The Fishery and Aquaculture Industry Research Fund (FHF)

Photo: Per Eide © Norwegian Seafood Export Council

MODERN SALMON HARVEST

Project Owner: FHF, Project Manager: FHL

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INTRODUCTION

The Norwegian fish farming industry has undergone prodigious growth since its start four decades ago. In that time, production volume has grown year after year, peaking in 2008 with almost 900,000 tonnes of salmon and trout, and turnover of around NOK 19 billion.

In the modern food production industry, animal welfare has almost become synonymous with good finances, and wellbeing is an important part of that. In fish farming, the focus on **fish welfare** is changing our production setup, as this is an important aspect of the production of high quality food. Moreover, both statutory and customer requirements are helping accelerate changes to and the establishment of new production methods in the industry.

In a value chain covering two to three years from brood stock, hatchery, the production in cages, transport, harvest, and on to consumers in markets throughout the world, high quality and good fish welfare are important foundations of a future-oriented industry.

The Norwegian aquaculture industry takes all of these challenges seriously and requires advanced skills and welfare-adapted technology in all links of the value chain. The ethical and humane harvest of fish is part of this, and has been the basis of major initiatives to reorganise harvesting methods used in the fish farming industry.

This brochure summarises the results of a number of projects over recent years carried out under the auspices of the Norwegian Fishery and Aquaculture Research Fund (FHF)'s Action Plan Salmon programme, led by the Norwegian Seafood Federation (FHL).

THE HARVESTING PROCESS

In the infancy of the industry, salmon was harvested at the cage-side and brought to land. As the industry and volumes grew, the harvesting process was «industrialised» and is largely handled as follows:

- Starvation prior to harvest
- Crowding and pumping onboard well-boats
- Crowding and pumping to transit nets or
- Crowding and pumping directly to stunning and bleeding
- Live chilling (RSW) and stunning
- Gutting and packing

Companies which process fish to fillets often mature the fish as a result of having to wait approximately three days for the fish to go through rigor mortis. However, in recent years, producing fish before the onset of rigor has become more important for many processors. However, this relies on providing optimum fish welfare in order to avoid stress.

PRE-RIGOR FILLETING

Pre-rigor filleting involves fish being harvested and filleted before the onset of rigor mortis.

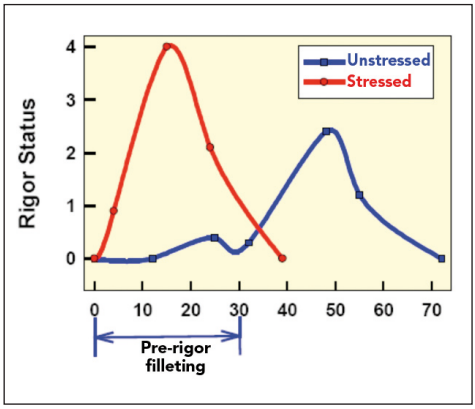
Pre-rigor fillets can be on the market three to five days earlier compared to post-rigor. This has the following practical advantages:

- Customers can be offered fresher fish
- Firmer muscle tone
- Slightly brighter red, less gaping and less drip loss
- Extended shelf-life
- If fish is to be frozen, it is advisable to freeze fish prior to the onset of rigor for optimum fillet quality
- Reduced storage and refrigeration costs

The processing of pre-rigor fish results in fillets which are somewhat different to fish processed in the traditional manner. Fillets produced immediately after harvest shrink, get thicker and are darker in colour. Firmer fillets are harder to proc-

ess and make pin-bone removal more difficult. Mechanical bone removal still presents a technological challenge, and is still in the development stage.

It is crucial to have fish with low levels of stress in order to successfully process pre-rigor fish. The pH of the white muscle in unstressed fish is usually quite high, around pH 7.5. Stored on ice, it can take up to 24 hours before onset of rigor. This is the key to effective pre-rigor filleting.



