatt å representere en optimal forvaltningsenhet (Ådlandsvik, 2015). Smitterisiko mellom alle par av anlegg inngår som datagrunnlag for modellen, og dette grunnlaget kan også brukes om det er ønskelig å utvikle tiltak på et mindre geografisk område. Andre modeller som er utviklet for trafikklyssystemet (Veterinærinstituttets risikomodell og SINMOD) bruker også detaljerte data som gjør det mulig å utvikle lokale skadefunksjoner innenfor produksjonsområdene. Det kan imidlertid være både praktisk og kostnadsmessig utfordrende. Høyoppløselige hydrodynamiske modeller kan benyttes til å få en bedre oppløsning av risiko for spredning mellom anlegg og dermed en mer treffsikker forvaltning.

Reguleringen på PO nivå har vært kritisert for at den ikke tar hensyn til variasjon i lusenivåer mellom lokaliteter og selskaper, der oppdrettere med god kontroll på lus tar like mye av støyten ved en nedjustering av tillatelseskapasiteten. En mer differensiert tilnærming har lenge vært etterspurt av næringen, og det burde være mulig å realisere basert på rapporterte lusedata. I dag finnes det unntak fra trafikklyssystemet for selskaper som kan dokumentere lavere lusenivå. Unntak reguleres gjennom egne forskrifter, men det kan være fordelaktig å innføre en viss automatikk i den prosessen.

### 6.3.3 Kan forvaltningen nyttiggjøre seg nytt kunnskapsgrunnlag/data innsamlet av næringen?

Selskapene i akvakulturnæringen er i dag pålagt å samle inn og rapportere informasjon/data, til bruk i ulike deler av forvaltningen. I tillegg blir det samlet inn store mengder informasjon/data til internt bruk for eksempel for å optimalisere drift eller til eksternt bruk, slik som for eksempel dokumentasjon til ulike typer sertifisering. Vi vil derfor i dette avsnittet se på potensialet til å kunne bruke data fra oppdrettsselskapene som i dag ikke rapporteres til å bidra til en bedre forvaltning.

For å svare på forskningsspørsmålet gjentar vi kort hvilke miljøparametere som i dag rapporteres av oppdrettsselskapene som del av den pålagte rapporteringen til forvaltningen, slik at fokus i avsnittet videre blir på data som i dag *ikke* rapporteres. Vi fokuserer på tre nye kilder til data:

- Miljørapporter (årsrapporter, bærekraftsrapporter, Collier-Fairr)
- Sertifiseringer (ASC, Global GAP)
- Løpende miljøregistreringer (data fra anleggene; strøm, oksygen, temperatur) og data fra fiskehelsepersonell.

For å vurdere omfanget av og innholdet i denne miljørapporteringen, og for å få innsikt i hvordan selskapene jobber med dokumentering og rapportering av data og bærekraft, har vi intervjuet flere aktører. I det følgende vil vi bruke Lerøy som case for bærekraftsrapportering.

Til slutt oppsummerer vi denne informasjonen og vurderer om det noe av informasjonen som samles inn av selskapene som kan brukes til forvaltning.

**Miljøparametere som er pålagt rapportert til forvaltningen**

For å synliggjøre hva som blir potensiell ny informasjon, vil vi først gå kort gjennom hvilke miljøparametere som i dag rapporteres til myndighetene.

Innrapportering av data fra selskapenes registrering av miljøparametere i driftsfasen er i stor grad er regulert av forskrift for drift av akvakulturanlegg (akvakulturdriftforskriften – FOR-2008-06-17-822). Næringen har en rekke lovpålagte registreringer som rapporteres inn til ulike myndighetsorgan som Mattilsynet, Fiskeridirektoratet, Statsforvalteren og Fylkeskommunen. Rapportering av miljøparametere som er pålagt rapportering til forvaltningen skjer i stor grad gjennom Altinn. Det rapporteres da på skjema for lakselus (til Mattilsynet) og skjema Miljørapportering (FD-0003 til Fiskeridirektoratet). Havbruksselskap rapporterer også biomasse, settefisk og driftsplaner for akvakulturanlegg i sjøvann på andre skjema (FD 0006 til Fiskeridirektoratet).

Havbruksnæringen samler inn data gjennom lokalitetssøknader, forundersøkelser og B- og C-undersøkelser, jf. Introduksjon i kapittel 2.3. Resultatene fra C- undersøkelsene rapporteres til Vannmiljø og kan enkelt hentes ut der. Resultatene fra B-undersøkelsene rapporteres nå direkte inn Fiskeridirektoratets nye rapporteringsportal og dataene fremstilles i offentlige kartverktøy eller kan lastes ned. Funn fra undersøkelser som havbruksaktører evt gjør utover ovenfornevnte undersøkelser finnes det, etter det vi vet, ikke noe system for å rapportere inn.

### 6.3.3.1 Miljø- og bærekraftsrapportering

Bærekraft er et offentlig uttalt mål, både på internasjonalt og nasjonalt nivå. Norge ønsker at havbruksnæringen skal vokse på en bærekraftig måte. Det innebærer at veksten skal være bærekraftig for både miljø, økonomi og samfunn. Men Bærekraft er imidlertid et komplekst, men samtidig diffust begrep, som ikke enkelt lar seg operasjonalisere eller omsette til konkret handling. Private reguleringer eller "selvregulering" av bærekraft i havbruksnæringen er økende (Eikenæs 2020). Dette skyldes i stor grad at bærekraftsutfordringene også skaper problemer for næringens omdømme og lønnsomhet. Markedene for oppdrettslaks er internasjonale og ulike land har både ulike reguleringer og i noen tilfeller svake håndhevingsmekanismer (Eikenæs 2020). Med bærekraftfokus i samfunnet generelt vil flere investere og handle med selskaper med sunne verdier, som forstår og innpasser globale bærekraftsutfordringer i virksomheten sin.

Det økte fokuset på bærekraft har medført at mange havbruks bedrifter rapporter årlig gjennom egne bærekrafts rapporter, har med bærekraft som tema i årsrapporter, eller tar del i ulike vurderinger og sertifiseringer knyttet til bærekraft.

I desember 2022 rapporterer kyst.no også at Norske akvakulturselskap er i toppen på Coller FAIRR Protein Producer Index[14]. Coller FAIRR Protein Producer Index er vurdert til å være den mest detaljerte vurderingen av de største kjøtt-, meieri- og oppdrettsfiskprodusentene i verden. Rangeringene for hvert av de 60 selskapene som vurderes bestemmes av en risiko- og mulighetsscore på tvers av miljømessige, sosiale og styringsrelaterte kriterier, inkludert klimagassutslipp, avskoging og mattrygghet (ESG).

Denne indeksen rangerer 4 norske selskap blant de 10 beste proteinprodusentene i verden. Øverst på indeksen finner vi Mowi (nummer 1 for fjerde år på rad), fulgt av Grieg Seafood og Lerøy Sefood som nummer 2 og 3. Salmar er nummer 10. Å være på topp på denne rangeringen er ikke mulig uten en svært omfattende overvåking og dokumentasjon av mange parametere som inngår i begrepet økonomisk-, sosial- og miljømessig bærekraft. Å score høyt på slike vurderinger ansees å bli viktigere og viktigere fremover, og man kan dermed forvent at datatilfanget vil øke.

### 6.3.3.2 Sertifiseringer

I tillegg til pålagt rapportering har mange oppdrettsselskap etablert en praksis hvor de frivillig sertifiserer seg etter internasjonale standarder som ASC, Global GAP og BAP. Oppdrettsselskaper må oppfylle en rekke krav i de ulike standardene for å kunne bli sertifisert.

Motivasjonen for frivillig sertifisering ser ut til å handle om selskapenes ønske om å stå i posisjon til å imøtekomme fremtidige strengere myndighetskrav, sikre fremtidige gode produksjonsvilkår, bedre næringens og selskapers omdømme og gi samfunnsaksept samt imøtekomme nåværende markedsetterspørsel og fremtidige markedstrender (Hassel 2016). En annen viktig faktor er at selskap produserer matfisken i et felles hav-, kyst- eller fjordsystem som kan være påvirket av andre aktører. Det å operere i en felles sjøallmenning gir intensiv for å etablere strenge miljøkrav, og motivasjon for selskapenes egeninteresse for frivillig sertifisering (Vormedal, 2020). Tatt i betraktning at lakseoppdrett er en relativ ung

[14] Company Ranking In The Coller FAIRR Index | FAIRR (lastet ned:14.02.2023)

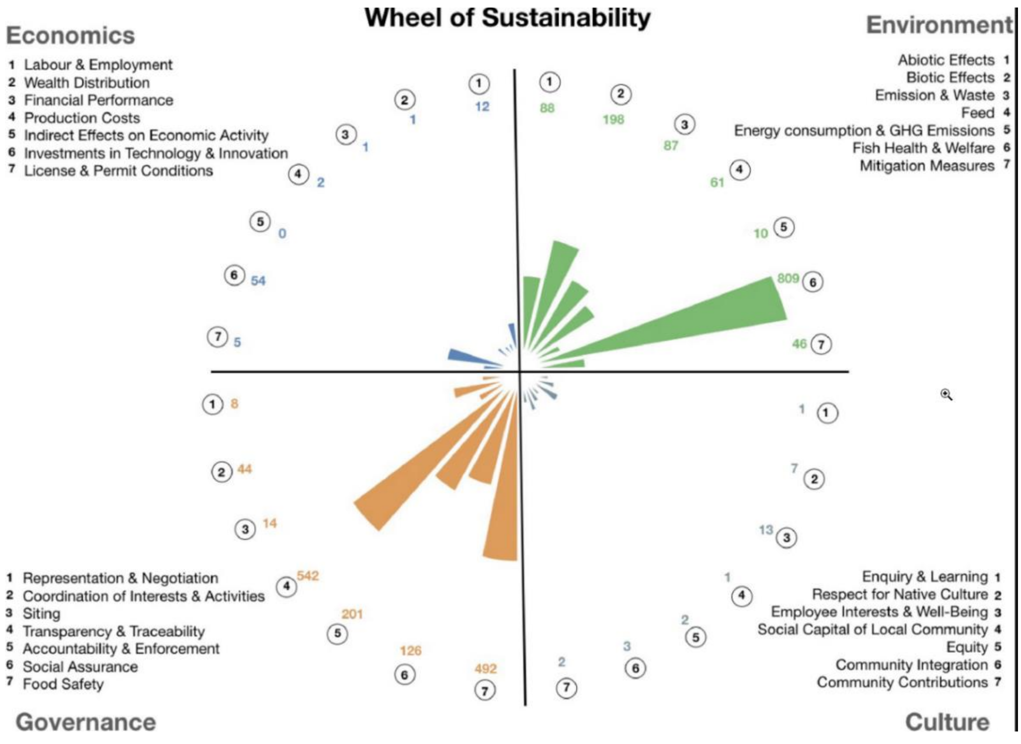
næring som har utviklet seg raskt, er tillit og aksept viktig. Sertifisering kan også være en del av å bygge omdømme i verdikjeden (Olsen et al. 2021).

Det finnes en rekke ulike sertifiseringsordninger som er aktuelle for akvakultur (Tabell 6-7), hvor miljømessig bærekraft så langt har hatt mye fokus (Osmundsen et. al. 2020). Dette blir vist gjennom en analyse som viser hvilke parametere og dimensjoner av bærekraftbegrepet som sertifiseringsorganene setter søkelys på.

*Tabell 6-7. Utvalg av sertifiseringsordninger i bruk i norsk akvakultur*

| Sertifiseringsordninger i bruk i Norge |
|---|
| Aquaculture Stewardship Council (ASC) |
| GLOBAL G.A.P. |
| Friend of the Sea (FOS) |
| International Featured Standards (IFS) |
| BRC Global Standards (BRC) |
| Best Aquaculture Practice (BAP) |

Kartleggingen av sertifiseringsordningene viser at GLOBAL G.A.P har den mest omfattende standarden, som dekker 24 av 28 underdomener i Bærekraftshjulet (Figur 6-3), tett fulgt av ASC (21 av 28) og GAA (BAP) (20 av 28). FOS-sertifiseringen er hovedsakelig opptatt av miljø da den dekker alle de syv miljøkategoriene som er under miljø, selv om den også berører en del bærekraftspørsmål innen økonomi- og styring (Governance) (Osmundsen et al. 2020).

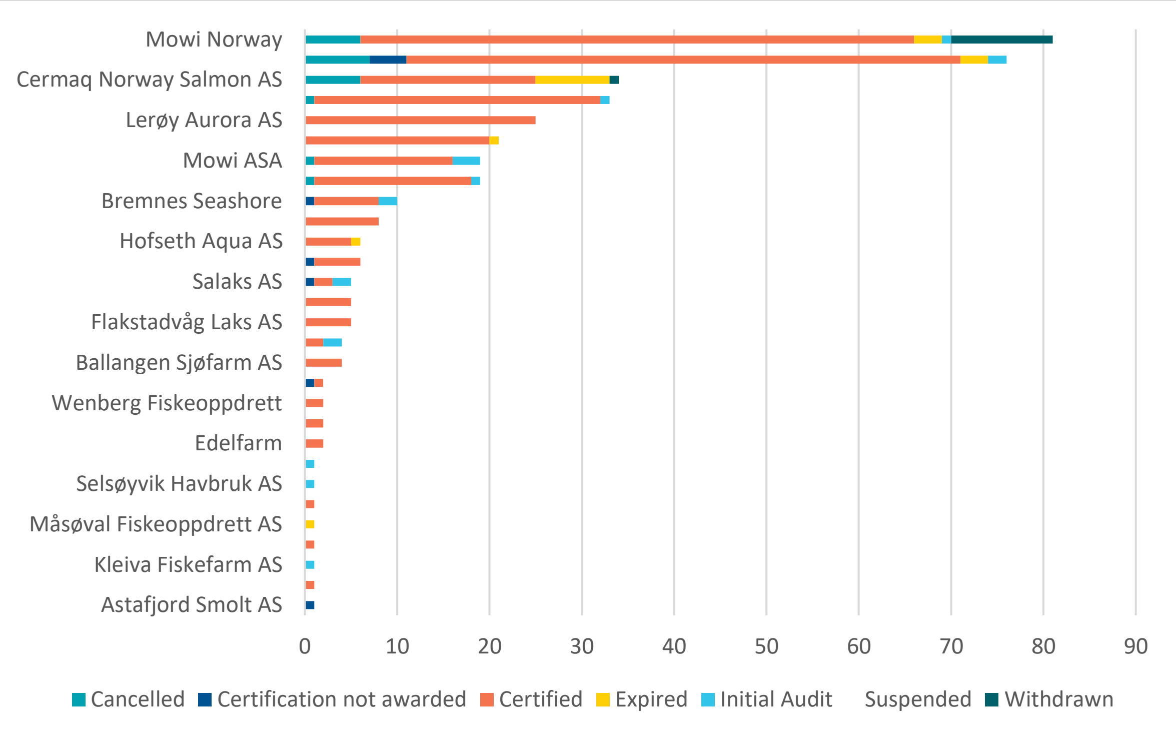



*Figur 6-3. Bærekraftshjulet – Kilde: Osmundsen et al. (2020).*

Vi kan ikke beskrive alle sertifiseringsordningene her, men vi vil se nærmere på innholdet i en mye brukt sertifiseringsordning ASC (Aquaculture Stewardship Council[15]).

ASC ble grunnlagt i 2010 som et felles initiativ fra World Wildlife Fund (WWF) og Dutch Sustainable Trade Initiative (IDH), og har som hovedmål å fremme bærekraftig akvakultur gjennom vitenskapsbaserte standarder for ansvarlig akvakulturpraksis.). ASC er vurdert til å utvikle og forvalte de strengeste standardene i bransjen. Sertifiseringen skjer på lokalitetsnivå og det er cirka 400 norske lokaliteter for laks og ørret som enten er, har vært eller er i gang med å bli sertifisert etter denne standarden.

Som vi ser av Figur 6-4 så er det sertifisert anlegg langs hele landet. Alle de store nasjonale og internasjonale selskap er på ASC sin kundeliste, samt mange mindre nasjonale aktører.




*Figur 6-4. Oversikt over norske selskap/underavdelinger som har eller har hatt sertifiseringsprosess med ASC (pr. 08.02.2023). Kilde: ASC/Nofima.*

ASC har tatt en proaktiv rolle i å utvikle privat regulering av mer bærekraft i havbruksnæringen. ASC-standarden er også oppfattet som å gå lenger enn norsk lovgivning på flere områder, og setter dermed en beste praksis som strekker seg ut over norsk lovgivers krav.

### 6.3.3.3 Løpende miljøregistreringer

Det er mye data som samles inn ute på det enkelte anlegg i dag, uten at det nødvendigvis blir en del av et felles kunnskapsgrunnlag. Dette kan gjelde både driftsrelaterte data fra anleggene, slik som strøm, oksygen, temperatur osv., og det kan gjelde data fra fiskehelsepersonell.

[15] https://asc-aqua.org/

Med en mere systematisk og standardisert innsamling av drifts- og miljødata fra et større antall lokaliteter langs kysten vil man for eksempel kunne forske på årsakssammenhenger. Sandberg m fl. (2012) påpekte at en systematisk og standardisert innsamling av data på tilstanden for fisk, utstyr og mennesker på eksponerte lokaliteter gjør det mulig å forske på årsaksforhold i kommersielle anlegg og at denne kunnskapen kan bidra til å forebygge rømming, til å øke forståelsen om lakselus, og til utvikling av ny teknologi, samt for å sikre og dokumentere at fiskevelferden blir ivaretatt i et fremtidig enda mer eksponert oppdrett. Datadelingsplatformen Aquacloud (https://aquacloud.ai/about/) har også jobbet med standardisering av data som i dag samles inn av medlemmene. Selv om datadeling i Aquacloud i første omgang foregår mellom medlemmer blir det fremhevet hvilket potensiale høykvalitets "big data" kan ha dersom juridiske og konkurransemessige aspekter tillater bredere deling i fremtiden.

I tillegg til de data som registreres løpende av hvert enkelt selskap, herunder lovpålagt rapportering som biomasse og lusetall, samler fiskehelsepersonell inn svært mye data for sine helserapporter. Innsamling av slike data gjøres i all hovedsak manuelt, legges inn i interne systemer og blir i liten grad delt eller brukt til analyse på en måte som kommer næringen og forvaltningen som helhet til gode. Å samle, systematisere og analysere slike data på et nasjonalt nivå vil være kunne være avgjørende for å kunne ta langsiktige strategiske beslutninger som kan bidra til bedre fiskehelse og velferd, og hjelpe fiskehelsepersonell og forvaltning i sitt forebyggende arbeid (Hamadi m fl. 2021)[16].Case studie: oppdrettsselskapenes miljø- og bærekraftsrapportering.

For å vurdere omfanget av miljørapportering har vi i dette prosjektet sett på miljørapportering fra et større norsk oppdrettsselskap, Lerøy.

Lerøy er et av verdens største sjømatselskap, med hovedkontor i Bergen. Havbruksaktiviteten foregår i hovedsak i 3 selskap som produserer i ulike regioner i Norge, Lerøy Vest, Lerøy Midt og Lerøy Aurora som opererer i Troms og Finnmark. Lerøy sine lokaliteter er stor grad plassert i områder hvor andre selskaper også har produksjon. Et unntak er Varangerfjorden i Øst-Finnmark, hvor ingen andre oppdrettsaktører har produksjon av laks.

Etter samtaler og intervjuer med sentrale personer hos Lerøy Seafood, vil gå nærmere inn på hvilke parametere selskapet fokuserer på for å ivareta lov og forskrifter, samt de målinger og dokumentasjon som er ledd i frivillig sertifisering som ASC (Aquaculture Stewardship Council), GLOBAL G.A.P. m. flere.

Innenfor **miljømessig bærekraft** arbeider Lerøy med en rekke prosjekter knyttet til klima, f.eks. ved å sette forskningsbaserte mål samlet for konsernet i tråd med 1,5-gradersmålet, elektrifisering av flåter og båter, deltagelse i grønt skipfartsprogram og prosjekt knyttet til flytransport og fiskefôr. Videre er det jobbet med reduksjon i matsvinn og plast som ikke kan gjenvinnes eller gjenbrukes, prosjekter knyttet til fiskehelse og fiskevelferd, lus, ulike sertifiseringer og fôrråvarer. De har fortsatt arbeidet med å sikre at vi ikke bidrar til avskoging ved produksjon av råvarer til fôr, samt at man bruker ressurser på nye alternative fôrråvarer.

Også innenfor **samfunnsmessig bærekraft** ble det gjennomført en rekke initiativ i 2021. Dette innebærer lederopplæring og en årlig medarbeiderundersøkelse – Great Place to Work. Det er implementert en ny e-læringsplattform og tatt i bruk et nytt verktøy for

[16] https://www.tekna.no/fag-og-nettverk/miljo-og-biovitenskap/bio-og-klimabloggen/mye-data-lite-informasjon---hvor-mye-data-samler-fiskehelsepersonell-inn/

leverandøroppfølging. Det er gjennomført ringvirkningsanalyser for hele virksomheten hvor måling av verdiskaping, sysselsetting og innkjøp ned på lokalt nivå er sentralt. Bidrag til samfunnet i form av skatter er dokumentert.

Lerøy jobber **systematisk med registreringer av informasjon** som samles inn fra alle selskapsområdene, dette brukes som grunnlag og dokumentasjon som er nødvendig for å oppfylle både offentlige myndigheters krav og frivillig sertifisering av system og produkter. Data samles både i lokale systemer og i et overordnet webbasert system som heter Cemasus, dette er en nettbasert skytjeneste som kobler bærekraft, miljø, risikostyring og ledelse, en metode og verktøy for å utarbeide og forbedre bærekraftstrategier. Grunndataene samles inn på lokasjonsnivå (bedrift, prosessanlegg eller lokalitet) og summeres opp på konsernnivå.

I tillegg utgir Lerøy med jevne mellomrom en rapport[17] som er en del av selskapets bærekraftsbibliotek, som rapporterer på 17 overordnede bærekrafts-KPIer (Key Performance Indicators). KPI'er er måletall som brukes for å evaluere måloppnåelse. KPI'ene er med på hjelpe bedriften å sikre at strategien som er satt oppnås.

Av disse KPI'ene har vi definert 13 til å være miljørelatert. I rapporten gis utdypende beskrivelser på utfordringer, tiltak og prestasjonsmål. I Tabell 6-8 har vi summert noen av de parameterne det måles på og styres etter. Mange av parameterne etterspørres ikke i dagens havbruksforvaltning, men er vanlige styringsmål for de største havbruksaktørene.

[17] Lerøy - KPI'er (leroyseafood.com)

*Tabell 6-8: KPI-er (key performance indicators relatert til miljø) fra Lerøy's bærekraftsrapportering*

| Konkrete mål (KPI) | Resultatmål | 2021 | 2020 | 2019 |
|---|---|---|---|---|
| Ikke organisk søppel<br><br>Øke andelen av ikke-organisk avfall som gjenbrukes eller materialgjenvinnes | +5 % | -0,49 | -6,99 | NA* |
| Ferskvann | -5 % | -1,90 % | -5,09 % | NA* |
| Rømming | 0 fisk i 2022 | 4 fisk | 208 fisk | 85 fisk |
| Lakselus | Gj.snitt ikke over 0.11 pr. fisk | 0,18 | 0,16 | 0,18 |
| Sertifisering (Prod.anlegg GSFI)[18] | 100 % | 88 % | 85 % | 73 % |
| Medisinering | 0 | 0 | 18,99 kg | 0 |
| Fiskehelse og fiskevelferd Overlevelse i sjø (%) | 94% i 2021 | 92,5 | 92 | 93,4 |
| Fiskehelse og fiskevelferdOverlevelse på land (%) | 89% i 2022 | 88,8 | 94 | 91,5 |
| Biologisk mangfold Andel i Brakksone % | 100% | 100 | 100 | 100 |
| Biologisk mangfold Gjennomsnittlig for B-undersøkelser | B-poengsum: 1,5 for 2021 | 1,49 | 1,37 | 1,55 |
| Biologisk mangfold Gjennomsnittlig Brakk (dager) | Minimum 60 dager | 142 | 138 | 140 |
| Plast | For 2021 brukte gruppen 6 029 351 kg plast innenfor de identifiserte områdene, omtrent på samme nivå som 2020. | | | |
| Plast – Bruk plast (alle former) | Mål 2024 reduksjon 50% | 6029351 kg | 6009237 kg | |

[18] GFSI - Global Food Safety Initiative

### *Oppsummering: Kan noe av informasjon som samles inn av selskapene brukes til forvaltning? I tilfelle hva?*

På grunn av prosjektets tidsramme og omfang har en uttømmende analyse potensialet for å hente inn data fra næringen ikke vært mulig, men det er likevel mulig å peke på noen muligheter. Samtidig vil vi understreke at det vil stilles store krav til datakvalitet for at dette skal fungere, og at omfattende initiativer nok må til for å samle og bearbeide informasjon til nytte for forvaltningen.

Havbruksnæringen blir ofte pekt på som en av de næringer som har størst potensial for å hente ut verdien av deling og samarbeid rundt data (Meld. St. 22 (2020–2021) – Data som ressurs). Både store og små selskaper har merder i samme fjordsystem og bruker samme driftsmetode, og de har derfor de samme utfordringene, som krever felles innsats og tiltak. Deling av informasjon og teknologi som kan bidra til mer bærekraft i oppdrett og forvaltning av ressurser kan dermed være en viktig faktor for å løse ut mulig vekst i næringen.

Det er derfor viktig å få til en optimalisert produksjon og et samarbeid både mellom næring, forvaltning og forskning, og et godt samvirke mellom næringsaktørene som driver i samme område. Et sentralt verktøy i dette arbeidet er digitalisering, som også har fått en stor og viktig plass i Nærings- og fiskeridepartementet sin havbruksstrategi, *Et hav av muligheter*. Digitaliseringen involverer prosessen fra observasjoner registreres, lagres, systematiseres, analyseres og presenteres. En av utfordringene er ofte at dette krever at ulike systemer må kunne kommunisere med hverandre. Da må det blitt etablert en felles terminologi, systemer for deling og ivaretagelse av dataeiers rettigheter til sine egne data.

Norge er i dag en av de ledende nasjonene innen digital samhandling mellom næringslivet og offentlig sektor. Det gjelder blant annet på områder som geodata, metereologidata, offentlige næringsregistre og elektronisk dialog via for eksempel Altinn-plattformen. En annen offentlig løsning for deling av havrelaterte data er BarentsWatch (i regi av Kystverket) hvor 29 ulike forvaltningsetater og forskningsinstitusjoner deltar med egne datasett og utvikling av tjenester. BarentsWatch består av en åpen løsning med tjenester for sluttbrukere som presenteres i portalen barentswatch.no, deriblant «FiskInfo» og «Fiskehelse».

Men det er i dette avsnittet også pekt på potensiale og behov for å videreutvikle dette arbeidet. Dette kan for eksempel være å få til en mere systematisk og standardisert innsamling av drifts- og miljødata fra et større antall lokaliteter langs kysten. Man vil da for eksempel bedre kunne forske på årsakssammenhenger ved anleggene. Dette vil være kunne være nyttig i forhold til forebyggende rømmingsarbeid, økt forståelse om lakselus, underlag til utvikling av ny teknologi, og for å sikre og dokumentere at fiskevelferden blir ivaretatt i for eksempel et fremtidig mer eksponert oppdrett. Det er også pekt på potensial for å samle data fra fiskehelseundersøkelser og systematisere og analysere slike data på et nasjonalt nivå. Dette vil kunne være avgjørende for å kunne ta langsiktige strategiske beslutninger som kan bidra til bedre fiskehelse og velferd, og hjelpe fiskehelsepersonell og forvaltning i sitt forebyggende arbeid. Det er imidlertid viktig med kvalitetssikringsarbeid av slike data for å sikre at konklusjoner og beslutninger gjøres på rett grunnlag.

Videre er det pekt på at havbruksnæringen også i økende grad bruker private reguleringer eller "selvregulering" for å oppnå en mer bærekraftig næring, dette er også vist i casestudien til Lerøy der vi så på innsamlede miljødata og sertifiseringer. Noen av sertifiseringsordningene har hatt en proaktiv rolle i å utvikle privat regulering og utvikle mer bærekraft i havbruksnæringen. En del av parameterne som etterspørres i slike sertifiseringer etterspørres ikke i dagens havbruksforvaltning i Norge (for eksempel plast), men er vanlige styringsmål for de største havbruksaktørene. Noen av standardene i slike ordninger er også oppfattet å gå lenger enn norsk lovgivning på flere områder (for eksempel kobber i ASC), og setter dermed en beste praksis som strekker seg ut over norsk lovgivers krav. Mange av bedriftene har også satt seg mål om mere bærekraft og bruker indikatorer (KPIer) og bærekraftsrapporter for å se om de oppnår målene sine.

Kanskje vil forvaltningen kunne utforske disse sertifiseringene og KPIer og se på om det finnes områder forvaltningen for eksempel burde strammes inn, eller om det er nye faktorer som kunne/ burde inkluderes i forvaltningen.

Det finnes allerede initiativer for innsamling av stordata fra næringen. Aquacloud[19] er et eksempel på opprettsaktører og aktører på leverandørsiden som går sammen om datadeling. Enklere tilgang til data gjennom moderne programmeringsgrensesnitt (API-er) vil øke tilfanget av nye løsninger og senke terskelen for å samle unn data til ulike formål. Aquacloud utvikler retningslinjer og protokoller for data og datautveksling basert på åpne standarder innenfor tre hovedområder: sensordata, miljødata og data om fiskehelse. Slik kan man for eksempel få til tidlig varsling ved luseoppblomstring, algeoppblomstring eller kritiske værforhold.

Sanntidsdata i stort omfang kan også gi bedre forvaltning, fordi det kan gjøres vurderinger av bæreevne og belastning i et fjordsystem både for å følge løpende drift og ved vurdering av utvidelser, ny kapasitet osv.

