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Norwegian Fish Health Report 2023

Nematocyst magnified 15,000 times. Jellyfish have tentacles with stinging cells containing venom and small barbs to paralyze and capture small prey, but these stinging cells can also harm fish.
Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

Norwegian Fish Health Report 2023

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Nematocyst magnified 15,000 times. Jellyfish have in 2023 caused significant losses in the aquaculture industry. The damage to the fish is due to the jellyfish's stinging cells, which contain thousands of nematocysts. When something touches a nematocyst, an explosive capsule inside the cell is triggered, and a long stinging thread with barbs and poison is rapidly shot out. Jellyfish need the nematocysts to immobilize prey when they are hunting for food, but the nematocysts do not distinguish between prey and fish—or humans. The image is photographed with a scanning electron microscope and then colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

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Enhance biosecurity must be implemented

By Edgar Brun

The aquaculture year of 2023 has been eventful and turbulent, with much negative focus. However, the global demand for Norwegian salmon remains consistently high, and Norway has never before had such large revenues from salmon exports as in 2023. The biological costs in production including health and welfare, treatments, mortality costs, and are greater than ever. Although the salmon louse is the major driver of these costs, this years' Fish Health Report also documents several challenging in health and welfare conditions within the industry. In 2023, more fish died during the sea phase than ever before. Outbreaks of "old" diseases like BKD show that pathogens remain present and can "pop-up" at any time. PD virus further demonstrates the potential for pathogens to hitch hike, spreading over large geographical areas.

In the past year, there have been several episodes of mass mortality due to a variety of reasons. Some cases, primarily considered as gill problems, are in most cases a complex issue linked to weaken conditions, stress and poor environmental conditions.

The frequency of emergency slaughtering and use of emergency harvest boats is increasing. This practice involves on-farm slaughtering of fish that would not withstand regular transport to the slaughterhouse and would otherwise have died and been lost to consumption. Concurrently, we see an increased proportion of fish classified as "production-class" i.e. fish that do not meet the criteria for the export grad of 'Superior Norwegian Salmon." From a resource perspective, it is sensible to maximise the number of fish that reach the market. However, this development in increased emergency slaughtering may undoubtedly camouflage a number of underlying welfare challenges. It is therefore important that we understand the cause of this trend and the actual condition of the fish in question.

The green footprint of the industry has been difficult to see amidst the news headlines that dominated 2023. An industry we should all be proud of has correctly received much negative attention in the past year. But in such a situation, have there been any positive signs? Signs of a greener production promising a better biological sustainability through good health and welfare?

Perhaps somewhat surprisingly, the answer is yes. In a year of great challenges, the Norwegian Seafood Federation has produced a guide for the aquaculture industry: "Best Practice for Good Biosecurity and Improved Disease Control." Biosecurity is a prerequisite for a sustainable production. Biosecurity involves measures to control introduction and further spread of diseases to and from a population, allowing production of safe food in an economically, environmentally, and socially responsible manner. Properly implemented as routine procedures, biosecurity aims to meet the needs of current and future generations. Many commendable initiatives have been taken by individual farmers. But biosecurity for a whole industry requires requires cooperation and transparency. In the 2022 Fish Health Report, the question was raised, "Are we mature enough to specify health and welfare goals for the world's largest salmon producing industry?" The biosecurity guidelines developed by the Norwegian Seafood Federation, is actually a maturity test for the industry to test the willingness of the industry to mobilise necessary resources to effectively prevent and control diseases.

In the same biosecurity document, The Norwegian Seafood Federation states on welfare; *Aquaculture is today the largest livestock production in Norway, and therefore, it is natural that the industry enters the driving seat in this field.* Sitting in the driver's seat offers several opportunities. One of

Edgar Brun, head of department. Photo: Eivind Røhne them is to take sole control of where to go; direction, ambition, how fast and which process. Let us hope that is not the intention. A better way would be to openly ask and discuss what should the ambition be for the industry, and what a reasonable time line is.

The industry has always shown a great ability to reach its goals and ambitions. If those in the driving seat express a willingness to listen and an eagerness to comply with demands, it will be exciting and promising to follow a progressive aquaculture industry, led by Seafood Norway, paving the way for better animal welfare.

This commitment must build upon the newly presented Official Norwegian Report (NOU 2023:23), which perhaps for the first time, clearly indicates a possible path towards a “green” coast indicating sustainable production.

Biosecurity is dependent on cooperation. There is significant international focus of regulatory requirements and in 2023, the Norwegian Food Safety Authority also developed guidelines to assist in design and implementation of biosecurity measures at site level. Implementation and follow up of these guidelines will be an important supplement to the Norwegian Seafood Federation best practice document. With these different guidelines appearing, it is essential to emphasize that biosecurity should be naturally integrated as part of daily work and decision-making. Biosecurity is not an ‘add-on’ but is the essential core of the production chain.

The Fish Health Report has a separate chapter on biosecurity this year, precisely to underline how important the Norwegian Veterinary Institute considers this field of work. Our role includes having a solid national overview of the health situation within the industry. This overview is necessary for national preparedness and our ability to provide advice for cost-effective biosecurity measures at both the national and regional levels. Preparedness and biosecurity are closely linked and requires that the Norwegian Veterinary Institute be allowed sufficient national insight into the disease situation of the industry, information exchange and transparent data flow.

The economics of health are important and is yet another new chapter in the Fish Health Report. Disease in any animal production is a cost, not only for the individual producer but also through direct and indirect use of society's common resources. It is therefore important to keep focus and execute continuous effort towards reducing the disease burden in the aquaculture industry. It is essential that society is attentive to both the health situation and the measures implemented by the industry as well as the authorities.

Summary

By Ingunn Sommerset

According to monthly reports, 37.7 million farmed salmon and 2.4 million rainbow trout (larger than 3 grams) died in land-based hatcheries in 2023. Additionally, 62.8 million salmon and 2.5 million rainbow trout died during the sea phase of production. Overall, the same three health issues stand out in 2023 as in 2022: delousing injuries, complex gill diseases, and winter ulcer. A significant change in 2023 is that injuries caused by jellyfish are ranked among the top ten health challenges. Regarding serious, infectious diseases, there are concerns about the increase in cases of bacterial kidney disease (BKD) and four diagnoses of pancreas disease (PD) north of the endemic PD zone. These diseases have not caused particularly high mortality at the farm level but pose a serious risk of further transmission. A positive development is that the national decrease in number of PD cases continued in 2023, coinciding with increased vaccine coverage, especially in Mid-Norway.

Mortality in Norwegian aquaculture

The early stages of salmon and rainbow trout production takes place in freshwater (juvenile stage), followed by adaption to- (smoltification) and transfer to- sea water (ongrowing stage). Authorities require monthly reporting of living and lost/dead fish during both the hatchery phase and the grow-out phase. However, it is difficult to combine these data and thus estimate total production mortality from initial feeding to slaughter. This is due to the lack of traceability caused by movement of fish groups within facilities and between hatcheries and grow-out facilities, as well as varying data quality in the public records.

The Norwegian Food Safety Authority receives monthly reports on the number of dead fish and viable stock at the tank level from hatcheries. The reports do not specify whether the dead fish died naturally or were euthanized. In the early stages of production in hatcheries, some destruction/mortality is expected, and therefore, the Fish Health Report does not include the weight class 0-3 grams in analyses. The number of dead hatchery fish (over 3 grams) reported in 2023 was 37.7 million salmon and 2.4 million rainbow trout. This represents an increase of approximately 2 million salmon compared to 2022, which is a negative trend considering the reported decrease in smolt stocking in 2023. 33 million fewer smolt were stocked in 2023 compared to the previous year. For rainbow trout, there is a slight decrease in both reported mortality and stocking numbers. The way the data is reported complicates the calculation of annual percentage mortality in the hatchery phase.

Loss of fish in the sea phase (dead fish, rejects, escapes, and other losses) is reported monthly to the Norwegian Directorate of Fisheries, and in 2023, this amounted to 70 million salmon and approximately 2.9 million rainbow trout. The category "dead fish" represents the largest losses, totalling 62.8 million salmon and 2.5 million rainbow trout. As in previous reports, the Fish Health Report uses the number of fish in the "dead fish" category to calculate percentage mortality. This is done by calculating monthly mortality per site in rates, which unlike percentages, can be summed and thus used to calculate mortality risk over time intervals longer than a month. The calculated annual mortality risk (hereinafter referred to as mortality) in the sea phase for salmon was 16.7 percent in 2023 and for rainbow trout 14.0 percent. This is the highest annual mortality recorded for salmon in the sea phase in recent years, while for rainbow trout, there is a decrease from the two previous years. There are significant geographical differences in mortality, with production area 3 (PA3) having the highest mortality at 25 percent, followed by PA2 at 22 percent, while PA13, PA1, and PA11 all had less than 10 percent mortality in 2023.

Fish farms typically evaluate mortality at the end of the production cycle in the sea phase rather than on a calendar year basis. Therefore, this year's report delves deeper into mortality figures for production cycles in the sea phase. The median mortality for completed production cycles (at the site level) in Norway in 2023 was 18.8 percent, with half of the completed production cycles falling within the range of 12.2 to 26.9 percent. There are also significant geographical differences, and especially in PA1-PA5, there are very few sites with less than five percent mortality.

For the first time, an overview of the main categories of cause of death for farmed salmon, as recorded by companies participating in the industry initiative "AquaCloud," is presented. In 2023, there were 355 ongrowing salmon farms participating, equivalent to 43 percent of the standing biomass at sea. The main causes of mortality recorded at the national level were "Infectious Diseases" at approximately 38 percent, "Injuries (Trauma)" at approximately 33 percent, and "Unknown Cause" in third place at approximately 20 percent. The five most common subcategories in "Infectious Diseases" were: Winter ulcer, CMS, gill disease, HSMB, and pasteurellosis. This aligns well with results from the survey and compiled data from diagnostic laboratories in 2023.