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MODERN HARVEST TECHNOLOGY

In recent years, alternative methods for stunning fish have been introduced. The need for change is the result of customers and the industry itself wishing to see good fish welfare practices implemented. It is also the result of statutory requirements (Regulations for harvest sites and production facilities for aquaculture animals). The fish has to be stunned prior to bleeding and must die as a result of blood loss from the brain. This is done by cutting the arteries in the gill arches. The use of CO_2 to anaesthetise the fish is one of the main causes of stress and reduces the time until the onset of rigor mortis. Recent research has shown that crowding and pumping are also important factors for stress-related rigor. CO_2 is allowed as means of sedation, but will be banned as an anaesthetic once the industry has appropriate alternatives.

The handling of live fish during harvest procedures will nevertheless provoke stress responses. It is important to find **solutions** which make the process as gentle as possible, both from an animal welfare and product quality perspective. Ethical stunning and harvest methods for fish require:

- Instantaneous death, or
- Instantaneous loss of consciousness which lasts until the fish is bled, or
- If anaesthesia is slow, fish must not experience pain, fear or significant discomfort until they lose consciousness.

In order to establish whether a fish is **unconscious**, look for spontaneous autonomous movements, response to touch/stimuli and reflexes. The cerebral functions of fish which react to external stimuli with flight reactions may also be regarded as being intact. Reflexes such as gill movements and rolling eyes (i.e. their eyes follow the horizontal when the fish is rocked from side to side) disappear later, and fish do not lose consciousness until these reflexes are no longer present. However, one must be aware that reflexes may be absent in conscious fish which are still/paralysed after chilling.

Today, companies must possess expertise in fish welfare and must be able to manage this in practice.

Recent development has moved in the direction of two methods for the stunning of fish:

- Electrical stunning
- Percussive stunning

Electrical stunning
Fish are stunned when the current passes the threshold at which it penetrates the animal's brain and makes it unconscious. The same method is used to stun mammals and poultry. In the case of fish, modern electrical stunning equipment is based on exposing the whole fish to an electrical current. Systems have been developed for either stunning fish in or out of water (dry stunning). Our projects have examined the following electrical stunning system suppliers:

– Stansas, supplied by Seaside AS
– Single stunner, supplied by Sotra Maskin Produkter AS

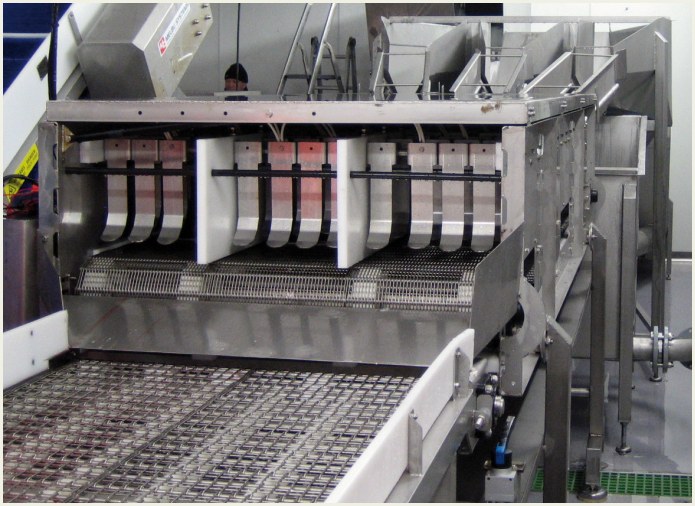
Sotra Maskin Produkter AS
Sotra Maskin Produkter launched its Singelbedøver (Single stunner) in May 2005. As the name implies, this technology stuns fish one at a time. The procedure is traditional and this technology uses both landing and pumping via pipes directly to a straining box and then into an electrified groove. The actual stunner consists of two half groves. When the fish touches both sides, it

An electric stunner from Sotra Maskin Produkter AS. Photo: Reidar Skorpen

is electrocuted and stunned. Sotra Maskinprodukter also produces a Multi-Stunner.

