NordCAW seminar 15th November 2018, Oslo, Norway:

Challenges and actions taken to improve fish welfare in Nordic aquaculture

Program

Time	Tentative title	Speaker	Affiliation	Country
09:30-09:35	Welcome and practical information	Cecilie Mejdell	NVI	Norway
09:35-09:55	Sentience in fish: pain and the role of consciousness	Janicke Nordgren	NMBU	Norway
19:55-10:15	Cognition in fish: How smart are fish?	Tore Kristiansen/ Cecilie Mejdell	MRI	Norway
10:15-10:45	Fish farming in the Nordic&Baltic area – a brief overview	One per country		All
	Coffee & strech legs			
11:05-11:20	Measuring welfare – welfare indicators	Stine Gismervik	NVI	Norway
11.20-11:40	Enriching the captive environment of fish – why and how	Pekka Hyvärinen	Luke	Finland
11:40-12:00	Practical work with fish health – the fish health service	David Persson	AVF	Norway/ Sweden
12:00-12:20	A non-invasive method for fish health control: e-DNA	Ilka Nousiainen/ David Arney	Estonian University	Estonia
	Lunch			
13:10-13:30	Cleaner fish - welfare concerns	Trygve Poppe	NMBU	Norway
13:30-13:50	Future farming technologies in large scale fish farming - prospectives	Leif Magne Sunde	Sintef	Norway
13:50-14:10	New technology - same old problems?	Bjørn Olav Rosseland	NMBU	Norway
	Short break			
14:30-14:50	Gene technology/CRISPR - welfare and ethics implications	Hilde Mellegård	Bioteknologi-rådet	Norway
14.50-15:20	Fish slaughter: Is there a humane way to harvest and slaughter farmed fish?	Albin Gräns	SLU	Sweden
15.20-15.50	Welfare actions in fisheries	Hanne Digre	Sintef	Norway
15.50-16:00	Concluding remarks, end of seminar	Lotta Berg	SLU	Sweden

Welcome and practical information

On behalf of NordCAW, Cecilie Mejdell (senior scientist at the Norwegian Veterinary Institute) opened the seminar and welcomed the audience and introduced the presenters.

Sentience in fish: pain and the role of consciousness

Janicke Nordgreen, Associate professor, Norwegian University of Life Sciences.

Abstract missing

Cognition in fish: how smart are fish?

Cecilie M. Mejdell, DVM, senior researcher Norwegian Veterinary Institute

It has been claimed that since the fish brain lacks a neocortex, fish are unable to feel an think; they have only reflexive, innate behaviours. However, all fish species studied so far area ble to learn. Their hunting skills improve with practice, they can learn by watching others and thereafter modify own behaviour, and learned behaviour may be transferred to new generations. Koi fish area ble to distinguish music styles, and show reversal learning. Fish have a good memory, and aversive events like being hooked may be remebered for years. There is sparse evidense of tool use in fish, but tuskfish open clams by smashing them against rocks and some captive cod learned to use an external tag to more effectively manipulate a feeder. Individual recignition is widespread across fish species. They may show preferences for certain conspecifics based on previous experience. Fish may cooperate within a group, and hunting cooperation with individuals of other species (e.g. between groupers and moray eel or octopus) is well documented. The pointing behaviours displayed fulfil criteria of being a referential gesture, otherwise only attributed to humans, great apes and ravens. The mutual relationship and interactions between a cleaner fish and its client indicate that fish are able to understand the intention and thoughts of other individuals. There is also some evidense that wrasse fish may has passed the mirror test, indicating self consciousness. In conclusion, fish are sophisticated animals with complex behaviours, and we have for too long underestimated their cognitive abilities.

Fish farming in the Nordic & Baltic area – a brief overview

Denmark: Ida T. Møller; Estonia: David Arney; Faroe Islands: Sara Vallin; Finland: Pekka Hyvärinen; Iceland: Sigridur Gisladottir; Latvia: Liene Ansone; Lithuania: Vytautas Ribikauskas; Norway: Brit Tørud; Sweden: Per Hjelmstedt.