The category "Environmental Conditions" contributed less than 1 percent of mortality from 2020 to 2022, while in 2023, it accounted for 2.9 percent, with the subcategory "jellyfish" accounting for 1.7 percent of the site-specific mortality for sites sharing data. Access to dead fish numbers distributed across standardized categories provides important knowledge about causal relationships and risk factors associated with increased mortality over time and space. By increasing focus on best practices in dead fish classification and increasing the number of participating sites, the data can be used even more effectively to implement targeted measures to reduce mortality in the industry.

Mortality data for different species of cleaner fish are still incomplete, and it is also challenging to obtain good figures on monthly standing stocks. 33.9 million individual cleaner fish were stocked in 2023 (Fisheries Directorate biomass register as of 20.02.2024). This represents a further reduction from the previous year, indicating that the decreasing trend in the number of cleaner fish released from the "peak year" of 2019 continues.

Table of the number of positive sites or watercourses with confirmed listed fish diseases in Norway.

Disease	Category	2017	2018	2019	2020	2021	2022	2023
Farmed fish: salmonids								
Infectious salmon anaemia (ISA)	C	14	13	10	23	25	15	18
Pancreas disease (PD)	F	176	163	152	158	100	98	58
Furunculosis	F	0	0	0	5	5	2	0
Bacterial Kidney Disease (BKD)	F	1	0	1	1	0	1	12
F. psychrophilum in rainbow trout	F	1	4	4	2	1	4	1
Farmed fish: Marine species								
Francisellosis	F	0	0	0	0	0	0	0
Furunculosis (lumpfish)	F	0	0	0	3	0	1	0
VNN/VER	F	0	0	0	0	1	0	0
Wild salmonids (fresh water)								
Gyrodactylus salaris	F	0	0	1	0	0	0	2
Furunculosis	F	2	0	2	0	0	0	0

Notifiable fish diseases

After implementation of the new Animal Health Legislation in Norway as of 28.04.2022, notifiable diseases of aquatic animals are categorised from A to G, according to the European Union Commission Implementing Regulations 2018/1882 (Chapter 1 Statistical basis for the report). A disease that belongs to category C is also automatically included in categories D-G. In addition to the notifiable diseases regulated by the European Economic Community, diseases in the previous "list 3" are now included in the national list, category F. The table on the previous page shows the annual numbers of detections of listed fish diseases 2017-2023.

Infectious salmon anaemia (ISA) was confirmed at 18 sites in 2023, with suspicion of ISA in an additional five sites, all of which were emptied of fish by the end of last year. A significant proportion of last year's confirmed outbreaks and suspicions were on the West Coast.

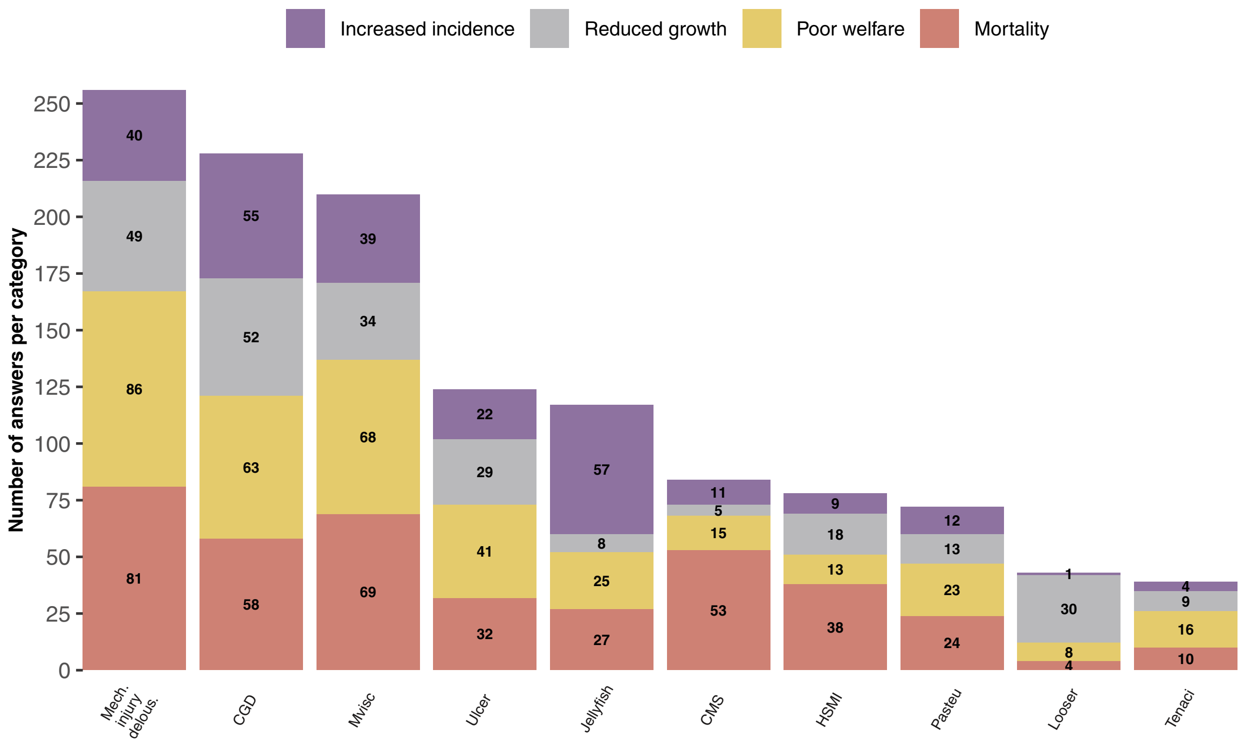


Figure The 10 most important fish health problems of salmon in ongrowing facilities (sea water sites). Results from the 2023 annual survey among fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents were asked to indicate the five most important health problems on a list of 35 different problems. The respondents (N = number of persons who answered the question) were asked whether the problems were related to mortality (N=102), reduced welfare (N=102), poor growth (N= 99) or were perceived as a growing problem (N=100).

Abbreviations: Mech injury delouse = mechanical damage related to delousing, CGP = gill disease complex/multifactorial, Mvisc = infection with *Moritella viscosa* (classic winter ulcers), Ulcer = ulcers unspecified cause, CMS = cardiomyopathy syndrome, HSMI = heart and skeletal muscle inflammation, Past = infection with *Pasteurella* sp. (pasteurellosis), Looser = runted fish, runt syndrome, emaciation, Tenaci = infection with *Tenacibaculum* spp. (non-classical winter ulcers)

There has been a decreasing trend regarding pancreas disease (PD) in recent years, and in 2023, 58 cases were detected, compared to 98 cases in 2022. However, four PD outbreaks caused by PD virus genotype SAV2 on the Helgeland coast last autumn are serious. It is not known how the infection was introduced so far north of the endemic PD zone. Rapid emptying of the sites with PD has hopefully prevented further spread of the infection.

Bacterial kidney disease (BKD) caused by *Renibacterium salmoninarum* saw a significant resurgence in 2023. Most detections were in PO6, where there was suspected transmission via transport of infected fish and/or via wellboats. The bacterium can also spread through infected roe, and there are no effective vaccines or medications against BKD, making general biosecurity measures and screening essential combat tools. As the table shows, there were few or no cases of the other nationally listed fish diseases in 2023.

Vaccination can be an important measure to reduce infection, and new to this year's report is a separate chapter on "Biosecurity," which includes statistics on vaccines with marketing authorization for farmed fish in Norway. The statistics, along with information from the survey, indicate that vaccination is increasingly being used against ISA and PD, but also against non-notifiable diseases such as yersiniosis, winter ulcer, and pasteurellosis.

Non-notifiable fish diseases

The basis data for unlisted diseases is discussed in Chapter 1 Statistical basis for the report and is comparable to the two previous years due to agreements between the Norwegian Veterinary Institute and over 20 aquaculture companies regarding access to data from analysis conducted by private laboratories. However, more diseases and pathogens are included in the agreements for 2023 than in previous years.

Although statistics on diseases are presented individually, it is not uncommon for fish to have multiple diseases simultaneously. This can include two different viral diseases, co-infections with multiple types of bacteria, combinations of infection with viruses, bacteria, fungi, and parasites, or combinations of infection and production disorders.

Ingunn Sommerset, Section leader for aquatic biosecurity at Norwegian Veterinary Institute and editor of the Norwegian Fish Health Report 2023. Photo: Eivind Senneset

The viral diseases cardiomyopathy syndrome (CMS) and heart and skeletal muscle inflammation (HSMB) are among the most frequently detected diseases in salmon in ongrowing fish, and both can be associated with increased mortality following salmon lice treatments. In 2023, CMS was detected at approximately the same number of sites as in 2022, while HSMB was detected at approximately the same number of sites as in 2021, after an apparent decrease in 2022. For infectious pancreatic necrosis (IPN), the situation is stable with low incidence. Salmon Gill Pox Virus (SGPV) or salmon pox virus was detected in 124 facilities last year. In approximately half of the cases, virus detection was associated with clinical disease or pathological changes in the gills. However, the survey assesses the significance of the salmon pox virus as low compared to other health problems.

Winter ulcers may collectively represent the greatest health and welfare challenge associated with bacterial infections in Norwegian sea-farmed salmon, affecting a large number of sites along the entire coast every year. Following bacteriological investigation, identification of different genetic variants of *Moritella viscosa* and/or *Tenacibaculum* spp. may be identified — often in combination or with other marine bacteria. There were 320 sites with confirmed *M. viscosa* infection (classic winter ulcer) in 2023, compared to 296 in 2022. The number of sites with confirmed infection with *Tenacibaculum* spp. (tenacibaculosis/atypical winter ulcer) was 155 in 2023, compared to 205 in 2022.