Electrical stunning – Stansas

The electric stunner from Stansas is supplied with or without an accompanying percussive stunning and bleeding machine. The fish are fed in and the water strained away before sliding into the electric stunner. This consists of a horizontal metal netting conveyor belt, which makes up one pole of the electrical circuit, over which are suspended 10 rows of 4–5 lateral metal slats, forming the other pole of the circuit. The slats are hinged individually and ensure contact with the fish regardless of its size. The conveyor belt is narrow enough to prevent normal sized salmon lying crosswise; a position which experience shows increases the risk of



An electric stunner from Seaside AS. Photo: Frode Håkon Kjølås

spinal rupture and subsequent blood spots.

Stunning and bleeding machine, SI-5
Produced by Seafood Innovation in Australia, distributed by Stranda Prolog AS in Norway

The stunning machine causes fish to lose consciousness by concussion and brain haemorrhage. The system exploits natural fish behaviour by getting the fish to align properly and actively swim to the place of percussion. Fish are pumped/landed from the harvest net or well-boat and over to the back of a shallow vat of water. This vat is dark in colour and is covered with black rubber. There are «stalls» at the opposite end of the vat with outlets down to the stunning machines. Another set of machines make the bleed incision before the fish end up in an exsanguination tank.

HARVEST AT THE CAGE

Harvest of fish at the cage site (Dead-haul) is an «old» method which was used during the infancy of the fish farming industry. Today, most fish are transported alive to the processing plants. This method, which showed successful results regarding both fish quality and fish welfare, has many advantages.

<u>The advantages of dead-haul:</u>

- Improved hygiene in closed transport
- Eliminates the problem of transport fatalities caused by high sea temperatures and weak fish
- Better fish welfare compared with live transport
- More efficient transport to processors with 5–6 times higher density
- Reduced starvation time provides better feed conversion rates and larger volumes
- Completely chilled fish delivered to the processing plant (RSW)

Experience from industrial trials shows that if long pre-rigor times are important, percussive slaughter is better and it may take more than 40 hours before

onset of rigor mortis. Nevertheless, it is important not to crowd fish too much and to have a gentle pumping/landing process.

More research is being carried out on the subject of «dead-haul» and quality under the auspices of the FHF Action Plan Salmon programme.

Harvesting at the net-side. Photo: Kjell Midling

10 CHECKLIST FOR FISH WELFARE AT HARVEST

The following items are intended for use as a checklist for fish welfare during harvest as part of an internal inspection system.

Waiting cages

The conditions in the waiting cages must be equivalent to ordinary farming conditions except that fish are not fed. Density and water quality must not differ from farming conditions. Fish with visible injuries, dead fish, lice-infected fish etc should lead to contact with the supplier or carrier.

- Do the conditions comply with good aquaculture practice?
- Are fish swimming calmly?

Harvest cages

Waiting cages become harvest cages when preparations are made for harvest, usually by crowding. Oxygen saturation must be checked, particularly at high temperatures. Acceptable levels for oxygen are 70–80% saturation.

- Is oxygen saturation measuring equipment easily available?
- Is there oxygenation equipment?
- What criteria apply to starting oxygenation?

Crowding

The degree of crowding and the time fish are kept crowded is of great significance to fish welfare. Close and/or long-lasting crowding exhausts fish and reduces product quality. The location and the design of pump inlets also affect

Crowding. Photo: Alistair Smart

how much fish need to be crowded. Enduring stress can lead to loss of mucus and subsequent scale loss. Blue/green colouration on fish indicates stress.

- What method/equipment is used for crowding fish?
- How long are fish kept crowded?
- Can fish be crowded several times?

Level 1 (Target):
The fish are swimming calmly, but not necessarily in the same direction, no dorsal fins are breaking the surface and no white sides are visible.

Level 2 (Good):
There is normal swimming activity close to pump intake, few dorsal fins breaking the surface and no white sides visible.

Level 3 (Undesirable):
There is anxious behaviour with frantic swimming in different directions, more than 20 dorsal fins breaking the surface and some white sides visible most of the time.