Nye rapporteringskrav kan også være på trappene, som omfatter flere av stressorene drøftet tidligere i dokumentet. Fiskeridirektoratet og Miljødirektoratet har hatt ute forslag til revidering av regelverket for forurensning fra akvakulturanlegg for matfisk og stamfisk i sjø, som hadde høringsfrist 4. januar 2021. I forslaget fremmes en rekke punkter som vil øke rapporterings- og registreringsplikt. I høringsuttalelsen fra Advokatforeningen 20 ble følgende økt rapportering/journalføring trukket frem:

- Henvendelser mottatt av innehaver av akvakulturtillatelse om støy, lukt og lys (som anses som en forskriftsfesting av forventninger som allerede ligger som krav i aktørenes internkontroll).
- Bruk av impregnerte nøter og hvilke virkestoffer disse er satt inn med, samt når og hvordan nøtene er grovrengjort.
- Navn på fôr og eventuell konsentrasjon av prioriterte stoffer, EU-utvalgte stoffer og vannregionspesifikke stoffer.
- Rapportering av eventuelle miljøgifter i fôret, samt forbruket av legemidler.
- Registering i databasen Vannmiljø av resultater fra miljøundersøkelsen.
- Krav om å treffe tiltak for å minimere utslipp av miljøgifter ved rengjøring av impregnerte nøter (også dette anses som en forskriftsfesting av forventninger som allerede ligger som krav i aktørenes internkontroll).

Det som vurderes hentet inn av data gjennom pålagt rapportering bør også vurderes i lys av de kunnskapsbehov som her er identifisert rundt de forskjellige stressorer.

[19] https://aquacloud.ai/about/
[20] https://www.advokatforeningen.no/horingsuttalelser/2021/januar/revidering-av-forurensningsregelverket-for-akvakultur-i-sjo/

### 6.3.4 Hvordan vil oppdrett av nye arter og nye produksjonskonsepter påvirke dagens regulering og muligheter for vekst i havbruksnæringen?

I denne delen vil vi gi en oppsummering av miljøpåvirkning fra de mest aktuelle nye arter og nye produksjonskonsepter for Norge. Deretter vil vi vurdere hvordan nye produksjonskonsepter for lakseoppdrett kan eller bør reguleres for å gi mulighet for vekst uten økt miljøpåvirkning

Nye konsepter for oppdrett har for de fleste stressorer mindre miljøavtrykk enn konvensjonelle løsninger. Lukkede eller semi-lukkede anlegg kan i prinsippet ligge nærmere hverandre, og på grunnere og mindre strømsterke lokaliteter enn åpne anlegg, slik at tidligere forlatte eller antatt uegnede lokaliteter kan tas i bruk.

I tillegg til nye konsepter vil nye økosystem tas i bruk som følge av flere oppdrettsarter. Den raske utviklingen i norsk havbruksproduksjon innebærer følgelig en romlig ekspansjon fra de tradisjonelle merdlokalitetene til oppdrettsvirksomhet i et mangfold av økosystemer: på land, i fjord og til havs. Dette medfører behov for nye typer krav og reguleringer, og ikke minst kunnskap om miljøpåvirkning.

I det følgende vil vi først diskutere forvaltning av nye oppdrettsarter (forskningsspørsmål 4), før vi diskuterer nye produksjonskonsepter (forskningsspørsmål 5).

#### 6.3.4.1 Regulering av nye oppdrettsarter?

I 2019 fikk Forskningsrådet utredet kunnskapsgrunnlaget for nye arter i oppdrett[21]. Her ble 30 aktuelle arter evaluert i forhold til ulike kriterier som miljømessig bærekraft, marked, lønnsomhet, egnethet for Norge og utviklingsstatus. Rapporten viste blant annet at det er utfordrende for forvaltningen å regulere nye oppdrettsarter fordi regelverket er utviklet for laks og dermed ikke nødvendigvis fanger opp utfordringer og muligheter som nye arter bringer med seg. For eksempel er det restriksjoner på å ha flere arter i samme anlegg med utgangspunkt i smitterisiko, mens flere arter i samme anlegg også kan gi muligheter for å bedre miljøtilstanden, for eksempel ved at tare og blåskjell utnytter næringsstoffer og partikler fra lakseoppdrett. I dag foregår det forsøk som er basert på dispensasjoner fra regelverket.

I hvilken grad nye arter påvirker miljøet avhenger av deres biologi, dvs. om de er lavtrofiske (trenger ikke å bli fôret) eller om de er karnivore. Det avhenger også av hvilken teknologi de mest sannsynlig blir produsert i (åpen, eller semi-lukket i sjø eller i landbaserte anlegg). Forekomsten av ville bestander av artene har også betydning. Og det er flere forhold som spiller inn.

Vi kan se på eksempler på ulike arter som er aktuelle i dag og som er i ulike kategorier:

- Torsk, som er karnivor og som må fôres med formulert fôr og som har en reproduksjonsbiologi som tilsier at den kan spre gener til det ytre miljøet, dvs. kunne påvirke kysttorskbestander genetisk. Arten produseres i merder som laks og vil dermed kunne påvirke miljøet på samme måte med utslipp av medikamenter, kjemikalier, patogener og organisk materiale.
- Sukkertare, som utnytter lys og næringsstoffer og som dermed ikke vil ha utslipp av medikamenter, kjemikalier eller organisk materiale, men som likevel ikke kan utelukkes

[21] https://www.regjeringen.no/contentassets/9cfc832dff32478ca0a3929a2580a032/rapport-nye-arter-del-1-og-del-2-med-isbn-nr.pdf

å smitte ville bestander. I dag er det krav om at dyrking bare kan gjøres med stedegne bestander fordi en ikke vil påvirke ville bestander lokalt.

- Flekksteinbit, som for tiden er aktuell for landbasert oppdrett da den er en arktisk art som helst ikke skal ha temperaturer over 10 °C. I en landbasert produksjon vil man i mosetning til i åpen sjøbasert produksjon (som torsk) kunne rense en del av utslippet for organiske materiale. Man kan også hente inn mer stabilt dypvann og slippe ut vann i det mest gunstige dypet i forhold til spredning av organisk materiale. Videre tillater ikke artens reproduksjonsbiologi at det slippes ut befruktede egg fra produksjonen og den klekkede yngel er så stor at den er enklere å forhindre rømming av. Endelig finnes det svært få fjordbestander av flekksteinbit, og disse har ikke stor betydning i fiskeriene. Dermed vil ikke evt. rømt flekksteinbit kunne pare seg med ville bestander og påvirke disse genetisk.

Disse eksemplene viser noen viktige forskjeller mellom arter og de 30 aktuelle vurderte artene i Nye arter rapporten, eller andre arter man måtte vurdere som aktuelle i Norge, kan i grove trekk deles inn på lignende måter.

Lavtrofiske arter som lever av lys, næringstoffer eller partikler i vann kan som nevnt ha en positiv effekt på miljøet. Dette er forhold som gir en del muligheter for å utnytte kysten vår langt bedre enn vi gjør i dag. Det gjøres allerede en del forskning og utviklingsarbeid på hvordan tare og blåskjell kan utnytte næringsstoffer fra lakseoppdrett eller resipienter som påvirkes av næringsstoffer fra andre kilder (eksempelvis blåskjelldyrking i Danmark basert på næringsstoffer fra avrenning fra landbruket). I en fremtidig forvaltning åpner dette for at man kan sette sammen en artsportefølje som skaper synergier artene seg imellom, samt optimaliserer bruken av arealer, slik at man kan oppnå en langt høyere utnyttelse av den miljømessige kapasiteten til arealene og økosystemene. Før man kommer så langt at man kan tenke på en slik tilnærming til forvaltningen, må kunnskapsstatus og teknologiutviklingen være kommet langt lengre for de ulike artene enn de er i dag. Hertil kommer det at produksjonen av ulike arter må være lønnsomme hver for seg.

Nye arter kan også stå for andre økosystemtjenester, som å gi bedre vilkår for tare som igjen bidrar til å skape miljøer for oppvekst av andre arter. Fangst av kråkeboller for oppfôring til et godt betalende marked gir samtidig gunstig effekt for tareskogrestaurering. Utsett av gråsteinbityngel kan også gi økt predatorpress på kråkeboller, med samme gunstige effekt på restaurering av tareskog.

For å kunne oppnå en slik helhetlig forvaltning hvor man tenker både oppdrett, gjensidig nytte mellom ulike arter og ikke minst sett i sammenheng med forbedring av økosystemer i ubalanse, må forvaltningen evne å etterspørre kunnskaper som de må ha for å kunne forvalte utviklingen av de ulike artene, samtidig som de kan utforme nytt regelverk eller tilpasser eksisterende regelverk for de ulike artene. Hvis forvaltningen ikke evner å innhente nødvendig kunnskap og utforme regelverket for nye arter, vil man risikere at næringsaktører får redusert sine muligheter til å utvikle nye næringer, eller i verste fall bli hindret fra å gjøre det.

#### 6.3.4.2 Regulering av nye produksjonskonsepter?

I dette avsnittet vil vi diskutere hvordan nye produksjonskonsepter for lakseoppdrett kan reguleres for å gi mulighet for vekst uten økt miljøpåvirkning (forskningsspørsmål 5).

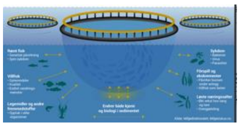
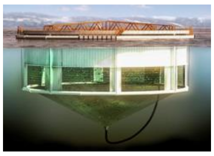
Diskusjonen tar utgangspunkt i de ulike stressorene vi tidligere har diskutert, og ser på i hvilken grad disse vil utgjøre en mindre utfordring i produksjonsformer med ulik grad av lukking eller skjerming fra omkringliggende vannmiljø.

Det er rimelig å tro at miljøpåvirkningen fra de fleste stressorene kan reduseres eller unngås i lukkede anlegg. For viktige stressorer som lus og rømming vil risikoen være sterkt redusert, kanskje ned mot null, avhengig av konsept og teknologi. Det er kjent at rømming har forkommet ved flytting av fisk selv i lukkede anlegg, og selvsagt kan forekomme ved nye uhell. På samme måte kan man risikere at vann som ikke skal slippes ut urenset, blir sluppet ut. Slike tilfeller må forstås som enkelthendelser eller uhell, risikoen for eksempel rømming fra lukkede anlegg må forventes å være lav. Siden det finnes begrenset produksjon med mange av de konseptene som er under utprøving eller utvikling, vil denne diskusjonen ta utgangspunkt i forventede fordeler som kan oppnås ved ulike konsepter.

#### 6.3.4.3 Stressorer som kan reduseres i lukkede eller semi-lukkede anlegg

Det har i de siste årene blitt utviklet en mengde oppdrettskonsepter som skal redusere næringens påvirkning på det omkringliggende miljø, og ikke minst skjerme fisken for påvirkning fra ytre stressorer. Påvirkningen, begge veier, vil være avhengig av graden av lukking. I tabellen under har vi brukt som eksempel noen hovedtyper av gradvis mer lukkede anlegg. For enkelhets skyld har vi holdt oss til tre grader av lukking. Man kan allerede ved relativt enkle midler eller tiltak oppnå en viss redusert eksponering. For eksempel kan lusepåslag reduseres ved å bruke luseskjørt, tubenot eller ved å senke hele merden dypere ned i vannet. Med en hel fysisk barriere, eller lukking av merden, kan mye mer av eksponeringen kontrolleres. Fullstendig isolasjon fra omgivelsene kan først oppnås om man i tillegg renser vann som kommer inn i og går ut av merden. Disse tre hovedtypene gir noen viktige forskjeller. I tabell 6.7 har vi beskrevet forventet effekt på miljøpåvirkningen fra viktige stressorer for anlegg med ulike grader av lukking, samt for offshore anlegg.

*Tabell 6-9. Klassifisering av semilukkede systemer etter grad av lukking for ulike stressorer.*

| | Åpne merder<br> | Delvis fysisk barriere<br> | Fysisk barriere/lukket i sjø<br> | Offshore<br> |
|---|---|---|---|---|
| | | | | |
| Faste næringsstoffer | | Noe reduksjon | Stor reduksjon | Like utslipp, økt resipientkap. |
| Løste næringsstoffer | | Marginal reduksjon | Noe reduksjon | Like utslipp, økt resipientkap. |
| Lus | | Nokså stor reduksjon | 100 % reduksjon | Noe reduksjon |
| Sykdom | | Noe reduksjon | Stor reduksjon | Noe reduksjon |
| Andre fremmedstoffer | | Noe reduksjon | Stor reduksjon | Like utslipp, økt resipientkap. |
| Rømming | | Lik risiko | Stor reduksjon | Lik risiko |

For offshoreanlegg er ikke poenget å lukke ute eksponeringen mot det eksterne miljøet, men heller å flytte anlegget lenger bort fra andre anlegg, og fra lakseelver, slik at kontakt reduseres. Det er også et poeng av resipientkapasiteten samtidig kan økes.

I det følgende vil vi peke på noen mulige effekter av ny teknologi, med eksempler fra noen konsepter. For prosjekter som har hatt utviklingskonsesjoner har det vært stilt krav om åpenhet rundt resultatene fra driften. Det finnes dermed åpent tilgjengelig mye kunnskap og dokumentasjon av biologiske resultater, driftsmessige forhold og utslipp[22].

For **lukkede anlegg i sjø** kan vi bruke Akvafuture[23] som et illustrerende eksempel. Akvafuture er et lukket anlegg i sjø, hvor slam suges opp og (til en viss grad) renses. Anlegget er bygget med vanlige 90-meters plastringer som basis, men med tett plastduk istedenfor not. I tillegg er det bygget betongelementer som «kapsler inn» ringene, og gjør det enkelt å bevege seg mellom merdene. Siden merdene er lukket kan de ligge sammenkoblet, forbundet med land og i grunnere og mer smule farvann enn åpne merder.

Selv med slamopptak og rensing av utløpsvann vil slike anlegg uansett medføre organiske utslipp, og med utløp fra få punkter fra anlegget kan dette gi risiko for høye punktutslipp.

[23] https://www.akvafuture.com

Sluttrapporten fra Akvafuture[24] peker på at slamuttak fra Hamnsund-anlegget bidrar til å redusere det organiske utslippet fra produksjonen ved anlegget. Dataene viser at det har vært et begrenset miljøavtrykk fra anlegget, dokumentert gjennom en serie av lokalitetsundersøkelser gjennomført ved anlegget.

Hvor mye slam lukkede anlegg kan fange opp er et viktig spørsmål. I sluttrapporten oppgis det at det er testet et nytt og forbedret system for slamoppsamling. På lokaliteten Hamnsundet gjenvant Akvafuture i 2019 75 tonn med slam tørrstoff (TS) av utfôret mengde 3319 tonn TS (omregnet fra 3531 tonn fôr, 94 % TS). Det er ikke presentert estimater på hvor mye slam som er sluppet ut fra produksjonen, men slamutslipp fra sjøbasert matfiskoppdrett er av Aas og Åsgård (2017) estimert til 38 % (13 % fôrspill og 25 % feces) og av Torrissen m.fl. (2016) ut fra modellberegninger til 33 % (7 % fôrspill og 26 % feces). Ut fra disse tallene så er det produsert et sted mellom 1095 til 1260 tonn TS med slam i anlegget til Akvafuture. Dvs. at anlegget anslagsvis har hatt en oppsamling av 6-7 % av produsert slam. Sett i forhold til utfôret mengde er oppsamlingen 2,2 %. I slamrenseanlegg på land har Aas m.fl. (2021) vist at det fanges opp 12 % slam målt i forhold til utfôret mengde og en vanlig dimensjoneringsfaktor i RAS-anlegg er at renseanlegget fanger ca. 15 % slam av utfôret mengde.

Rapporten viser også hvordan det skjer en endring i den mikrobielle diversiteten og i forekomst av smittsomme agens i miljøet gjennom produksjonen.

For vårt formål er det interessant å se på hvilke faktorer som ved slike anlegg utgjør produksjonsbegrensende faktorer. For lus og lusesmitte er lukkingen veldig effektiv. Selv om det kommer inn et lite antall lus gjennom inntak fra dypt vann, har disse vist seg å ikke formere seg i anlegget. Lus og utslipp fra lusesmitte er dermed ikke produksjonsbegrensende. Lukkede anlegg i sjø kan med tanke på lus plasseres nær hverandre og nært anlegg med åpne merder. For organiske utslipp og sykdom kreves det fortsatt undersøkelser for å vurdere påvirkning fra det aktuelle anlegg mot aktuell resipient.

Rapporten fra Akvafuture peker på at «detaljerte undersøkelser av lokaliteter fortsatt er viktig. Vi vil spesielt peke på (1) langtidsserier med kartlegging av havstrøm og miljøforhold, (2) behov for modellering av strømbildet på lokaliteten etter at anlegget er utplassert, (3) grundig overvåking av det bentiske miljøet i og rundt anleggssonen og (4) beregning av netto belastning på lokaliteten, med fratrekk for den andelen av det sedimenterbare utslippet som samles opp til gjenbruk.

Det er ikke dokumentert at man klarer så høy oppsamling av organisk materiale som det hevdes i ulike sammenhenger. I Akvafutures tilfelle er dette under 6-7 % og det er lite som tyder på at andre lukkede merdløsninger klarer vesentlig høyere enn dette. Da må man i så tilfelle inn med flere rensetrinn og etter hvert opp i samme teknologi som i landbaserte anlegg.

Selv om en skulle klare å oppnå begrenset akkumulering av organisk materiale under anlegget vil gode brakkleggingsrutiner være viktig for å rense hele lokaliteten for smitte som har sitt opphav i fisken og drifta på anlegget».

[24] Sluttrapport fra prosjektet: https://www.akvafuture.com/storage/sluttrapport-2020/Sluttrapport%20Akvafuture%20Final.pdf

For **offshore anlegg** er Salmars Ocean Farm 1 og Nordlaks sin Havfarm gode eksempler. Begge har før avleggelse av sluttrapport gjennomført (nesten) to sykluser for laks fram til slakteklar størrelse.

**Lus**: For lus har begge konseptene hatt lavere forekomst enn nærliggende lokaliteter i mindre eksponerte lokaliteter. Salmar hadde ikke behov for avlusing i første produksjonssyklus, men produksjonssyklus to ble avluset med medikamenter. Nordlaks har i perioden juli 2019 til desember 2022 gjennomført fire medikamentelle avlusninger pga. stigende lusetall (data fra BarentsWatch) i tillegg til at post-smolt som blir satt i anlegget allerede er avluset før den settes i Havfarmen (Nordlaks 2022). To case er selvsagt lite for å slå fast at lus ikke vil være produksjonsbegrensende for offshore produksjon av laks, men disse tilfelle indikerer i det minste at lus vil være mindre produksjonsbegrensende med dagens regelverk enn i tettere avgrensede fjordområder. Imidlertid er Havforskningsinstituttet bekymret for at de enorme merdene til havs skal gi en dobbeltsmitte, først langs kysten og så ute i havet.

**Organiske utslipp.** Organiske utslipp er like store som ved innaskjærs anlegg, men kan spres over større areal, og gir dermed mindre punktbelastning. Litt forskjellige utslag ble rapportert for de to konseptene, og utslag vil variere over tid. Med Nordlaks sitt konsept, hvor Havfarmen i praksis ligger på svai, kan været ha stor betydning (samme vindretning over tid kan gi punktbelastning, mens skiftende vindretninger gir større spredning).

**Sykdom**. Disse konseptene har hatt lav eller normal sykdomsfrekvens. Potensiell spredning av sykdom er en viktig begrunnelse for avstandskrav mellom anleggene. Med beliggenhet offshore, og dermed stor avstand fra andre anlegg, er det å forvente at anleggene både er mindre utsatt for smitte og i mindre grad bidrar til smittespredning.

#### 6.3.4.4 Muligheter for vekst ved delvis lukking i sjø

Hvor mye kan produksjonen økes om man gjennom ulike former for og grader av lukking klarer å redusere betydningen av de viktigste kapasitetsregulerende stressorene? Det ligger ikke innenfor rammene til dette prosjektet å estimere tallfestede vekstmuligheter, til det er usikkerhetene for mange, men vi vil likevel tillate oss noen enkle kalkulasjoner for å synliggjøre hvilken størrelsesorden vi kan se for oss at endringene kan bli.

**Lus**: For lus har man forsøkt flere former for fysisk barriere for å holde lusepåslagene nede, fra enkle luseskjørt til merder med fysiske barrierer i de øvre vannlag (som i for eksempel Aquatraz). La oss anta at dagens relativt lave lusenivåer allerede er betydelig påvirket av den utbredte bruken av luseskjørt. Og la oss videre anta at om man introduserer en fast barriere, dypere enn dagens luseskjørt, er det rimelig å anta at mer lus kan holdes ute, og lusenivået blir lavere, for eksempel 50 % lavere.

Betyr det at produksjonen kan dobles uten at lusebestanden og lusepåslagene blir større enn ved dagens situasjon? Det er mulig. Men det har også vist seg at strengere lusegrenser har hatt begrenset virkning på lusepåslaget på vill laks (se for eksempel Larsen og Vormedal, 2021). Om det ikke er en direkte sammenheng mellom lusebestand i oppdrettsanleggene og lus på villfisk, så er det heller ikke gitt at en 50 % reduksjon i lusepåslaget vil gi stor effekt på villaksen. Den største effekten vil kanskje komme først ved kraftig reduksjon, eller ved fullstendig filtrering av vannet, slik at lus ikke kommer verken ut eller inn. Da kan man til gjengjeld se bort fra påvirkning fra oppdrett på villaksen.

En regulering som går på utslipp av lus, og som tillater økt produksjon ved dokumentert nullutslipp, er mulig.

**Faste næringsstoffer:** For faste næringsstoffer er det mulig å samle opp en del allerede ved en delvis lukking av merden, gitt at man har tett bunn og oppsamling av de faste næringsstoffene.

Vannet fra lukkede anlegg må slippes ut jevnlig, etter større eller mindre innsats for filtrering eller rensing. Flere av konseptene under utprøving har muligheter for oppsamling av slam. Slam brukes blant annet som jordforbedringsmiddel og til biogassproduksjon, og består av fôrrester og gjødsel (faeces) som fanges opp med filtersystem og eventuelt tørkes før det transporteres bort. Faeces går lett i oppløsning og er vanskelig å samle opp, og slam inneholder derfor generelt en betydelig andel fôr. Fôr og gjødsel har ulik sammensetning, og kvaliteten til slammet er derfor avhengig av andel fôr i slammet. Mengden fôr har derfor betydning for bruken av slam.

Fôr som fortsatt er i pelletsform lar seg relativt lett samles opp, men målinger har vist at oppsamlingen av slam har moderat effektivitet. Dette skyldes trolig at særlig faeces lett går i oppløsning og er vanskelig å samle opp (Aas, 2021). Rapporten fra Aas (2021) viser eksempler på utregning av utslipp av fôrrester og faeces: Eksempelet tar utgangspunkt i ett tonn utfôring, og man regner 10 % forspill og 75 % utnyttelse av fôret. Det betyr at det slippes ut om lag 300 kilo med fôrrester og faeces i vannet. I landbaserte anlegg klarer man å filtrere ut cirka 35 % av dette, slik at man selv med filtrering slipper ut om lag 200 kilo, eller 20 % av utfôret mengde.

Det er også energikrevende å samle opp, tørke og transportere slammet. Det er mulig å bedre utnyttelsen av slam, men det vil kreve utvikling av ny teknologi.

**Løste næringsstoffer**: Løste næringsstoffer er vanskelig å samle opp ettersom utslippsvannet må slippes ut til en eller annen resipient, som kan ha god eller dårlig mottakskapasitet.

**Hva betyr dette for hvor mye vekst vi kan tillate ved lukkede anlegg i sjø?**

Potensialet for å hente ut økte vekstmuligheter gjennom lukkede anlegg i sjø er vanskelig å anslå, da det er mange viktige begrensninger på tilgjengelig areal for oppdrett i sjø; faktorer som dybde og strømforhold er avgjørende for egnetheten, men i tillegg vil hensyn til fiskeri, verneområder, båttrafikk, forsvarets skyteområder og mye annet gjøre det vanskelig å automatisk anta at en reduksjon at miljøpåvirkningene vil gjøre vekst mulig. Ved produksjon i lukkede anlegg i sjø vil man kunne redusere en del stressorer, som lus og sykdom, mens utslipp til resipienten fortsatt vil være betydelig. Som vist til fra Aas (2021) klarer dagens landbaserte anlegg bare å rense ut 35 % av det organiske utslippet. Skal man klare dette i lukkede anlegg i sjø må man ta i bruk tilsvarende renseanlegg som landbaserte anlegg har. Inntil videre har flertallet av lukkede konsepter ikke denne muligheten, eller det vil fordyre vesentlig en teknologi som allerede har flere ganger høyere investeringskostnader enn åpne merder. Lukkede sjøanlegg med kun slamfeller i utløpet kan ta ut under 10 % av det organiske utslippet.

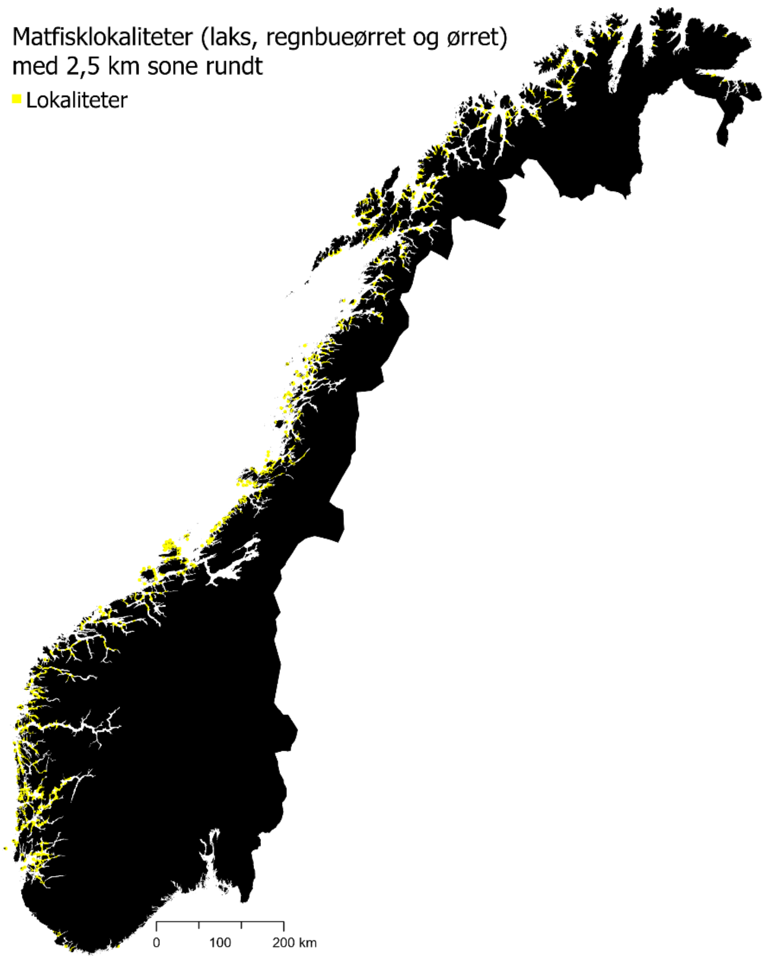
Om faste næringsstoffer er vekstbegrensende, og om man kan filtrere bort 35 % av næringsstoffene, så kan man med et lukket system ha en produksjon som er om lag 50 % større enn et tilsvarende åpent anlegg uten at utslippene blir større. Om det bare er mulig å rense 5 %, betyr det at produksjonen bare kan økes med 11 % for å gi samme utslipp. Det kan imidlertid tenkes at man med lukkede anlegg kan spre utslippene over større områder, slik at punktbelastningen blir mindre og at lokaliteten og nærområdet dermed kan tåle større belastning enn det som kommer gjennom åpne merder.

**Avstandsanbefalinger og arealbruk**

Det er mange faktorer som bestemmer utnyttelsen av sjøarealene, ettersom tilgjengeligheten til oppdrettsarealer påvirkes av mange andre interesser, både fiskeri, turisme, transport osv.

Vi tenker likevel at man kan få en indikasjon på økte produksjonsmuligheter ved å se på dagens arealbruk, og mulighetene for å øke produksjonen gjennom redusert avstand. Som nevnt i kapittel 5 opererer Mattilsynet med anbefalte minsteavstander mellom anlegg når de behandler akvakultursøknader, og de ulike minsteavstandene avhenger av en rekke faktorer. Sykdom er blant annet en viktig faktor for bestemmelse av avstand. For lokaliteter som skal etableres og ikke er del av en koordinert brakkleggingsgruppe er anbefalt minsteavstand for matfiskanlegg 5 km i sjø til både andre lokaliteter og til blant annet slakteri, settefisk- og stamfiskanlegg. Nye lokaliteter (uten tilknytning til koordinert brakkleggingsgruppe) gis som hovedregel ikke godkjenning nærmere enn 5 km, mens eksisterende lokaliteter, gitt samme kriterier, som hovedregel ikke gis godkjenning for utvidelse dersom de er nærmere enn 5 km fra andre akvakulturanlegg for laksefisk (Mattilsynet, 2022).

Overflatearealet som i dag er godkjent for plassering av akvakulturlokaliteter i sjø for matfiskproduksjon av laks, regnbueørret og ørret er ca. 90 $km^2$ (regnet ut fra fiskeridirektoratets *Flate ihht Akvakulturregisteret*, per 03.02.23) Med en 5-km sone rundt lokalitetene er i overkant av 24 000 $km^2$ av den norske kystsonen utilgjengelig for etablering av nye lokaliteter. Tilsvarende areal med 2,5 km sone rundt er omtrent 11 000 $km^2$ (illustrert i Figur 6-5). Reduseres sonen til 1 km opptar dagens lokaliteter ca. 3 130 $km^2$ av sjøarealet. Samlet lokalitets-MTB for lokalitetene er rett i overkant av 3,4 millioner tonn.




*Figur 6-5.* Arealbruk matfisklokaliteter, basert på 2,5 km sone rundt flateareal (Kilde: Fiskeridirektoratet og Eurostat, bearbeidet av Nofima).

***Brakkleggingsområder i Norge***

Av dagens lokaliteter var vel 65% del av et definert brakkleggingsområde, basert på data fra Mattilsynet som Nofima behandlet i forbindelse med rapporten *Områdesamarbeid i norsk havbruk*, i 2019 (Karlsen et al. 2019). Hvert brakkleggingsområde består av lokaliteter med nærhet i avstand, som er ventet å kunne påvirke hverandres resipient når det kommer til utbredelse av lakselus og sykdom. Størrelsen på brakkleggingsområdene er svært varierende, og antallet lokaliteter som inngår i hvert område kan være fra bare én til over 20. De koordinerte brakkleggingsområdene vil være styrende for hvilke areal som er tilgjengelig for etablering av nye lokaliteter så vel som for utvidelse av eksisterende lokaliteter. I 2017 meldte Mattilsynet at de i større grad enn tidligere ville kreve koordinering i brakkleggingsgrupper når de godkjenner driftsplaner og behandler søknader knyttet til etablering og utvidelse av lokaliteter, som tiltak for bedre fiskehelse og fiskevelferd (Mattilsynet, 2017).