The number of cases with detection of *Yersinia ruckeri* in salmon at sea continued to increase in 2023. Some of the detections may represent findings from routine screening without clinical disease, but the large and increasing number of requested doses of injectable vaccine against yersiniosis from 2020 to 2023 may indicate significant problems with the disease. However, any effect of increased vaccine coverage is expected to manifest itself when vaccinated fish are released into the sea. It is known that stressful handling and similar practices may play a role in the development of yersiniosis.

The pasteurellosis epidemic, which has been ongoing in farmed salmon on the West Coast since 2018, also continued in 2023. However, the number of detections in 2023 (27 sites) shows a significant decrease compared to 2022 (52 sites). The disease is caused by a bacterium currently known as *Pasteurella "atlantica* genomovar *salmonicida."* Frequent concurrent infections with other agents, as well as reports of much handling, may indicate additional factors contributing to increased outbreak risk.

Salmon lice and other parasites

The salmon louse (*Lepeophtheirus salmonis*) remains the most important parasite challenge for farmed salmon. The levels of lice in 2023 were slightly lower than in 2022, and lower than the five-year period from 2017 to 2021, both for adult female lice and pre-adult stages. The production of salmon lice larvae during the outward migration of wild salmon was on par with 2022 in most production areas. In 2023, as in 2022, most delousing operations were non-medicinal, although there was a 17 percent decrease in the number of such treatments. The number of thermal treatments decreased by 24 percent from 2022, and mechanical delousing was the most common method used in 2023. The number of weeks with medicinal lice treatment remained at about the same level as in 2022, with a 6 percent reduction.

The sea louse *Caligus elongatus* appears to have caused fewer problems in 2023 than in previous years. The parasite *Parvicapsula pseudobranchicola* is particularly problematic in terms of mortality, growth, and fish welfare for farmed fish in Troms and Finnmark. In 2023, this parasite was detected at a total of 25 sites, most in PA12 and PA13, but there were also findings in PO9, PO8, and one case in PO6.

The amoeba *Paramoeba perurans*, which causes amoebic gill disease (AGD), was detected throughout the year from Vestland county to Nordland, and the number of detections in 2023 (73 sites) was at the same level as the previous year. In complex gill diseases in salmon at sea, AGD may be present along with other parasites, such as the microsporidian *Desmozoon lepeophtherii*. The microsporidian was detected by PCR at 142 sites with salmon and four sites with rainbow trout in PA1-PA8. 86 of the salmon detections and one rainbow trout detection were associated with clinical signs.

The parasite *Spironucleus salmonicida* also posed challenges in Finnmark in 2023. Systemic spironucleosis is a serious diagnosis with significant consequences for fish health, welfare, and economy. Compiled data from the Norwegian Veterinary Institute and private laboratories show that spironucleosis was detected in salmon in three fish farming sites in Finnmark in 2023. PCR analyses alone revealed findings of *Spironucleus salmonicida* at ten different sites with salmon in the same area, one of which was reported to have clinical significance.

Fish Welfare

In the 2023 survey, injuries resulting from intensive delousing was once again ranked highest as a major welfare problem for salmon farming, see figure on page 10. However, there was a reduction in reported non-medicinal delousing weeks, from 3145 weeks in 2022 to 2609 weeks in 2023, and thermal delousing used alone is no longer the most used method. The number of welfare events reported to the Norwegian Food Safety Authority for farmed fish and broodstock also decreased in 2023, as did events related to non-medicinal delousing, which fell from 42 percent of events in 2022 to 34 percent in 2023. Whether the decrease is due to changes in reporting procedures or is a real decline is unclear. There is otherwise a relatively good correlation between the ranking of the most important causes of mortality and the causes of reduced welfare, except for CMS, which is significantly higher ranked as a cause of death than as a cause of poor welfare.

In the fry stage, the greatest health problems are still related to non-infectious diseases and suboptimal production conditions. In the 2023 survey, water quality seems to have received increased focus as a cause of problems in the fry stage compared to previous years. Otherwise, the ranking of various problems is relatively stable. 2023 is the first year the number of reported welfare events during fry production has decreased or levelled off, but a large proportion are still very serious. Most are categorized as "other" and "unexplained mortality," and based on the classification of free text for the category "other," the thematic concerns include human error, water quality, and equipment failure, closely followed by disease/parasites, often in various combinations of categories. There is still a need for increased knowledge about how operational conditions in the fry stage affect fish performance in the sea-farmed stage. Field experience and research show that less intensive fry production is beneficial for the development of a robust smolt.

In 2023, the Norwegian Veterinary Institute also gained access to slaughter data from the Norwegian Food Safety Authority. Each slaughter report provides information on the species and quantity slaughtered, as well as quantities of fish in various quality classes and the main reason for downgrading. There may be various reasons for downgrading, but a common factor for a large proportion of downgraded fish is that they have undergone a period of reduced welfare prior to slaughter. The most common reason for downgrading in 2023 was "wounds/injuries" for salmon, while for rainbow trout, it was "defects." The average superior share (best quality) for the total of 614 sites of salmon and rainbow trout that reported slaughter data for 2023 was 83 percent, representing a decrease from 2022 and 2021. There is variation in the superior share between production areas, with PO5 and PO7 having the highest at 89 percent, while PO3 and PA12-PA13 have the lowest at 79 and 78 percent, respectively. Both slaughter volume and superior share vary throughout the year, and both are highest in the second half of the year. Slaughter data is considered one of several indicators that can be used as a management-based welfare indicator for farmed fish.

Wild Fish Health

Wild-fish health is a large, complex, and interdisciplinary field that research communities have only just begun to delve into. Historically, in Norway, large resources have been allocated to relatively few issues, including the parasites *Gyrodactylus salaris* and salmon lice, both in salmonid fish. The reporting system for sick wild fish (the sick wild fish portal) was established in 2020 as a direct result of the red skin disease outbreak in Enningdalselva in 2019. The cause of red skin disease is still unknown, and further work will be resource-intensive. The sick wild fish portal is now entering its fifth year and will continue to be an important contribution to knowledge about wild fish health.

In 2023, *G. salaris* was detected in two new watercourses: Gylelva and Ebbestadelva. The investigation was commissioned by the Norwegian Environment Agency in connection with ongoing treatment in the Driva region and preparation for treatment in the Drammen region. Both locations are small watercourses that do not have annually reproducing salmon stocks. In January 2024, the Fust watercourse, as the last watercourse in the Vefsna region, was declared free of infection. This means that all infection regions north of the Driva region have been declared free of infection, and the number of infected salmon stocks has been significantly reduced.

Pink salmon is an invasive fish species with a natural distribution in the Pacific Ocean but has spread to both sides of the northern Atlantic Ocean following extensive releases in Russia. Pink salmon have a strict two-year life cycle, and it is the population that spawns in odd years that is most numerous in Norway. In 2023, through fishing and targeted control measures, a catch of 364,000 pink salmon was recorded in Norway. There is a great need for knowledge about the ecological and economic effects of pink salmon, including the potential spread of pathogens. Therefore, the Norwegian Veterinary Institute has organized health monitoring of pink salmon in the years 2019, 2021, and 2023. Health monitoring in 2023 did not detect any serious notifiable fish diseases.

1 Statistical basis for the report

By Victor H S Oliveira, Torfinn Moldal, Eve Marie Louise Zeyl Fiskebeck and Ingunn Sommerset

The data in the Fish Health Report is mainly taken from: Official registers (The Directorate of Fisheries, the Norwegian Food Safety Authority and Veterinary Drug Register), the journal record systems at the Norwegian Veterinary Institute and private laboratories as well as a survey among employees in the fish health services and inspectors from the Norwegian Food Safety Authority. New to this year's report is data from the fish health database AquaCloud.

In the individual chapters of the report, there is a clear distinction between what data/information the different figures are based on and the author's assessment of the situation.

Official data

On April 28th, 2022, Norway implemented a new regulation for animal health. This includes lists of diseases and requirements regarding when to report disease. Regarding aquatic animals, it states: «In the event of a suspicion or detection of a listed disease in aquatic animals, as mentioned in Annex II of the EU regulation 2016/429, or in the national disease list for aquatic animals in § 6, except for salmon lice, operators and any natural or juridical person must immediately report to the Norwegian Food safety authority. In addition, the Norwegian Food Safety Authority (NFSA) must report «abnormal mortality and other signs of severe diseases» in aquatic animals and, if abnormal and unexplained mortality occur, in farmed animals.

Both the EU and national lists of diseases for aquatic animals are presented in a simplified version in Table 1.1. These diseases are notifiable and therefore constitute official data.

The category A disease epizootic hematopoietic necrosis

Table 1.1. Lists of notifiable diseases in the EU and Norway for aquatic animals as of February 2022.