Level 4 (Unacceptable):
There is extremely high activity with haphazard swimming, surface panting and declining activity as fish become exhausted. Many dorsal fins and white sides are visible everywhere and it is impossible to maintain an even pumping rate.

Level 5 (Extreme Crowding):
The fish are exhausted and will die if they are not given more room. Many fish are floating on the side.

- Are there areas of shallow water or pockets in the net where fish can get caught?
- Is there supervision during crowding (personnel on deck)?
- Is there a difference in fish colour at the beginning and the end?
- Fish behaviour, the number of dorsal fins above the surface and the number of white fish sides visible can provide a measure of the degree of crowding.

Pump and pipe systems

In general, siphon pumps (Mammut) are gentler than vacuum pumps and double pumps are considered gentler than single pumps. Lift height on the suction side (vacuum side, next to pump) should be as low as possible; whilst the height fish are «pushed up» (pressure side) is probably of less significance. Therefore, pumps should be located near the surface (floating jetties in areas with large differences of ebb and flow). Windows in pumps allow operators to observe the fish, but light can have an adverse impact on the fish. The number of meters of pipe fish travel through (and the pipe dimension) is important for the oxygen content of the water. **A rule of thumb is that salmon consume the oxygen in 0.5 litres of water per kilo fish per minute.** It is important that the pipe surfaces are smooth. Be careful about the design of joints. Check open pipe parts, which are used for example for pumping from well-boats. If there are sharp flanges there, it is very likely the inside of the pipes in use will have similar flanges. Recently lacerated fins on fish may indicate the presence of sharp edges in pipes/pumps. Bends in pipes must not be too acute and 90° angles should be avoided. Sharp bends can cause sores on snouts and bruising of muscles.

- What kind of pumps are used?
- Where are the pumps located?
- For vacuum pumps: lifting height on the suction and pressure side?
- Are the pipes smooth on the inside?
- Are joints located in the right direction relative to the movement of the fish in the pipe?

- Are there many recent fin injuries and/or recent sores on snouts (examine dead fish)?
- Do customers/cutting departments report bruises on fillets?
- Are there fish with crushing injuries (which may indicate bad closing devices in pumps)?

Wet brailing

When using wet brailing, it is important to ensure there is plenty of water in the brail and that the biomass is not too great so as to avoid friction between fish and external load.

Straining (and sorting)

Time out of water is stressful for fish. The time in air should therefore be as short as possible. Right angle passages for fish should be avoided. Check the speed of fish in such passages as well. Fish must not be moving so fast that they are thrown against the walls.

- Number of metres and seconds fish are out of water?
- Number of passages with sharp (90°) angles?
- Are fish being thrown against edges, walls or other obstacles during straining/sorting prior to stunning?

Live chilling

Given the fact that a large part of the water in a live chilling tank must be recirculated, the quality of water in the tank progressively deteriorates. Carbon dioxide accumulates and this reduces the pH of the water. Total ammonium, organic materials and other components also accumulate. The water becomes less clear and often reddish in colour, which must be the result of bleeding (such as bleeding from gills and physical injuries). Foam may form, probably as a result of mucus loss by fish, which increases stress. Oxygen is added and oxygen saturation should not fall below 70–80 %. The water temperature should not fall below -0.5 °C for salmon. If the water temperature is lower than approx -1.5 °C, salmon can die of hypothermia. Rainbow trout are more sensitive to low seawater temperatures than salmon and encounter problems at +0.5 °C. Violent activity when fish enter

the live chilling tank may be due to temperature shock (temperature drop from the water environment where the fish come from), effect of pumping or low oxygen levels. If CO_2 is added, behavioural reactions may also be caused by CO_2/low pH. Live chilling is regarded as a **sedation method** and not a stunning method. Therefore, it must be combined with a stunning method prior to bleeding. It is important to be aware that fish which are chilled live will have slower responses, and eye reflexes (vestibulo-ocular reflexes) may be particularly sluggish and difficult to see.