### 6.3.5 Scenarioer for regulering for miljømessig bærekraftig vekst i næringen

I dette avsnittet diskuterer vi hvilke muligheter en mer differensiert (mellom områder) og direkte (på målbare miljøparametre) miljøforvaltning av akvakulturnæringen kan gi for miljømessig bærekraftig vekst i næringen.

Med en mer treffsikker regulering kan man i prinsippet produsere mer i de beste områdene og på de beste lokalitetene, mens produksjonen kan reduseres andre steder. Dette åpner for større produksjon, men også for å frigi arealer. Man kan tenke seg at en gitt produksjon vil gi lavere samlet fotavtrykk om man utfører en større del av produksjonen i de mest egnede områder. Alternativt kan man med et gitt miljøavtrykk samlet sett produsere mer når en større andel av produksjonen skjer på de beste lokalitetene eller de beste områdene. Det vil også være mulig å produsere mer med teknologi som gjennom ulike former eller grader av lukking vil gi mindre fotavtrykk per kilo produsert. Det er også mulig å tenke seg at tillatt produksjon på en lokalitet eller i et område reguleres etter faktiske utslipp.

Om man skulle ønske å regulere produksjonen mer direkte, basert på målbare miljøparametere, vil det reise seg en del nye spørsmål som forvaltningen må ha kunnskap om. Gitt at man ønsker å øke produksjonen i et område, hvordan vil ulike stressorer utvikle seg? Hva er det første taket man støter på om man vil øke produksjon? Hvilken stressor vil først nå grenseverdier for akseptabel miljøpåvirkning? Hvilke stressorer er mest kritiske for gitte økosystemer eller lokaliteter?

Før vi nærmer oss slike spørsmål, kan det være nyttig å se på hvilke faktorer som begrenser veksten i dag, og hvilke reguleringer som begrenser den.

I dag er veksten i produksjonen først og fremst begrenset av lusesituasjonen, men også av tilgangen på egnet oppdrettsareal. I fremtiden vil også tilgangen på fôrråvarer kunne være en begrensning, men i dette avsnittet vil vi fokusere på miljøpåvirkningens og miljøreguleringenes betydning for vekst. Da begrenses samlet produksjon gjennom *konsesjons-MTB* av trafikklyssystemet, mens utnyttelsen av de produksjonsmulighetene som ligger i denne MTBen også begrenses av *lokalitets-MTB*, eller tilgangen på gode lokaliteter som er klarert for bruk. Vekst i produksjonen forutsetter over tid vekst i begge formene for MTB, mens det på kort sikt også kan komme vekst i produksjon gjennom bedre utnyttelse av konsesjons-MTB. Utnyttelsen kan for eksempel økes gjennom flere lokaliteter eller ved å produsere mer på de beste lokalitetene.

I Tabell 6-10 har vi sammenfattet status på miljøparametere for hvert produksjonsområde fra Havforskningsinstituttets risikorapport (Grefsrud m fl. 2022). Denne viser at det i hovedsak er problemstillinger knyttet til lus og rømming som er vurdert å ha størst miljøpåvirkning. I to produksjonsområder har utslipp av kobber også ført til rød vurdering fra HI. Utslipp av næringsstoffer, både partikulært organisk materiale og næringssalter, er markert grønt i alle produksjonsområder.

*Tabell 6-10. Oversikt over status på miljøparametere pr. produksjonssone 2022 4 (Kilde: Havforskningsinstituttet)*

| Produksjonsområde | Partikulært organisk materiale på bløtbunn | Utslipp av kobber | Utslipp av næringssalter | Ytterligere innkryssing av rømt oppdrettslaks | Endring av forekomst av PD i villfisk | Endring av forekomst av ILA i villfisk | Negative effekter på sjøørret og sjørøye | Dødelighet på utvandrende postsmolt | Dødelighet hos oppdrettslaks i sjø | Dødelighet hos regnbueørret i sjø |
|---|---|---|---|---|---|---|---|---|---|---|
| 1: Svenskegrensen til Jæren | grønn | grønn | grønn | grønn | grønn | grønn | grønn | grønn | rød | x |
| 2: Ryfylke | grønn | gul | grønn | grønn | grønn | grønn | rød | gul | rød | x |
| 3: Karmøy til Sotra | grønn | rød | grønn | rød | gul | grønn | rød | rød | rød | grønn |
| 4: Nordhordland til Stadt | grønn | rød | grønn | rød | gul | grønn | rød | rød | rød | gul |
| 5: Stadt til Hustadvika | grønn | gul | grønn | gul | grønn | grønn | rød | gul | rød | gul |
| 6: Nordmøre og Sør-Trøndelag | grønn | gul | grønn | gul | gul | grønn | gul | gul | gul | x |
| 7: Nord-Trøndelag med Bindal | grønn | gul | grønn | rød | grønn | grønn | rød | gul | grønn | x |
| 8: Helgeland til Bodø | grønn | grønn | grønn | rød | x | grønn | gul | grønn | grønn | x |
| 9: Vestfjorden og Vesterålen | grønn | grønn | grønn | rød | x | grønn | grønn | grønn | grønn | x |
| 10: Andøya til Senja | grønn | grønn | grønn | gul | x | grønn | gul | gul | grønn | x |
| 11: Kvaløy til Loppa | grønn | grønn | grønn | rød | x | grønn | grønn | grønn | gul | x |
| 12: Vest-Finnmark | grønn | grønn | grønn | gul | x | grønn | grønn | grønn | gul | x |
| 13: Øst-Finnmark | grønn | grønn | grønn | grønn | x | grønn | grønn | grønn | gul | x |

I dette kapittelet vil vi illustrere noen mulige effekter av ulike reguleringsprinsipper gjennom å se for oss ulike scenarioer for vekst. Formålet med scenarioene er altså ikke å predikere vekst, men å gi forståelse for konsekvensene av ulike valg, eller ulike prinsipper for vekstregulering.

Vi vil i det følgende skissere potensialet for vekst gjennom tre scenarioer

- Scenario 1: Vekst med lus som eneste regulator
- Scenario 2: Differensiert vekst mellom områder
- Scenario 3: Miljøstyrt vekst

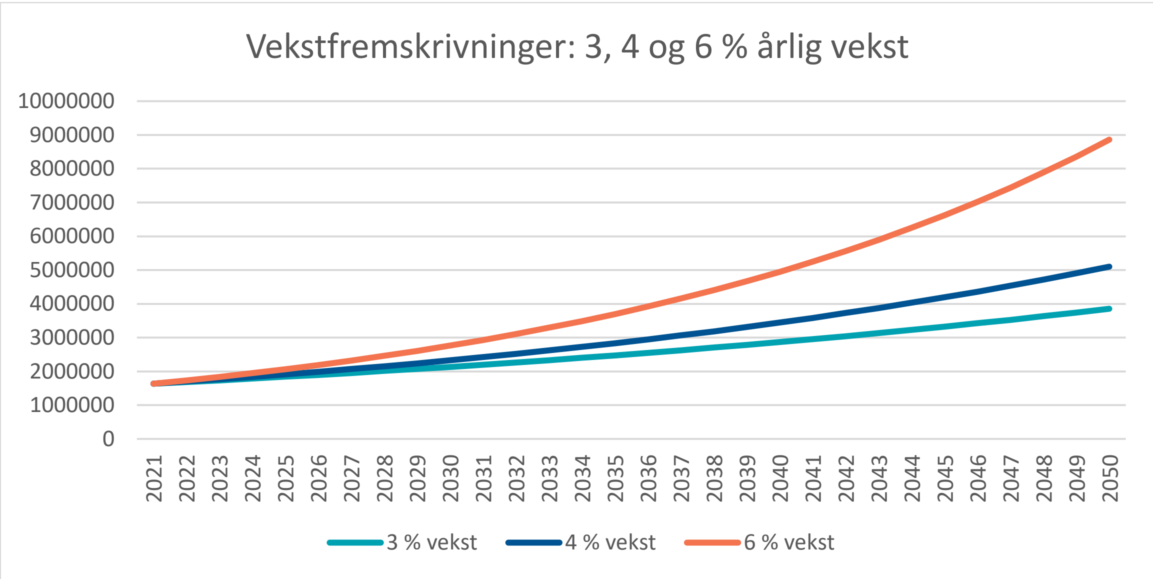
Det første scenarioet gir noen indikasjoner på hvor stor vekst vi kan se for oss om trafikklyssystemet videreføres, og eventuelt justeres. Med fokus på trafikklyssystemet betyr dette samtidig at vi snakker om vekst i konsesjons-MTB.

I scenario 2 ser vi for oss ulik vekst i ulike områder, hvor vekstbegrensningene kan være en kombinasjon av konsesjons- og tillatelseskapasitet.

I scenario 3 vil vi peke på noe andre miljøfaktorer som kan være vekstbegrensende. For det første er areal en begrensning. I dag opereres det med en grense på 5 km mellom anlegg, som kan reduseres til 2,5 kilometer om de aktuelle anleggene har koordinerte driftsplaner. Kortere avstand gir grunnlag for større produksjon (gitt at annen miljøpåvirkning er akseptabel). Selv om Tabell 6-10 viser at organiske utslipp i liten grad er begrensende, så er det i praksis en stor begrensning gjennom at produksjonskapasiteten på gode lokaliteter begrenses gjennom lokalitets-MTBen. Hva om denne kan økes (og kanskje mye) på de beste lokalitetene? (her antar vi implisitt at det er den lokale/regionale miljøbelastningen som er vekstbegrensende, og ikke konsesjons-MTB/lus).

### 6.3.5.1 Scenario 1: Lus som fortsatt regulator?

Veksten i oppdrettsnæringen reguleres i dag gjennom trafikklyssystemet, hvor ulik status på lakselusproblemet kan gi vekst eller reduksjon i konsesjonsbiomasse med inntil 6 % annethvert år, avhengig av trafikklysets farge. Store deler av kysten har hatt grønt lys for vekst, men med noen områder med gult (null vekst) og noen områder med rødt (minus 5-6 %), er det naturlig at veksten blir noe mindre enn 3 % årlig. Etter innføringen av trafikklyssystemet har veksten i gjennomsnitt vært på 2,9 %. Med en vekst på 3 % fram til 2050 vil man i 2050 kunne ha en produksjon på 3,85 millioner tonn (Figur 6-6). La oss kalle det et primærscenario for en vekst som fortsatt er styrt av lus som eneste indikator i trafikklyssystemet.

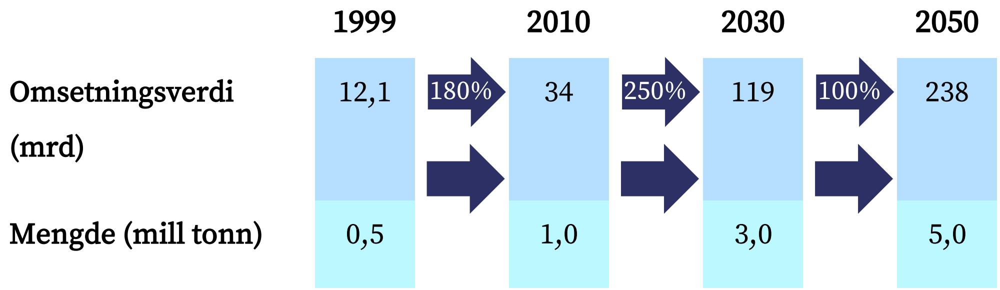



*Figur 6-6. Produksjonsvekst ved ulike fremtidige vekstrater.*

Om man ser litt lenger tilbake, så har veksten siden 2000 vært på 6 % årlig. Med slik årlig vekst fram mot 2050 vil produksjonen i 2050 være på nesten 9 millioner tonn. Over en periode på nesten 30 år utgjør selv små forskjeller i årlig vekstrate en stor forskjell (for å sette effekten av større vekstrater i ytterligere perspektiv: med 10 % årlig vekst ville produksjonen i 2050 blitt på 25 millioner tonn…). Med en vekst på om lag 4 % vil vi nå 5 millioner tonn i 2050, vi kan betrakte det som en variant av primærscenarioet, men da må i tilfelle veksttakten økes innenfor trafikklyssystemet.

Det er vel 10 år siden 5 millioner tonn i 2050 dukket opp som både en mulighet (Olafsen et al. 2012) og etter hvert nærmest en politisk visjon.

Når vi nå er kommet et stykke mot 2050 ser ikke dette scenarioet urealistisk ut. Når vi ser på verdiutvikling frem mot 2030 så skal det bare 9 % økning til på 8 år for at verdien vil overstige den som ble predikert, mens volumøkningen ikke er på det nivå de hadde sett for seg.




*Figur 6-7. Scenario for vekst i verdi og volum mot 2050 for havbruk, laks og ørret (Olafsen et al. 2012, modifisert av Nofima).*

I perioden fra 2012 til i dag er det innført produksjonssoner og trafikklyssystem, hvor miljøstatus bestemmer vekstmulighetene. I neste scenario vil vi se på hvor veksten kan eller må komme om man skal nærme seg en produksjon på 5 millioner tonn i 2050.

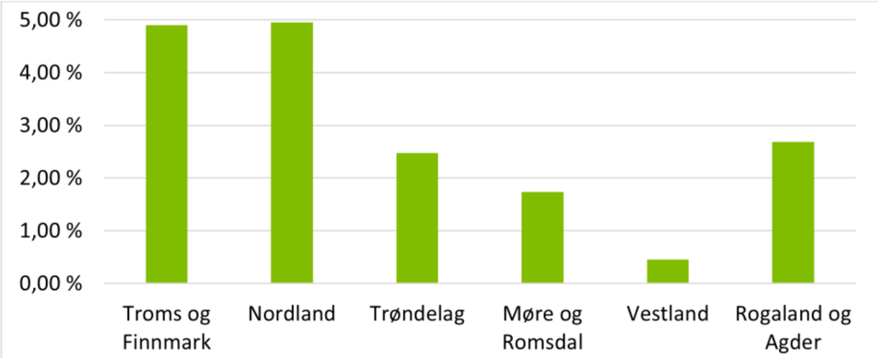
#### 6.3.5.2 Scenario 2: Differensiert vekst mellom områder

Diskusjonen så langt i rapporten viser at det for flere stressorer bør være mulig å regulere miljøpåvirkningen mer presist.

I scenario 1 fokuserte vi på vekst i produksjonen styrt av lus. Den veksten som tillates gjennom trafikklyssystemet er vekst i konsesjons-MTB, eller produsentenes tillatelse til å ha en gitt biomasse i sjøen, uavhengig av hvilken lokalitet fisken holdes på. De andre miljøpåvirkningene vi har diskutert har imidlertid størst betydning for fastsettelsen av lokalitets-MTB, og dermed utviklingen i denne.

Sentrale elementer i et scenario med differensiert vekst vil være mer vekst i de områdene som har minst lus (produksjonsområder), men kan også innebære mer lokal vekst i de beste områdene (beste lokaliteter/fjordsystemer). Vi har ikke studert vekstpotensial på lokalitetsnivå, men det kan være nyttig å reflektere litt rundt vekstrater på fylkesnivå eller PO-nivå.

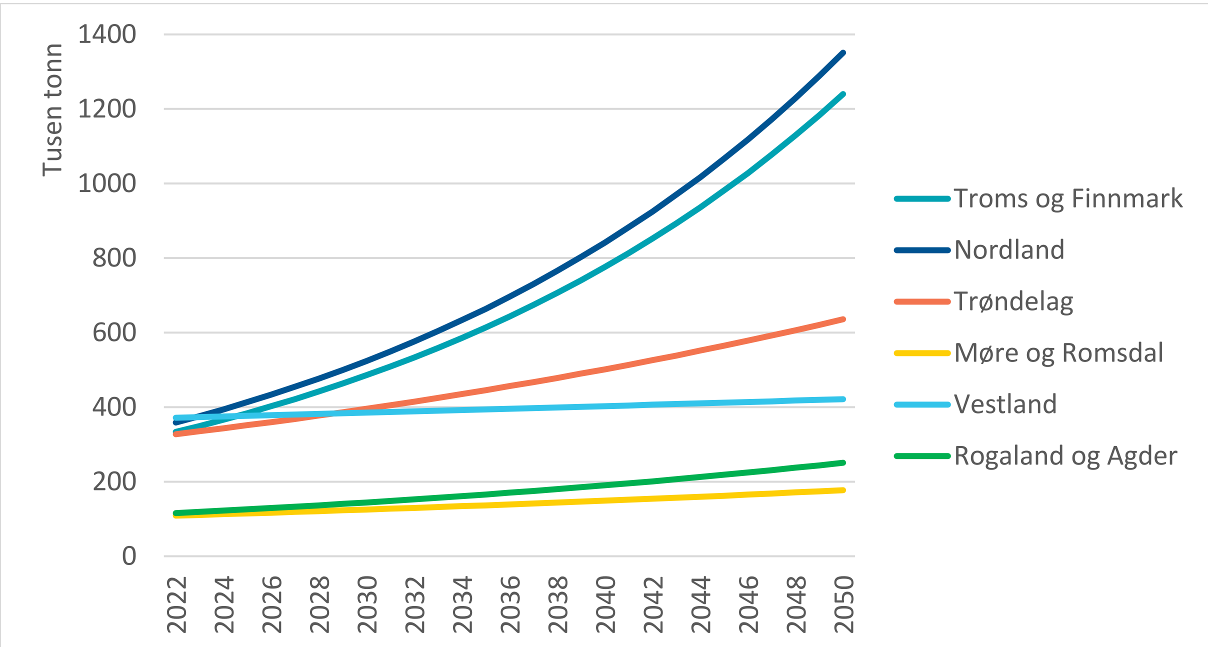
Utviklingen de siste årene viser at det har vært store forskjeller i vekst i de ulike fylkene. Årlig snittvekst fra 2012 til og med 2022 for hele landet var på 2,65% (Fiskeridirektoratet/Nofima). Mens Nord-Norge har hatt en vekst på 5% årlig som vist i Figur 6-8, har Vestland hatt mindre enn 0,5 % i samme periode.




*Figur 6-8. Fylkesvis gjennomsnittlig vekst i lakseproduksjon perioden 2012 til 2022 (Kilde Nofima/Fiskeridirektoratet).*

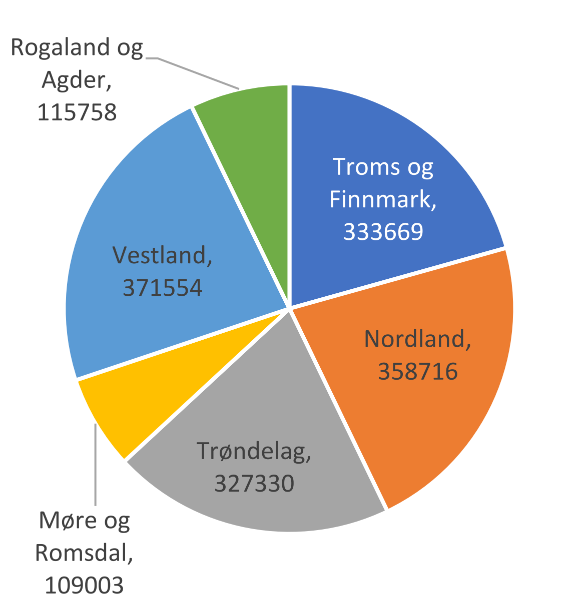
Vestland var klart største produksjonsfylke i 2012, men er i 2022 bak Troms og Finnmark, Nordland og Trøndelag når det gjelder produksjon av laks. Om vi inkluderer ørret har Vestland likevel den største produksjonen av fylkene i 2022. Store miljøutfordringer relatert til lus og sykdom er årsaken til svak vekst i fylket. En vekst i Nord-Norge som har vært større enn veksten gjennom trafikklyssystemet kan skyldes bedre utnyttelse av konsesjons-MTBen, overflytting av fisk gjennom interregionalt biomassetak osv.

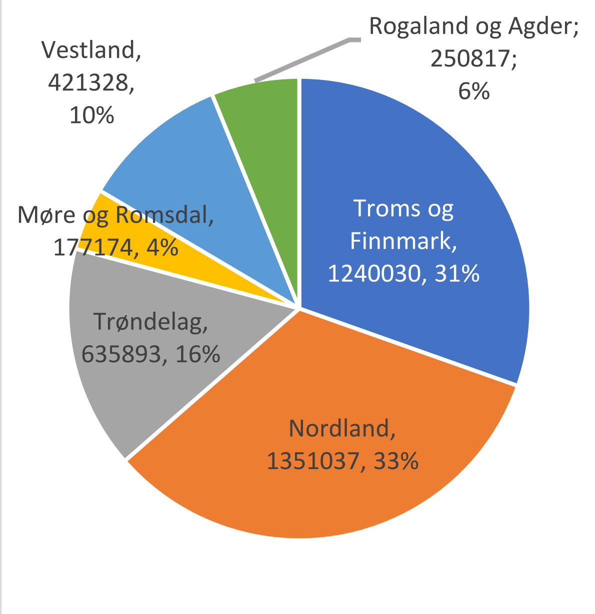
Om vi antar at veksten fram mot 2050 vil ligne veksten som har funnet sted de siste 10 årene, vil veksten i de ulike fylkene kunne være som i Figur 6-9. Med så ulike vekstrater vil vi i fram mot 2050 få veldig ulike vekstbaner.




*Figur 6-9. Vekst med historiske vekstrater for de ulike fylkene.*

Så ulike vekstbaner vil også påvirke fordelingen mellom de ulike fylkene ganske betraktelig. I Figur 6-10 har vi vist fordelingen av produksjonen av laks og ørret i 2022 (venstre kakediagram) og fordelingen slik den ville vært i 2050 med de vekstrater vi har sett fra 2012 til 2022. I 2022 var produksjonen nokså jevnt fordelt mellom de fire største fylkene, som hadde mellom 20 og 23 % av produksjonen, mens både Møre og Romsdal og Rogaland og Agder (til sammen) hadde cirka 7 %.




*Figur 6-10. Produksjon av laks og ørret i norske fylker i 2022 (venstre) og i 2050 (høyre) forutsett vekst med vekstratene i figur 6,8.*

Om vi fortsetter til 2050 med de vekstratene de ulike fylkene har hatt de siste 10 årene, så vil fordelingen i 2050 se ut som til høyre i figuren. Nordland og Troms og Finnmark vil ha vokst til omtrent det tredoble av dagens produksjon, og hver stå for rundt en tredjedel av produksjonen. Vestland, som i dag har størst produksjon av laks og ørret (med en andel på 23 %), vil i 2050 bare står for 10 % av produksjonen.

La oss minne om at den sterkere veksten i nord til en viss grad har vært en «opphentingsvekst», etter at næringen i sin tidlige fase hadde størst vekst fra Vestlandet og nordover til Nordland, og etter at man i Troms og Finnmark for en del år siden hadde lavere utnyttelse av konsesjons-MTBen enn lenger sør. Men samtidig er det fortsatt mye som taler for at veksten vil være sterkere i nord enn lenger sør. Det er fortsatt mindre tett mellom anleggene i nord, det er mindre sykdom og lavere dødelighet. En lavere temperatur, som i næringens barndom ble sett på som en ulempe, har de siste årene vært en fordel, og kan med økende havtemperatur bli en viktig faktor som tilsier større vekst i nord enn i sør.

### 6.3.5.3 Scenario 3: Miljøstyrt vekst

Diskusjonen så langt i rapporten viser at det for flere av de diskuterte stressorene er mulig gjennom bedre kunnskap om miljøpåvirkning, og bedre data, indikatorer eller analysemetoder, er mulig å få til å regulere næringen mer presist. Det betyr også at det burde være mulig å utnytte de beste lokalitetene mer effektivt.

I dette scenarioet har vi derfor stilt følgende spørsmål: Hva om veksten konsentreres om de beste lokalitetene?

Med et slikt utgangspunkt melder det seg straks spørsmål om hvor mye de beste lokalitetene kan vokse, og hvor mye veksten kan øke før miljøpåvirkningen blir uakseptabel.

Det er tidligere diskutert hvordan endret lokalitetsstruktur i et produksjonsområde (PO 3), kan påvirke produksjonsmulighetene (Huserbråten et al. 2020). Havforskningsinstituttet (HI) og Veterinærinstituttet (VI) analyserte, på oppdrag fra Nærings- og fiskeridepartementet, effektene på smittespredning gitt ulike scenarioer av endret lokalitetsstruktur i produksjonsområde 3, i 2020. Gjennom disse ble det funnet at en strategisk relokering av produksjonskapasitet, fra mer smittespredende lokaliteter til de mindre spredende, sannsynligvis ville redusere smittepress mellom lokalitetene, uten å måtte redusere den totale kapasiteten. I ett av scenariene som ble testet med Havforskningsinstituttet sine modeller ble det indikert at smitte mellom lokalitetene kan reduseres med 46% for lakselus og 30% for virus, ved å redusere fra dagens 135 lokaliteter ned til 100 matfisklokaliteter **uten å redusere den totale produksjonen.** I rapporten ble det påpekt at en viktig faktor å utrede dersom flytting av kapasitet skulle bli aktuell, ville være miljømessige tålegrenser for belastning på lokalitetene som ville endt med utvidet kapasitet (Huserbråten et al. 2020).

Hva om fremtidig lokalitets-MTB ble konsentrert på de beste lokalitetene? Et slikt scenario kan bli reelt gjennom flere regulatoriske grep.

Hvor stor ville økningen i kapasitet være dersom de med god miljøtilstand fikk økt lokalitetskapasitet? For eksempel kan alle lokaliteter som har status Meget god tillates å øke så lenge miljøstatusen en er Meget god. Avhengig av hva man definerer som akseptabel miljøpåvirkning kan dette strekkes lenger også. Hva om alle lokaliteter med status Meget god tillates å gå ned til God miljøstatus, for eksempel?

Og på den andre siden; hvordan ville bildet sett ut dersom de med dårlig eller meget dårlig miljøtilstand fikk redusert kapasitet?

Vi skal i det følgende illustrere noen mulige utviklingstrekk. Selv om den samlede risikoen fra partikulært organisk materiale på bløtbunn og utslipp av løste næringssalter er vurdert som lav Tabell 6-10, vil man ved økt produksjon kunne oppleve at organiske utslipp blir vekstbegrensende. Vi har her valgt å bruke resultater fra B-undersøkelser (per 03.02.23) for å illustrere potensialet i vekst i akvakulturproduksjon basert på miljøundersøkelser. Hver lokalitetsrapport har én samlet tilstandsvurdering, der 1 er meget god, 2 er god, 3 er dårlig og 4 er meget dårlig. Fremstillingen forteller kun noe om øyeblikksbildet, og tar ikke hensyn til økning over tid. Merk at vi her snakker om lokalitetskapasitet, til forskjell fra kvantifiseringen av konsesjons-MTB i forrige scenario.

*Tabell 6-11. Mulige vekstscenarier basert på resultat fra miljøundersøkelser.*

| Tilstand (B-undersøkelser) | Antall | Samlet lokalitets-MTB | ± 6% | ± 10% | ± 20% | ± 50% | ± 100% | + 200% | + 400% |
|---|---|---|---|---|---|---|---|---|---|
| Meget god | 564 | 2 197 726 | 131 864 | 219 773 | 439 545 | 1 098 863 | 2 197 726 | 4 395 452 | 8 790 904 |
| God | 191 | 637 886 | 38 273 | 63 789 | 127 577 | 318 943 | 637 886 | 1 275 772 | 2 551 544 |
| Dårlig | 72 | 241 012 | -14 461 | -24 101 | -48 202 | -120 506 | -241 012 | | |
| Meget dårlig | 18 | 50 740 | -3 044 | -5 074 | -10 148 | -25 370 | -50 740 | | |
| **Sum** | *845* | *3 127 364* | **152 632** | **254 386** | **508 772** | **1 271 930** | **2 543 860** | **5 671 224** | **11 342 448** |

Dersom alle med lokalitetstilstand Meget god fikk øke lokalitetskapasitet med 6 %, ville man kunne ha en vekst i lokalitets-MTB på i overkant av 130.000 tonn. Om også de med god lokalitetstilstand fikk økt kapasitet med tilsvarende mengde (6%), ville lokalitets-MTB totalt kunne vokse med ca. 170.000 tonn. På den andre siden ville lokalitets-MTB bli redusert med omtrent 1.500 tonn dersom de med meget dårlig tilstand måtte redusere kapasiteten med 6%. Skulle også de med miljøtilstand vurdert som dårlig få kutt i kapasitet med 6%, ville til sammen rett over 17.000 tonn av dagens lokalitetskapasitet være berørt.

For lokalitets-MTB er det imidlertid ingen grunn til at økningene skal foregå i like små trinn som trafikklyssystemet gir for konsesjons-MTB. Der hvor forholdene ligger til rette for det, og dagens lokalitets-MTB ligger litt eller mye under lokalitetens eller områdets bæreevne, kan man se for seg vekstregimer hvor vekst på lokalitet gis trinnvis økt kapasitet etter dokumentert god miljøtilstand (noe som delvis gjøres allerede i dag). Tabell 6-11 viser at allerede 20 eller 50 % økning i kapasitet på lokaliteter med Meget gode miljøforhold vil gi betydelige tillegg i lokalitetskapasiteten. En 50 % økning for lokaliteter med Meget god miljøstatus (det gjelder omtrent 2/3 av lokalitetene) vil gi 1,1 millioner tonn økt lokalitets-MTB.

Slike betraktninger er nyttige enten man søker vekst eller flytting fra dårlige til gode lokaliteter. Vi kan både fra disse betraktningene og diskusjonen om PO3 (Huserbråten et al, 2020) se at det finnes et stort potensial for å utnytte områdene bedre, som bør undersøkes. Det vil nok kreve litt utredning og undersøkelser, ettersom det kan slå ulikt ut for ulike aktører, på litt tilfeldig vis. Det kan også tenkes noen systematiske forskjeller, ettersom større selskaper med drift i flere områder kan tenkes å ha større fleksibilitet til å håndtere flytting fra noen lokaliteter og oppbygging på andre.

Vi har også sett på dette scenarioet for to casebedrifter som vi har brukt i prosjektet (Lerøy og Eidsfjord sjøfarm). For Lerøy sine lokaliteter vil tilsvarende tilfelle (6% opp for de med meget god tilstand) gi en økning i lokalitets-MTB på vel 15.000 tonn, og dersom de med god tilstand inkluderes, en økning på nesten 19.000 tonn. Skulle MTB for lokaliteter med meget dårlig tilstand reduseres med 6% ville knappe 200 tonn av Lerøys lokalitetskapasitet bli berørt. Inkluderes de med dårlig som tilstand i reduksjon, snakker vi om knappe 1.500 tonn.