List	Name of listed disease in fish	Category	Species/group of species
EU	Epizootic hematopoietic necrosis	A, D, E	Rainbow trout and perch
EU	Infectious hematopoietic necrosis (IHN)	C, D, E	Many species, EEA Agreement's Annex I, Chapter I, Part 1.1, No. 13a (Regulation (EU) 2018/1882)
EU	Viral haemorrhagic septicaemia (VHS)	C, D, E	Many species, EEA Agreement's Annex I, Chapter I, Part 1.1, No. 13a (Regulation (EU) 2018/1882)
EU	Infectious salmon anaemia, HPR-deleted	C, D, E	Atlantic salmon, rainbow trout and sea trout
EU	Koi herpesvirus disease	E	Carp and Koi
National (Norway)	Bacterial kidney disease (BKD, *Renibacterium salmoninarum*)	F	Salmonids
National (Norway)	*Gyrodactylus salaris* infection	F	Atlantic salmon, rainbow trout, arctic char, brook trout, grayling, lake trout and sea trout
National (Norway)	Viral nervous necrosis (VNN)/Viral encephalopathy and retinopathy (VER), Nodavirus	F	Marine fish species
National (Norway)	Furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*)	F	Salmonids
National (Norway)	Pancreas disease (PD, Salmonid alphavirus)	F	Atlantic salmon, rainbow trout and sea trout
National (Norway)	Systemic *Flavobacterium psychrophilum* infection	F	Rainbow trout
National (Norway)	Francisellosis (*Francisella* sp.)	F	Atlantic cod
National (Norway)	*Lepeophtheirus salmonis* (salmon lice) infection	F	Salmonids
National (Norway)	Disease not listed to date	G	

has never been detected in Norway. Categories C and F diseases, along with number of detections, are shown in the table in the «Summary» of this report. The figures are based on data from the Norwegian Veterinary Institute (NVI), which assist the Norwegian Food Safety Authority in keeping an up-to-date overview of the listed diseases. The NFSA notifies the NVI of diseases detected by external laboratories such that these are registered alongside detections made by the NVI. As the National Reference Laboratory, the NVI shall confirm, in principle, all diagnoses of notifiable diseases made by external laboratories. The definition of the term «official data» in the Fish Health Report (FHR) is the number of new detections in a site after fallowing. This means that the real number of infected sites in 2023 may be higher, since there may have been sites with stocked fish diagnosed with a disease in the previous year.

In addition to diseases' data, other official data is used in this report. From the Directorate of Fisheries, the NVI receives the sites' monthly biomass reports, which includes average weight, number of live fish, dead fish, as well as other categories of lost fish from sea production. From the NFSA, the NVI receives weekly data on salmon lice counts and number of delousing treatments carried out on sites, figures on prescribed medicines from the Veterinary Drug Register, as well as reports on welfare-related incidents. Additionally, the NFSA serves as a source for access to monthly reports from hatcheries on the number of live and dead fish, as well as average weight at tank level. The NVI also utilizes the Directorate of Fisheries' «Aquaculture Register» which provides an overview of all aquaculture permits and information about them.

Data from the Norwegian Veterinary Institute

The NVI receives samples for diagnostic examinations from fish health services and the NFSA. These are examined at the institute's laboratories in Harstad,

Samples embedded in paraffin. Photo: Eivind Senneset

Trondheim, Bergen and Ås. Information about submitted diagnostic samples is stored in the institute's electronic record system. Data are extracted and sorted so that primarily samples submitted for diagnostic purposes are in this report. Samples sent for other purposes such as research, ring tests and surveillance are excluded.

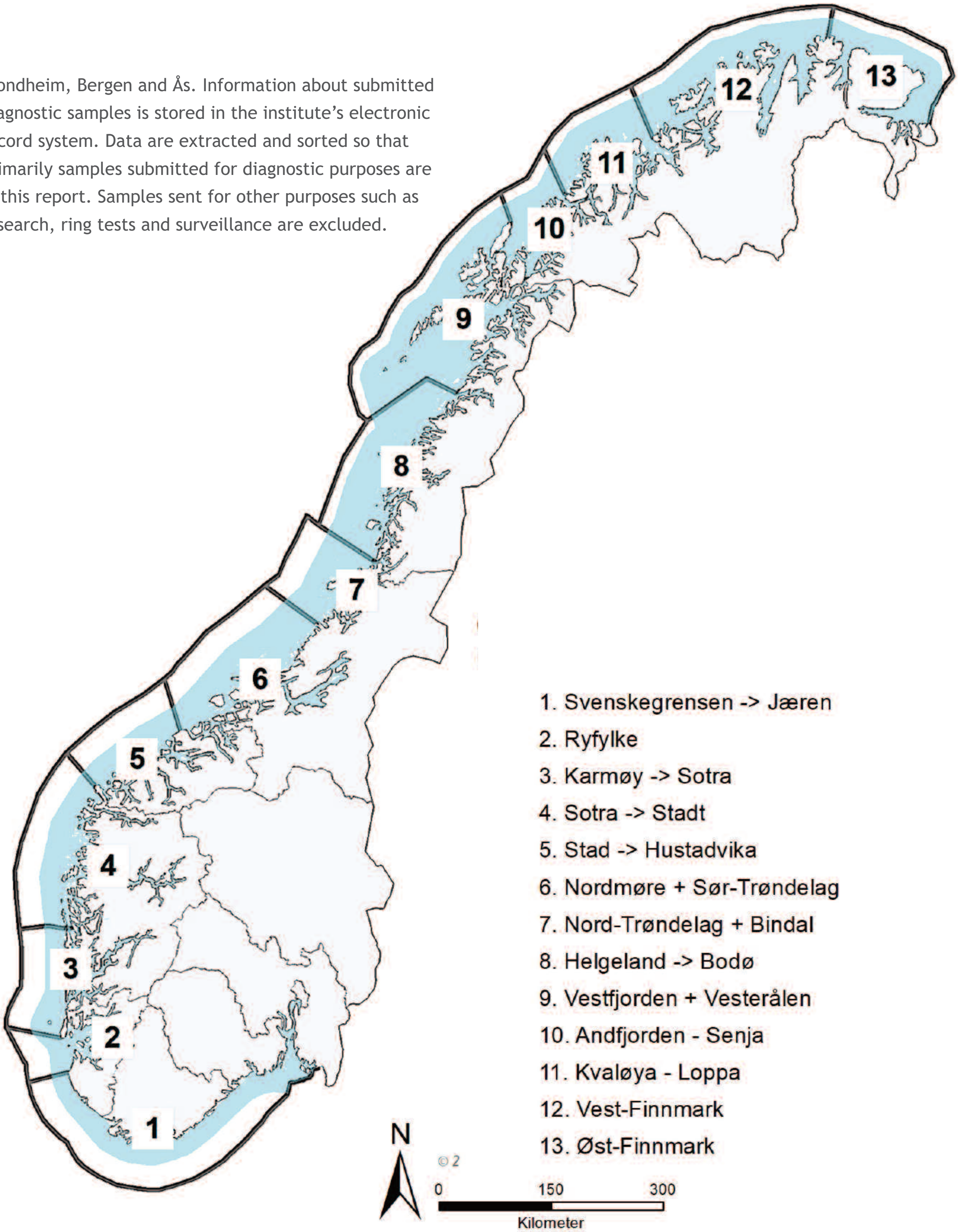


Figure 1.1. Overview of production areas (PA) in Norway

Data from private laboratories and compiling data

Non-notifiable diseases are not subject to mandatory reporting. Therefore, the data from the NVI alone cannot provide a complete picture of the national situation. In an attempt to compensate for this, agreements have been made in recent years with major and many medium-sized aquaculture companies in Norway, in order to gain access to data on the detection of a selection of non-notifiable diseases. The data are retrieved from electronic record systems at the private laboratories PatoGen AS, Pharmaq Analytiq AS, and Blue Analytics AS. All the data have been reviewed and approved by the aquaculture companies before being included.

Twenty-three aquaculture companies (some with subsidiaries) have shared data on the following diseases and their associated pathogens:

- Heart and skeletal muscle inflammation and (HSMI) and HSMI-like diseases
- Cardiomyopathy syndrome (CMS)
- Infectious pancreatic necrosis (IPN)
- Yersiniosis
- Pasteurellosis
- Classical winter ulcer
- Tenacibaculosis/non-classical winter ulcer
- Parvicapsulosis
- Amoebic gill disease (AGD)
- Infection with lumpfish flavivirus
- Mykcobacteriosis
- Flavobacteriosis in other species than rainbow trout
- Systemic spironucleosis
- Infection with ISAV HPR0
- Atypical furunculosis
- Salmon gill pox disease
- Epitheliocystis
- Infection with *Salmoxcellia vastator*
- Infection with *Desmozoon lepeophtherii*

Although there have been some changes in corporate structure due to acquisitions, mergers on one hand, and the division of production between sea and land into separate companies on the other hand, the data coverage for 2023 can be considered comparable to 2021 and 2022. The selected diseases and their causative agents primarily affect farmed salmon, rainbow trout, and to some extent cleaner fish in the sea phase. Detections in other fish species and the aquatic environment, where information is available, have also been included.

The coverage rate in the dataset, i.e., the proportion of active sites included in 2023, is calculated from reported biomass via the «Altinn» portal to the Directorate of Fisheries. In 2023, there were a total of 867 sites with Atlantic salmon and rainbow trout (food fish, broodstock, and research and development sites) that were active for at least one month, with a monthly average of 605 active sites. We received data on the aforementioned non-notifiable diseases in 2023 from 640 sites, of which 56 did not have reporting in «Altinn». Similarly, in 2022, we received data from 612 sites, of which 51 did not have reporting in «Altinn».

For each disease or pathogen, we collated the data from the various laboratories, including data from the NVI, so that each site is counted only once per detected disease or pathogen. In some cases, the same disease or pathogen may have been detected at the same stocking in 2022 as in 2023, and the overview may therefore not necessarily be used to determine the number of new outbreaks in 2023. The exception is for notifiable diseases (see the description above).

In some cases, fish health personnel diagnose non-notifiable diseases based on characteristic macroscopic findings and pathogen detection alone (for example, by PCR). Fish health managers in each company were asked to provide the clinical status of the population from which the positive sample was taken as «sick» or «healthy». Information on clinical status was available for approximately 63 percent of cases where only the pathogen was detected, and this additional information has been used in several chapters concerning non-notifiable diseases.