- How do fish react when entering the tank (the degree of agitation)?
- What is the temperature where the fish come from?
- What is the temperature in the live chilling tank?
- What is the pH of the water?
- If CO_2 is added to the water, how much and how is it regulated?
- What is the oxygen saturation (measured both at inlet and outlet)?
- How long do the fish stay there?
- What is the degree of foaming?
- What is the extent of red colouration in water?

Stunning equipment in general

All stunning equipment should be properly installed and maintained in order to operate as intended. Uneven input of fish can affect the functioning/capacity of the equipment. Stunning must be viewed in relation to the design of the rest of the harvest line.

- What method of stunning is used?
- How is the fish influx to stunning controlled?
- Is the fish flow even?
- Are there good communications between the person in charge of pumping in and the person responsible for stunning/bleeding?
- How well is the equipment maintained?
- Is a log kept of maintenance, about what is done, when and by whom?

Comments on electrical stunning

It may be difficult to distinguish electrical stunning from electrical immobilisation (i.e. partially paralysed but conscious fish). Therefore, it is important to adjust

machinery in accordance with the manufacturer's instructions, which should in turn be in line with recent knowledge (research results). Defective cleaning can increase resistance in the system and thus reduce the strength of the current fish are exposed to. Electrical stunning is usually reversible so that fish can regain consciousness a few minutes later if they are not bled immediately. Keep in mind that live chilling can make it particularly difficult to assess reflexes.

- Has equipment been aligned according to the supplier's instructions?
- Can fish be exposed to current without the current passing through their heads?
- Are fish immobilised immediately when they come into contact with the current?
- Are the electrodes free of fouling?
- How long are fish exposed to the current?
- Are fish bled immediately after stunning?

It is important for fish welfare that fish are electrocuted through the head first for rapid stunning. Systems for this have now been developed by Melbu Systems AS.

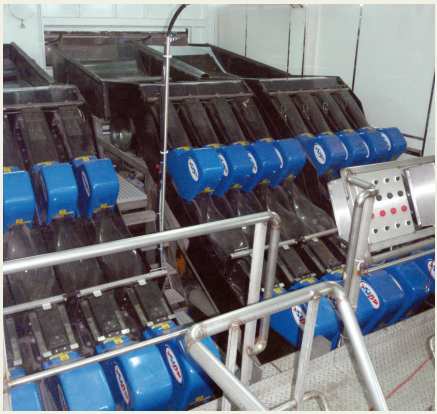
Percussive stunning using SI-5

This system is based on exploiting normal behavioural responses whereby fish actively try to leave a dark vat towards the flow of water (and light) and thus end up in the groove that takes them to the percussive stunning machine. If fish are under stress, they will not line up properly. They may swim calmly around the inlet and must be forced in the di-

One way aligning fish, developed by Melbu Systems AS. Photo: Kai Jensen

rection of the outlet by increasing the fish density in the vat, or they are drawn passively with other fish. In such cases, the fish must be fed «manually» out of the behaviour tank.

Start by taking a look at the direction of fish coming out of the stunning machine to assess their condition and the need for «help». It is also possible to observe stunning and stabbing and assess the number of fish which need backing up with a manually operated stunning machine. (Machines should preferably have a counter which can be used to register the number of nonconformities).



SI-5 is supplied by Stranda Prolog AS. Photo: Kjell Midling

After/during stunning:

- Are all fish coming onto the observation table the right way round having passed the SI-5 stunner/bleeder?
- The number of squirming fish?
- Are the stunning marks located correctly?
- The number of fish without stunning marks or marks in the wrong place?
- Are fish turned as they should be (in case of automatic bleeding)?
- Are the bleeding incisions precise and correctly placed?
- Do fish often get stuck in the machinery, and how is this dealt with?

The behaviour vat:

- The appearance of the fish?
- Fish density in the behaviour vat?
- The number of fish out of balance?
- Do fish swim out themselves facing in the right direction?
- If not, what is the water level?