For Eidsfjord sjøfarm ville en økning på 6% for meget god miljøtilstand resultere i nesten 1.400 tonn mer i lokalitets-MTB. Dersom i tillegg de med god tilstand skulle økes, ville lokalitets-MTB steget med om lag 2.200 tonn. I motsatt ende ville reduksjon (på 6%) som følge av meget dårlig tilstand bety nedgang med 140 tonn for Eidsfjord sjøfarm, samt total nedgang på over 900 tonn ved inkludering av de med dårlig tilstand.

Av disse scenarioene kan vi se at forholdet mellom potensiell vekst og potensiell reduksjon i MTB, basert på miljøpåvirkning har en risiko for å tilfalle og berøre svært ulikt mellom forskjellige innehavere.

## 6.4 Diskusjon

Avslutningsvis vil vi diskutere mulighetsrommet for bedre forvaltning gjennom forbedring og mer effektiv utnyttelse av kunnskap. I det ligger det et ønske om at man kan utløse et potensial for både redusert fotavtrykk og økt produksjon. Diskusjonen vil dreie seg om de spørsmålene vi reiste ved innledningen til dette kapittelet, nemlig om bedre kunnskapsgrunnlag kan bidra til

1) en mer treffsikker, lokaltilpasset og samfunnsøkonomisk effektiv akvakulturforvaltning

2) en mer helhetlig og samfunnsøkonomisk effektiv forvaltning av miljøpåvirkning fra både havbruksnæringen og annen miljøpåvirkning fra menneskelig aktivitet og

3) om dette kan bidra til en miljømessig forsvarlig vekst.

### 6.4.1 Hvordan kan et bedre kunnskapsgrunnlag og bedre utnyttelse av eksisterende kunnskap gi en mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv akvakulturforvaltning?

I kapitlene over har vi oppsummert kunnskapsstatus og potensial for at eksisterende og ny kunnskap kan tas i bruk i reguleringen av ulike stressorer.

Vi har i avsnitt 6.3.1(Tabell 6-2) identifisert og oppsummert om en rekke stressorer er viktige, status på kunnskapsgrunnlaget om dem og i hvor stor grad stressoren er dekket i forvaltningen. Vi fant der at vi kan snakke om fire hovedgrupper av stressorer:

**Stressorer som er viktige, har et godt kunnskapsgrunnlag og er godt dekket i forvaltning:**

- *partikulære organiske utslipp (bløtbunn)*
- *løste næringssalter*
- *rømming (laks/ørret)*
- *sykdom*
- *antibiotika.*

**Stressorer som er viktige, med et godt kunnskapsgrunnlag, men er dårlig dekket av forvaltning i dag, noe som betyr at vi har identifisert en stressor som krever større oppmerksomhet av forvaltningen fremover:**

- *rømming (rensefisk)*
- *parasitter*
- *antibegroingsmidler*
- *avlusingsmidler*

**Stressorer som det finnes for lite kunnskap om miljøpåvirkning i dag, men hvor det er behov for å avdekke hvilken betydning de kan ha for forvaltning og næringen:**

- *partikulære organiske utslipp (hardbunn)*
- *kunstige strukturer (inkl. anlegg, lys, lyd)*
- *plast*
- *uønskede fôringredienser*
- *nanopartikler*
- *desinfiseringsmidler.*

**Stressorer som har betydning i dag, men potensielt større betydning i fremtiden, avhengig av blant annet vekst i havbruksnæringen:**

- *Alle unntatt én er vurdert til å ha større betydning i fremtiden*

Vi har i avsnitt 6.4.1 og Tabell 6-5 vurdert mulighetene, for alle identifiserte stressorer, for mer lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning. Der hadde vi fokus på om eksisterende kunnskapsgrunnlag kunne utnyttes bedre, til bedre forvaltning.

Gitt at vi også har vist at det meste av tilgjengelig kunnskap tas i bruk i forvaltningen (Tabell 6-6), ville en gjengivelse av hele tabellen her bli gjentakende. Vi vil istedenfor oppsummere kort de stressorene som har størst potensiale for mer lokaltilpasset, treffsikker eller samfunnsøkonomisk effektiv forvaltning, oppsummert i Tabell 6-12. Fremstillingen her er stikkordsmessig, mer utfyllende vurderinger er gjengitt tidligere.

Tabellen nedenfor oppsummerer de stressorene som ifølge vår vurdering har det største potensialet for forbedret forvaltning.

*Tabell 6-12. Muligheter for å regulere stressorer mer lokaltilpasset, treffsikkert og samfunnsøkonomisk effektivt.*

| | **Mer lokaltilpasset?** | **Mer treffsikker?** | **Mer samfunnsøkonomisk effektiv?** |
|---|---|---|---|
| Partikulære næringsstoffer (hardbunn) | Trenger mer kunnskap om hardbunn | | Kan føre-var erstattes av kunnskap?<br><br>Kartlegging er kostbart |
| Løste næringssalter | | | Samkjøring av overvåkningsprogrammer |
| Sykdom | Bedre koordinering av driftsplaner | | mindre avstand med bedre koordinasjon |
| Lus | Differensierte lusegrenser? | ? | Bedre forvaltning/mindre behandling kan ha betydelig samfunnsøkonomisk effekt |
| Lusemidler | | Det finnes uutnyttede data | |
| Kobber | Ved bedre overvåkning | ? | |

**Partikulære næringsstoffer (hardbunn):** Godt kunnskapsgrunnlag om bløtbunn, dårligere for hardbunn.

**Løste næringsstoffer:** Overvåkning som settes i gang og tiltak som iverksettes i vannforvaltningen skal også inkludere kost-nytte analyser, i praksis begrenset med faktiske kost-nytte analyser. Løste næringssalter tilføres miljøet fra flere kilder, og flere næringer pålegges krav om overvåkning i tillegg til de nasjonale overvåkningsprogrammene. En større grad av samkjøring mellom overvåknings programmer vil kunne gjøre forvaltningen av denne stressoren mer samfunnsøkonomisk effektiv.

**Sykdom:** mindre avstand med bedre koordinasjon kan gi bedre utnyttelse av tilgjengelig oppdrettsareal. Mattilsynet oppfordrer til forebyggende koordinering som i dag skjer på frivillig basis. Hydrodynamiske modeller og spredningsmodeller som brukes i trafikklyssystemet kan mulig være nyttig for å evaluere risiko for sykdomsspredning.

**Lus:** Relativt lokaltilpasset forvaltning ved arealplanlegging og lokalitetssøknad, samt ved unntakssøknader i trafikklyssystemet. Andre elementer er imidlertid lite lokaltilpasset, for eksempel ved samme lakselusgrense for alle anlegg.

**Lusemidler:** Før lusemidler brukes på et anlegg skal det gjøres en risikovurdering om miljøeffekter av fiskehelsepersonell/veterinær. Review indikerer at det finnes data om giftighet, konsentrasjoner i miljøet (modellert og målt i noen tilfeller) og miljørisiko. De eksisterende data og modellverktøy kan brukes mer aktivt for å oppnå en mer treffsikker forvaltning.

**Kobber:** Mer systematisk prøvetaking ved B- og C-undersøkelser vil kunne gi grunnlag for mer treffsikker forvaltning. Selv om vår gjennomgang har vist at det meste av tilgjengelig kunnskap tas i bruk, kan forvaltningen likevel bli mer treffsikker ved at flere eksisterende datakilder og verktøy blir brukt direkte eller for å underbygge nye forvaltningsgrep. Et eksempel på dette er planlegging av produksjonskapasitet på lokalitet eller vannforekomst. Gitt at det for et aktuelt område er etablert marine grunnkart, og de kombineres med strøm- eller spredningsmodeller, vil kunnskap av relevans for lokalitetsetablering være tilgjengelig fra man starter å vurdere lokalisering, for eksempel under kommunal kystsoneplanlegging. Mens man i dag til en viss grad gjetter/resonnerer seg fram til hva som er gode lokaliteter, for så å sette i gang undersøkelser om egnethet, kan bedre kartlegging og modeller danne grunnlag for mer systematiske søk etter de virkelig gode lokalitetene. Spredningsmodeller tar hensyn til strøm, fortynning osv., og bør også kombineres med oppdatert kunnskap om tålegrenser (grenseverdier) for ulike stressorer og resipienter. Flere stressorer kan håndteres ved hjelp av slike modellverktøy, bl.a. lus, sykdom, partikulært organisk materiale og avlusningsmidler.

Grunnkart og spredningsmodeller kan også være viktige verktøy for å få mer av produksjonen over på (enda) bedre lokaliteter. En dreining av produksjonen fra dårligere til de beste lokaliteter kan imidlertid kreve bedre koordinering mellom kommuner, ulike industriaktører og andre interessenter. Et eksempel der bedre forvaltning vil kreve ny kunnskap er regulering av miljøgifter, med kobber som den kanskje mest nærliggende å vurdere. Bruken av kobber er utstrakt, alternative antibegroingsmidler er få og man begynner å få en del kunnskap om miljøpåvirkningen. Forekomsten av kobber kan imidlertid være «patched», det vil si at den kan gjenfinnes i opphopninger noen steder, men ikke målbar like ved. Resultater kan derfor variere mye på den enkelte lokalitet eller innenfor et område. Til og med to prøver fra samme grabb kan variere mye. I forvaltningen fører dette gjerne til at man ser økning i verdiene i C-undersøkelser, og ber om utvidede målinger, for eksempel en gradientstudie. Med økte indikasjoner på økt miljøpåvirkning, eller ved større usikkerhet, kan man øke kravene til brakklegging. Med bedre data og kunnskap om påvirkning kan kravene til brakklegging kanskje heller reduseres, om man kan dokumentere lav påvirkning.

For alle nevnte stressorer kan data samlet av næringen selv kan bidra til mer presis forvaltning. Dette forutsetter imidlertid at datainnsamling og kommunikasjon skjer på en systematisk måte.

Et viktig utgangspunkt for dette prosjektet har vært å vurdere skala eller geografisk nivå for regulering av miljøpåvirkning fra havbruk. Regulering på lavest mulige nivå kan gjøre det mulig å utnytte de best egnede områdene til økt produksjon, og redusere belastningen på mindre gode områder. For noen typer miljøpåvirkninger kan utvidelse av geografisk skala være mer aktuelt, for eksempel vil det fortsatt være viktig å forvalte lus på regionalt/PO-nivå, og sykdom kan også smitte over større områder, og må kunne overvåkes og forvaltes med tanke på regional kontroll.

#### 6.4.1.1 Mer samfunnsøkonomisk effektiv havbruksforvaltning?

Vi har tidligere definert samfunnsøkonomisk effektiv forvaltning som en forvaltning hvor prioriteringer og interesseavveininger innenfor et politikk-område og mellom politikk-områder gjøres slik at den samlede effekten som oppnås (f.eks. miljøforbedring, menneskelig nytte) blir størst mulig til en gitt kostnad, eller til lavest kostnad for en gitt samlet effekt.

Et relevant spørsmål er om forbedringer i miljøkvaliteter eller redusert miljørisiko som er oppnådd etter tiltak i én sektor kunne vært oppnådd til en lavere kostnad hvis man hadde gjort tiltak i en annen sektor. Kostnad kan både bety direkte kostnader for tiltak for å redusere miljøeffekter, men det kan også være indirekte tap i form av redusert vekst i produksjon med tilsvarende redusert verdiskaping.

Innenfor denne definisjonen vil en mer treffsikker forvaltning som også er tilpasset det aktuelle geografiske nivået være et bidrag til økt økonomisk effektivitet. Det forutsetter imidlertid at kostnadene for selve forvaltningsprosessene står i et rimelig forhold til de reduserte miljørisiko- eller miljøeffekter, eller den økte effektiviteten, som oppnås. Det blir da et spørsmål om kostnadene for generering, innsamling og analyse av nødvendige data, samt for å ta en beslutning i forvaltningen, er mindre enn gevinstene med reduserte miljøeffekter. Det vil også oppstå spørsmål om hvem som skal betale for den økte kunnskapen, men dette er mer et fordelingsspørsmål enn et effektivitetsspørsmål.

Vi vil i det følgende diskutere elementer ved en del av de viktigste stressorene som kan ha stor samfunnsøkonomisk betydning.

**Partikulære organiske utslipp:**

Organiske utslipp er ikke bare en miljøpåvirkning, men de vil ganske fort også kunne representere et fiskehelseproblem om de blir for store. Det er derfor i utgangspunktet godt samsvar mellom god miljøstatus og økonomisk effektivitet.

Også reguleringen av partikulære organiske utslipp kan føre til samfunnsøkonomisk ineffektivitet i tilfeller hvor de er unødvendig strenge. Her kan man få motstrid mellom føre-var-prinsippet og økonomisk effektivitet. Føre-var-prinsippet legger i sin natur til grunn en sikkerhetsmargin for miljøpåvirkning. Uten god kunnskap om hvor grensene for å kunne beholde god miljøstatus går, og med en stor sikkerhetsmargin, vil man kunne innføre unødvendig streng regulering: da vil man ikke utnytte de fortrinn som ligger i økosystemtjenester[25]. For merdbasert havbruk i sjø er de naturgitte forholdene (dybde, strøm, oksygen, temperatur, skjermet skjærgård osv.) av stor verdi for oppdretteren, og en stor del av forklaringen på at vi med norsk kostnadsnivå er veldig konkurransedyktige i oppdrett av laks. Gode miljøforhold påvirker direkte fiskehelseforhold som har stor betydning for produksjon, slik som veksthastighet, dødelighet og kvalitet.

**Kobber:**

Det er uklart om det er gjort noen samfunnsøkonomiske betraktninger rundt å tillate så høye utslipp av kobber. Det er foreløpig lite kunnskap om hvor tilgjengelig ulike kobberformer er

[25] For generell diskusjon av økosystemtjenester på land og sjø i Norge: https://www.regjeringen.no/contentassets/c7ffd2c437bf4dcb9880ceeb8b03b3d5/no/pdfs/nou201320130010000dddpdfs.pdf

i sedimentet, og om konsentrasjoner i vannsøylen. Det er også behov for mer kunnskap om hvordan kobberet spres og fortynnes rundt anleggene, og om hvilke arter og livsstadier som er mest sårbare for kobberutslippene fra oppdrett.

**Sykdom:**

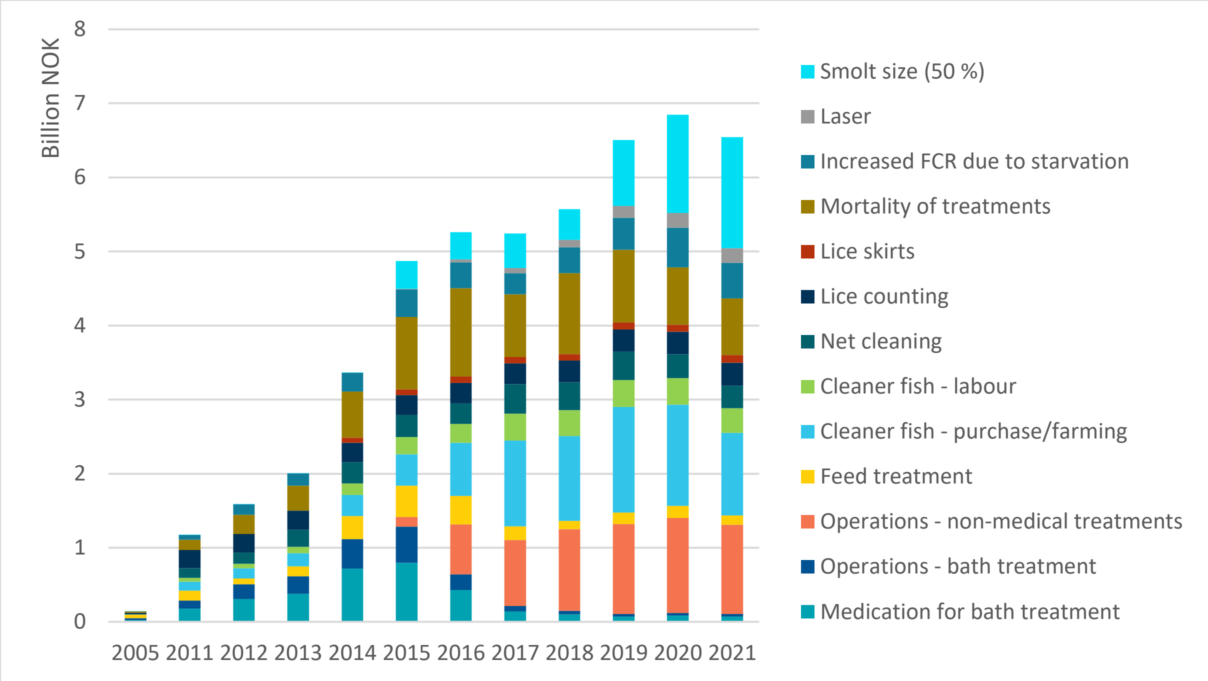
Det er meget godt samsvar mellom fiskehelse og økonomisk effektivitet: lite sykdom gir både kortere tid i sjø, lavere dødelighet, lavere fôrkostnader og lavere kostnader til håndtering (Iversen et al. 2020). Alle reguleringer som bidrar til bedre fiskehelse, vil derfor i utgangspunktet også øke økonomisk effektivitet. Takket være relativt strenge reguleringer, har norsk oppdrettsnæring klart å unngå stor sykdomsrelatert nedgang i produksjon, noe som har vært tilfelle i andre land (Asche et al. 2009). Men også når det gjelder sykdom er det mulig at for store sikkerhetsmarginer vil kunne gi unødig stenge reguleringer som begrenser veksten mer enn nødvendig. For å finne optimale reguleringer bør en nytte-kostnadsvurdering gjøres både for hvert patogen og for sykdomssituasjonen samlet. Det finnes flere eksempler på kostnader ved sykdomshåndtering i vitenskapelig litteratur (Hall et al. 2014; Pettersen et al. 2015), selv om det fortsatt er begrenset kunnskap om sykdoms samlede påvirkning på kostnadsnivået i oppdrett.

**Lus:**

Lus har siden innføringen av trafikklyssystemet vært hovedregulatoren for vekst i næringen. For å begrense lusepresset og bestanden av lus har man satt strenge lusegrenser, som har ført til mye behandling hos oppdretterne. Høy kjemikalie- og medisinbruk har ført til resistens og mindre effektive kjemikalier, som igjen har ført til økt bruk av kjemikalier, med avtakende effekt. Fra 2016 har ikke-medikamentelle metoder for avlusing tatt over som de viktigste behandlingsmetodene, men dødeligheten knyttet til behandling er høy. Termisk avlusing førte til den største økningen i dødelighet (+ 31 %), fulgt av mekanisk (25 %), hydrogenperoksid (21 %) og medisinske (azamethipos, cypermethrin og deltamethrin (+ 14 %) (Overton et al. 2019). Reguleringen av lus er rettet mot å redusere påvirkning på villaks, men samtidig har altså lusebekjempingen blitt et fiskehelseproblem i oppdrettsnæringen.

Reguleringene har også bidratt til høye kostnader både for forebygging og behandling, opp mot 7 milliarder i direkte kostnader i året, se **Error! Reference source not found.**. I tillegg kommer indirekte kostnader knyttet til mer ineffektiv drift.

Høyere dødelighet representerer også en betydelig omdømmemessig utfordring, som ikke er forsøkt kostnadsberegnet her.




*Figur 6-11. Kostnader knyttet til forebygging og behandling av luseproblemene i oppdrett av laks[26].*

Med lus som hovedregulator og de betydelige kostnader som lusebekjempelse medfører i hele næringen, er det grunn til å undersøke effektiviteten til de virkemidlene som forvaltningen bruker, og om det er mulig å oppnå samme mål med andre virkemidler som har en lavere økonomisk eller fiskehelsemessig kostnad. Manglede evaluering av alternative reguleringstiltak er imidlertid en av de største svakhetene i offentlige utredninger generelt ifølge rapporten fra DFØ (2020). Samme rapport peker på betydelige utfordringer ved utredninger av tiltak som innføres i ulike sektorer, noe som svekker samfunnsøkonomisk lønnsomhet.

Trafikklyssystemet er et typisk eksempel på et virkemiddel hvor det kan stilles spørsmål ved samfunnsøkonomisk nytte. Selv om tanken har vært å utvide trafikklyssystemet ved å inkludere flere stressorer, er det fortsatt lus som er den eneste indikator som styrer vekst eller sanksjoner. Grunnen er at lusenivået anses å ha stor samvariasjon med biomasse i sjøen (Meld. St. 16 (2014-2015)). En viktig antagelse bak trafikklyssystemet er at nedjustering med 6 % i røde POer vil ha en effekt på lusenivået, og gi bedre forutsetninger for overlevelse for villaks. Når det tillates vekst i grønne områder antar man samtidig at økningen skal føre til mer lus. Effekten på lusebestanden av vekst eller nedjustering i biomasse har imidlertid ikke vært bekreftet empirisk ennå, og det er sannsynlig at sammenhengen mellom biomasse i oppdrett, lus og påvirkning på villaks er langt mer kompleks (Nikitina, 2019). Om en marginal endring i biomasse ikke fører til målbar effekt på miljø, kan et sånt system ikke anses som effektivt og andre virkemidler bør vurderes.

Det mangles også en vurdering av verdi av villaksebestander som kunne rettferdiggjøre evt. nedjustering i biomasse under trafikklyssystemet. Bruk av økonomisk betydning av miljøgoder i forvaltningen av oppdrett er omstridt, men det er likevel et argument som bør inkluderes i utredning av vekstmuligheter.

[26] Dette er oppdaterte beregninger basert på metodikken fra (Iversen et al, 2017), NOFIMA vitenarkiv: Kostnadsutvikling i lakseoppdrett – med fokus på fôr- og lusekostnader (unit.no)

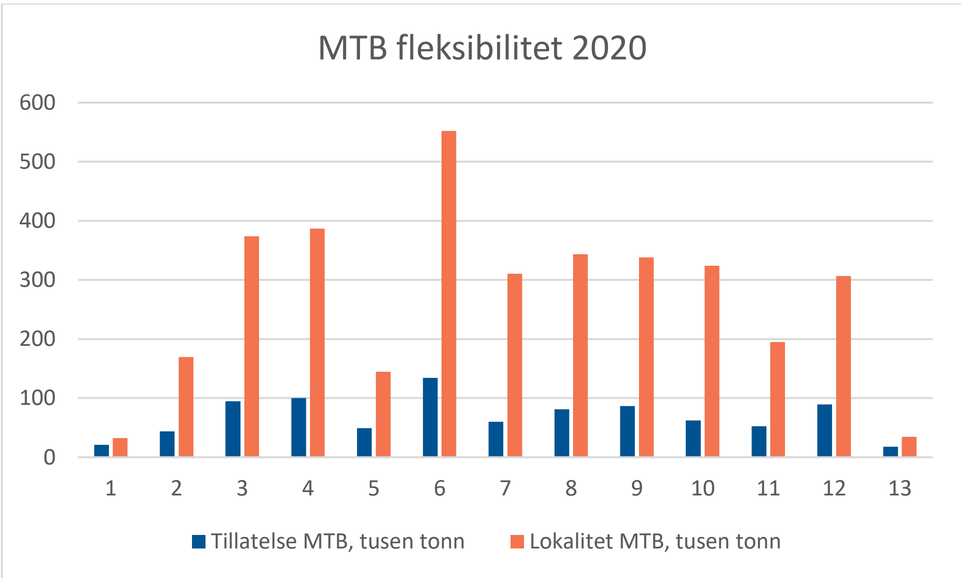
Når det gjelder alternative virkemidler for regulering av lus, vil teknologiskift til lukkede og landbaserte anlegg være en aktuell mulighet å utrede. Siden disse typer teknologi krever betydelig investering, har oppdretterne nølt med å ta dem i bruk. Mulighet for vekst gjennom teknologitilpasning er et aktivt forskningsområde der økonomiske analyser er et viktig element (Bjørndal & Tusvik 2020; Tveterås et al. 2021). Mulighet for vekst kan differensieres etter miljøpåvirkningen som følger teknologien. For eksempel kan det vurderes å tillate vekst i enkelte områder med høyere lusenivå forutsatt at produksjon skjer i lukkede anlegg.

Andre mulige virkemidler kan regulere biomasse i et område, samt avstand mellom lokaliteter og til kysten, som er viktige faktorer som påvirker lusenivået i vannmiljøet. Regulering med hensyn til tetthet og plassering kan være et alternativ til biomassejustering. Slike endringer har allerede skjedd i norsk oppdrett, der avstand mellom lokalitetene har økt, samtidig som biomassen på lokalitetene ble større (McIntosh et al. 2022).

**Regulering av MTB og fleksibilitet**

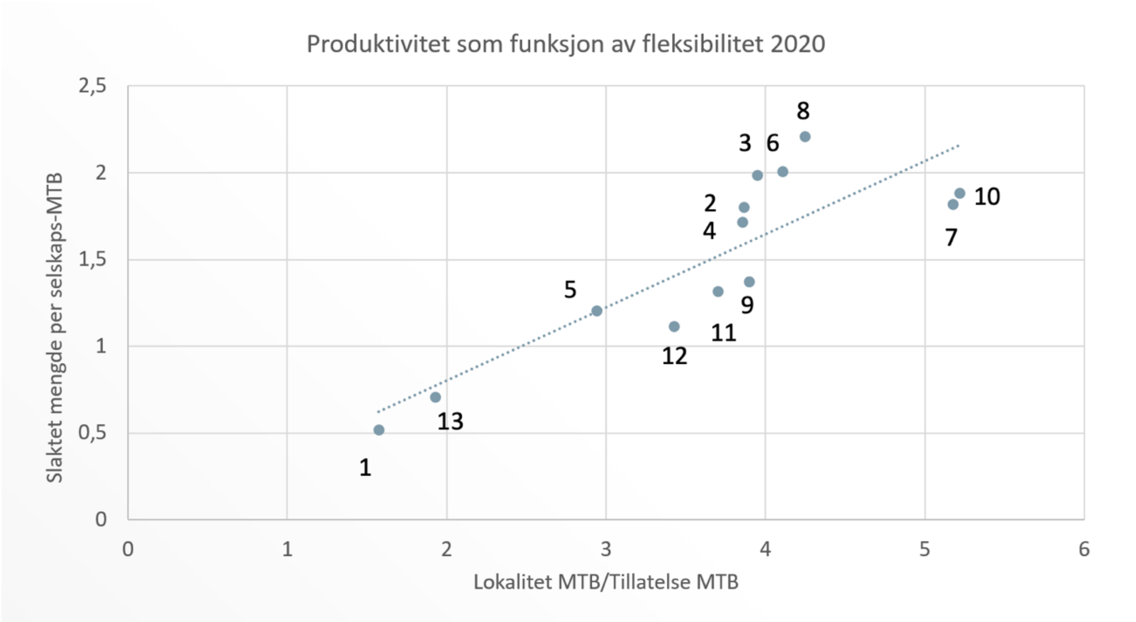
Et potensial for en mer treffsikker, lokaltilpasset og samfunnsøkonomisk effektiv forvaltning ligger i tilpasningen mellom tillatelses-MTB og lokalitets-MTB. Tillatelses-MTB gis for et gitt produksjonsområde, men for å kunne ta i bruk tillatelsen må tillatelsen også knyttes til en eller flere lokaliteter.

Det finnes vesentlige forskjeller mellom produksjonsområdene når det gjelder forholdet mellom tillatelses-MTB og lokalitets-MTB, se Figur 6-12.




*Figur 6-12. Samlet tillatelses-MTB og lokalitets-MTB i ulike produksjonsområder. Kilde: Akvakulturregister 2020.*

Dette forholdet forteller noe om selskapenes fleksibilitet til å utnytte lokalitetene best mulig, og dermed evnen til å produsere mest mulig per konsesjon. Oppdrettsselskapene mener, basert på erfaring, at de behøver en lokalitetsbiomasse på omtrent 4 ganger konsesjonsbiomassen for å kunne utnytte konsesjonen godt. Dette ser vi også godt i våre beregninger, det er en klar positiv sammenheng mellom tilgjengelighet på lokalitetsbiomasse og utnyttelsesgrad av en konsesjon. I de fleste produksjonsområdene ligger dette forholdstallet på mellom 3,5 og 4,5 Figur 6-13.




*Figur 6-13. Forhold mellom produktivitet og MTB-fleksibilitet produksjonsområdene i 2020.*

Å ha nok lokalitetsbiomasse betyr selvsagt ikke bare noe for produktiviteten, men det er ikke minst viktig for å kunne gjøre det på miljøvennlig vis. Det er spesielt to forhold som er viktige her. God tilgang på klarert lokalitets-MTB gjør det mulig å brakklegge lenger, og det gir fleksibilitet til å flytte fisk ved eventuelle algeoppblomstringer, sykdomsutbrudd osv. Dette tilfellet viser godt samsvar mellom hensynet til samfunnsøkomisk effektivitet og miljømessig bærekraft. Mer tilgjengelig lokalitetsbiomasse vil forbedre begge.

### 6.4.2 Mer helhetlig forvaltning av miljøpåvirkning (fra både havbruksnæringen og annen menneskelig aktivitet).

I kapittel 4 har vi gitt anbefalinger om hvilke kunnskapsmangler som bør dekkes for en mer helhetlig forvaltning av næringen sett i sammenheng med miljøpåvirkning fra andre næringer, i en økosystembasert tilnærming. I dette kapittelet oppsummerer vi vurderinger av mulighetsrom og anbefalinger for forbedringer i forvaltningen.

Vi har gjennom kartleggingen av kunnskapen og bruken av den i forvaltningen i dette prosjektet så vidt berørt enkelte sider av et stort antall og komplekse tema og problemstillinger. Prinsippet om helhetlig økosystembasert forvaltning utfordrer næringsliv, forvaltningsorganer og forskningsmiljøer på et grunnleggende nivå, med store krav til kunnskapsgrunnlag og koordinering av de mange aktører som må være involvert for å oppnå en helhetlig forvaltning. Grunnet prosjektets tidsramme har vi ikke kunnet gjøre en uttømmende vurdering av hva som skal til for å oppnå en mer helhetlig økosystembasert forvaltning. Men vi presenterer her noen tanker vi har gjort oss under prosjektets gang, støttet av andre nylige rapporter om temaet.