Data from AquaCloud

The NVI has entered into a collaboration with Seafood Norway and AquaCloud regarding quality assurance of their "fish health database." The database receives daily reports from aquaculture companies' management systems, where, among other things, recorded mortalities in sea farms are classified into standardized causal categories.

The classification system for mortalities has been developed by the Norwegian University of Life Sciences (NMBU) on behalf of the industry and is also included in the Norwegian Standard NS 9417:2022. As part of the collaboration agreement, the publication of descriptive statistics on the six main cause categories (level 1) in regional areas that preserve the anonymity of the aquaculture companies' sites is permitted. Publication of data on more detailed cause categories (levels 2 and 3) requires written approval before being used in the FHR. The number of sites that reported data in 2023 was 355, representing approximately 43 percent of salmon farming sites along the coast.

Data from the annual survey

As in previous years, the NVI used an electronic survey to obtain additional information from fish health services and fish health personnel, employed by farming companies or breeding companies, as well as inspectors from the NFSA. In the survey, the respondents were (among other things) asked to rank how important they perceive various diseases in hatcheries, grow-out and broodstock facilities with salmon and rainbow trout, as well as diseases and syndromes in lumpfish and wrasse. The same questionnaire also asked about the effects of delousing treatments, fish welfare assessed according to different water quality parameters, impact and side-effects of vaccines. For some of the topics, free text could be entered in order to provide additional information.

The questionnaire was sent to 316 people, of which 230 work in private fish health services or farming or breeding companies, and 86 work as inspectors in the NFSA. There were 112 people who completed the survey

As in previous years, the Norwegian Veterinary Institute utilised an electronic survey to gather additional information from fish health services and fish health personnel employed by farming companies as well as inspectors from the Norwegian Food Safety authority. Photo: Eivind Senneset (response rate of 35 per cent), which is the highest recorded number for this survey. Out of these, 86 respondents worked in fish health services or farming or breeding companies, while 26 worked as inspectors in the NFSA. All respondents were offered to be mentioned by name as contributors, and those who wished to do so are listed under Acknowledgements towards the end of the report.

Data from the survey was used under relevant topics in the individual chapters of the report itself. An overall ranking of various disease and welfare challenges from the survey is shown in Appendix A - E.

Geografisk fordeling

Until 2020, the FHR displayed geographical distributions of data at the county level. The Aquaculture Production Area Regulation introduced on October 15, 2017, established regulations for commercial aquaculture of salmon, trout, and rainbow trout in thirteen geographically defined areas, known as production areas (abbreviated «PA» in the report), see Figure 1.1. With few exceptions, this year's edition of the FHR presents cumulative data per production area instead of per county. As there are relatively few sites in PA1 and PA13, data for these production areas are combined with PA2 and PA12, respectively, in the presentation of data for non-notifiable diseases to ensure confidentiality.

2 Mortality in salmonid production

By Victor H.S. Oliveira, Hege Løkslett, Annika Krutto, Ingunn Sommerset, Lars Qviller and Edgar Brun

Mortality in farmed salmonid is associated with several determinants, such as infectious diseases, adverse environmental conditions, injuries during handling, or other management-related factors. The significance of various diseases for mortality, among other things, is discussed in several other chapters of this report.

A new addition to this year's report is an overview of the causes of death in Atlantic salmon at marine sites, where data from the production systems of farmers have been made available for summary statistics. These data enhance the quality of assessments of fish mortality and contribute to a better understanding of the health situation in the Norwegian aquaculture industry, along with other sources such as disease statistics, reports of welfare incidents to the Norwegian Food Safety Authority, and the survey sent to fishery health personnel in connection with this report.

2.1 Some fish production statistics

Based on data from the Directorate of Fisheries at the end of February 2024, around 300 million salmon were released into the sea in 2023. This corresponds to the number of salmon smolts released into the sea reported for the period 2019–2021, following a peak in 2022 of over 340 million smolts released (Table 2.1.1). It is worth noting that there is a significant difference between the number of smolts released reported in the biomass statistics and the number reported as sold smolts in the Directorate of Fisheries' annual aquaculture statistics. For example, in 2022, sales of 425 million salmon smolts were reported (data as of October 2023), while reported releases in 2022 were 340 million salmon (data as of February 2024). The number of rainbow trout released into the sea in the period 2019–2023 has varied between 13 and 21 million, with 17 million reported in 2023 (Table 2.1.1). The downward trend in the use of cleaner fish continues, as reflected in both the number of sea sites reporting the use of cleaner fish and the reported number of cleaner fish released. Compared to the peak year of 2019, there was a 45% reduction in cleaner fish released in 2023. The health and welfare challenges for cleaner fish are discussed in Chapter 5 Fish Welfare and Chapter 12 Health Situation for Cleaner Fish.

The biomass of salmonids at sea at active sites is reported at the end of each month. The average monthly biomass in 2023 was approximately 825,000 tons for salmon and 43,000 tons for rainbow trout. This represents an increase compared to 2022 but a decrease compared to the peak year of 2021.

The slaughter figures for 2023 show a continued decline in the slaughtered biomass of salmon from the peak year of 2021, with a reduction of around 20,000 tons from 2022 to 2023. However, this constitutes only a small portion of the total amount of salmon slaughtered annually, which exceeds 1,500,000 tons in round weight. For rainbow trout, there is a 6% increase in slaughtered biomass observed in 2023 compared to the previous year.

2.2 Losses in juvenile salmonids production

The first production period for salmon and rainbow trout takes place in freshwater, and is called the hatchery phase. Fertilized eggs (eye roe) hatch into yolk sac fry, which are then fed and develop further from fry to fingerlings and parr, before they undergo a physiological adaptation to seawater and are called smolts.

In the hatchery phase, producers report to the food safety authority data on fish losses monthly. Every lost fish is recorded in the same manner, here considered as a dead fish (without distinguishing between dead and euthanized fish), alongside the total stock and their average weight. Unfortunately, the quality of data for fish in the hatchery phase, as recorded in official databases to date, does not match the quality of data available for fish in the sea phase, which are farmed for food consumption. Reports of fish mortality are made per tank unit without the ability to identify and trace fish groups. As juvenile fish grow, they are moved to new tanks, and processes such as sorting, splitting, and possibly mixing of fish groups often occur. Additionally, certain larger facilities may have multiple spawning cycles throughout the year. Due to these practices, there are inherent limitations in using juvenile fish data for detailed mortality calculations, including the assessment of mortality rates and risks involving individual fish groups. Proposals for improvements to the reporting of fish losses in hatcheries are discussed in **https://www.vetinst.no/rapporter-og-publikasjoner/rapporter/2019/dyrevelferd-i-settefiskproduktionen-smafiskvel** (available only in Norwegian).

Losses related to destruction/departure and mortality are expected at the very early stage in salmonid hatcheries. Therefore, the figures presented exclude the weight class 0-3 grams. Fish within this weight class represent around 45 percent of the total deaths during the hatchery phase. Figure 2.2.1. displays the reported

Table 2.1.1 Production data for farmed fish based on available figures from Directorate of Fisheries, as of February 14, 2024, ref. **https://www.fiskeridir.no/Akvakultur.**

	2019	2020	2021	2022	2023
Number of sites					
Salmon - number of active hatcheries throughout the year	138	132	133	131	128
Salmon - number of active sites at sea throughout the year	818	831	830	834	815
Salmon, average monthly active sites at sea	567	575	581	568	569
Rainbow trout - number of active hatcheries throughout the year	24	25	22	22	19
Rainbow trout - number of active sites at sea throughout the year	82	76	65	66	78
Rainbow trout, average monthly active sites at sea	53	46	43	40	49
Salmonids - grow-out production, number of sites on land (fresh water and salt water)	43	48	58	58	64
Salmonids - number of sites reporting stocking of cleaner fish	473	464	397	317	283
Number of transferred smolts to sea in millions					
Salmon	288	289	304	340	307
Rainbow trout	20.8	17.5	13.0	18.0	17.4
Cleaner fish*	60.9	57.3	48.3	36.2	33.7
Biomass at sea in tons					
Salmon - monthly average	767,340	797,825	837,234	814,462	825,144
Salmon - monthly range (Min–Max)	699,781–813,789	714,152–903,267	773,068–904,681	750,003–867,673	764,801–891,383
Rainbow trout - monthly average	45,146	43,608	40,960	37,056	43,557
Rainbow trout - monthly range (Min–Max)	38,113–52,160	40,567–45,358	36,984–44,591	33,541–41,582	35,302–49,597
Slaughter figures, tons in round weights					
Salmon	1,361,747	1 393 129	1,557,739	1,539,375	1,519,961
Rainbow trout	79,870	92,865	84,077	76,653	81,251
Post sea-transfer dead fish in millions					
Salmon	53.2	52.1	54.1	56.8	62.8
Rainbow trout	3.1	2.8	2.7	2.6	2.5

*The directorate of fisheries corrected errors in the numbers for 2019, 2020, and 2021 as of February 28, 2023.