Short presentations from all countries were given.

Abstracts missing.

Measuring welfare- welfare indicators

Kristine Gismervik, Norwegian Veterinary Institute

Welfare in fish can be challenging both to define and measure. Three normal interpretations of welfare focuses on 1) The animals own experience including feelings like fear and pain, 2) The animals biological function including good health and normal development, or 3) A most natural life. Taking this different views into considerations, welfare can be defined as the animals individual mental and physical state by coping with its environment. In FISHWELL, welfare is defined as the quality of life as perceived by the animal itself, according to Stien et. al. 2013. Welfare can also be viewed as how the welfare needs of the animals are met (resources like feed, environment like water quality, health, behaviour and feelings). Welfare indicators are measurements or observations that give information about the degree of fulfilment of welfare needs. Operational welfare indicators (OWIs) are indicators that can be used "on farm". They should reflect welfare, be reproducible, simple to record and interpret. "LABWIs", laboratory based welfare indicators, is defined as indicators that need some laboratory processing. The FISHWELL handbook describes welfare indicators for farmed Atlantic salmon, and can be viewed as a toolbox of knowledge on how welfare can be measured in different production systems, operations and during development of new technology. The knowledge will evolve further as more welfare measurements are performed and the knowledge base is extended. Although it's important that the information on welfare measurements are species, life stage, system or operation specific, the FISHWELL handbook on salmon can be a framework to look at also for developing welfare indicators in other fish species. The sister handbook of farmed rainbow trout will come in 2019. The FISHWELL handbook is a result of collaboration between Nofima, the Institute of Marine Research, the Norwegian Veterinary Institute, Nord University (all Norwegian institutions) and the University of Stirling in the UK. It is financed by FHF (Norwegian Seafood Research Fund), and the English version of the book can be downloaded here: https://nofima.no/en/nyhet/2018/11/the-english-version-of-the-fishwell-atlantic-salmon-welfare-handbook-is-out-now/

Enriching the captive environment of fish - why and how

Pekka Hyvärinen, Natural Resources Institute Finland (Luke), Paltamo, Finland

Recent evidence suggests that an enriched rearing environment has significant positive effects on several traits underlying growth and well-being of fish. Simple enriching method includes changes in water current speed and direction and changes in water level. In addition enriched tanks have different size of structures (gravel and shelters) on the bottom depending on the size of fish. The method was developed and tested at the Kainuu Fisheries Research Station (www.kfrs.fi) of Luke, together with Universities of Jyväskylä, Helsinki, Eastern Finland and Oulu. Results show that juveniles or smolts reared with the enriched method: 1. had higher feeding rate of natural food and faster growth after release, 2. had higher survival in nature, 3. were less vulnerable to angling, 4. had higher disease resistance and 5. had lower mortality in the rearing tank than fish reared with the standard method. The tested enriching method was applicable for production scale densities and the results suggests that it is economically and ecologically viable solution for rearing Brown trout and Atlantic salmon juveniles and smolts.

Practical work with fish health –the fish health service

David Persson, Leader of the Norwegian association of aquatic veterinarians (AVF)

Preventive medicine is the key to success in the fish production. Without good health and welfare the production is not sustainable in the long run and the economy of the production is of course dependent on biology of the fish. In Norway there is mandatory farm visits from veterinarian 6-12 times per year in each farm with fish. This is regulated in the legislation to ensures good follow up on the fish health and to detect and prevent severe diseases from spreading. All fish are vaccinated against a series of diseases and therefore there are almost no antibiotic treatments against bacterial diseases in the industry.

Challenges to fish health today in Norway are the multiple treatments necessary to keep the amount of salmon louse below the regulatory limits, resulting in increased overall mortality in the sea phase of the production. There are widespread resistance in the salmon lice population against the common pharmaceutical drugs used to treat against the lice. This has resulted in development of new technology and methods to remove the lice from the fish without pharmaceuticals, where the welfare of the fish not always has been prioritized enough.