Økosystembasert forvaltning (ØBF) er en fremvoksende, integrert tilnærming til miljøforvaltning, ansett som instrumentell for å nå FNs bærekraftsmål. Økosystembasert forvaltning har ingen absolutt, enhetlig eller distinkt definisjon (NINA 2020), men kan tolkes til å representere helhetlige, integrerte tilnærminger på tvers av sektorer og nivåer, med sikte på å støtte beslutningstaking som er relevant for å opprettholde økosystemer og deres bæreevne. Etableringen av de såkalte Malawi-prinsippene om økosystemtilnærming fra 1998 var viktig for å få på plass noen sentrale elementer (se tekstboks om Malawi-prinsippene Kap 5.3.1). I norsk sammenheng kan man kjenne igjen flere av prinsippene i sentrale paragrafer i naturmangfoldloven.

Denne skal anvendes innenfor alle relevante næringer på både konkrete og strategiske beslutninger. Prinsippet om økosystembasert forvaltning (§ 10) er generelt formulert: «En påvirkning av et økosystem skal vurderes ut fra den samlede belastning som økosystemet er eller vil bli utsatt for». Ettersom både økosystemer og samlet belastning er vanskelige å avgrense i tid og rom (se kunnskapsinnhenting og casestudie i kapittel 4.3), vil det ofte være stor usikkerhet ved anvendelsen av prinsippet. Hvordan denne og annen usikkerhet skal håndteres er angitt ved føre var prinsippet (§ 9): "Når det treffes en beslutning uten at det foreligger tilstrekkelig kunnskap om hvilke virkninger den kan ha for naturmiljøet, skal det tas sikte på å unngå mulig vesentlig skade på naturmangfoldet. Foreligger en risiko for alvorlig eller irreversibel skade på naturmangfoldet, skal ikke mangel på kunnskap brukes som begrunnelse for å utsette eller unnlate å treffe forvaltningstiltak".

Prinsippene kan anvendes der beslutninger angår to ulike objekter (Fauchald 2020). For det første kan de anvendes på elementer i naturen – for eksempel beslutninger om et verneområde eller om arter som utnyttes gjennom jakt eller fiske. Her vil typisk hensikten være å sikre at naturelementene forvaltes i tråd med langsiktige mål for økosystemene. For det andre kan de anvendes på beslutninger om menneskelige aktiviteter – for eksempel beslutninger om hvordan næringsaktører skal opptre for å oppnå langsiktig økologisk bærekraft i en næringssektor.

Prinsippet om økosystembasert forvaltning utfordrer som nevnt næringsliv, forvaltningsorganer og forskningsmiljøer på et grunnleggende nivå. Det er en økende felles forståelse av hva ØBF innebærer og betyr, og hva som er sentrale hindringer (Aas 2020). Norge er fortsatt i en tidlig fase i utvikling av «sann» ØBF. Naturmangfoldloven legger til rette for ØBF, men mulighetene er så langt i liten grad tatt i bruk, for mange av prinsippene er veiledende og ikke forpliktende (Fauchald 2020).

Både denne rapporten og flere andre har pekt på sentrale barrierer for å kunne realisere en mer helhetlig økosystembasert forvaltning og for ytterligere å styrke (det naturfaglige) kunnskapsgrunnlaget og å videreutvikle beslutningsstøtteverktøy for forvaltning (se kapitel 4, Eriksen et al., 2023, Aas m.fl. (2020)). Dette vil imidlertid ikke være tilstrekkelig, ifølge Aas m.fl. (2020) i deres gjennomgang av internasjonal forskningslitteratur om temaet. De peker på at en sterk sektororganisering og fragmentert forvaltning er en sentral barriere. De konkluderer at det ikke vil være tilstrekkelig med ytterligere styrking av (det naturfaglige) kunnskapsgrunnlaget og produksjon av beslutningsstøtteverktøy, men at det først og fremst kreves mer kunnskap om utfordringene med fragmentert forvaltning, sektorbarrierer, politikk og maktforhold. Fauchald (2020) mener at i norsk kontekst har økonomiske interesser for en stor næringssektor og for samfunnet som helhet blitt sett på som et hovedhinder for å anvende ØBF i akvakultursektoren.

Vi vil nå diskutere hvordan man med den kunnskapen man har kan styrke det naturvitenskaplige kunnskapsgrunnlaget, videreutvikle beslutningsstøtte-verktøy for forvaltning og diskutere utfordringene med sektororganisering og fragmentert forvaltning.

Det er som vist et stort behov for å kartlegge og øke kunnskapen om våre kyst- og sjøarealer og hvordan økosystemene påvirkes av ulike aktiviteter, selv om det har kommet på plass bedre kunnskapsgrunnlag de siste årene (jf. kapittel 5 her, og også kapittel 4 i Eriksen et al., 2023). Økosystembasert forvaltning innebærer at vi skal ha en overordnet plan for forvaltning av hele økosystemet. Vi skal ikke bare opprettholde et vedvarende høyt uttak av kommersielle ressurser, men også hindre at menneskelig aktivitet får negativ innvirkning på de resterende delene av økosystemet.. Dette medfører at man i større grad enn før må kjenne til økosystemets struktur og virkemåte for å kunne forutsi konsekvenser av menneskelig aktivitet. Påvirkninger fra akvakultur skjer som nevnt i kunnskapsinnhentingen på ulik geografisk utstrekning, og for å vurdere sannsynligheten for at mulig akvakulturvirksomhet i et område ikke forringer eller forstyrrer økosystem og naturverdier, må vi skaffe oss kunnskap om både ulike påvirkningstyper og mulige effekter på ulike arter og naturtyper.

#### 6.4.2.1 Relevante økosystemer

Både denne og andre rapporter har pekt på at et viktig moment derfor er å øke vår forståelse av den romlige fordelingen av fysiske drivere og relevante økosystemkomponenter (mottakere til press) gjennom kartleggingsinnsats, som allerede startet av pilotprosjektet Marine Grunnkart. Det er store utfordringer ved å identifisere de relevante økosystemer i beslutningsprosesser. Kunnskapsstatus og de verktøy myndighetene har for innsamling, analyse og formidling av data trekker i retning av at strategiske beslutninger baseres på virkninger for spesifikke arter og naturtyper snarere enn for økosystemene (Fauchald 2022).

Man må skaffe seg kunnskap om viktige marine naturtyper, viktige arter, rødlista arter, og økologiske funksjonsområder. Data samlet inn av kystkartleggingsprosjekter bør i tillegg brukes til å: a) videreutvikle NiN-klassifiseringssystemet[27] for pelagiske og bunndyrhabitater sammen, da det er viktig å standardisere CIA-innspill (Cumulative Impact Assessments), b) skape kunnskap for å forbedre predikerende habitatmodeller, som kan gi et kostnadseffektivt alternativ til storskala biologiske in-situ kartlegging (kan være samfunnsøkonomisk).

I denne rapporten og i SALTs rapport (Eriksen et al., 2021) er det pekt på å anbefale at det utarbeides mer tydelige standardiserte retningslinjer på regionalt nivå fra sektormyndighetene på hvilke arter og naturtyper med tilhørende verdier som skal ivaretas i utredningene på f.eks. kommuneplannivå, inkludert hvordan de kan ivaretas. SALT konstaterer at dette også ses i sammenheng med hvilke utredninger aktører pålegges å gjøre i forbindelse med konsesjonsbehandlingen etter akvakulturloven. Det er i dag eksempler på at næringen opplever egne og særlige strenge krav til forundersøkelser av sårbare naturtyper i enkelte statsforvalterembeter. Næringen opplever dette problematisk da det ikke er etablert standardiserte metoder for hvordan kartlegging og overvåking av sårbare naturtyper skal gjennomføres, og at den ulike forvaltningspraksisen gir ulike konkurransevilkår for næringsaktørene i havbruk i ulike fylker. SALT har pekt på at det vil være stor geografisk variasjon i utbredelsen til de ulike naturtypene, og mens noen regioner har få forekomster av en naturtype vil andre ha mange. Per i dag er imidlertid kunnskapen om utbredelse for dårlig, noe som burde medføre relativt like krav i ulike regioner. Utbredelse i regioner kan spille inn på hvordan de blir behandlet i planleggingen, både på kommunalt nivå og sektornivå.

[27] NiN viser til kartlegging natur etter systemet Natur i Norge (NiN), se https://www.miljodirektoratet.no/tjenester/natur-i-norge/

### 6.4.2.2 Kartlegging av miljøtilstanden

Vi har i denne rapporten også pekt på viktigheten å kvantifisere følsomheten eller mottakelighet til den mottakende økosystemkomponenten for påvirkningen av multipress (terskelverdier) og identifisere egnede indikatorer for økosystemhelse i områder utsatt for multipress. Begge er kritiske for forvaltningen ettersom de gir grunnlag for å iverksette tiltak, og iverksette avbøtende tiltak når indikatorer viser at påvirkningen nærmer seg uakseptable forhold. Aas (2020) har også pekt på at det trengs flere studier av utvikling og bruk av gode indikatorer. Disse bør være tverrfaglige. «Gode» indikatorer bør ideelt sett koble økosystemtilstander og forvaltningstiltak bedre, og samtidig være kostnadseffektive og enkle å forstå. En spesifikk utfordring identifisert er å utvikle indikatorer som forbinder økosystemtilstander (og deres eventuelle forbedringer) og styringstiltak. Forskning for å forbedre indikatorer, spesielt operative eller instrumentelle indikatorer, anbefales å være tverrfaglig, i tillegg til å være tydelig på vitenskapens rolle (hvor vitenskapen slutter) og når politikken tar over (Aas og referanser i den).

### 6.4.2.3 Kartlegging av trusselfaktorer

I henhold til nml §10 må det også foreligge informasjon om den samlede belastning økosystemet utsettes for. Dette innebærer en plikt til å utrede trusselfaktorer. I en veileder fra Klima- og miljødepartementet identifiseres fire trusselkategorier: 1) Det konkrete tiltaket, 2) Andre tiltak av samme art (andre oppdrettsanlegg), 3) Andre typer tiltak eller inngrep (eksempelvis deponering av gruveavfall) og 4) Andre påvirkningsfaktorer (eksempelvis klimaendringer). På et generelt nivå har myndighetene og næringen relativt god oversikt over de to første kategoriene. Men kommunene må for eksempel gjennom kystsoneplanleggingen gjøre en helhetlig og økosystembasert vurdering av konsekvensene ved eventuelle tiltak som avsetting av arealer til akvakultur, jf. KU-forskriften § 21 tredje ledd og naturmangfoldloven § 10.

Videre må kommunene vurdere hvordan tilrettelegging av akvakultur i et areal kan påvirke vannmiljøet. Informasjon fra Vann-nett på vannforekomstnivå kan brukes for å si noe om hvilke områder som trolig har god nok vannutskifting til å håndtere partikulære utslipp, men også her er det viktig å ta hensyn til forskjeller innenfor vannforekomsten (Eriksen et al., 2023). Dette kan blant annet gjøres ved å kombinere vannforekomstene med strømkart som inkluderer vannsøyle og bunn. Uten havbunnskartlegging er det vanskelig å si noe konkret om miljøpåvirkningen lokalt, men strømmodellering på ulike dyp kan gi indikasjoner på områder som tåler utslipp fra akvakultur. Som vist over gjennomfører næringen ulike undersøkelser både i forbindelse med lokalitetssøknader og B- og C-undersøkelser. Fra både denne rapporten og SALTs er det pekt på at disse funn og undersøkelser som havbruksaktører gjør utover nevnte undersøkelser finnes det, etter det vi vet, ikke noe system for å rapportere inn, for eksempel ved nye funn av koraller eller andre naturverdier. Til sammen utgjør disse rapportene et stort datasett som potensielt kunne gitt verdifull informasjon til både planleggere og sektormyndigheter, og med en stor engangsinnsats på historiske rapporter og et elektronisk rapporteringsskjema for framtidige undersøkelser, kunne dette vært gjennomførbart i overskuelig framtid. SALT foreslår at et system for enkel og fortløpende innrapportering vil videre kunne opprettholde et oppdatert datasett.

For å få til en mer helhetlig vurdering som pekt på i rapporten for flere av stressorene vil man kunne få til en mere overordnet vurdering hvor man inkluderer vurdering av f.eks. næringssaltutslipp fra et potensielt oppdrettsanlegg opp mot totalmengden fra andre anlegg i området. Videre vil man for eksempel kunne inkludere utslipp fra andre kilder, som for eksempel avløp, sammen med kunnskap om strømforhold og resultater fra eventuelle overvåkningsprogrammer og undersøkelser i området.

#### 6.4.2.4 Tiltaksidentifisering og -vurdering

Det å identifisere og vurdere aktuelle tiltak kan være krevende, slik våre analyser av vurderinger etter vannforskriften har eksemplifisert. For det første er det mye kunnskapsmangel. I tiltaksprogrammet for Vannforvaltningsplan for Troms og Finnmark er cirka halvparten av alle identifiserte tiltak om forskning/kunnskap, noe som indikerer at behovet for at kunnskapsgrunnlaget er stort.

Når det gjelder videre vurdering og prioritering av tiltak anbefales det i vannforvaltningsplanen for Tromso og Finnmark at tiltak prioriteres *innenfor* hver sektor og ikke mellom sektorene, slik at sektorene ikke stilles opp mot hverandre ved gjennomføringen av vannforvaltningsplanen. Dette begrenser potensielt den samfunnsøkonomiske effektiviteten for alle tiltak totalt sett. Det kan jo da være at et tiltak gjennomført i én sektor har mye større kostnad for en gitt forbedring i vannmiljø enn tiltakene i en annen sektor. På den andre siden ville det å gjennomføre nytte-kostnad sammenligninger for alle aktuelle tiltak, mellom alle sektorer, være en oppgave som ville krevet store administrative ressurser. Det er angitt at kost-effekt vurderinger bør legges til grunn for å prioritere tiltak for vannmiljø innen enkeltsektorer. Det pekes imidlertid på at det mangler kostnadsberegninger for noen tiltak.

I vannforvaltningen angis det at noen typer vannforekomster med særlige kvaliteter eller utfordringer bør prioriteres høyt for tiltak, og flere av disse er eller kan være særlig relevante for akvakultur, som vannforekomster med verdifulle og trua arter, utvalgte og sårbare naturtyper, og slike som krever særskilt beskyttelse (som nasjonale laksevassdrag og fjorder).

I vannforvaltningen har vi også sett at det er trukket fram at det å prioritere avbøtende og forebyggende tiltak for å opprettholde miljøtilstanden i vannforekomstene kan være samfunnsøkonomisk fornuftig, siden det da vil bli mindre behov for ressurser til reversering av negative påvirkninger senere.

#### 6.4.2.5 Utvikling av nye planverktøy

Med ny og viktig kunnskap om hav i stadig endring, er det et stort behov for å bygge bro mellom forskning og forvaltning, slik at forvaltningen skjer i tråd med den oppdaterte kunnskapen. Arealplanlegging, og vedtak om arealbruk og bevaring basert på arealplanlegging, er viktig for at vi skal oppnå mer økosystembasert forvaltning. Siden det er pekt på at marin arealplanlegging er instrumentell for å nå FNs bærekraftsmål, og retningslinjer og forskrifter understreker at denne skal drives av økosystembasert forvaltning, er det viktig at dagens kunnskapsgrunnlag kan gjøres bedre tilgjengelig for kommuner på annen måte enn den er i dag.

Veiledning om hvordan kunnskap i kart kan kombineres for å gjøre ulike vurderinger kan være til hjelp i planleggingen. I dette prosjektet har vi sett på hvordan man skulle kunne utvikle slike hjelpemidler. Vi har sett på kumulative konsekvensutredningsmodeller basert på en avansert kvantitativ GIS-løsning. Denne romlig løste utgangen antas å være et passende og støttende beslutningsverktøy for ØBF. Andre har også pekt på at SEA-instrumentet (Strategic Environmental Assessment) også kan utvikles på måter som det kan tjene en mer spesifikk rolle i å styrke ØBF (Aas 2020 og referanser i den). Sammenlignet med miljøkonsekvensvurderingen (EIA), gir SEA anbefalinger på strategisk nivå og gir bedre kontroll over interaksjoner og kumulative effekter. Det er ingen enkelt tilnærming til SEA, som kan ha forskjellige former i henhold til de spesifikke behovene (https://europa.eu/capacity4dev/public-environment-climate/wiki/strategic-environmental-assessment).

Anbefalinger om ØBF oppsummert:

- Styrke kunnskapsgrunnlaget og videreutvikle beslutningsstøtte-verktøy for forvaltning)). Dette gjelder
    - data om økosystemer (kartlegging av økosystemkomponenter)
    - data om menneskelig aktivitet: industrier som har påvirkning på samme resipient i økosystemet og på hverandre.
    - indikatorer/grenseverdier spesifikk for økosystemkomponenter utsatt for stress fra flere kilder
    - nye planløsninger (GIS og SEA)
- Tilrettelegge for at kunnskap (data og verktøy) kan lettere brukes i forvaltningen, f.eks. gjennom etablering av kombinerte datasett.
- Bedre kartlegging av trosselfaktorer i kystsoneplaner, der flere kilder av påvirkninger utenom det konkrete tiltak skal vurderes.
- Videreutvikle retningslinjer om koordinering av krav etter sektorlover og forskrifter, spesielt mellom vannforvaltning og kystsoneplanlegging.
- (Videre) integrering av økosystembasert tilnærming i retningslinjer for vannforvaltning og kystsoneplanlegging, men det må støttes med indikatorer og data om disse naturtyper som muliggjør slike vurderinger.
- Det er behov for lokaltilpasset, treffsikker og samfunnsøkonomisk effektiv forvaltning også når det gjelder helhetlig økosystembasert forvaltning. Tilpasning av krav skal gjøres for ulike økosystemer, regioner og aktører. Innenfor samfunnsøkonomisk effektivitet er det et viktig mål å vurdere fordeling av kostnader som krav for helhetlig forvaltning innebærer, mellom ulike aktører.

For en mer helhetlig og økosystembasert forvaltning vil det være viktig å styrke kunnskapsgrunnlaget og videreutvikle beslutningsstøtteverktøy for forvaltningen, med bedre data om økosystemer og all menneskelig aktivitet som har påvirkning på samme resipient i økosystemet og på hverandre.

### 6.4.3 Miljømessig forsvarlig vekst?

I dag er lus den viktigste begrensningen for vekst i oppdrettsproduksjonen. Men luseproblemene er større i noen regioner enn i andre. Så lenge lus begrenser veksten i mange produksjonsområder, vil det være viktig å utnytte de områdene som er best egnet i de områdene hvor lusen ikke er produksjonsbegrensende. Det i seg selv betyr større grad av lokal forvaltning. Et viktig spørsmål i dette prosjektet har vært å belyse hva som kreves av kunnskap for å kunne få til en mer lokal forvaltning.

I områder hvor lus ikke er begrensningen for vekst kan neste skritt være å søke kunnskap om hvilken eller hvilke stressorer som vil være de neste som begrenser veksten.

Sykdom er ikke direkte kapasitetsbegrensende, men en viktig begrunnelse for avstandskravene som i dag begrenser utnyttelsen av arealene. Avstand brukes i dag som et føre-var-tiltak, for å sikre at sykdomsspredning eller annen miljøpåvirkning unngås, eller iallfall kommer under en eller annen kritisk grense. Det praktiseres en hovedgrense på 5 kilometer, som kan reduseres til 2,5 om det finnes koordinerte driftsplaner for de aktuelle anleggene. Et viktig spørsmål vil være hvordan avstand kan brukes mer målrettet i fremtiden.

Er det tilstrekkelig kunnskap om de parameterne som brukes til å stille avstandskrav til at man kan vurdere å redusere avstandskravene? Krav til avstand kan allerede i dag reduseres ved koordinering av driftsplaner, kan praksisen med reduserte avstandskrav utvides eller utvikles videre? For eksempel ned til 1-2 kilometer?

Utslipp av organisk materiale er en av de best overvåkede miljøpåvirkningene, og er av HI ikke utpekt som produksjonsbegrensende i noen av produksjonsområdene (Grefsrud et al, 2022). Likevel blir utslippene gjennom begrensningene på lokalitets-MTB, kombinert med mangelen på nye, gode lokaliteter, en viktig vekstbegrensning. Når veksten i noen områder er begrenset av lus, er det desto viktigere at de beste lokalitetene i områder med lite lus utnyttes godt. Kanskje er det mulig å øke produksjonen betydelig på de beste lokalitetene? Kanskje er den store andelen lokaliteter med miljøstatus Meget god en indikasjon på at man kan tillate mer produksjon noen steder? Dette leder oss over på en viktig diskusjon for hva som kan defineres som miljømessig bærekraftig vekst, nemlig den om hva som kan regnes som akseptabel miljøpåvirkning.

Hvor «dårlig» kan havbunnen være før man må reduserer? Hva med påvirkning som ikke er reversibel, eller som bruker lang tid på å bli redusert? Dette er spørsmål som vil være avgjørende for hvor store vekstmulighetene vil være. Dette betyr også at selv med økt kunnskapsnivå så vil det være behov for avveininger mellom ulike hensyn, og mellom akseptabel og ikke-akseptabel påvirkning og miljørisiko.

Vi så i avsnitt 6.3.5 på ulike scenarioer for miljømessig bærekraftig vekst, avhengig av blant annet forvaltningsregimer.

Med **lus som fortsatt eneste regulator for vekst**, og dermed med en antagelse om at fremtidig vekst kan bli omtrent som de siste årene, vil man likevel kunne oppnå en produksjon på nær fire millioner tonn i 2050. Det er imidlertid ikke store endringer i vekstratene som skal til før man når 5 millioner tonn i 2050, det vil man nå med om lag 4 % årlig vekst.

Med en mer **differensiert vekst mellom områder**, basert på de siste 10 års vekst i forskjellige regioner i Norge, viste vi at man over tid kan se store endringer i den regionale sammensetningnen av oppdrettsproduksjonen. Nord-Norge kan med siste års veksttakt ha neste 2/3 av den norske produksjonen i 2050, mens Vestland, som i 2022 var største oppdrettsfylke vil ha redusert sin andel av laks og ørret fra 23 til 10 %. Men la oss minne om at den sterkere veksten i nord til en viss grad har vært en «opphentingsvekst», etter at næringen i sin tidlige fase hadde størst vekst fra Vestlandet og nordover til Nordland, og etter at man i Troms og Finnmark for en del år siden hadde lavere utnyttelse av konsesjons-MTBen enn lenger sør.

Med en **miljøstyrt vekst**, hvor vekst tillates etter tilstanden også på andre målbare miljøparametere enn lus, kan veksten tilpasses forskjellen i miljøstatus og bæreevne for ulike lokaliteter og vannsystemer. Det er tidligere diskutert hvordan endret lokalitetsstruktur i et produksjonsområde (PO 3), kan påvirke produksjonsmulighetene (Huserbråten et al. 2020), hvor en av konklusjonene var at man i PO3 kunne redusere fra dagens 135 lokaliteter ned til 100 matfisklokaliteter **uten å redusere den totale produksjonen. Vi pekte på mulighetene for å produsere mer på lokaliteter med miljøstatus Meget god, og pekte på at** en 50 % økning for lokaliteter med Meget god miljøstatus (det gjelder omtrent 2/3 av lokalitetene) vil gi 1,1 millioner tonn økt lokalitets-MTB.

Slike betraktninger kan være nyttige enten man søker vekst eller flytting fra dårlige til gode lokaliteter.

# 7 Referanser fra kapittel 5 og 6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# 8 Appendices

## 8.1 Appendix A – Search profiles (aquaculture)

### 8.1.1 Organic waste – particulate matter

Searches were performed on May 19th and May 23rd 2022 by Hilde Iren Flaatten, senior librarian at the University of Oslo Library of Medicine and Science. See section 3.3.1.2 for subsequent deviations of the standard search procedure.

**Web of Science**

((TS=(((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen*" OR netpen* OR "net pen*" OR farm* OR fishfarm*) AND (salmo* OR trout* OR oncorhynchus mykiss)))) AND TS=((faec* OR feces OR fecal OR feaces OR feacal OR excrement* OR excret* OR carbon OR ((feed* OR food*) NEAR/4 spill*) OR "uneaten feed*" OR "uneaten food*" OR ((organic or particulate) NEAR/3 (waste* OR material* OR matter*)) OR ((waste* OR excess*) NEAR/4 (feed OR food*))))) AND TS=((impact* OR effect* OR indicat* OR biolog* OR divers* OR biodiverse* OR abundan* OR pollut* OR enrich* OR ecolog* OR trophic OR chemi* OR eutrophicat* OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR benth* OR epibent* OR infauna* OR epifauna* OR ecosystem* OR "eco system*" OR substrate* OR pelagic OR water OR composition* OR reprodu* OR dispers* OR sediment* OR lethal OR "sub lethal" OR threshold* OR phytoplankton* OR zooplankton* OR plankton*)) and 2010 or 2011 or 2012 or 2013 or 2014 or 2015 or 2016 or 2017 or 2018 or 2019 or 2020 or 2021 or 2022 (Publication Years) and English (Languages)

**Scopus**

TITLE-ABS-KEY ( aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm* ) AND TITLE-ABS-KEY ( salmo* OR trout* OR "oncorhynchus mykiss" ) AND TITLE-ABS-KEY ( ( faec* OR feces OR fecal OR feaces OR feacal OR excrement* OR excret* OR carbon OR ( ( feed* OR food* ) W/4 spill* ) OR "uneaten feed" OR "uneaten food" OR "uneaten foods" OR ( ( organic OR particulate ) W/3 ( waste* OR material* OR matter* ) ) OR ( ( waste* OR excess* ) W/4 ( feed OR food* ) ) ) ) AND TITLE-ABS-KEY ( ( impact* OR effect* OR indicat* OR biolog* OR divers* OR biodiverse* OR abundan* OR pollut* OR enrich* OR ecolog* OR trophic OR chemi* OR eutrophicat* OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR benth* OR epibent* OR infauna* OR epifauna* OR ecosystem* OR "eco system" OR "eco-system" OR "eco system" OR "eco-systems" OR "eco systems" OR substrate* OR pelagic OR water OR composition* OR reprodu* OR dispers* OR sediment* OR lethal OR "sub lethal" OR "sub-lethal" OR threshold* OR phytoplankton* OR zooplankton* OR plankton* ) ) ) AND ( LIMIT-TO ( PUBYEAR , 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-TO ( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO ( PUBYEAR , 2014 ) OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR , 2012 ) OR LIMIT-TO ( PUBYEAR , 2011 ) OR LIMIT-TO ( PUBYEAR , 2010 ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )

**Zoological record (Claviate)**

((TS=(((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen*" OR netpen* OR "net pen*" OR farm* OR fishfarm*) AND (salmo* OR trout* OR oncorhynchus mykiss)))) AND TS=((faec* OR feces OR fecal OR feaces OR feacal OR excrement* OR excret* OR carbon OR ((feed* OR food*) NEAR/4 spill*) OR "uneaten feed*" OR "uneaten food*" OR ((organic or particulate) NEAR/3 (waste* OR material* OR matter*)) OR ((waste* OR excess*) NEAR/4 (feed OR food*))))) AND TS=((impact* OR effect* OR indicat* OR biolog* OR divers* OR biodiverse* OR abundan* OR pollut* OR enrich* OR ecolog* OR trophic OR chemi* OR eutrophicat* OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR benth* OR epibent* OR infauna* OR epifauna* OR ecosystem* OR "eco system*" OR substrate* OR pelagic OR water OR composition* OR reprodu* OR dispers* OR sediment* OR lethal OR "sub lethal" OR threshold* OR phytoplankton* OR zooplankton* OR plankton*)) and 2010 or 2011 or 2012 or 2013 or 2014 or 2015 or 2016 or 2017 or 2018 or 2019 or 2020 or 2021 or 2022 (Publication Years) and English (Languages)

### WorldCat Dissertations and Theses (WorldCatDissertations)

WorldCat dissertations and theses results for: ((kw: aquacultur* OR kw: cage* OR kw: fishcage* OR kw: netcage* OR kw: fishpen* OR kw: fish w pen* OR kw: netpen* OR kw: net w pen* OR kw: farm* OR kw: fishfarm*) AND (kw: salmo* OR kw: trout* OR (kw: oncorhynchus and kw: mykiss))) and ((kw: faec* OR kw: feces OR kw: fecal OR kw: feaces OR kw: feacal OR kw: excrement* OR kw: excret* OR kw: carbon OR (kw: feed* w4 spill*) OR (kw: food* w4 spill*) OR kw: uneaten w feed OR kw: uneaten w food OR kw: uneaten w foods OR ((kw: organic OR kw: particulate) AND (kw: waste* OR kw: material* OR kw: matter*)) OR ((kw: waste* OR kw: excess*) AND (kw: feed OR kw: food*)))) and (kw: impact* OR kw: effect* OR kw: indicat* OR kw: biolog* OR kw: divers* OR kw: biodiverse* OR kw: abundan* OR kw: pollut* OR kw: enrich* OR kw: ecolog* OR kw: trophic OR kw: chemi* OR kw: eutrophicat* OR kw: habitat* OR kw: environment* OR kw: offshore OR kw: fjord* OR kw: marine OR kw: coast* OR kw: fish* OR kw: seabed* OR kw: benth* OR kw: epibent* OR kw: infauna* OR kw: epifauna* OR kw: ecosystem* OR kw: eco w system OR kw: eco-system OR kw: eco w system OR kw: eco-systems OR kw: eco w systems OR kw: substrate* OR kw: pelagic OR kw: water OR kw: composition* OR kw: reprodu* OR kw: dispers* OR kw: sediment* OR kw: lethal OR kw: sub w lethal OR kw: sub-lethal OR kw: threshold* OR kw: phytoplankton* OR kw: zooplankton* OR kw: plankton*) and yr: 2010-2022 and la= "eng"

### ORIA (Norwegian) – universally applied to all stressors!

Search focus: Norske fagbibliotek
Tittel inneholder: ((aquacultur* OR akva* OR cage* OR fishcage* OR netcage* OR fishpen* OR fish pen* OR netpen* OR net pen* OR farm* OR fishfarm* OR oppdrett* OR fisk*) AND (laks* OR ørret* OR salmo* OR trout* OR "oncorhynchus mykiss"))
ELLER Tittel inneholder: lakseoppdrett* OR ørretoppdrett* OR oppdrettslaks OR oppdrettsfisk* OR oppdrettsørret)
Emne inneholder: ((aquacultur* OR akva* OR cage* OR fishcage* OR netcage* OR fishpen* OR fish pen* OR netpen* OR net pen* OR farm* OR fishfarm* OR oppdrett* OR fisk*) AND (laks* OR ørret* OR salmo* OR trout* OR "oncorhynchus mykiss"))
ELLER Emne inneholder: lakseoppdrett* OR ørretoppdrett* OR oppdrettslaks OR oppdrettsfisk* OR oppdrettsørret)
Filtre: 2010-2022, engelsk, nordisk
Materialtype: Avhandliner, Rapporter, Konferanseforedrag

## 8.1.2 Dissolved nutrients

Searches were performed by Astrid Harendza (Akvaplan-niva) on the 1st of August 2022.