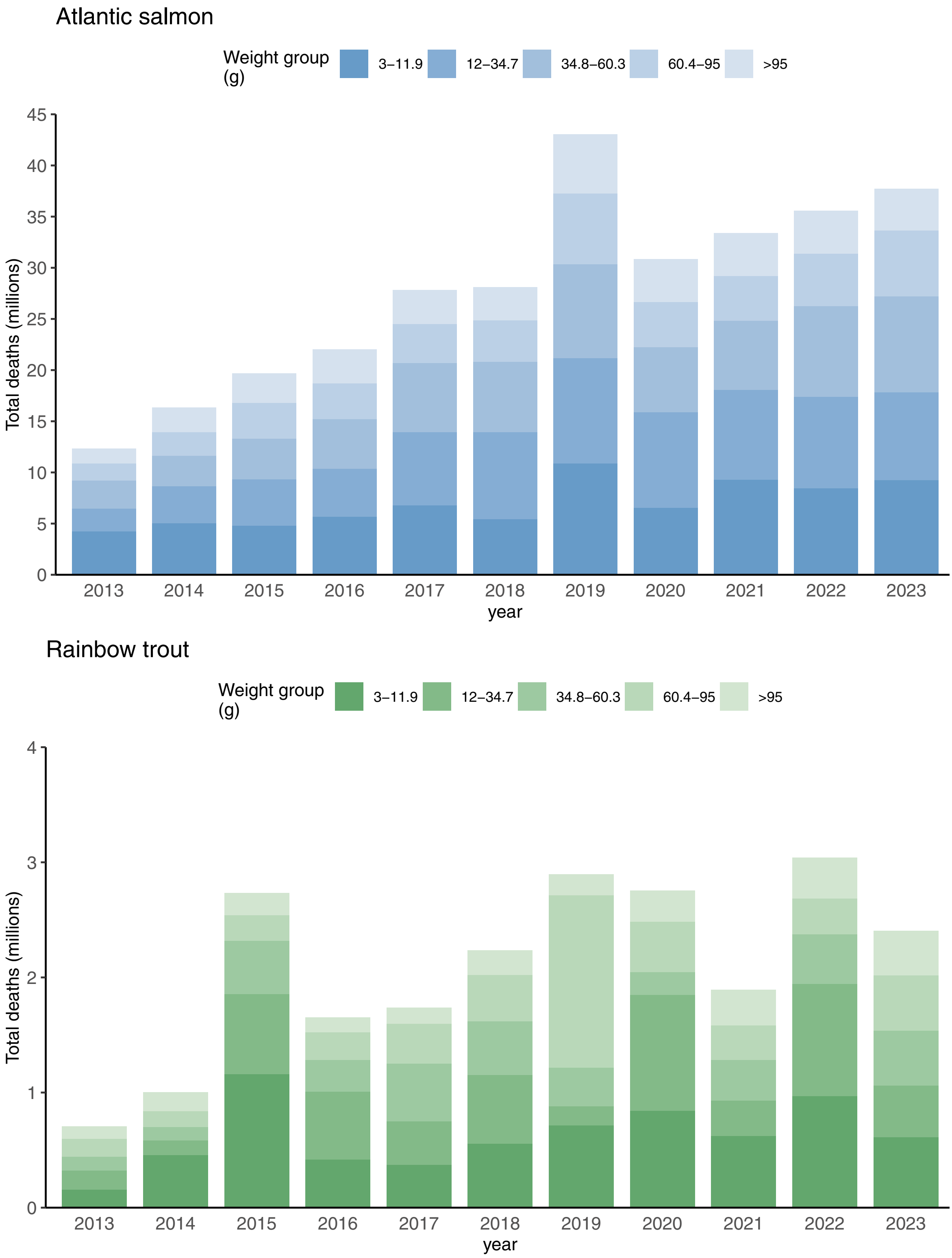


Figure 2.2.1 Mortality of salmon and rainbow trout in hatcheries (in number of individuals) reported to the Norwegian Food Safety Authority, divided into different weight classes.

number of dead salmon and rainbow trout to the Food Safety Authority in the hatchery phase from 2013 to 2023. In 2023, the deaths of 37.7 million salmon and 2.4 million rainbow trout larger than 3 grams were reported to the Food Safety Authority from the hatcheries. For salmon, this marked a continuation of the increasing trend observed in previous years, except for 2019, which had an unexplained peak of more than 43 million reported deaths. The most recent increase in the total salmon deaths in hatcheries apparently was not accompanied by a larger production of smolts in 2023, based on the number of salmon transferred to sea, which was 33 million less than in 2022 (Table 2.1.1). For rainbow trout, the number of transfers to sea has remained relatively stable in the past few years, while the total reported deaths have fluctuated. In 2023, there was a decrease of just over 0.5 million in the reported deaths of hatchery rainbow trout compared to 2022.

While it is not feasible to calculate mortality rates for individual fish groups (cohorts) in hatcheries (due to the lack of accessible data), this year's report introduces the presentation of mortality rates in hatcheries per weight groups. This approach can provide pertinent information about the developmental stages of juvenile salmon that are most susceptible to mortality. Data from hatcheries for calculation of mortality, which include both dead and alive fish, are reported at the tank level. The mortality rate calculation takes into account the number of live fish within specific weight groups present in the tank over the course of a month. In general, mortality in the hatchery phase is calculated according to similar principles as described under subsection 2.3, but several steps are taken to adapt the method to the nature of the source data. Please see Gåsnes et al. (2021) for a detailed description of the calculation method for fish in hatcheries.

Monthly mortality for Atlantic salmon in different weight groups is presented in figure 2.2.2. In this figure, the plots are characterized by their large boxes (the boxes have a large extent along the y-axis), illustrating that mortality varied widely in all the weight groups. Looking at the general range where half of the tanks observations fall (interquartile range, area colored in blue in the rectangle in the boxplot) the group with smallest fish

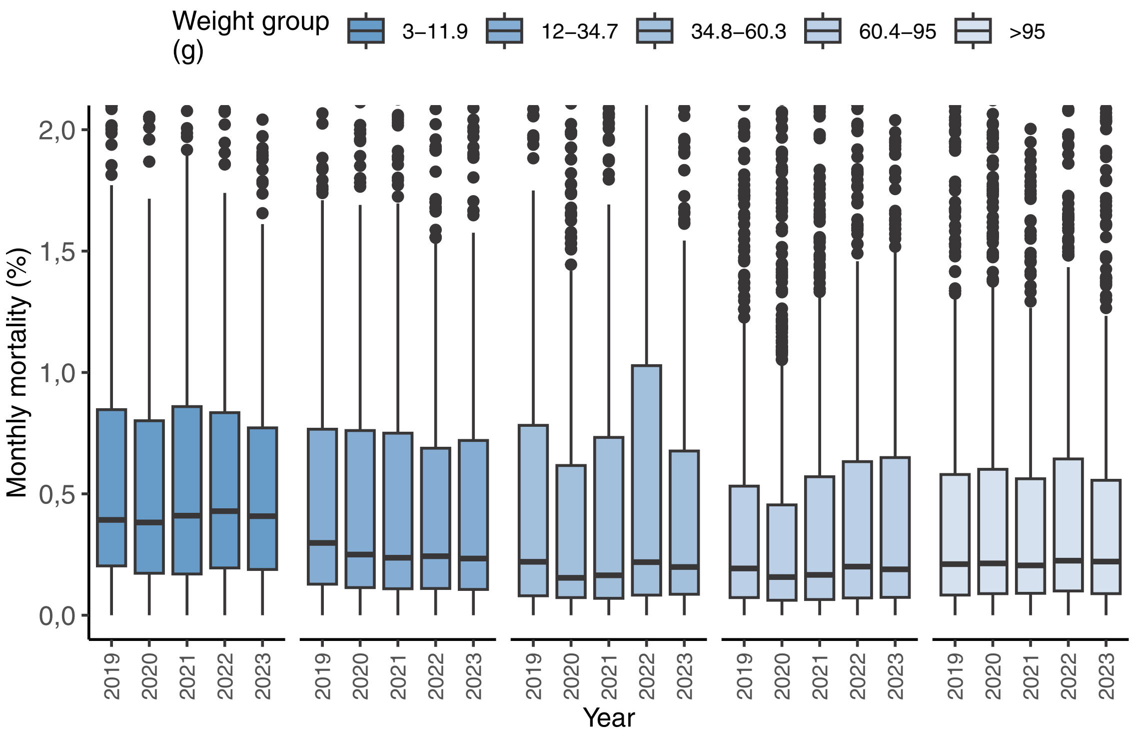


Figure 2.2.2 Distribution of Atlantic salmon monthly mortality across different weight groups in hatchery tanks from 2019 to 2023. The solid lines inside the boxes represent the median mortality rates, while the colored boxes indicate the interquartile range, the intervals for mortality in half of the tanks (25% over and 25% under the median). Black dots represent outlier observations. It should be noted that outliers exceeding the plot's axis limits are not displayed, although they are accounted for in calculating the central tendency of mortality depicted in the figure.

(under 12g) had the highest mortality, approximately 0.2–0.8%. As fish grow, the mortality tends to decrease; for the heaviest fish group, weighing more than 95 g, the general mortality range was observed to be approximately 0.1–0.6 %. In the study of Gåsnes et al. (2021), other factors influencing mortality patterns in Norwegian hatcheries with salmonids were described, with data spanning from 2011 to 2019. Among their findings, noticeably the season with highest mortality was during the summer months, while the lowest mortality was during the winter months. In addition, the northern regions of Norway presented highest mortality, in contrast to the southwest region of Norway, which recorded the lowest mortality.

2.3 Losses and mortality of fish during the sea phase

Loss of salmonids during the sea production phase is reported to the Norwegian Directorate of Fisheries and categorized as "dead", "discarded," "escaped," or "other." "Dead fish" includes fish recorded as deceased due to various causes and removed from the cages, including fish that have been destroyed. "Discarded" refers to fish unsuitable for human consumption that are sorted out during slaughtering. "Escaped" indicates the number of fish that have escaped from the cages. "Other" is recorded for fish lost due to reasons other than dead fish, discarded, and escaped, and counting errors may be recorded under this category. These definitions are available at **https://www.fiskeridir.no/Akvakultur/Tall-og-analyse/**

Akvakulturstatistikk-tidsserier/Laks-regnbueoerret-og-oerret/Matfiskproduksjon (accessed 14 February, 2024).