Observation on bleeding table

- Are fish lying still?
- Is there movement and, if so, are there conscious fish with clonic convulsions or squirming?
- Is there any panting and/or are there eye reflexes?
- Do fish react to bleeding or other handling?
- The proportion of non-stunned fish?
- Is there functioning backup equipment?
- Can the flow of fish to bleeding be adjusted and can the staff there be adapted?
- Are there non-stunned and non-bled fish in the exsanguination tank?
- What measures are taken to prevent this?
- For SI-5 with automatic bleeding: the proportion of fish with exsanguination cuts in necks or rear parts?

Exsanguination tank

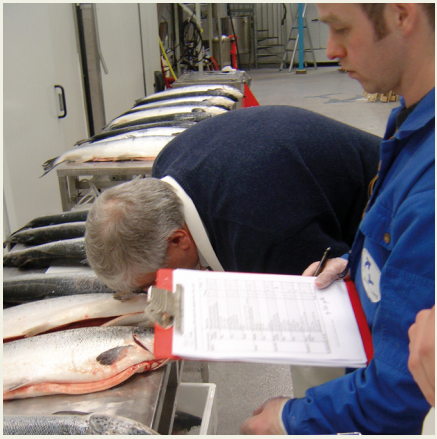
- Can swimming activity be seen in the exsanguination tank?

After the exsanguination tank

- Are there signs of life (panting movements, eye movements) on the conveyor belt to the gutting machine?
- Is there equipment for killing fish (iron bars etc) available to staff operating the gutting machine?

Quality

Less than 24 hours pre-rigor time for ice stored fish after percussive stunning shows that fish have been exposed to handling stress. The normal pre-rigor



Quality Control. Photo: Kjell Midling

time for fish taken directly from the slaughter net in Norway is 10–12 hours. Due to direct impact on musculature, electrical stunning results in reduced pre-rigor times. Where fish are completely exhausted upon killing, the onset of rigor takes only approx two hours.

- Does the company know the time taken for rigor mortis to set in, and how long this is?
- Downgrading due to external (sores jaw breaks) and internal (broken backs, bleeding) injuries?
- Complaints about injuries from customers (bleeding etc)?

The handling of other fish

Although there are good procedures for handling live fish carefully, this behaviour is not always transmitted to comprise fish in general. Take a look at the floor and in the collection vat for rejected fish.

- What happens to fish squirming on the floor?
- How are pollock, wrasse, harvested fish with deformities and other «valueless» fish treated?
- Are the fish rejected from the conveyor belt killed?

Break procedures

Production is continuous at some facilities (employees do not all take breaks at the same time), while at other facilities all employees take breaks together. When the harvest is stopped, fish should not be left in pipes or densely crowded in harvest nets. Fish in harvest nets will be crowded longer, and this will exhaust fish more. Fish left in water-filled pipes can die from a lack of oxygen. The approximate amount of oxygen consumed by salmon is that in 0.5 litres of water per salmon kilo per minute. Fish left lying in places without water will suffocate.

- Are pipes emptied before breaks?
- Is it possible to evacuate pipes during operating stoppages?
- Are breaks adapted to trawls?

Training

Training is important for several reasons: to establish the foundation for good attitudes through an understanding for fish as a living animal, for recognising the

signs to be looked for when assessing stress and the degree fish are stunned, for proper operation and maintenance of equipment and reacting to problems and for the ability to correct possible faults.

- Have employees in contact with live fish taken a training course which includes proficiency in fish welfare?
- Have all employees who operate equipment which affect live fish (stunning equipment etc) been trained in the use of that equipment?
- Are they able to detect faults, such as signs of poor stunning?
- Have enough people been trained in maintaining and repairing equipment?
- Are these people always present at site during harvest?

All reports can be downloaded from the FHF website at www.fhf.no.

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Project Manager: Kristian Prytz, FHl, phone +47 99 58 53 87, kristian.prytz@fhl.no
Brochure prepared by: Roy Robertsen
Graphic production: al:design, Bodø

Norwegian Fishery And Aquaculture Industry Research Fund (FHF)
PO Box 429, Sentrum
0103 Oslo
Norway
Phone: +47 23 89 64 08
E-mail: post@fhf.no
www.fhf.no