### Web of Science

(TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TS=(phosphor* OR phosphate OR phosphorus OR nitrogen OR ammonium OR ((dissolve* OR solub*) NEAR/2 (nutrient* OR waste*) OR excretion* OR urea)) AND TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR (water NEAR/2 quality) OR enrich* OR eutrophicat* OR biolog* OR ecolog* OR chemi* OR divers* OR abundan* OR composit* OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR ecosystem* OR "eco system*" OR pelagic OR water OR nutrient* OR plankton* OR phytoplankton OR zooplankton OR ((primary) NEAR/2 (produc*)) OR "chl a" OR chloroph* OR (total NEAR/2 (nitr* OR phosphor*)) OR epifauna* OR infauna* OR benth* OR epibent* OR invertebrate OR threshold* OR indicator*)) AND 2010 or 2011 or 2012 or 2013 or 2014 or 2015 or 2016 or 2017 or 2018 or 2019 or 2020 or 2021 or 2022 (Publication Years)AND English (Languages)

### Scopus

(TITLE-ABS-KEY ((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR ("net-pens" OR farm* OR fishfarm*) AND (salmo* OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TITLE-ABS-KEY (phosphor* OR phosphate OR phosphorus OR nitrogen OR ammonium OR ((dissolve* OR solub*) W/2 (nutrient* OR waste*)) OR excretion* OR urea)) AND TITLE-ABS-KEY (impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) W/2 (stress* OR effect*)) OR pressure* OR (water W/2 quality) OR enrich* OR eutrophicat* OR biolog* OR ecolog* OR chemi* OR divers* OR abundan* OR composit* OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR ecosystem* OR "eco system*" OR pelagic OR water OR nutrient* OR plankton* OR phytoplankton OR zooplankton OR ((primary) W/2 (produc*)) OR "chl a" OR chloroph* OR (total W/2 (nitr* OR phosphor*)) OR epifauna* OR infauna* OR benth* OR epibent* OR invertebrate OR threshold* OR indicator*))
AND ( LIMIT-TO ( PUBYEAR , 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-TO ( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO ( PUBYEAR , 2014 ) OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR , 2012 ) OR LIMIT-TO ( PUBYEAR , 2011 ) OR LIMIT-TO ( PUBYEAR , 2010 ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )

### WorldCat Dissertations and Theses (WorldCatDissertations)

((kw: aquacultur* OR kw: cage* OR kw: fishcage* OR kw: netcage* OR kw: fishpen* OR kw: fish w pen* OR kw: netpen* OR kw: net w pen* OR kw: farm* OR kw: fishfarm*) and (kw: salmon OR kw: salmo OR kw: trout* OR (kw: oncorhynchus and kw: mykiss) OR (kw: Atlantic and kw: cod) OR (kw: Gadus and kw: marhua))) and ((kw: phosphor* OR kw: phosphate OR kw: phosphorus OR kw: nitrogen OR kw: ammonium OR ((kw: dissolve* w2 nutrient*) OR (kw: solub* w2 nutrient*) OR (kw: dissolve* w2 waste*) OR (kw: solub* w2 waste*) OR kw: gill* OR kw: excretion* OR kw: urea))) and ((kw: impact* OR kw: effect* OR kw: risk* OR kw: pollut* OR kw: stress* OR kw: multi-stress* OR kw: multistress*) OR ((kw: multi* OR kw: collective* OR kw: cumulative* OR kw: combi*) AND (kw: stress* OR kw: effect*) OR kw: pressure* OR (kw: water w2 quality) OR kw: enrich* OR kw: eutrophicat* OR kw: biolog* OR kw: ecolog* OR kw: chemi* OR kw: divers* OR kw: abundan* OR kw: composit* OR kw: trophic OR kw: habitat* OR kw: environment* OR kw: offshore OR kw: fjord* OR kw: marine OR kw: coast* OR kw: ecosystem* OR (kw: eco w system*) OR kw: eco-system* OR kw: pelagic OR kw: water OR kw: nutrient* OR kw: plankton* OR kw: phytoplankton OR kw: zooplankton OR (kw: primary w2 produc*) OR (kw: chl w "a") OR kw: chloroph* OR (kw: total w2 nitr*) OR (kw: total w2 phosphor*) OR kw: epifauna* OR kw: infauna* OR kw: benth* OR kw: epibent* OR kw: invertebrate OR kw: threshold* OR kw: indicator*)) and yr: 2010-2022 and la= "eng" and mt: deg

**ORIA (Norwegian) –** see section 8.1.1.

#### 8.1.3 Environmental contaminants

Searches were performed by Maj Arnberg (Akvaplan-niva) for web of science and Oria the 1th of August, 2022, Astrid Harendza (Akvaplan-niva) 3th of August, 2022 for Wordcat, and Anja Striberny (NOFIMA) for Scopus 3th of August, 2022.

### Web of Science

TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TS= (metal* OR "heavy metal" OR Zink OR Zn or Copper OR Cu OR PCB OR HCB OR dioxin OR pharmaceutic* OR pesticide* OR plastic* OR microplastic* OR "micro-plastic*" OR macroplastic* OR "macro-plastic*" OR disinfectant* OR "in feed" OR "bath treatment" OR ((delicing OR delousing) NEAR/1 (agent*)) OR "emamectin benzoate" OR Slice OR EMB OR Deltamethrin OR AlphaMax OR "hydrogen peroxide" OR H2O2 OR PARAMOVE OR diflubenzuron OR "Releeze vet" OR teflubenzuron OR "Ektobann vet" OR azamethiphos OR "Salmosan Vet" OR Imidacloprid* OR "Ectosan Vet" OR "antibiotics" OR antifouling OR anti-fouling OR "Econea" OR Tralopyril OR chlorin* OR disinfectant* OR "Virkon" OR "Quarternary ammonium compound" OR QAC OR Roccal* OR Chlorhexidin* OR Virosan OR Nolvasan OR alcohol* OR ethanol* OR isopropanol* OR Iodophors OR (phenol* NEAR/2 derivative*OR Lysol)) AND TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR “Additive effects”* OR “Synergistic effects*” OR “antagonistic effects*” OR detect OR concentration* OR quantification* OR assessment* OR "environmental standards" OR thresholds* OR PNEC OR accumulation* OR sediment* OR benthos* OR pelagic* OR biota OR fish* OR environment* OR indicat* OR "risk assessment" OR biolog* OR ecolog* OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine or coast* OR fish* OR seabed* OR benth* OR epibent* OR infauna* OR epifauna* OR ecosystem* OR "eco system*" OR substrate* OR water OR composition* OR reprodu* OR sediment* OR lethal OR "sub lethal" OR phytoplankton* OR zooplankton* OR plankton* OR invertebrate)

## Scopus

( ( TITLE-ABS-KEY ( aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen*" OR netpen* OR "net pen*" OR farm* OR fishfarm* ) AND TITLE-ABS-KEY ( salmon OR salmo OR salmonid* OR trout* OR "oncorhynchus mykiss" ) ) AND PUBYEAR > 2009 AND PUBYEAR > 2009 ) AND ( ( TITLE-ABS-KEY ( ( ( aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen*" OR netpen* OR "net pen*" OR farm* OR fishfarm* ) AND ( salmon OR salmo OR salmonid* OR trout* OR "oncorhynchus mykiss" ) ) ) AND TITLE-ABS-KEY ( ( ( metal* OR "heavy metal" OR zink OR zn OR copper OR cu OR pcb OR hcb OR dioxin OR pharmaceutic* OR pest icide* OR plastic* OR microplastic* OR "micro-plastic*" OR macroplastic* OR "macro-plastic*" OR disinfectant* OR "in feed" OR "bath treatment" OR ( ( delicing OR delousing ) W/1 ( agent* ) ) OR "emamectin benzoate" OR slice OR emb OR deltamethrin OR alphamax OR "hydrogen peroxide" OR h2o2 OR paramove OR diflubenzuron OR "releeze vet" OR teflubenzuron OR "ektobann vet®" OR azamethiphos OR "salmosan vet" OR imidacloprid* OR "ectosan vet" OR "antibiotics" OR antifouling OR anti-fouling OR "econea" OR tralopyril OR chlorin* OR disinfectant* OR "virkon" OR "quarternary ammonium compound" OR qac OR roccal* OR chlorhexidin* OR virosan OR nolvasan OR alcohol* OR etha nol* OR isopropanol* OR iodophors OR ( phenol* W/2 derivative* OR lysol ) ) ) ) ) AND PUBYEAR > 2009 AND PUBYEAR > 2009 ) AND ( TITLE-ABS-KEY ( ( impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ( ( multi* OR collective* OR cumulative* OR combi* ) W/2 ( stress* OR effect* ) ) OR pressure* OR "Additive effects*" OR "Synergistic effects*" OR "antagonistic effects*" OR detect OR concentration* OR quantification* OR assessment* OR "environmental standards" OR thresholds* OR pnec OR accumulation* OR sediment* OR benthos* OR pelagic* OR biota OR fish* OR environment* OR indicat* OR "risk assement" OR biolog* OR ecolog* OR trophic OR habitat* OR environment* OR offshore OR fjo rd* OR marine OR coast* OR fish* OR seabed* OR benth* OR epibent* OR infauna* OR epifau na* OR ecosystem* OR "eco system*" OR substrate* OR water OR composition* OR reprodu* OR sediment* OR lethal OR "s

ub lethal" OR phytoplankton* OR zooplankton* OR plankton* OR invertebrate )
) AND PUBYEAR > 2009 AND PUBYEAR > 2009 )

### WorldCat Dissertations and Theses (WorldCatDissertations)

((kw: aquacultur* OR kw: cage* OR kw: fishcage* OR kw: netcage* OR kw: fishpen* OR (kw: fish w pen*) OR kw: netpen* OR kw: net w pen* OR kw: farm* OR kw: fishfarm*) and (kw: salmon OR kw: salmo OR kw: trout* OR (kw: oncorhynchus and kw: mykiss) OR (kw: Atlantic and kw: cod) OR (kw: Gadus and kw: marhua))) and ((kw: metal* OR (kw: heavy w metal) OR kw: Zink OR kw: Zn or kw: Copper OR kw: Cu OR kw: PCB OR kw: HCB OR kw: dioxin OR kw: pharmaceutic* OR kw: pesticide* OR kw: plastic* OR kw: microplastic* OR kw: micro-plastic* OR kw: macroplastic* OR kw: macro-plastic* OR kw: disinfectant* OR (kw: in and kw: feed) OR (kw: bath* w treatment) OR (kw: delicing OR kw: delousing w2 agent*) OR (kw: emamectin w benzoate) OR kw: Slice OR kw: EMB OR kw: Deltamethrin OR kw: AlphaMax OR (kw: hydrogen w peroxide) OR kw: H2O2 OR kw: PARAMOVE OR kw: diflubenzuron OR (kw: Releeze w vet) OR kw: teflubenzuron OR (kw: Ektobann w vet) OR kw: azamethiphos OR (kw: Salmosan w Vet) OR kw: Imidacloprid* OR (kw: Ectosan w Vet) OR kw: antibiotics OR kw: antifouling OR kw: anti-fouling OR kw: Econea OR kw: Tralopyril OR kw: chlorin* OR kw: disinfectant* OR kw: Virkon OR (kw: Quarternary w ammonium w compound) OR kw: QAC OR kw: Roccal* OR kw: Chlorhexidin* OR kw: Virosan OR kw: Nolvasan OR kw: alcohol* OR kw: ethanol* OR kw: isopropanol* OR kw: Iodophors OR (kw: phenol* w2 derivative*) OR kw: Lysol)) and ((kw: impact* OR kw: effect* OR kw: risk* OR kw: pollut* OR kw: stress* OR kw: multi-stress* OR kw: multistress* OR ((kw: multi* OR kw: collective* OR kw: cumulative* OR kw: combi*) AND (kw: stress* OR kw: effect*)) OR kw: pressure* OR kw: detect OR kw: concentration* OR kw: quantification* OR kw: assessment* OR (kw: environmental w standards) OR kw: thresholds* OR kw: PNEC OR kw: accumulation* OR kw: sediment* OR kw: benthos* OR kw: pelagic* OR kw: biota OR kw: fish* OR kw: environment* OR kw: indicat* OR (kw: risk w assessment) OR kw: biolog* OR kw: ecolog* OR kw: trophic OR kw: habitat* OR kw: environment* OR kw: offshore OR kw: fjord* OR kw: marine OR kw: coast* OR kw: fish* OR kw: seabed* OR kw: benth* OR kw: epibent* OR kw: infauna* OR kw: epifauna* OR kw: ecosystem* OR (kw: eco w system*) OR kw: substrate* OR kw: water OR kw: composition* OR kw: reprodu* OR kw: sediment* OR kw: lethal OR (kw: sub w lethal) OR kw: phytoplankton* OR kw: zooplankton* OR kw: plankton* OR kw: invertebrate)) and yr: 2010-2022 and la= "eng" and mt: deg

### ORIA (Norwegian)

### 8.1.4 Escapes

Searches were performed by Anja Striberny (Nofima) on the 13.07.2022.

### Web of Science

(TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua" OR lumpfish OR lumpsucker OR "Cyclopterus lumpus" OR "cleaner fish" OR "Arctic charr" OR "Salvelinus alpinus" ))) AND (TS=(escape* OR fugitive* OR breakout OR (cage NEAR/3 spawn*) OR (egg NEAR/3 release*) OR (larvae NEAR/4 escape) OR (larvae NEAR release) OR (cage NEAR/4 reproduc*))) AND (TS=(impact* OR effect* OR risk* OR pressure* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR biolog* OR ecolog* OR divers* OR abundan* OR composit* OR disper* OR trophic OR habitat* OR environment* OR offshore OR fjord* OR river* OR marine OR coast* OR ecosystem* OR "eco system*" OR fish OR stock OR wild OR native* OR population*))

Timespan: 2010-01-01 to 2023-01-01 (Publication Date)

**Scopus**

( TITLE-ABS-KEY (aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua" OR lumpfish OR lumpsucker OR "Cyclopterus lumpus" OR "cleaner fish" OR "Arctic charr" OR "Salvelinus alpinus") AND TITLE-ABS-KEY (escape* OR fugitive* OR breakout OR (cage W/3 spawn*) OR (egg W/3 release*) OR (larvae W/4 escape) OR (larvae W release) OR (cage W/4 reproduc*)) AND TITLE-ABS-KEY (impact* OR effect* OR risk* OR pressure* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) W/2 (stress* OR effect*)) OR native* OR endemic OR natural OR wild OR indigenous OR habitat* OR environment* OR offshore OR fjord* OR river* OR marine OR coast* OR ecosystem* OR "eco system*" OR fish OR organism* OR population* OR health*)

**WorldCat Dissertations and Theses (WorldCatDissertations)**

**ORIA (Norwegian)**

### 8.1.5 Disease and parasites

Searches were performed by Anja Striberny (Nofima) on the 11.07.2022.

**Web of Science**

(TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua" OR lumpfish OR lumpsucker OR "Cyclopterus lumpus" OR "cleaner fish" OR "Arctic charr" OR "Salvelinus alpinus")))AND(TS=(pathogen* OR virus* OR viral* OR bacteria* OR disease* OR parasite* OR copepod* OR protist OR ISA* OR "infectious salmon anaemia virus" OR "piscine orthoreovirus" OR PRV OR "salmon alphavirus" OR SAV* OR "pancreas disease" OR PD OR "infectious pancreatic necrosis" OR "infectious hematopoietic necrosis" OR IHNV OR "viral haemorrhagic septicaemia" OR VHS OR IPN OR HSMI OR "salmonid gill poxvirus" OR SPGV OR francisell* OR furunculosis OR"aeromonas salmonicida"OR tenacibac* OR BKD OR "renibacterium salmoninarum" OR epitheliocystis OR "proliferative gill inflammation" OR PGI OR vibriosis OR "aemoebic gill disease" OR trichinodinosis OR "microsporidial gill disease" OR MGDS OR "proliferative kidney disease" OR pkd OR "salmon lice" OR "salmon louse"OR "sea louse" OR "sea lice" OR "Lepeophtheirus salmonis" OR "caligus elongatus" OR "eubothrium crassum" OR saprolegnia OR tetracapsul* OR Gyrodactylus OR Trichodina OR Ichthyobodo OR "Caligus curtus" OR "cod louse" OR "cod lice"))AND(TS=((impact* OR effect* OR risk* OR pressure* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*))) AND (native* OR endemic OR natural OR wild OR indigenous) AND (habitat* OR environment* OR offshore OR fjord* OR river* OR marine OR coast* OR ecosystem* OR "eco system*" OR fish OR organism* OR population* OR health*)))

Timespan: 2010-01-01 to 2023-01-01 (Publication Date)

**Scopus**

( TITLE-ABS-KEY ( ( aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm* ) AND ( salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua" OR lumpfish OR lumpsucker OR "Cyclopterus lumpus" OR "cleaner fish" OR "Arctic charr" OR "Salvelinus alpinus" ) ) AND TITLE-ABS-KEY ( ( pathogen* OR virus* OR viral* OR bacteria* OR disease* OR parasite* OR copepod* OR protist OR isa* OR "infectious salmon anaemia virus" OR "piscine orthoreovirus" OR prv OR "salmon alphavirus" OR sav* OR "pancreas disease" OR pd OR "infectious pancreatic necrosis" OR "infectious hematopoietic necrosis" OR ihnv OR "viral haemorrhagic septicaemia" OR vhs OR ipn OR hsmi OR "salmonid gill poxvirus" OR spgv OR francisell* OR furunculosis OR "aeromonas salmonicida" OR tenacibac* OR bkd OR "renibacterium salmoninarum" OR epitheliocystis OR "proliferative gill inflammation" OR pgi OR vibriosis OR "aemoebic gill disease" OR trichinodinosis OR "microsporidial gill disease" OR mgds OR "proliferative kidney disease" OR pkd OR "salmon lice" OR "salmon louse" OR "sea louse" OR "sea lice" OR "Lepeophtheirus salmonis" OR "caligus elongatus" OR "eubothrium crassum" OR saprolegnia OR tetracapsul* OR gyrodactylus OR trichodina OR ichthyobodo OR "Caligus curtus" OR "cod louse" OR "cod lice" ) ) AND TITLE-ABS-KEY ( ( impact* OR effect* OR risk* OR pressure* OR stress* OR multi-stress* OR multistress* OR ( ( multi* OR collective* OR cumulative* OR combi* ) W/2 ( stress* OR effect* ) ) ) AND ( native* OR endemic OR natural OR wild OR indigenous ) AND ( habitat* OR environment* OR offshore OR fjord* OR river* OR marine OR coast* OR ecosystem* OR "eco system*" OR fish OR organism* OR population* OR health* ) ) )

### 8.1.6 Noise

Searches were performed by Astrid Harendza (Akvaplan-niva) on the 1st of August 2023.
Due to the limited literature available for this topic, a year restriction was not applied to Web of Science and Scopus searches.

#### Web of Science

(TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TS=(noise* or sound*) AND TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*)))

#### Scopus

(TITLE-ABS-KEY ((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TITLE-ABS-KEY (noise* or sound*) AND TITLE-ABS-KEY (impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) W/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary W/2 produc*)))

#### WorldCat Dissertations and Theses (WorldCatDissertations)

((kw: aquacultur* OR kw: cage* OR kw: fishcage* OR kw: netcage* OR kw: fishpen* OR kw: fish w pen* OR kw: netpen* OR kw: net w pen* OR kw: farm* OR kw: fishfarm*) and (kw: salmon OR kw: salmo OR kw: trout* OR (kw: oncorhynchus and kw: mykiss) OR (kw: Atlantic and kw: cod) OR (kw:

Gadus and kw: marhua))) and ((kw: noise* or kw: sound*)) and ((kw: impact* OR kw: effect* OR kw: risk* OR kw: pollut* OR kw: stress* OR kw: multi-stress* OR kw: multistress* OR ((kw: multi* OR kw: collective* OR kw: cumulative* OR kw: combi*) and (kw: stress* OR kw: effect*)) OR kw: pressure* OR kw: lethal OR (kw: sub w lethal) OR kw: threshold* OR kw: indicator* OR kw: biolog* OR kw: divers* OR kw: biodiverse* OR kw: abundan* OR kw: composit* OR kw: ecolog* OR kw: ecosystem* OR (kw: eco w system*) OR kw: trophic OR kw: habitat* OR kw: environment* OR kw: offshore OR kw: fjord* OR kw: marine OR kw: coast* OR kw: fish* OR kw: seabed* OR kw: sediment* OR kw: substrate* OR kw: benth* OR kw: epibent* OR kw: infauna* OR kw: epifauna* OR kw: pelagic OR kw: phytoplankton* OR kw: zooplankton* OR kw: plankton* OR (kw: primary w2 produc*))) and yr: 2010-2022 and la= "eng" and mt: deg

**ORIA (Norwegian)** see section 8.1.1.

### 8.1.7 Light

Searches were performed by Astrid Harendza (Akvaplan-niva) on the 1st of August 2023.
Due to the limited literature available for this topic, a year restriction was not applied to Web of Science and Scopus searches.

#### Web of Science

(TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TS=(((artificial* OR electric*) NEAR/3 light*) OR "artificial light at night" OR "ALAN" OR (loss NEAR/3 darkness) OR "light pollution") AND TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*)))

#### Scopus

(TITLE-ABS-KEY ((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TITLE-ABS-KEY (((artificial* OR electric*) W/3 light*) OR "artificial light at night" OR "ALAN" OR (loss W/3 darkness) OR "light pollution") AND TITLE-ABS-KEY (impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) W/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary W/2 produc*)))

#### WorldCat Dissertations and Theses (WorldCatDissertations)

((kw: aquacultur* OR kw: cage* OR kw: fishcage* OR kw: netcage* OR kw: fishpen* OR kw: fish w pen* OR kw: netpen* OR kw: net w pen* OR kw: farm* OR kw: fishfarm*) and (kw: salmon OR kw: salmo OR kw: trout* OR (kw: oncorhynchus and kw: mykiss) OR (kw: Atlantic and kw: cod) OR (kw: Gadus and kw: marhua))) and ((kw: artificial* w3 light) OR (kw: electric* w3 light*) OR (kw: artificial w light w "at" w night) OR kw: ALAN OR (kw: loss w3 darkness) OR (kw: light w pollution)) and ((kw: impact* OR kw: effect* OR kw: risk* OR kw: pollut* OR kw: stress* OR kw: multi-stress* OR kw:

multistress* OR ((kw: multi* OR kw: collective* OR kw: cumulative* OR kw: combi*) and (kw: stress* OR kw: effect*)) OR kw: pressure* OR kw: lethal OR (kw: sub w lethal) OR kw: threshold* OR kw: indicator* OR kw: biolog* OR kw: divers* OR kw: biodiverse* OR kw: abundan* OR kw: composit* OR kw: ecolog* OR kw: ecosystem* OR (kw: eco w system*) OR kw: trophic OR kw: habitat* OR kw: environment* OR kw: offshore OR kw: fjord* OR kw: marine OR kw: coast* OR kw: fish* OR kw: seabed* OR kw: sediment* OR kw: substrate* OR kw: benth* OR kw: epibent* OR kw: infauna* OR kw: epifauna* OR kw: pelagic OR kw: phytoplankton* OR kw: zooplankton* OR kw: plankton* OR (kw: primary w2 produc*))) and yr: 2010-2022 and la= "eng" and mt: deg

**ORIA (Norwegian)** - see section 8.1.1.

### 8.1.8 Artificial structure

Searches were performed by Astrid Harendza (Akvaplan-niva) on the 1st of August 2023.
Due to the limited literature available for this topic, a year restriction was not applied to Web of Science and Scopus searches.

#### Web of Science

(TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TS=((artific* OR man-made) NEAR/3 (structur* OR substrat* OR habitat* OR environment*) OR non-native OR "non native" OR invasive OR non-indigenous OR "non indigenous") AND TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*)))

#### Scopus

(TITLE-ABS-KEY ((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen" OR "fish-pen" OR "fish-pens" OR "fish pens" OR netpen* OR "net pen" OR "net-pen" OR "net pens" OR "net-pens" OR farm* OR fishfarm*) AND (salmon OR salmo OR trout* OR "oncorhynchus mykiss" OR "Atlantic cod" OR "Gadus marhua")) AND TITLE-ABS-KEY ((artific* OR man-made) W/3 (structur* OR substrat* OR habitat* OR environment*) OR non-native OR "non native" OR invasive OR non-indigenous OR "non indigenous") AND TITLE-ABS-KEY (impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) W/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary W/2 produc*)))

**WorldCat Dissertations and Theses (WorldCatDissertations)**

((kw: aquacultur* OR kw: cage* OR kw: fishcage* OR kw: netcage* OR kw: fishpen* OR kw: fish w pen* OR kw: netpen* OR kw: net w pen* OR kw: farm* OR kw: fishfarm*) and (kw: salmon OR kw: salmo OR kw: trout* OR (kw: oncorhynchus and kw: mykiss) OR (kw: Atlantic and kw: cod) OR (kw: Gadus and kw: marhua))) and (((kw: artific* OR kw: man-made) and (kw: structur* OR kw: substrat* OR kw: habitat* OR kw: environment*)) OR kw: non-native OR (kw: non w native) OR kw: invasive OR kw: non-indigenous OR (kw: non w indigenous)) and ((kw: impact* OR kw: effect* OR kw: risk* OR kw: pollut* OR kw: stress* OR kw: multi-stress* OR kw: multistress* OR ((kw: multi* OR kw: collective* OR kw: cumulative* OR kw: combi*) and (kw: stress* OR kw: effect*)) OR kw: pressure* OR kw: lethal OR (kw: sub w lethal) OR kw: threshold* OR kw: indicator* OR kw: biolog* OR kw: divers* OR kw: biodiverse* OR kw: abundan* OR kw: composit* OR kw: ecolog* OR kw: ecosystem* OR (kw: eco w system*) OR kw: trophic OR kw: habitat* OR kw: environment* OR kw: offshore OR kw: fjord* OR kw: marine OR kw: coast* OR kw: fish* OR kw: seabed* OR kw: sediment* OR kw: substrate* OR kw: benth* OR kw: epibent* OR kw: infauna* OR kw: epifauna* OR kw: pelagic OR kw: phytoplankton* OR kw: zooplankton* OR kw: plankton* OR (kw: primary w2 produc*))) and yr: 2010-2022 and la= "eng" and mt: deg

**ORIA (Norwegian) -** see section 8.1.1.

### 8.1.9 Operational Standards for Aquaculture

Operational standards for Aquaculture used by Scottish environmental protection agency (SEPA) for regulating the use of chemicals in aquaculture. (source: https://www.sepa.org.uk/media/152957/wat-sg-53-environmental-quality-standards-for-discharges-to-surface-waters.pdf).

**Table 9: Operational Standards for Aquaculture**

**Table 9a Operational Water Quality Standards used by SEPA for regulating the use of chemicals in aquaculture**

| Substance | Environmental Quality Standard (µg/l – except for AMX which is ng/l) | | | | Reference |
|---|---|---|---|---|---|
| | Freshwater | | Marine | | |
| | AA | MAC | AA | MAC | |
| Salmosan (active ingredient: Azamethiphos) | - | - | - | 0.25 (after 3 hrs)<br>0.15 (after 24 hrs)<br>0.04 (after 72 hrs) | SEPA Policy 17 (1998) |
| Pyceze (active ingredient: Bronopol) | - | 70 | - | - | SEPA Guidance (2002) |
| Excis (active ingredient: Cypermethrin) | Use Cypermethrin standards specified in Table 4 | | | | 2015 SG Direction |
| Aquaguard (active ingredient: Dichlorvos) | Use not permitted | | | | DoE (1991) |
| Slice (active ingredient: Emamectin Benzoate) | - | - | - | 0.00022 | SEPA Recommendation (1999) |
| Ivermectin | Use not permitted | | | | - |
| Malachite Green | Use not permitted | | | | SEPA Guidance (2002) |
| AMX (active ingredient: Deltmethrin) | - | - | 0.3 ng/l | 9.0 (after 3 hrs)<br>6.0 (after 6 hrs)<br>4.0 (after 12 hrs)<br>2.0 (after 24 hrs)<br>1.0 (after 48 hrs) | SEPA Guidance (2008) |
| Calicide (active ingredient: Teflubenzeron) | - | - | 0.006 | 0.03 | SEPA Policy 29 (1999) |

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Supporting Guidance (WAT-SG-53) SEPA

**Table 9b Operational Sediment Quality Standards used by SEPA for regulating the use of chemicals in aquaculture**

| Substance | Sediment Quality Standard | | | | Reference |
|---|---|---|---|---|---|
| | Freshwater | | Marine | | |
| | AA | MAC | AA | MAC | |
| Slice (active ingredient: Emamectin Benzoate) | - | - | - | 0.763 µg/kg-wet weight (5cm core depth outside zone of effects area. 100m from edge of cages, increased up to 150m where strong directional currents exist) | SEPA Recommendation (1999) |
| Calicide (active ingredient: Teflubenzeron) | - | - | 10.0 mg/kg-dry weight (5cm core depth applied within the immediate under cage impact zone, up to 25m from cage edges) | 2.0 µg/kg-dry weight (5cm core depth outside zone of effects area. 100m from edge of cages, increased up to 150m where strong directional currents exist) | SEPA Policy 29 (1999) |

AA – Annual Average
MAC - Maximum Allowable Concentration

## 8.2 Appendix B - Search profiles (other industries)

Here, the primary research question is presented, as well as the developed search strings for each theme and the result using the entire search profile (concept 1+2+3 (+4)). The coding in the presented examples is used for the Web of Science search engine. The initial search focus is on traditional open pen farming of salmon and trout. Concept 1 describes the "population" (aquaculture and species) and will thus constitute the first input for the search profiles in each theme also for AP2.