Veterinarians play an important role in the fish production and is the key to further development of the industry and to help technology to solve the biological challenges in the production.

A non-invasive method for fish health control: e-DNA

Ilka Nousiainen (presented by David Arney).

The use of environmental DNA (eDNA) is an emerging method for the detection of species present in a range of different environments (soil, glaciers, aquatic sediments and water bodies). This non-invasive method negates the need for the direct observation of the organisms and the catching, handling and extraction of their body tissue for analysis. This method can provide rapid results (within an hour), but some unresolved issues include: the need for purification of samples as environmental samples often contain PCR inhibitors, DNA degradation due to environmental effects, and for analysis requiring complete genomic DNA invasive methods remain necessary. However, the detection of rare or invasive species and pathogens in a broad range of environments is a potential application of this method. Salmonid fishes in the wild and at fisheries, in the northern hemisphere, suffer from proliferative kidney disease (PKD), which is caused by an immune reaction against the parasite *Tetracapsuloides bryosalmonae*. This is an endoparasite, whose primary hosts are bryozoans, and whose secondary hosts are salmonid fish. The spores of the parasite are released and may infect the fish during the spring and summer, and the symptoms following infection, swelling of the kidney and consequent kidney dysfunction and anaemia, are temperature-dependent (above 15^0 C is the threshold for symptomatic expression, below this temperature infection can occur but symptoms are mild or non-existent). A study has been designed to investigate the spatial and temporal occurrence of the parasite in rivers. The method of eDNA will be used to detect, quantify and monitor *T. bryosalmonae* (as well as the bryozoan hosts) in rivers. As the parasite is hard to detect directly, presence or absence of the parasite is usually inferred from secondary sources (fish or bryozoan samples) and these methods involve the killing of sampled fish. They are also not accurate estimates of parasite abundance in the environment as individual variation in parasite resistance and proliferation within the host can influence the parasite load. Therefore, extracting eDNA from water samples is a more feasible and accurate detection method. It will also not adversely affect the welfare of the free-living fish in the rivers investigated.

Cleanerfish - welfare concerns

Trygve T. Poppe, Professor Emeritus NMBU

Cleanerfish (wrasses and lumpsuckers) are widely used in Norwegian aquaculture in order to keep the number of sea-lice (*Lepeoptheirus salmonis*) on the farmed salmon at an acceptable level. They are kept in the cages in co-culture with the salmon. Cleanerfish are caught in traps along the coast (wrasses) or farmed (lumpsuckers). The production of lumpfish has reached a level of more than 25 million individuals making them the second most important farmed species in Norway after salmon.

The vast majority of these fish will die from handling stress, diseases and unspecified causes during the production of the salmon. Lumpfish appear to be very susceptible to diseases and a vast number of serious parasitic, bacterial and viral diseases have been diagnosed in recent years. Cleanerfish are protected under the same law (The animal welfare act) as traditional farm animals and salmon, but a mortality close to 90% seems to be considered as acceptable.

The sad conclusion is that cleanerfish are produced only to become “slaves” and are doomed to die during the production. This enigmatic fact raises important ethical and animal welfare questions that are important to address for those involved in the production at various levels.

Future farming technologies in large scale fish farming – prospectives

Leif Magne Sunde, Research Manager Aquaculture Operations Seafood Technology, SINTEF Ocean, *Trondheim, Norway*

The Atlantic salmon farming industry in Norway has developed over two phases; from using wooden cages (ca 1970-1995) to large plastic cages (ca 1995-2015), and is now entering a third phase where several new farming concepts, including closed systems on land as well as open and closed systems in fjords, coastal areas, and at exposed sites are introduced. The two main drivers for this diversification in production systems are the challenges related to sea lice (*Lepeophtheirus salmonis*) and the development licences announced by the Norwegian authorities in Nov. 2015. In total, 104 concepts have been submitted until the application deadline in Nov. 2017. Per Nov. 2018, 8 proposals are approved, and so far, 3 of the concepts have been built.