In 2023, registered losses amounted to over 70 million salmon and approximately 2.9 million rainbow trout. Of these losses, 62.8 million were dead salmon and 2.5 million were dead rainbow trout, representing approximately 89% and 86% of the total losses for salmon and rainbow trout, respectively. The record-high number of dead salmon in Norway must be viewed in connection with the peak in the reported number of smolts released into the sea in 2022 (over 340 million). However, for rainbow trout, the increase in released fish has not been accompanied by an increase in the number of dead fish, as the number of dead rainbow trout has decreased since 2019.

Details on the distribution of lost fish per category over the past five years can be found at **http://apps.vetinst.no/Laksetap.** It is important to note that interpretations based solely on the number of dead fish provide a limited perspective. For a more accurate assessment of mortality, the number of dead fish must be considered in relation to the population size over specific time periods.

The Norwegian Veterinary Institute uses data monthly reported by the farmers to the Norwegian Directorate of Fisheries' biomass statistics. The reported number of dead and alive fish at the end of each calendar month (at the site level) is used to generate information on mortality in monthly summaries, annual statistics, and data at the production cycle level. This is done using recognized epidemiological methods, which account for the fact that the stock of live fish (fish that can die) changes over time. The monthly death rate for each site is calculated by dividing the total number of dead fish by the number of fish at risk of dying. The number of fish that can die at a site may vary throughout a month, and therefore, we use an average calculation, where the number of fish that can die in a month is the number of fish alive at the beginning plus the number of fish alive at the end of the month, divided by two (Toft et al., 2004; Bang Jensen et al., 2020). Then we calculate the average death rate for the sites within each Production Area (PA) or nationally, for each month of the calendar year. These monthly average values are then summed and converted to the annual cumulative mortality risk, calculated using a specific formula that takes into account accumulating risk over the year, as described by Bang Jensen et al. (2020). The annual cumulative mortality risk quantifies the probability of a fish dying within a given year, with the resulting value expressed as a percentage ranging from zero to 100%.

Figure 2.3.1 displays monthly death rates from 2021 to 2023. The figure highlights mortality variations throughout the season and includes median and interval ranges. Such detailed analysis is useful for observing trends, identifying seasonal influences, and identifying unusual patterns, as well as for comparing mortality across different regions and at the national level. Additionally, we present annual mortalities in percentage in Table 2.3.1, as a compilation for the past three years. The monthly and annual mortality calculations provide valuable insights and the opportunity to identify current challenges that have led to increased mortality. A good understanding of mortality contributes to the decision-

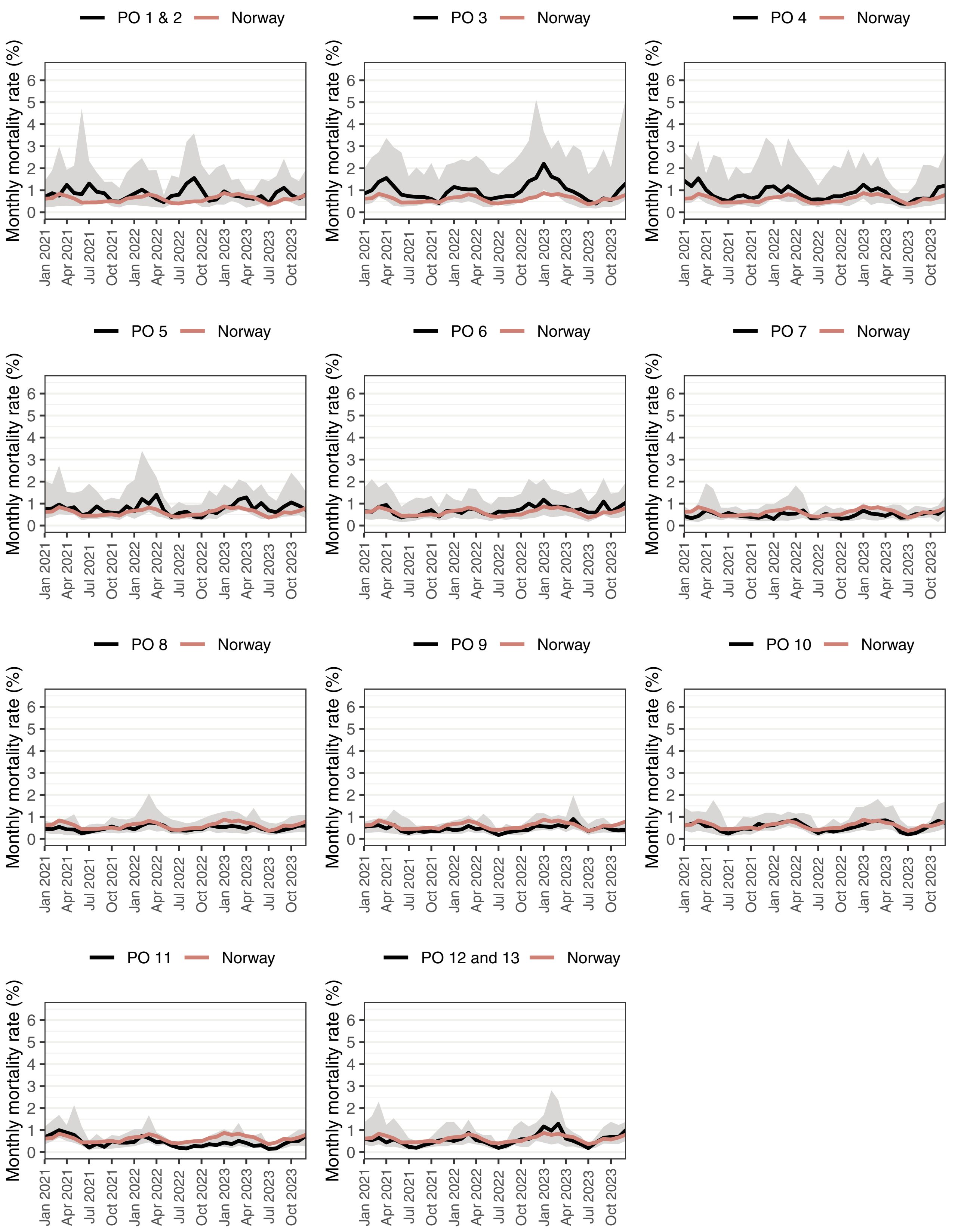


Figure 2.3.1 Development of monthly death rates (expressed as percentages) per production area between 2021 and 2023. Solid lines represent the medians for the respective PAs (black line) and nationally (red line), and the gray area illustrates the spread among the middle 50% of sites within the PA. 25% of the sites are above the gray area, and 25% are below it.

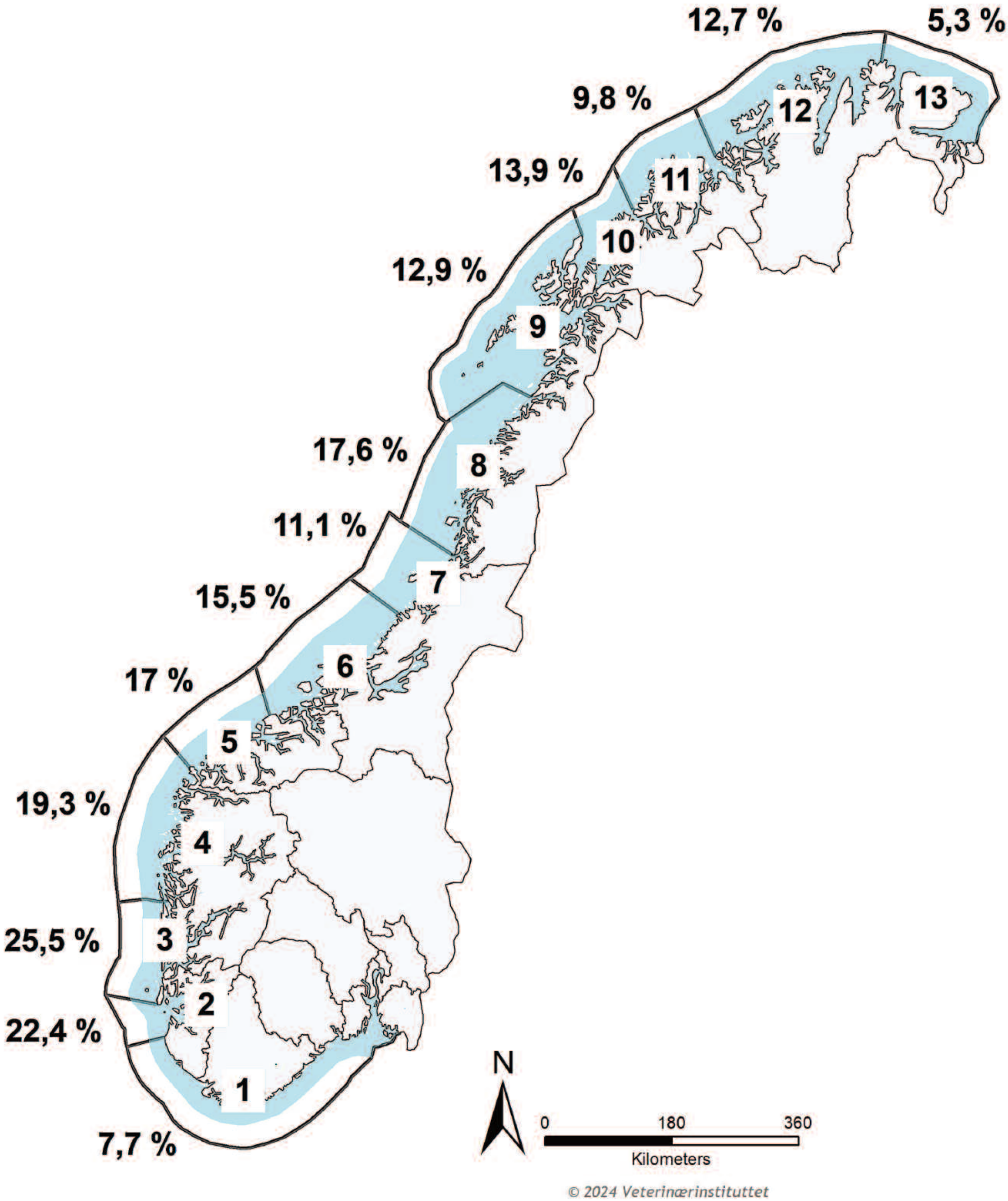


Figure 2.3.2 Geographical distribution of annual cumulative mortality risk in farmed salmon per production area in 2023.

making process in proactive management for both current and future fish populations.