*Concept 1 (salmon and trout):*

TS=((aquacultur* OR cage* OR fishcage* OR netcage* OR fishpen* OR "fish pen*" OR netpen* OR "net pen*" OR farm* OR fishfarm*) AND (salmon OR salmo OR salmonid* OR trout* OR oncorhynchus mykiss))

**Particles**

*Primary question*: What is the impact of the release of particles from anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=((coast* NEAR/3 industr*) OR sewage OR sewerage OR (sewage NEAR/3 (sludge OR wastewater OR effluent)) OR agriculture OR farming OR (food NEAR/2 cultivation) OR (food NEAR/3 industr*) OR (food NEAR/2 process*) OR slaughter* OR dairy* OR brewer* OR (pharmaceutic* NEAR/3 industri*) OR mining OR mine* OR (mineral* NEAR/3 industr*) OR dredge* )

*Concept 3 (stressor):*
TS=(particle* OR grain* OR fragment* OR sediment* OR substrate* OR material* OR matter* OR tailing*)

*Concept 4 (receiver):*
TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR water OR (water NEAR/2 quality) OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR reprodu* OR chemi* OR pollut* OR enrich* OR eutrophicat* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*))

*Results (Web of Science):* **595** retrieved records

**Dissolved nutrients**

*Primary question*: What is the impact of change of nutrient levels due to anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/2 (industr* OR sector OR harvest*)) OR shipping OR cruise*OR ((maritime OR marine OR naval) NEAR/3 (industr* OR sector* OR transport* OR freight*)) OR sewage OR sewerage OR (sewage NEAR/3 (sludge OR wastewater OR effluent)) OR agriculture OR farming OR (food NEAR/2 cultivation) OR (food NEAR/3 industr*) OR (food NEAR/2 process*) OR slaughter* OR dairy* OR brewer* OR (("fish process*" OR "fish-process*") NEAR/3 (industr*)) OR "fish process*" OR "fish-process*"OR (pharmaceutic* NEAR/3 industr*))

*Concept 3 (stressor):*
TS=((dissolve* NEAR/2 (nutrient*) OR phosphor* OR phosphate OR phosphorus OR nitrogen OR ammoni* OR ((dissolve* OR solub*) NEAR/2 waste*) OR ("organic* NEAR/2 waste*")))

*Concept 4 (receiver):*
TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR water OR (water NEAR/2 quality) OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR reprodu* OR chemi* OR pollut* OR enrich* OR eutrophicat* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*))

*Results (Web of Science):* **424** retrieved records

## Physical damage

*Primary question*: What is the impact of change of nutrient levels due to anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/3 (industr* OR sector OR harvest*)))

*Concept 3 (stressor):*
TS=(trawl* OR dredg*)

*Concept 4 (receiver):*
TS=(seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate*)

*Results (Web of Science):* **1062** retrieved records.

## **Chemical components and plastics** (Contaminants).

*Primary question*: What is the impact of the release of contaminants and plastics from anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/2 (industr* OR sector OR harvest*)) OR shipping OR cruise* OR ((maritime OR marine OR naval) NEAR/3 (industr* OR sector* OR transport* OR freight*)) OR sewage OR sewerage OR (sewage NEAR/3 (sludge OR wastewater OR effluent)) OR agriculture OR farming OR (food NEAR/2 cultivation) OR (food NEAR/3 industr*) OR (food NEAR/2 process*) OR slaughter* OR dairy* OR brewer* OR (("fish process*" OR "fish-process*") NEAR/3 (industr*)) OR "fish process*" OR "fish-process*" OR (chemical NEAR/3 industr*) OR (metallurg* NEAR/3 industr*) OR "Metal manufacture" OR mining OR "excavating minerals" OR mine* OR (mineral* NEAR/3 industr*) OR ((petroleum OR oil OR "oil and gas" OR offshore OR off-shore) NEAR/3 (industr* OR sector*)) OR (pharmaceutic* NEAR/3 industr*))

*Concept 3 (stressor):*

TS=(contamina* OR pollut* OR cocs OR ecotox* OR toxic*OR pharmaceutic* OR pesticid* OR insecticid* OR biopesticid* OR organochlorine OR DDT OR BHC OR Lindane* OR chlorobenzoate OR disinfectant* OR desinfectant* OR antifouling* OR "anti fouling*" OR antifoulant* OR "anti foulant*" OR "organotin tributyltin" OR TBT OR phenol* OR (oil NEAR/3 (compound* OR mixture*)) OR paraffin* OR petrol* OR bunker* OR gasoil OR gasoline OR gasolene OR PAH OR phenanthrene OR naphthalene OR fluorene OR fluoranthene OR hydrocarbon* OR "hydro-carbon*" OR fuel* OR biofuel* OR salt OR salts OR acid* OR pH OR "grey water" OR chemical* OR cyanide* OR "Sodium

Isobutyl Xanthate" OR "SIBX" OR PCB OR PCBs OR HCB OR polychlorinated biphenyl* OR Siloxanes* OR metal* OR Copper OR Cu OR Zinc OR Zn OR Vanadium OR V OR Nickel OR Ni OR Arsenic OR As OR Cobalt OR Co OR Cadmium OR Cd OR Lead or Pb OR Silver OR Ag OR Chromium OR Cr OR Tinn OR Sn OR iron OR Fe OR Mercury OR Hg OR plastic* OR macroplastic* OR microplastic* OR (chlorinated NEAR/3 compound*) OR "hydrophobic organic compound*" OR chlorocarbon* OR "chloro-carbon*" OR chlorohydrocarbon* OR "chloro-hydrocarbon*" OR chlorobenzilate OR methoxychlor* OR cyclodiene* OR aldrin* OR dieldrin* OR chlordane OR heptachlor OR endrin* OR methoxychlor OR sewage* OR sewerage* OR sludge* OR wastewater* OR "waste-water*" OR spillwater* OR "spill-water*" OR "mine waste*" OR ((leachates OR leaching) NEAR/3 water*) OR ((mining OR dust) NEAR/3 particle*) OR effluent* OR (anthropogenic NEAR/3 (emission* OR release* OR discharge*)))

*Results (Web of Science):* **2183**

## Noise

*Primary question*: What is the impact of noise due to anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=(((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/2 (industr* OR sector OR harvest*)) OR angling OR shipping OR cruise* OR ((maritime OR marine OR naval) NEAR/3 (industr* OR sector* OR transport* OR freight*)) OR (recreation* NEAR/3 (shipping* OR vessel)) OR ((mari* OR ship) NEAR/2 traffic) OR ((petroleum OR oil OR "oil and gas" OR offshore OR off-shore) NEAR/3 (industr* OR sector*)) OR navy OR military OR "marine renewable*" OR "marine renewable energy" OR "ocean energy" OR ((contruction* OR building) NEAR/3 industr*) OR trawl* OR dredg* OR boat OR vessel OR propell* OR cavitation OR engine* OR "onboard machine*" OR hull OR drill* OR "pile-driving" OR piling OR seismic OR explosive* OR sonar* OR turbine*))

*Concept 3 (stressor):*
TS=(noise* or sound*)

*Concept 4 (receiver):*
TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*))

*Results (Web of Science):* **52** retrieved records

## Light

*Primary question*: What is the impact of artificial light pollution due to anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/2 (industr* OR sector OR harvest*)) OR angling OR shipping OR cruise* OR ((maritime OR marine OR naval) NEAR/3 (industr* OR sector* OR transport* OR freight*)) OR (recreation* NEAR/3 (shipping* OR vessel)) OR ((mari* OR ship) NEAR/2 traffic) OR ((petroleum OR oil OR "oil and gas" OR offshore OR off-shore) NEAR/3 (industr* OR sector*)) OR agriculture OR port* OR harbour* OR marina OR railway* OR airport* OR ((contruction* OR building) NEAR/3 industr*) OR construction* OR urban* OR village* OR cities OR city OR settlement* OR near-shore OR nearshore OR touris* OR resort*)

*Concept 3 (stressor):*
TS=((artificial* NEAR/3 light*) OR "artificial light at night" OR ALAN OR (loss NEAR/3 darkness) OR "light pollution" OR (electric* NEAR/2 light*))

*Concept 4 (receiver):*
TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*))

*Results (Web of Science):* **7** retrieved records

## Warming

*Primary question*: What is the impact of warming of water due to anthropogenic activity on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=((coast* NEAR/3 industr*) OR (petroleum refiner*) OR (chemical plant*) OR ((pulp OR paper) mill*) OR (steel mill*) OR smelter* OR ((nuclear* OR power* OR energ*) NEAR/3 (plant* OR station*) OR 'power-plant' )))

*Concept 3 (stressor):*
TS=(((warm OR heat* OR cool* OR thermal*) NEAR/2 (water* OR effluent* OR discharge* OR plume*) OR "thermal pollution"))

*Concept 4 (receiver):*
TS=(biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic OR phytoplankton* OR zooplankton* OR plankton* OR (primary NEAR/2 produc*))

*Results (Web of Science):* **1541** retrieved records.

## **Stepping stones** (Artificial structures)

*Primary question*: What is the impact of the physical presence of artificial structures and vessel movement on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=(((coast* NEAR/3 industr*) OR fisheries OR fishery OR (fish* NEAR/2 (industr* OR sector OR harvest*)) OR angling OR shipping OR cruise* OR ((maritime OR marine OR naval) NEAR/3 (industr* OR sector* OR transport* OR freight*)) OR (recreation* NEAR/3 (shipping* OR vessel)) OR ((mari* OR ship) NEAR/2 traffic) OR ((petroleum OR oil OR "oil and gas" OR offshore OR off-shore) NEAR/3 (industr* OR sector*)) OR navy OR military OR port* or harbour* or marina OR "marine renewable*" OR "marine renewable energy" OR "ocean energy" OR ((contruction* OR building) NEAR/3 industr*)))

*Concept 3 (stressor):*
TS=((artific* OR man-made) NEAR/3 (structur* OR substrat* OR habitat* OR environment*) OR non-native OR "non native" OR invasive)

*Concept 4 (receiver):*
TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi*

OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic  OR phytoplankton*  OR  zooplankton* OR plankton* OR (primary NEAR/2 produc*))

*Results (Web of Science): 73 retrieved records*

### Hydropower

*Primary question*: What is the impact of hydropower on aquaculture (direct & indirect)?

*Concept 2 (industry):*
TS=(hydropower OR "hydro-power" OR hydroelectric OR "hydro-electric" OR (power NEAR/3 production))

*Concept 3 (stressor):*
TS=((river NEAR/2 regulation) OR (freshwater NEAR/2 discharge) OR ((regulat* OR modifi*) NEAR/3 (river* OR stream* OR run-off)))

*Concept 4 (receiver):*
TS=(impact* OR effect* OR risk* OR pollut* OR stress* OR multi-stress* OR multistress* OR ((multi* OR collective* OR cumulative* OR combi*) NEAR/2 (stress* OR effect*)) OR pressure* OR lethal OR "sub lethal" OR threshold* OR indicator* OR biolog* OR divers* OR biodiverse* OR abundan* OR composit* OR ecolog* OR ecosystem* OR "eco system*" OR trophic OR habitat* OR environment* OR offshore OR fjord* OR marine OR coast* OR fish* OR seabed* OR sediment* OR benth* OR epibent* OR infauna* OR epifauna* OR substrate* OR pelagic  OR phytoplankton*  OR  zooplankton* OR plankton* OR (primary NEAR/2 produc*) OR hydropgraphy)

*Results (Web of Science):* 3

## 8.3 Appendiks C – Forvaltning av miljøpåvirkning

Tabeller fra gjennomgang av saksdokumenter fra akvakulturforvaltning er gjengitt under.

### 8.3.1 Statsforvalteren

*Tabell 8-1 Analyse av saksdokumenter for tillatelse for akvakultur fra Statsforvalteren*

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| 30218 | Forurnsl. §11, §16 | Midlertidig | Utvidelse av produksjon | Møre og Romsdal | Begrense skader på naturmangfoldet | Generelt at økning I antall lakselus kan medføre skade på villfisk. | C-und, strandsone-und, overvåke makroalger, hvis Cu brukes skal utbredelse kartlegges |
| 30231 | Forurnsl. §11, §17, §7, §2. Naturmangfoldsloven §7 Vannforskriften | Permanent | Utvidelse av produksjon | Møre og Romsdal | Krav om kartlegging av koraller før utslippstillatelse gis. | Lakselus og rømning påvirker lokale laksebestander. Viser til Norsk Rodliste for arter 2021. Mattilsynet uttaler seg om svake B-und, og ber om lang nok brakkleggingstid av hensyn til fiskevelferd. Ulemper skal vurderes opp mot samfunns- og næringsmessige forhold. For-und, B-, C, og korall-und, Naturbase, Fdir kart, Artsdatabanken. Vurerer lav risiko for at oppdrett påvirker resipient generelt. Usikkert grunnlag for å vurdere påvirkning på hele økosystemet. Ansees som lav i dette tilfellet. Ser bort fra føre-var prisnsippet, pga god omsetning av org. materiale. Krav om makroalgeund. med ROV, basert på innsendt ROV-und. Påvist "medtatt" | C-und + alt ROV-und, strandsone-bef, overvåke makroalger, hvis Cu brukes skal utbredelse kartlegges |
| 53592 | Forurensl. §11, §16 | Permanent | Endring av plassering, areal og struktur anlegg | Møre og Romsdal | | Krav til ROV basert på uttalelse fra fisker om mulig korallforekomst. Krav til nullutslipp av lusemidler av hensyn til naturmangfold (føre var-prinsipp) | C-und + alt ROV-und, strandsone-bef, starndsone-und etter NS-EN ISO 19493:2007, overvåke makroalger, hvis Cu brukes skal utbredelse kartlegges |

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| 139466 | Forurensl. §11, §17, §2, §51 Naturmangfoldsl §7, §10. Vannforskriften. | Midlertidig | | Møre og Romsdal | | Krav til miljøforsvarlig drift for å unngå eller begrense skade på naturmangfoldet. Ved uønskede effekter på resipient trekkes tillatelsen. Lav sannsynlighet for overgjødsling. Lav sannsynlighet for uakseptabel risiko for permanent skade på gytefelt for torsk. Lokaliteten har begrenset kapasitet til omsetning av org materiale (For-und, str mlr). Lav sannsynlighet for at tilstand reduseres ihht Vannforekomsten. Spørsmål om økosystemet tåler belastningen samlet. Bruker føre-var prinsippet. "Vi mener derfor at den tilgjengelige kunnskap fortsatt ikke gir fullstendig svar på hvilke effekter utslipp av næringssalt og organisk stoff kan ha på naturmangfoldet. Vurdering av samlet påvirkning på økosystemet er derfor også noe usikker. Vi vil derfor fortsatt legge vekt på føre- var prinsippet." Positivt at selskapet er liten (èn konsesjon). | C-und, årlig strandsone-bef., overvåke Makroalger (Ihht Veileder for makroalger I Vannforskriften), kobber-und ved behov |
| 141380 | Forurensl. §11, §16, §29, §18 Naturmangfoldsloven §7, §7-12 Vannforskriften §§4-6 | Endring I vilkår | utvidet frist for overvåkingsprogram | Møre og Romsdal | | Endre frist for å utarbeide plan for overvåkingsprogram for makroalger. Ny frist gis med konkret dato, men skal gjennomføres når driftstillatelse er gitt. Støysonekart skal også utarbeides, med gitt frist. | C-und, årlig strandsone-bef., overvåke Makroalger (Ihht Veileder for makroalger I Vannforskriften), kobber-und ved behov |
| 14225 | Forurensl §25 | Tilsyn | | Vestland | | Inspeksjonen inngår i Statsforvaltaren sin aksjon for akvakulturanlegg i sjø i 2021. Særlig fokus på kobber og om det er gjennomfør målinger I hht | |

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| | | | | | | utslippstillatelsen. Viser til His risikorapport om Cu. | |
| 53876 | Forurensl §11, jf §16, §56, §78, §79. Naturmangfoldsloven §8, §9, §10, §11, §12 | Permanent | utvidelse av prodksjon | Vestland | | Utvidelse gis med forutsetning om at en annen lok legges ned (ingen endring I total MTB). Gis til tross for at resipienten totalt sett har langvarig negativ utvikling, og SF jobber med Vannforskr. Det vises til BAT. O2-metning i terskelfjorder (Osterøyfjorden) er temaet, som viser en negativ trend over år. Vurderingsparametre: O2, B- og C-und, støy, utslipp av kjemikalier, utslipp av plast, naturmangfold, eget overvåkingsprogram for fjorden | C-und, strandsone-bef, Cu-und dersom brukt, O2-måling I dypområdet til resipient |
| 138683 | Forurensl §11, jf §16 Naturmangfoldsloven | Permanent | Endring av plassering, og utvidelse av MTB | Vestland | Har brukt His Risikorapport, Ekspertgruppe for vurdering av lusepåvirkning, Lakseregisteret, VRL, som vurderingsgrunnlag for naturmangfold | Fylkesmannen meiner at kunnskapsgrunnlaget ikkje er til stades til å kunne auke utsleppsløyvet på lokaliteten. Kunnskapsgrunnlaget i søknaden er ikkje tilstrekkeleg til å kunne vurdera om ei utviding av produksjonen kan vera miljømessig forsvarleg. Vi kan ta spørsmålet om utviding opp til ny vurdering når resultat frå resipientgransking føreligg. Vår vurdering av søknaden etter naturmangfaldlova gjer at vi rår frå å auke biomassen av stamfisk på lokaliteten. Å auke oppdrettsbiomassen i Matrefjorden vil føre til auke lusepress på vill anadrom fisk i produksjonsområde 3. | C-und, strandsone-bef, Cu-und dersom brukt, O2-måling I dypområdet til resipient |

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| 140214 | Naturmangfoldsl §8-12 | Foreløpig | Ny lokalitet, tidsbegrenset | Vestland | Lokaliteten er flyttet etter at forrig lokalitet har høy forekomst av koraller. | Det gis utslippstillatelse for 3 prod. Sykluser. Overvåking av korallforekomst (naturmangfold, samt miljøund | C-und, tilleggsanalyser sediment prioriterte stoff, strandsone-bef, korall-overvåking |
| 140447 | | Midlertidig | Ny lokalitet, tidsbegrenset | Vestland | Gir tillatelse etter forurensingsloven, men anbefaler avslag til FK etter Naturmangfoldsloven, pga konflikt med vill anadrom fisk | På grunnlag av konfliktar med vill anadrom fisk rår vi Vestland fylkeskommune frå å gi løyve til etablering av akvakulturanlegg for stamfisk ved lokaliteten Almbakkevika. Vurdert berre etter forureiningslova, får Svanøy Havbruk AS mellombels løyve i seks år for utslepp frå produksjon av 1560 tonn MTB stamfisk av aure på lokalitet Almbakkevika. | C-und, tilleggsanalyser sediment prioriterte stoff, strandsone-bef, 2-målinger I dypområde, |
| 13858 | Forurens.lov §11 jf §16. Vurdert etter vannforskriften §4, og prinsippene I nat.mangf. Lov §8-12 | Permanent | Utvidet prod på 2 lok, nedtrekk på èn | Rogaland | Ligger I nærhet av Røvær naturreservat. Behov for oppdatering av gammel utslippstill- >øket omfang på miljøund | Det foreligge ingen miljødata som kan benyttes til klassifisering av vannforekomsten. Samlet lokalitets-mtb på 9540 t, men satt til maks 6500 tonn samlet av M.dir. Strømmålinger, B- og C-und, samt n konsekvens vurdering for naturmangfold. | C-und, strandsone-bef, overvåking makroalger, Cu-und hvis brukt, bunnkartlegging med hardhetsmodul |
| 14884 | Forurens.lov §18, 3dje ledd. Vurdert etter vannforskriften §4-6 og 12, og prinsippene I | permanent | Endring av tillatelser | Rogaland | Endring etter tilsyn av SF, gamle tillatelser | Faglig vurderingsgrunnlag: Gamle strømmålinger, B-und, bunnkartlegging med backscatter. Krav til nye C-und, bytte til notposer uten kobber. | C-und, tilleggsanalyser sediment prioriterte stoff, strandsone-bef, overvåking makroalger, Cu-und hvis brukt, bunnkartlegging med hardhetsmodul |

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| | nat.mangf. Lov §8-12 | | | | | | |
| 15721 | Forurens.lov §18, 1dje ledd, pkt 1-2. Vurdert etter vannforskriften §4-6 og 12, og vurdert etter nat.mangf. Lov §§4-6 og 12. | Permanent | Endring av tillatelser | Rogaland | Endring I tillatelse etter tilsyn | Faglig vurderingsgrunnlag: Vann-nett, Naturbase, strømmålinger, bunnkartlegging med backscatter, B-und, C-und, Ris risikorapport 2021 (kobber). SF vurderer at det er behov for å endre utslippstillatelsene på lokalitet Kjeringå og Nautvik jf. forurensningsloven § 18 første ledd punkt 1-3. På bakgrunn av lokalitetenes nærhet til sårbare naturtyper og bruk av kobberimpregnering på lokalitetene anser vi at det er behov for å utføre nye resipientundersøkelser. | C-und, tilleggsanalyser sediment prioriterte stoff, strandsone-bef, overvåking makroalger, Cu-und hvis brukt, bunnkartlegging med hardhetsmodul |
| 19881 | F.l. §11, 16, 18 | Permanent | Endring av tillatelser: økt MTB, utvidet areal | Troms og Finnmark | | Ingen saksfremlegg knyttet til tillatelsen, der begrunnelse for utvidelse gis. Det henvises til grensevrdier for C2, samt C3-Cn, samt grenseverdier for Cu, Cmd, og andre kjemikalier. Det vises også til begrensning av utsluppet legemidler | C-und, strandsone-bef, Cu-und dersom brukt |
| 24354 | F.l. §11, 16, 19 | Permanent | Endring av areal | Troms og Finnmark | | Ingen saksfremlegg knyttet til tillatelsen, der begrunnelse for utvidelse gis. Det henvises til grensevrdier for C2, samt C3-Cn, samt frenseverdier for Cu, Cmd, og andre kjemikalier. Det vises også til begrensning av utsiuppet legemidler | C-und, strandsone-bef, Cu-und dersom brukt |

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| 84953 | F.l. §11, 16, 20 | Permanent | Flytting av anlegg, 500m | Troms og Finnmar k | | Ingen saksfremlegg knyttet til tillatelsen, der begrunnelse for utvidelse gis. Det henvises til grensevrdier for C2, samt C3-Cn, samt frenseverdier for Cu, Cmd, og andre kjemikalier. Det vises også til begrensning av utsiuppet legemidler | C-und, strandsone-bef, Cu-und dersom brukt |
| 13825 0 | F.l. §11, 16, 21 | Permanent | Ny tillatelse? | Troms og Finnmar k | Tillatelsen fremstår som ufullstendig | Ingen saksfremlegg knyttet til tillatelsen, der begrunnelse for utvidelse gis. Det henvises til grensevrdier for C2, samt C3-Cn, samt frenseverdier for Cu, Cmd, og andre kjemikalier. Det vises også til begrensning av utsiuppet legemidler | C-und, strandsone-bef, Cu-und dersom brukt |
| 19763 | F.l. §6, 11, 16 | Midlertidig | Økning I biomass | Nordland | Lokaliteten har delvis lukkede merder, men har punktutslipp (samler ikke opp på land). Fyldig saksutredning og vurdering av tilgjengelig dokumentasjon. | Funn av koraller I C-und. Krav til dokumentasjon av utbredelse, krav til vurdering av partikkelspredning og sårbarhetsanalyse. Vurdere det som "lite sannsynlig" at resipienten påvirkes, basert på strømmålinger og C-und. Men siden det knytter seg usikkerhet til forekomster av koraller/svamper i området ved lokaliteten velger SF å pålegge Cermaq å kartlegge forekomster av koraller, svamper og andre sensitive arter, gi en faglig uttalelse om hvor viktig disse funnene er (f.eks. rødlistede arter eller naturtyper) og gi en helhetlig vurdering av biologisk mangfold i dette området. | C-und, kartlegge forekomst av koraller |
| 19777 | FL §11. 16. 18. Vennforskr. § 4-6, §12. Naturmanf. §§8-12 | Permanent | Økt biomasse, endret plassering | Nordland | Anadrome vassdrag og bestander som et eget vurderingspunk t | Pålegg om C-und. Pålegg om ekstra C-stasjon for å dokumentere resipientbelastning og O2-nivå I dypområder. Pålegg om overvåking av anadromt vassdrag I nærhet av lokalitet, da det ikke finnes kunnskap om vassdragets bestander. | C-und, ekstra C-stasjon I dypområdet til resipient inkl O2 måling, |

| Nr | Lov-hjemmel | Type vedtak | Vedtak gjelder | Fylke | Annet | Faglig vurderinger | Krav til overvåking |
|---|---|---|---|---|---|---|---|
| Sak 2020/ 6747 | FL§ 18 første ledd nr. 6. Naturmangfol dloven § 9 om føre-var-prinsippet | Varsel | Tilbaketreking av tillatelse | Nordland | Grundig saksfremlegg og redegjøring | Foreliggende kunnskap om naturmangfoldet i området og de effekter tillatelsen fra 2020 kan gi, innebærer at vi vurderer å trekke tilbake tillatelsen. Dette for å unngå mulig vesentlig skade på naturmangfoldet. Miljødirektoratets håndbok nr. 197 definerer korallforekomster blant utvalgte naturtyper i marint miljø, der det skal tas særskilt hensyn for å unngå en forringelse av naturtypenes utbredelse og forekomstenes økologisk tilstand. Et strengt føre-var-prinsipp, jf. naturmangfoldloven § 9, bør derfor legges til grunn for forvaltning av koraller og svampsamfunn | 6 ukers svarfrist, anmodning fra SF om overvåkingsprogram og redegjørelse for ulemper med vedtak. |

### 8.3.2 Fiskeridirektoratet

*Tabell 8-2 Kunnskapsgrunnlag og vurderinger i Fiskeridirektoratets uttalelser i akvakultursaker*

| | Sak / type | Kunnskapsgrunnlag | Vurderinger |
|---|---|---|---|
| 1 | 21/8254 Bjørøya AS ny lokalitet. Laksefisk, matfisk i sjø. | Kommunale høringen, AIS-sporing, innmeld bruk av området, kystsoneplan, fiskeridirektoratets kartlagte fiskeriinteresser, uttalelse fra Fiskarlaget, kartlagt biologisk mangfold, HI rapporter, undersøkelse på lokaliteten | Negativ påvirkning for fiskeriinteressene som bruker området. Anbefaler å begrense fortøyningsliner og være i dialog med lokale fiskere |
| 2 | 20/6159 NRS Farming utvidelse av MTB. Laksefisk, matfisk i sjø. | Kystsoneplan, kystnære fiskeridata, sporing av fiskefartøy, HI risikorapport, miljøundersøkelser | Var ikke funnet negativ påvirkning på miljø og fiskeriinteresser, herunder samiske interesser. |

| | Sak / type | Kunnskapsgrunnlag | Vurderinger |
|---|---|---|---|
| 3 | 21/374 Salmar Farming ny lokalitet. Laksefisk, matfisk i sjø. | Kystsoneplanen, reguleringsplan, høringen, kystnære fiskeridata, sporingsdata og sluttseddeldata, innmeldinger av faststående bruk, HI risikorapport | Kongekrabbefiske, linefelt, beiteområdet for kveite, gyteområdet for torsk i samme området. Etablering vil påvirke fiskeriinteressene. Anbefaler tilpasninger i reguleringsplan. Miljøpåvirkningen fra anlegget skal overvåkes ifølge forskriften. |
| 4 | 20/658 Bremnes Seashore ny lokalitet. Laksefisk, matfisk i sjø. | Kystnære fiskeridata fra 2012, uttalelse fra Fiskarlaget om fiskeriinteresser, registrert biologisk mangfold, B-undersøkelser | Avveining mot kommersielt fiskeri, fritids-og turistfiske, området med lokal viktighet. Søknad godkjent siden arealet er satt ut til akvakultur i kommunalplanen. Undersøkelse av bunnfauna bør gjennomføres. |
| 5 | 20/19663 Emilsen Fisk midlertidig tillatelse. Laksefisk, matfisk i sjø. | Kartlegging av tradisjonelle fiskeriinteresser, gytefelt for torsk registrert av HI i 2010, HI risikovurdering rapport (usikkerhet om påvirkning på torsk), KU av Salmar Farming og NINA. FD mener at kunnskap ikke er tilstrekkelig, og det er ingen forvaltningsråd om vurdering av påvirkning på torsk. Naturbase brukt for kunnskap om tareskogsforekomster. Studier om påvirkning av lusemidler på reker. B-undersøkelse, C-undersøkelse | Det vises til kunnskapsgrunnlaget (som tyder på negativ påvirkning på enkelte arter eller risiko), men ikke gjøres noen tydelige avveininger. Det er ikke lagt inn noe forbehold for innvilget søknad. |
| 6 | 20/303 Hauge Aqua Farming ny lokalitet («Egget») . Laksefisk, matfisk i sjø, i lukket anlegg. | Gjeldende arealplan. Tradisjonelle fiskeriinteressene i form av registrerte kaste- og låssettingsplasser og bruk av aktive og passive redskap i området, kystnære fiskeridata (herunder gyteområder). «Vi har ikke kunnskap om hvilke effekter et anlegg for oppdrett av laks eventuelt vil kunne få for gyteområdet for lyr.» «Vi kjenner ikke til andre registrerte forekomster av marint biologisk mangfold i området.». Refererer til studier om påvirkning av lusemidler | Avveining mot fiskeriinteresser. «Med<br><br>bakgrunn i at omsøkt areal for lokalitet Geilbukta er avsatt til akvakultur i Rauma kommune sin arealdelplan, samt at det registrerte fiskefeltet er relativt stort» kan det gis tillatelse. «Det foreligger lite forskningsbasert kunnskap om eventuell påvirkning fra oppdrettsanlegg for laks på gyteområder for lyr. Med bakgrunn i dette, samt avstand til gytefeltet, gytefeltets størrelse og tiltakets omfang, har vi ikke ytterligere merknader…» |
| 7 | 21/3486 Mowi endring av fortøyninger. Laksefisk, matfisk i sjø. | Viser til tidligere fiskerifaglige uttalelse (registrerte fiskeområder). | Avveining mot fiskeriinteresser. «På vestsiden av anlegget foregår noe garnfiske. Vi minner derfor igjen om viktigheten av at presis informasjon om fortøyninger og ankerfester blir rapportert.» |