This increased diversification opens for a broader use of the production areas, both on land, inshore and offshore. At the same time, these new concepts are more complex and require a higher competence regarding design and operation. With the production system's increase in size and abundance of fish populations (up to 1 mill. individuals per cage), e.g. movements of the water in rigid structures might bring up new challenges for the produced fish. Related to fish welfare several questions should be raised to ensure that the conditions are suitable: how can we have sufficient control in this farming systems?; how can we be sure that we 'see' the individuals, and operate within their 'expectations'?; how can we compensate through new technologies and get 'closer to the fish'?.

To secure good fish welfare, both in conventional cages as well as in new production concepts, it is important to strengthen the 'bridge' between biology and technology. This can be achieved through proper testing of the technology in an objective way before it is implemented in the industry. To operate the farming systems of today and tomorrow, it is furthermore important to develop new technologies enabling a closer follow-up of the fish in the production. In 2017, SINTEF Ocean and collaborating partners published the article "Precision fish farming: A new framework to improve production in

aquaculture" (Føre et al.), describing a concept whose aim it is to apply control-engineering principles to fish production, thereby improving the farmer's ability to monitor, control and document biological processes in fish farms. The article suggests new principles for day-to-day management and operations in existing and future farming technologies, and how new sensors, vision technology and machine learning, as well as algorithms and autonomous solutions, can contribute to secure better conditions for the farmed fish in the future.

References:

Føre, M., Frank, K., Norton, T., Svendsen, E., Alfredsen, J.A., Dempster, T., Eguiraune, H., Watson, W., Stahl, A., Sunde, L. M., Schellewald. C., Skøien, K. R., Alver, M. O., & Berckmans, D.. Precision fish farming; A new framework to improve production in aquaculture. Biosystems Engineering, http://www.sciencedirect.com/science/article/pii/S1537511017304488?via%3Dihub

New technology - same old problems?

Bjørn Olav Rosseland. Dr. philos., professor emeritus in ecotoxicology Faculty of environmental sciences and natural resource management, Norwegian university of life sciences, Ås, Norway

A good freshwater (FW) quality ensuring fish welfare, includes a proper mix of ions, organic substances, metals and gasses, and Norwegian legislation set limits to many of these parameters. In Norway, nearly 70% of Atlantic smolt production still occur in flow-through systems, while the rest are produced in Recirculating Aquaculture Systems (RAS). In recent years, onshore production of postsmolt in RAS, i.e. in a salinity > 10‰ to ensure a sea water (SW) adapted fish, has been tested. All systems need a lot of freshwater, which now in Scandinavia are undergoing chemical changes reflecting a reduction in “acid rain” and possibly a temperature increase. Total organic carbon (TOC or humics) are increasing while calcium (Ca) decreases. Disinfection of new water in RAS with ozone (O_3) wil split the TOC into low molecular mass (LMM) humics while releasing TOC-bound aluminium (Al) and iron (Fe) into LMM bioavailable toxic forms reacting with gill tissue. The same release of bioavailable metals will occur if TOC-rich FW are mixed with SW, especially within 1-10‰, a production form highly used in RAS and flow-through systems. In both cases, long retention time post mixing and silica-lye treatment pre-SW-mixing, might reduce or mitigate negative effects. Especially hyperoxia (high O_2), but also hypercapnia (high CO_2), must be avoided, as a long list of negative responses have been documented after periodic or constant gas supersaturation. Mixing of SW, especially in RAS, increases the chances of hydrogen sulfide (H_2S) production if anaerobic zones are created post biofilters. This respiratory-blocking caused by H_2S occur rapidly and can cause up to 100% mortality within a short period. Immediately dilution or alternative water supply might solve the acute mortality problem, while the bacterial biofilter community might suffer. Using experts instead of “self-trials-and-failure” is a proper strategy.