| | Sak / type | Kunnskapsgrunnlag | Vurderinger |
|---|---|---|---|
| 8 | 20/18443 Mowi ny lokalitet. Laksefisk, matfisk i sjø. | Gjeldende arealplan, kartlagte fiske- og ressursområdene (intervju med fiskere og HI data). Flere fiskefelt i nærheten (200-2400 m unna). Sporing- og sluttseddeldata er brukt å kartlegge aktivitet, men der ikke usannsynlig at det er mer fiskeriaktivitet i området. Innspill fra NFF (fraråder) og fiskere (mener anlegget er for nært rekefelt). B-undersøkelse og forundersøkelse | Flerbruksområdet i arealplan, ny akvakultur tillates, dersom<br><br>det dokumenteres at ingen av de andre formålene blir skadelidende. Mowi ASA oppgir at lokaliteten vil, sammen med søknad om lokalitet Bukkøy, være<br><br>vesentlig for å sikre bærekraftig vekst og drift i området. NFF mener akvakulturanleggene vil være til fortrengsel for fiskeriene. FD mener at etableringen er ikke i strid med gjeldene arealplan, fiskeplassen benyttes lite og kan fortsatt brukes delvis. Det stilles avstandskrav ved kjemisk lusebehandling mht nærliggende rekefelt. |
| 9 | 20/18328 Mowi ny lokalitet. Laksefisk, matfisk i sjø. | Samme som sak 20/18443 | Samme som sak 20/18443. Ikke i strid med gjeldene arealplan, fortøyningene ligger utenfor rekefeltet, lokaliteten har gode miljøforhold, liten risiko for vesentlig skade for fiskeriinteressene. |
| 10 | 21/11852 Mowi ny lokalitet. Laksefisk, matfisk i sjø. | Registrerte kaste- og låssettingsplasser og bruk av aktive og passive redskap i området. Kartlegging av kystnære fiskeridata, AIS- sporing. Uttalelsene fra Fiskarlaget. HI data om registrert biologisk mangfold (gyteområder), HI risikovurdering (usikkerhet om påvirkning på torsk). Studier om effekt av lusemidler. Forundersøkelse, B-undersøkelse, C-undersøkelse | En viss negativ effekt for fiskeriinteressene (krabbefiske) selv om det finnes flere alternative områder for å drive teinefiske. Forutsetter at de nordlige og vestlige fortøyningene fra<br><br>anlegg og flåte begrenses mest mulig, ingen fortøyninger legges grunnere enn 30 meter. Svært viktig at det oppnås<br><br>sameksistens med fiskerinæringen. |
| 11 | 21/10661Mowi ny lokalitet. Laksefisk, matfisk i sjø. | Arealplan, registrerte tradisjonelle og kommersielle fiskeriinteresser, gytefelt for torsk registrert av HI (regionalt viktig), HI risikovurdering (usikkerhet og kunnskapshull), ROV-undersøkelser med korallkartlegging ved lokaliteten – skal vurderes av Statsforvalteren, Naturbase, studier om påvirkning av lusemidler, B- og C-undersøkelse. | Anlegget vil<br><br>komme innenfor områder der det fiskes med garn etter breiflabb, torsk og sei og med<br><br>teiner etter sjøkreps. Vil ikke medføre vesentlig negativ effekt for fiskeri. |

| | Sak / type | Kunnskapsgrunnlag | Vurderinger |
|---|---|---|---|
| 12 | 22/4701 Måsøval Fiskeoppdrett ny lokalitet. Laksefisk, matfisk i sjø. | Arealplan, kartlagte fiskeriinteresser, registrering av biologisk mangfold av HI (lokalt viktig gytefelt for torsk), AIS og VMS sporing, HI risikorapport (usikkerhet), B-undersøkelse, Vann-Nett. | Vil ikke medføre noen vesentlig<br><br>negativ effekt for fiskeriinteressene i forhold til bruk av området.<br><br>Lokaliteten kommer innenfor gytefelt for torsk. Det foreligger ikke<br><br>tilstrekkelig kunnskap om mulig påvirkning, har foreløpig ikke generelle forvaltningsråd om dette. |
| 13 | 21/19610 Salaks utvidelse av tillatelse. Laksefisk, matfisk i sjø. | Kystnære fiskeridata, registrert biologisk mangfold (HI), ikke kjent med spesielle naturtyper i tiltaksområdet, innspill gjennom kommunal behandling, tidligere undersøkelser i forbindelse med lokalitetsklarering, HI risikorapport (lav risiko av effekt av næringssalter) | Lokaliteten ligger delvis innenfor en fiskeplass for aktive redskaper (seinot) og like nord for to låssettingsplasser for sei. I Solbergfjorden er det registrert et gytefelt for torsk som er nasjonalt viktig. Utvidelse vil ikke beslaglegge mer areal. Med bakgrunn i det<br><br>overvåkingsregimet vi har i dag, samt at dette er et reversibelt<br><br>tiltak, er vår oppfatning at det kan tillates en økning i biomasse. |
| 14 | 22/3097 Salmar Farming ny lokalitet. Laksefisk, matfisk i sjø. | Arealplan, registrerte fiskeriinteresser, AIS og sluttseddeldata, registrert biologisk mangfold (HI), risikorapport (usikkerhet),-B og C-undersøkelse. | Vil ikke medføre vesentlig negativ effekt for fiskeriinteressene. Ingen registrerte fiskefelt innenfor området. Ingen generelle forvaltningsråd om påvirkning på torsk |
| 15 | 21/19678 Salmar Farming ny lokalitet. Laksefisk, matfisk i sjø. | Arealplan, innspill gjennom kommunal behandling, kystnære fiskeridata, sporing og sluttseddeldata, oversikt over historiske innmeldinger av faststående bruk | Kommunen støtter ikke etablering på lokalitet med bakgrunn i ønsket om å rullere kystsoneplanen før nye etableringer. Det foregår fiske med snurrevad etter torsk og torskeartet fisk i området, men det meste lengere øst. Det foregår en del linefiske etter torsk og torskeartet fisk i Vannsundet som vil komme i konflikt med fortøyningsliner og ankerfester. Vest for omsøkt lokalitet er det registrert et gyteområde for torsk, sei og uer. |
| 16 | 22/7410 Salmar Farming ny lokalitet. Laksefisk, matfisk i sjø. | Arealplan, kartlagte fiskeriinteresser, kartlagt biologisk mangfold, Naturbase, uttalelse fra Fiskarlaget (fraråder), AIS og VMS sporing, sluttsedler, HI risikorapport (usikkerhet), Vann-Nett | Samlet sett bør være akseptabel for fiskeriinteressene med tanke på arealbruk i området. Det er flere gytefelt/gyteområder for torsk innenfor og nært omsøkt lokalitet. I Naturbase er det registrert tareskog- og skjellsandforekomster i området. Det er flere store taretrålerfelt i området. Det foreligger ikke |

| | Sak / type | Kunnskapsgrunnlag | Vurderinger |
|---|---|---|---|
| | | | tilstrekkelig kunnskap om mulig påvirkning fra akvakulturanlegg for laksefisk på nærliggende gytefelt/gyteområder for torsk. Med bakgrunn i et mangelfullt kunnskapsgrunnlag og føre-var-prinsippet (jf. naturmangfoldloven §§ 8 og 9), ber vi om at dette vurderes særskilt av fylkeskommunen, jf. naturmangfoldloven §§ 7-12.<br><br>Lokalitetsområdet er avsatt som flerbruksområde, der akvakultur er tillatt. |

### 8.3.3 Mattilsynet

*Tabell 8-3 Saker vurdert fra Mattilsynet*

| Saksnr. | Art, formål, Fylke | Type søknad. Resultat | Kunnskaps-grunnlag | Vurderinger (relevant for miljøhensyn) |
|---|---|---|---|---|
| 2019/ 155927 | Landbasert helkjede (settefisk + matfisk), laksefisk, Møre og Romsdal. | Ny lokalitet. Avslag. | Søknad. Skisserte tiltak desinfeksjon. Retningslinjer etablerings-søknader sine anbefalte minsteavstander. Ekstern analyse spredning avløpsvann. Avstand lakseførende vassdrag. Annen biosikkerhetsplan ang smitte-risiko. | Altfor kort avstand til allerede etablerte lokaliteter. Ser at svært mange tiltak som skal redusere smitterisiko er skissert, men «Når avstanden er langt under halvparten av anbefalt minsteavstand, vurderer regionen at vi med dagens regelverk, inkludert retningslinjer og støtte i klagesaksavgjørelser fra Hovedkontoret, ikke kan godkjenne. Vi behøver en eventuell overordnet revisjon der tilnærmingen til dette blir gjennomført og/eller en konkret klagesaksavgjørelse som sier noe annet.<br><br>Forskriftens § 7: «godkjenning kan gis dersom ...ikke innebærer en uakseptabel risiko for spredning av smitte.<br><br>Velger å avslå fordi vi ikke kan si at risikoen er ikkeeksisterende. Vi kan ikke garantere at ikke naboanleggene vi bli berørt ved sykdomutbrudd og smitte fra lokaliteten. Sannsynligheten vil trolig være svært liten, men konsekvensen potensielt svært alvorlig.<br><br>Vi kan ikke se at etablering av anlegget som omsøkt ville hatt vesentlig uønsket negativ effekt på villfisk, miljø eller naturmangfold vurdert ut fra Mattilsynet sitt sektorområde. |

| Saksnr. | Art, formål, Fylke | Type søknad. Resultat | Kunnskaps-grunnlag | Vurderinger (relevant for miljøhensyn) |
|---|---|---|---|---|
| | | | | Siden vi avslår grunnet smittevurderinger i forhold til etablerte sjøvannsinntak til annen virksomhet, gjør vi ikke videre vurderinger angående dette. |
| 2021/ 150474 | Matfisk i sjø. Torsk. Nordland. | Ny lokalitet. Godkjent. | Søknad. Retningslinje. Mattilsynet har innhentet data for Møkland fra Havforskningsinstituttets verktøy: Strømkatalogen. Fiskeridirektoratet sin uttalelse usikker på om etableringen av lokaliteten vil<br><br>kunne påvirke vill torsk, nærliggende gyteområder, samt eventuelle oppvekst- og beiteområder<br><br>for torsk og ber om at dette vurderes særskilt av fylkeskommunen som vedtaksmyndighet | Torsk og andre marine arter har en annen biologi og en annen produksjonssyklus enn laksefisk.<br><br>Dette byr på klare utfordringer når prinsippet om koordinert brakklegging og generasjonsskiller praktiseres på lakseoppdrettets premisser. Å etablere en torskelokalitet mellom lakselokaliteter kan føre til utfordringer når lakselokalitetene drifter med koordinert brakklegging og produksjon. En del smitteagens/sykdommer kan gå på tvers av arter, og dette betyr i prinsippet at torskelokaliteten bidrar til å opprettholde smittetrykket dersom lokaliteten har en annen produksjonssyklus enn de andre lokalitetene i området. Dette vil kunne redusere effekten av den koordinerte brakkleggingen.<br><br>Avstand til viktige lakseførende vassdrag:<br><br>I etableringsretningslinjen er det ikke angitt noen anbefalt minsteavstand fra torskeanlegg til viktige lakseførende vassdrag. Der er såvidt Mattilsynet kjenner til ingen vassdrag med oppgang av laks i nærheten. Mattilsynet har ikke grunn til å tro at etablering av den omsøkte lokaliteten vil innebære uakseptabel smitterisiko for ville bestander av laksefisk i nærområdet.<br><br>Smitterisiko med hensyn til lakselus: Lakselus har laksefisk som hovedvert. Torskelus har torsk som hovedvert, og vil ikke infisere laksefisk. Skottelus kan derimot infisere flere fiskearter, herunder både torsk og laks. Skottelus er likevel ikke regnet som et problem for laksefisk i Nordland. I henhold til Havforskningsinstituttets rapport nr. 2021-22 om mulig påvirkning fra oppdrettstorsk på ville torskepopulasjoner er det to varianter av skottelus, og det synes ikke å være samme type på voksen torsk som er vanlig på rognkjeks og laks. Mattilsynet vurderer at etablering av den omsøkte lokaliteten ikke vil medføre så stor negativ påvirkning på de ville bestandene av torsk eller laksefisk i nærområdet at det bør vektlegges. Forholdet til ville populasjoner av torsk og mulige effekter av smittsomme agens er viktige hensyn i vurderingen av en etableringssøknad. 8 km nordøst for omsøkt lokalitet har Fiskeridirektoratet registrert et gyteområde for skrei og kysttorsk. Det er dessuten kartlagt oppvekst- og beiteområde på yttersiden av området, 6 km nord. Det er ikke kartlagt fiskeriinteresser/ fiskeplasser i nærheten av anlegget. Vassdrag 4,2 km fra lokalitet har i henhold til lakseregisteret.no |

| Saksnr. | Art, formål, Fylke | Type søknad. Resultat | Kunnskaps-grunnlag | Vurderinger (relevant for miljøhensyn) |
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| | | | | en god/svært god bestand av laks og en redusert stamme av sjøørret. Vassdrag, 4,5 km fra lokalitet har en redusert stamme av sjøørret.<br><br>I etableringsretningslinjen er det ikke angitt noen minsteavstand til gyteområder for torsk. Det er imidlertid ikke tillatt å etablere oppdrettsanlegg for torsk i et gytefelt eller gyteområde. Det er heller ikke tillatt at fortøyninger strekker seg inn i slike områder. Dersom torsken på lokaliteten skulle rømme eller gyte i merdene vil den kunne påvirke bestanden av villtorsk i området negativt. Oppdrettstorsken er nå 6. generasjon i avlsprogrammet og aktørene mener man har fått kontroll på både kjønnsmodning og rømningsadferd gjennom avlen. I tillegg utsettes kjønnsmodningen gjennom lysstyring. Mattilsynet vurderer at etablering av den nye lokaliteten ikke vil medføre noen nevneverdig økt belastning på villfisk i området. Mattilsynet legger til grunn at etablering av lokaliteten ikke innebærer en risiko av betydning med hensyn til naturens mangfold. |
| 2021/<br><br>259430 | Matfisk i sjø, Laksefisk, Nordland | Ny lokalitet. Godkjenning. | Søknad inkludert diverse kart, Forundersøkelse, B-Undersøkelse, C-Undersøkelse, Strømmålinger, Oksygenmålinger. Matrise for smittehygienetiltak. Beredskapsplanverk.<br><br>Fiskeridirektoratets uttalelse til søknad.<br><br>Naturmangfold i området og tilstand.<br><br>Havstrømmer.<br><br>Laksesmolt-rute | Mattilsynet vurderer avstandskravet til omkringliggende akvakulturanlegg som oppfylt. Avstand til nasjonale laksevassdrag og laksefjorder vurdert som stor nok, da den er 50 km unna. Etablering av anlegg i grenseområdene mellom foreslåtte produksjonsområder. Mattilsynet legger til grunn at etablering av nye anlegg ved grensen mellom to produksjonsområder innebærer en uakseptabel risiko for spredning av smitte dersom etableringen fører til økt utveksling av lakselus mellom produksjonsområdene. Mattilsynet vil derfor avslå slike søknader". Her 50 km, som vurderes som akseptabelt. Vurdering av smitterisiko med hensyn til lakselus. Smittepresset av enkelte sykdommer og parasitter vil alltid kunne bli større i nærområder når det etableres en lokalitet eller biomassen økes. Mattilsynet har vurdert lusesituasjonen for nærområdet ved å gå gjennom innrapporterte lusetall for nabolokalitetene for perioden 2019 - 2022. Det har vært relativt høyt lusepress med enkelte overskridelser og mange lusebehandlinger i området. Vurdert plassering av lokalitet ifht andre lokaliteter i området. 11 og 35 km til nærmeste lokaliteter er vurdert som akseptabelt her.<br><br>Naturmangfoldloven: Mattilsynet vurderer rutinemessig i hvilken grad eventuelle smittsomme sykdommer og parasitter fra lokaliteten kan representere en fare for det omkringliggende naturmiljøet og avveier ulike hensyn, jf. lov om forvaltning av naturens mangfold (naturmangfoldloven). Vurderer rekefelt, gytefelt for torsk, skjellsandområde viktig for bløtbunnsfauna, krepsdyr og flere fiskearter, tarefelt. |

| Saksnr. | Art, formål, Fylke | Type søknad. Resultat | Kunnskaps-grunnlag | Vurderinger (relevant for miljøhensyn) |
|---|---|---|---|---|
| | | | | Lakseførende vassdrag i nærheten og deres tilstand, sjøørret, sjørøye. Mest sannsynlig smoltvandringsrute. Dersom lusegrenser oppfylles så trolig ok, vurderes det.<br><br>Bunnpåvirkning (for fiskehelse), vurdert topografi, strøm og dybde (minst 20 m anbefalt, her fra 40-120 m), samt B-undersøkelse. |
| 2022/ 009055 | Matfisk i sjø, Laksefisk, Troms | Ny lokalitet. Godkjenning. | Avstand andre akvakulturanlegg. Brakkleggingssoner for ulike anlegg. Strømretning.<br><br>Avstand til nasjonale laksevassdrag og laksefjorder. Tilstand villfisk-stammer der. Avstand annet produksjonsområde. Fargelegging område i trafikklyssystemet. Lusesituasjonen i området (luserapporter fra anlegg i området, samt lusebehandlinger). Fiskeridirektoratets uttalelse til søknad: Fiskeplasser og låssettingsplasser. Utredningsområde for marint vern (Andfjorden).<br><br>Strømmålinger, oksygen og omkringliggende geografi. Dybde under anlegg. B-undersøkelser. | Smitte av sykdommer. Avstandskrav oppfylt. Avstand til nasjonale laksevassdrag og laksefjorder. Vurdering av smitterisiko med hensyn til lakselus. Også til villfisk.<br><br>Naturmangfoldloven – vurderinger. Vill laksefisk vassdrag og tilstand (gytebestandsmål mv).<br><br>Plassering innenfor utredningsområde for marint vern. «Selv om lusenivået på ny lokalitet er innenfor grenseverdiene i forskrift om lusebekjempelse vil det medføre økt belastning av lakselus på villfisk i området. Den økte belastning vil sannsynligvis ikke medføre negative konsekvenser for de ville bestandene. Mattilsynet legger til grunn at etablering av lokaliteten ikke innebærer en risiko av betydning med hensyn til naturens mangfold.»<br><br>«Opphoping av bunnsedimenter» (vurderes for fiskevelferd/-helse for fisk i merden vha strøm, bunnforhold, dybde under merden og b-undersøkelse). |

| Saksnr. | Art, formål, Fylke | Type søknad. Resultat | Kunnskaps-grunnlag | Vurderinger (relevant for miljøhensyn) |
|---|---|---|---|---|
| 2022/ 016626 | Matfisk i sjø, Torsk. Møre og Romsdal. | Ny lokalitet. Godkjenning. | Beredskapsplaner<br><br>Kart/posisjoner<br><br>Forundersøkelser<br><br>Miljøundersøkelser<br><br>KU-vurdering<br><br>Vurdering av påvirkning på villtorsk<br><br>Forhold til annen akvakultur<br><br>Tidligere strøm-modellering ifht vill torsk gyteområder. | risiko for spredning av sykdommer. Særlig vurdert strømforhold, avstand til vassdrag, annen akvakulturrelatert virksomhet og andre former for grupperinger av akvakulturanlegg som har betydning for smitterisikoen. «For torsk har vi ikke de samme krav til koordinert brakklegging som for laksefisk. Anbefalte minsteavstander til andre matfisklokaliteter (uavhengig av art) er 2,5 km. Til stamfisklokaliteter er det 5 km. Det er ikke avstandskrav til lakseførende vassdrag når det gjelder torsk/marine arter.» det er ikke forbud mot å etablere matfisk av torsk (marine arter) i nasjonal laksefjord (forbud er definert i § 3), men etableringen skal skje minst 5 km fra nasjonalt laksevassdrag (§ 6).<br><br>Naturmangfoldsloven vurdering: avstand gytefelt torsk. Mattilsynet har foreløpig ikke revidert retningslinjene med tanke på forsvarlig avstand mellom gytefelt og oppdrettslokaliteter for torsk, men med mange torskesøknader har vi begynt å vurdere dette, bl.a. ved å se på avstander til gytefelt og spredningsmodeller fra Havforskningsinstituttet.<br><br>Ved avstander under 5 km skal vi vurdere spredningsfaren for sykdom mellom ville og oppdrettede bestander. I dette tilfellet vil det være mer enn 5 km avstand og vi vurder at dette vil være en avstand som må anses som forsvarlig for å kunne etablere torskeoppdrett, hva sykdomsspredning til villtorsk angår. |
| 2022/ 022705 | Matfisk i sjø. Torsk. Møre og Romsdal | Ny lokalitet. Godkjenning | Strømmålinger<br><br>Miljøundersøkelser<br><br>Bunnkartlegging<br><br>Oversikt over internkontrollsystemet<br><br>Vurdering av behovet for konsekvensutredning<br><br>Beredskapsplaner | risiko for spredning av sykdommer. strømforhold, avstand til vassdrag, annen akvakulturrelatert virksomhet og andre former for grupperinger av akvakulturanlegg som har betydning for smitterisikoen. Avstand til nasjonale laksevassdrag og laksefjorder. lokaliteten vil ikke ligge i nærheten av nasjonal laksefjord. Naturmangfoldloven. vurderer særlig forholdet til ville torskebestander i denne sammenheng. HI har registrert lokalt viktig gytefelt for torsk cirka 6,7 kilometer fra lokalitet. Vi er usikker på hvilken eventuell påvirkning etablering av et akvakulturanlegg for torsk ved lokalitet vil kunne medføre med tanke på risiko for eventuell sykdomsspredning fra oppdrettstorsk til ville torskebestander. Vi vurderer at det er forholdsvis god avstand (mer enn 5 km) til nærmeste gytefelt. Vi ser ut fra strømmodelleringer at gytefeltene trolig vil være forholdsvis lite påvirket av vann fra lokalitet.<br><br>Bunn-sedimenter under anlegg. Strøm, oksygen, B-undersøkelse, C-undersøkelse, topografi og omkringliggende geografi, bunnforhold. |

| Saksnr. | Art, formål, Fylke | Type søknad. Resultat | Kunnskaps-grunnlag | Vurderinger (relevant for miljøhensyn) |
|---|---|---|---|---|
| 2022/ 079956 | Planter. Makroalger. Troms. | Ny lokalitet. Godkjent. | | «I henhold til forskrift om dyrehelse og forskrift om etablering av akvakulturanlegg, skal etablering av akvakulturanlegg, utvidelse av produksjonsomfang og annen vesentlig endring være godkjent av Mattilsynet. Disse forskriftene gjelder akvakulturdyr og ikke vannplanter. Etablering av akvakultur av alger er ikke gjenstand for vurdering med hensyn til fiskehelse eller fiskevelferd, så lenge aktiviteten ikke direkte kan få følger for annen oppdrettsvirksomhet dette regelverket gjelder for. Nærmeste akvakulturanlegg for fisk ligger mer enn 10 km fra planlagt lokalitet. Mattilsynet vurderer at påvirkningen av algeanlegget på nærliggende lokaliteter for fisk vil være ubetydelig. Vi har ikke andre merknader til søknaden. |
| 2022/ 144192 | Matfiskproduksjon i sjø. Laksefisk. Finnmark. | Knytte etablert lokalitet til grønn tillatelse. Godkjent. | | «Mattilsynet anser ikke omsøkte tilknytning av to grønne tillatelser til en lokalitet som en vesentlig endring. Det er derfor ikke behov for at Mattilsynet skal behandle søknaden.» |

### 8.3.4 Fylkeskommunen

*Tabell 8-4 Vedtak i saker om akvakulturtillatelser fra fylkeskommuner*

| N | Vedtak, type tillatelse | FK | Kunnskaps-grunnlag | Vurderinger | Avveinings-metoder utenom Laksetildelings-forskrift |
|---|---|---|---|---|---|
| A | Matfisk laksefisk. Permanent etablering av lokalitet | TF | Statsforvalters vurdering om miljø, Fiskeridirektoratet om miljø, resultat B-undersøkelse, miljøundersøkelse, strømmålinger, «registreringer i området». | Vurderer miljøforsvarlighet basert på SF og FDir uttalelser.<br><br>Finner ikke grunn til å avslå søknade ut fra hensyn til det «biologiske mangfoldet, økologiske effekter eller | |

| N | **Vedtak, type tillatelse** | **FK** | **Kunnskaps-grunnlag** | **Vurderinger** | **Avveinings-metoder utenom Laksetildelings-forskrift** |
|---|---|---|---|---|---|
| | | | Vann-nett: miljøtilstand vannforekomst.<br><br>Kystsoneplan.<br><br>Fiskeriaktivitet jf sporing av fiske-fartøy. | naturmiljøet for øvrig, jf. § 10 (nml)<br><br>Økosystemtilnærming og samlet belastning».<br><br>Vanntilstand er god økologisk og forventes ikke å bli dårligere klassifisert. Vurderes som mijlømessig forvarlig jf nml §§8-12.<br><br>Ikke i strid med verneinteresser. | |
| B | Matfisk laksefisk. Arealendring, samt etablere fôrflåte, ikke MTB-endring | TF | Statsforvalters vurdering om miljø, Fiskeridirektoratet om miljø.<br><br>Miljøundersøkelser. Vann-nett miljøtilstand vannforekomst. | vurdert med hensyn til biologisk mangfold, forurensning av det ytre miljø og økologiske effekter.<br><br>«Det omsøkte tiltaket vil gjennom etablering av fôrflåte og utvidelse av areal kunne gi mindre forspill og bedre økonomisk og miljømessig drift. Dette er forhold som tillegges vekt».<br><br>Nml-vurderinger. Vannforskrift-vurdering.<br><br>Verneinteresser. | |
| 1 | Wilsgård Fiskeoppdrett (TFK 0001,12.10.21)<br><br>Tilknytting av grønn tillatelse | TF og Norland | Tidligere tilsagn om tildeling av grønn tillatelse og klarert lokalitet | Ingen | Oppfordrer søkeren til å minimere bruk av lusemidler og ta hensyn til andre bruksinteresser |

| N | **Vedtak, type tillatelse** | **FK** | **Kunnskaps-grunnlag** | **Vurderinger** | **Avveinings-metoder utenom Laksetildelings-forskrift** |
|---|---|---|---|---|---|
| 2 | Greig Seafood Finnmark AS (TFLA 0002, 30.09.20)<br><br>Konvertering til grønn tillatelse | TF | Tidligere tilsagn om tildeling av grønn tillatelse,<br><br>Tidligere godkjent lokalitet | ingen | ingen |
| 3 | NRS Farming AS (TFH 0002, 24.09.20)<br><br>Visningstillatelse og samlokalisering | TF | Tidligere klarering av lokalitet | ingen | ingen |
| 4 | MOWI ASA (TFH 0003, 24.09.20)<br><br>Økt kapasitet | TF | Trafiklyssystemet, tidligere klarering av lokalitet | ingen | ingen |
| 5 | Nordlaks Oppdrett AS (N H 0047 – 0059, 31.03.22)<br><br>Konvertering av utviklingsstillatelser | Nordland | Tildigere klarering av lokalitet basert på tilgjengelig kunnskap og undersøkelser | Påvirkning på villaks | ingen |
| 6 | Salmonor AS (TR-ND 0014-0017, 20.07.22) Konvertering av utviklingstillatelse | Trøndelag | Tildigere godkjent lokalitet, Fiskeridirektoratets tilsagn | ingen | ingen |
| 7 | Atlantis Subsea Farming (TR-ND 0009, 26.04.22)<br>Konvertering av utviklingsstillatelse | Trøndelag | Fiskeridirektoratets vedtak | ingen | ingen |

| N | Vedtak, type tillatelse | FK | Kunnskaps-grunnlag | Vurderinger | Avveinings-metoder utenom Laksetildelings-forskrift |
|---|---|---|---|---|---|
| 8 | Ocean Farming AS (TRF 0012-0019, 27.10.20)<br><br>Konvertering av utviklingstillatelser | Trøndelag | Tidlegere klarerte lokaliteter | ingen | ingen |
| 9 | Emilsen Fisk AS (TR-ND 003, 07.10.20)<br><br>Økt kapasitet | Trøndelag | Trafikklyssystemet, tidligere klarerte lokaliteter | ingen | ingen |
| 10 | Hauge Aqua Farming AS (M VS0025, 09.10.20)<br><br>Lukket anlegg, ny tillatelse | MR | Offentlige databaser, sektormyndigheter sine vurderinger, generell kunnskap om lukkede anlegg | Nasjonal laksefjord | Fordeler (økt bærekraft ved bruk av lukket anlegg) avveier mulige ulempene som havari og smitte |
| 11 | Nekton Havbruk AS (M SM0037, 26.10.15)<br><br>Grønne tillatelser | MR | Tidligere klarert lokalitet, undersøkelser, åpne databaser, lokale kunnskap | Gyteområde for kysttorsk, yngelområde for sjøfugl | ingen |
| 12 | Eide Fjordbruk AS (H L 0024-0027, 08.04.16) Nye tillatelser på etablert lokalitet | Vestland | Tidligere godkjent lokalitet | ingen | ingen |
| 13 | Engesund Fiskeoppdrett AS (H FJ0026, 22.02.16)<br><br>Grønn tillatelse og visningstillatelse | Vestland | Tidligere tilsagn om tildeling av grønn tillatelse og klarert lokalitet | Særlige regler for Hardangerfjorden | ingen |

| N | Vedtak, type tillatelse | FK | Kunnskaps-grunnlag | Vurderinger | Avveinings-metoder utenom Laksetildelings-forskrift |
|---|---|---|---|---|---|
| 14 | Sulefisk AS (SFSU 0038, 17.09.15)<br><br>Grønn tillatelse | Vestland | Tidligere klarert lokalitet, vurderinger av sektormyndighetene | ingen | ingen |
| 15 | Greig Seafood Rogaland AS (RB 0013, 09.10.20)<br><br>Økt kapasitet | Rogaland | Trafikklyssystemet, tidligere klarerte lokaliteter | ingen | ingen |
| 16 | Eidesvik Laks AS (R S 003, 23.09.20)<br><br>Økt kapasitet på eksisterende lokalitet | Rogaland | Tidligere godkjente lokaliteter | Ingen<br><br>Vurdering: Tilknytning av den nye tillatelsen på lokalitetene medfører ingen endring av godkjent areal eller lokalitetsbiomasse.<br><br>Det er fastsatt at det skal tillates en økning av tillatelsesbiomassen i de grønne produksjonsområdene. Hensyn knyttet til naturmangfoldloven og miljømessig bærekraft er ivaretatt, jf. Meld. St. 16 (20142015) «Forutsigbar og miljømessig bærekraftig vekst i norsk lakse- og ørretoppdrett.» | ingen |
| 17 | Rogaland Fjordbruk AS ( R SD 0033, 23.09.20)<br><br>Økt kapasitet, samlokalisering | Rogaland | Ikke nevnt | Ingen | Ingen |

| N | **Vedtak, type tillatelse** | **FK** | **Kunnskaps-grunnlag** | **Vurderinger** | **Avveinings-metoder utenom Laksetildelings-forskrift** |
|---|---|---|---|---|---|
| 18 | MOWI ASA (VAF 0023, 25.07.19)<br><br>Økt kapasitet | Agder | Trafikklyssystemet, tidligere godkjent lokalitet | Ingen<br><br>Vurdering: | ingen |