Gene technology/CRISPR - welfare and ethics implications

Hilde Mellegård, DVM, senior advisor, the Norwegian Biotechnology Advisory Board

Genetically modified (GM) plants that are herbicide tolerant and/or insect resistant have been on the international market for more than 20 years, and are the main categories of GM plants. However, since the development of gene editing, and in particular CRISPR (Clustered Regulary Interspaced Short Palindromic Repeats), organisms with several other traits have been developed or are in the pipeline. CRISPR, and other gene editing technologies, allows for efficient and precise editing of DNA sequences and for modifying gene expression. Examples of gene edited organisms include dairy cows with no horns, virus-resistant pigs, late blight-resistant potato, powdery mildew-resistant wheat and drought-tolerant maize. Gene edited, sterile salmon is another example, and have been developed by norwegian researchers. New technologies create new discussions, also on ethical implications. One need to ask; are gene edited organisms unethical to use or unethical not to use?

Fish slaughter -Is there a humane way to harvest and slaughter farmed fish?

Albin Gräns, Department of Animal Environment and Health, Swedish University of Agricultural Sciences

Humane slaughter requires that the fish is stunned before being bled. The ideal stunning method before slaughter is one that induces instantaneous and long-lasting unconsciousness allowing the staff sufficient time to kill the animal. A fundamental limitation when assessing the effectiveness of different stunning methods used for fish is the difficulty to determine when unconsciousness is induced, and to ensure that the fish has not only been immobilized but is completely unable to perceive pain or suffering. In 2004 the EFSA scientific panel on Animal health and welfare concluded in their scientific opinion that many of the commonly used methods to kill fish in aquaculture expose fish to substantial suffering over a prolonged period of time, and are therefore ethically unacceptable. In the same opinion they also highlighted that there were, for many species at the time, no commercially acceptable alternative methods available that could be used for the slaughter of fish in a humane way. Since 2004, a few European countries such as Norway, have gone in the forefront and banned the use of carbon dioxide stunning methods. Other countries, such as Sweden, have chosen to postpone any actions arguing that there is still not a commercially acceptable method that can stun fish humanely prior to slaughter. In the presentation, the current state of knowledge and some key knowledge gaps that still remains regarding the welfare of farmed fish during time of slaughter, was discussed. He further highlighted situations where common practices used in aquaculture are not fully aligned with the current state of knowledge, and how the transfer of practices between different fish species can be deceiving.

Welfare Actions in fisheries

Hanne Digre, Research Director at SINTEF Ocean, department of Seafood Technology

Limited focus has been placed on fish welfare and other ethical aspects of catching and killing processes for wild fish. For farmed fish, welfare requirements are included in laws and regulations, but for wild fish, the industry and government, probably for practical and economic reasons, has not prioritized animal welfare. Wild fish is included in the Norwegian Animal Welfare Act. In 2014, the Norwegian Council for Animal Ethics gave the following advices for commercial fisheries;

a) Strive to shorten the harvesting time, particularly the time fish are experiencing high levels of stress, fear or pain;

b) There must be made more gentle handling and minimal damage in the capture time;

c) The fish has to be stunned by electricity or percussion stunning, followed by killing by bleeding;

d) Bycatch must as far as possible be reduced,

e) Fish that have been in contact with the gears but do not get caught or are released after capture, should be undamaged and physically able to survive afterwards.

Animal welfare of wild fish can be jeopardised during capture, loading, holding before killing, stunning and killing as it involves procedures likely to cause pain and fear. In Norway there have been conducted several studies looking at how the different activities in the value chain influence fish welfare. Technological improvements have been conducting for the fishing gear, loading, storage, stunning and killing of wild fish. Stunning of alive catch will allow more rapid bleeding, gutting and rinsing of the fish, which will improve both welfare and quality of the fish. Electrical stunning has been identified as a fast and efficient method to render fish unconscious and insensible. Electrical stunners have been installed on several fishing vessels in Norway the last years.

Concluding remarks, end of seminar

On behalf of NordCAW, Lotta Berg (professor in animal welfare, Swedish Agricultural University) summarized the day, and thanked the presenters for sharing their knowledge and the audience for coming and for taking part in the discussions. She informed about next year's NordCAW seminar on wildlife and animal welfare, to be held in Helsinki, Finland.