In 2023, the national annual mortality risk, hereafter referred to as annual mortality, was calculated at 16.7% for salmon intended for consumption. This is the highest level recorded in the past five years. As in previous years, significant differences are observed across production areas (Figure 2.3.2). The highest mortality rates are found in Southern Norway: PA3 (25.5%), PA2 (22.4%), and PA4 (19.3%). It is worth noting that these areas also exhibit the largest variations in mortality between sites, as illustrated by the spread around the median in Figure 2.3.1. Mortality was below 10% in three production areas in 2023: PA1, PA11, and PA13 (Figure 2.3.2). Overall, annual mortality has ranged between 20–25% in PA2–PA4. PA5 falls in the middle range, with mortality ranging between 15-20%. For comparison, PA1 and the northern areas from PA6 to PA13 have consistently maintained mortality rates below 15%. An exception in recent years is the relatively high mortality in PA1 in 2022, with a clear peak in late summer (Fish Health Report 2022, Figure 2.2). From the affected aquaculture company, it has been stated that "the mortality during this period can be related, among other factors, to reduced gill health in combination with high sea temperatures in late summer and subsequent poor oxygen conditions, which in turn posed challenges related to labor-intensive delousing operations." Additionally, last year's mortality in PA8, which was as high as 17.6%, can be mentioned. One explanation for the increase in PO8 could be the required euthanization of farmed salmon in facilities that were diagnosed with pancreas disease (PD) at the end of the year, where regional food authorities reported that approximately 2.5 million salmon were stamped out before reaching harvest size.

The mortality numbers for rainbow trout have naturally varied somewhat more over the years, as there are fewer sites with this species. However, it is relevant to point out that the annual mortality in 2023 (14.0%) was the lowest in the period from 2019 to 2023. For more figures, see **http://apps.vetinst.no/Laksetap/.**

In addition to describing the percentage mortality per year, we can, similarly to above, also describe the percentage mortality per production cycle. We calculate the mortality per production cycle for sites that have

Table 2.3.1 Annual mortality in percentage in the production of salmon and rainbow trout in 2021-2023, divided by production areas (PO). Mortality is calculated from monthly death rates (see explanation in the text). More figures for counties, or for multiple years back, can be found in the interactive application "Statistics on losses and mortality of salmon and rainbow trout" at: **http://apps.vetinst.no/Laksetap/**

Salmon				Rainbow trout			
Production area (PA)*	2021 % mortality	2022 % mortality	2023 % mortality	Production area (PA)*	2021 % mortality	2022 % mortality	2023 % mortality
PA1	10.4	18.1	7.7	-	-	-	-
PA2	19.8	19.4	22.4	PA2 and PA3	17.8	15.1	16.6
PA3	19.9	23.8	25.5				
PA4	22.3	22.0	19.3	PA4	15.1	14.4	13.5
PA5	18.7	17.8	17.0	PA5	15.7	21.7	-
PA6	14.0	14.9	15.5	PA6	-	-	15.7
PA7	10.8	11.2	11.1				
PA8	12.1	14.6	17.6	-	-	-	-
PA9	13.5	9.5	12.9	-	-	-	-
PA10	10.9	14.4	13.9	-	-	-	-
PA11	12.5	9.1	9.8	-	-	-	-
PA12	13.0	11.4	12.7	-	-	-	-
PA13	10.2	9.9	5.3	-	-	-	-
Norway	15.5	16.1	16.7	Norway	14.9	17.1	14.0

*Mortality is calculated for PAs with more than five sites. Production areas with fewer than five sites are marked with a “-”.

been fully harvested in the current year, and include only sites that have had fish continuously present for at least 12 months from stocking to slaughter. Absence of monthly biomass reporting from a site is considered as the conclusion of a production cycle. Exclusions apply to sites with broodstock, fish from research and development concessions, teaching concessions, etc. Describing mortality across production cycles can be useful for tracking outcomes and challenges that sites have faced from stocking to slaughter, in periods that often extend beyond 12 months, in line with the actual production time at sea.

The median mortality risk for production cycles completed in Norway in 2023 was 18.6%, with the range indicating where half of the sites fell, from 12.2% to 26.9%. This is higher than what has been calculated for the past five years (2019–2023), although the variation is worth noticing (Table 2.3.2). In addition to national figures, this year's report also presents corresponding figures at the production area level (PA). Looking at mortality risk per completed production cycle for each PA, it can be seen that PA2, PA3, and PA4 have the highest mortality with medians of 24.6%, 25.2%, and 21.1%, respectively, in 2023. This corresponds well with the calculated annual mortality in 2022, where the same areas stood out with the highest mortality rates. Median mortality per production cycle is not provided for PA13 in Table 2.3.2, as individual sites can be identified when there are few active sites in an area.

When distributing mortality per completed production cycle from 2019 to 2023 in a scatter plot, with production areas divided into three regions (Figure 2.3.3), it can be seen that there is a very large variation within the regions. In areas where the majority of sites have

Table 2.3.2 Median (1st-3rd quartile) mortality risk for completed salmon production cycles distributed by production areas, and for the whole of Norway. Only production cycles of 12 months or more are included. Approximately 20% of the completed production cycles in the dataset were shorter than 12 months and were therefore excluded. Production areas with fewer than five sites with completed production cycles are not included and are marked with "-". The median represents the middle value, meaning that half of the production cycles had lower mortality and half had higher mortality. The interquartile range shows the middle 50% of sites, providing an indication of where most of those who completed the production cycles fall.

	2019 % mortality		2020 % mortality		2021 % mortality		2022 % mortality		2023 % mortality	
PA1	12.4	(8.1-14.7)	-		22.8	(19.0-25.4)	-		5.5	(13.9-18.8)
PA2	18.4	(12.5-25.7)	15.5	(11.0-20.3)	19.0	(14.8-26.2)	23.5	(16.7-31.0)	24.6	(21.6-31.8)
PA3	26.7	(18.9-37.0)	27	(20.6-34.5)	20.7	(16.4-29.7)	23.5	(16.0-33.8)	25.2	(18.7-37.0)
PA4	21.5	(11.8-28.6)	23.7	(18.0-36.5)	33.8	(21.7-39.2)	24.2	(16.1-31.2)	21.1	(17.1-28.6)
PA5	17.4	(14.2-23.5)	15.3	(11.4-17.2)	15.7	(9.8-26.4)	20.7	(11.8-36.8)	20.5	(16.3-26.6)
PA6	18.6	(12.0-27.4)	14.9	(10.4-22.6)	17.7	(11.6-24.6)	17.8	(12.8-22.6)	20.8	(16.7-28.2)
PA7	8.8	(7.1-12.9)	12.4	(10.8-14.6)	9.2	(6.6-13.2)	13.9	(11.0-17.0)	13.7	(9.7-20.9)
PA8	9.5	(6.3-13.7)	17.7	(9.8-30.1)	9.6	(7.5-21.8)	9.5	(7.4-14.8)	11.9	(9.1-16.4)
PA9	10.8	(7.1-15.7)	11.1	(7.0-29.2)	13.1	(7.5-21.8)	9.5	(6.0-15.7)	10.9	(8.0-17.4)
PA10	12.5	(9.0-14.1)	11.6	(8.5-20.2)	15.8	(11.5-20.9)	15.0	(11.4-18.6)	16.5	(11.9-22.6)
PA11	10.9	(8.8-24.7)	16.7	(7.0-20.4)	20.7	(12.4-29.3)	9.8	(6.0-15.7)	10.2	(5.9-15.9)
PA12	13.6	(9.4-23.7)	17.9	(11.1-19.9)	14.9	(10.4-25.9)	11.0	(8.6-19.4)	20.2	(16.6-26.5)
PA13	-		-		-		-		-	
Norway	15.0	(9.6-25.1)	17.9	(10.9-26.9)	17.5	(10.2-26.6)	16.6	(10.2-25.5)	18.8	(12.2-26.9)

production cycle mortality over 20%, some sites have managed to complete with under 10% mortality.

2.4 Cause-specific mortality in farmed Atlantic salmon

There is no requirement to register the cause of death in the official databases for the loss of farmed fish in either the hatchery or in the sea phase. The industry itself has taken the initiative for a unified registration of causes of loss and death by reporting to a health database in "AquaCloud".

The data is based on reporting by a classification system developed by the Norwegian University of Life Sciences (NMBU) and commissioned by NCE Seafood Innovation (Aunsmo et al. 2023). The system is based on a hierarchy categorization, where the producers register causes of mortality based on standardized mortality codes in three different levels (Level 1–3). This system has also been included into the Norwegian Standard NS9417:2022, highlighting its significance for aquaculture. For the first time, this report outlines the causes of death of farmed salmon registered at marine sites.

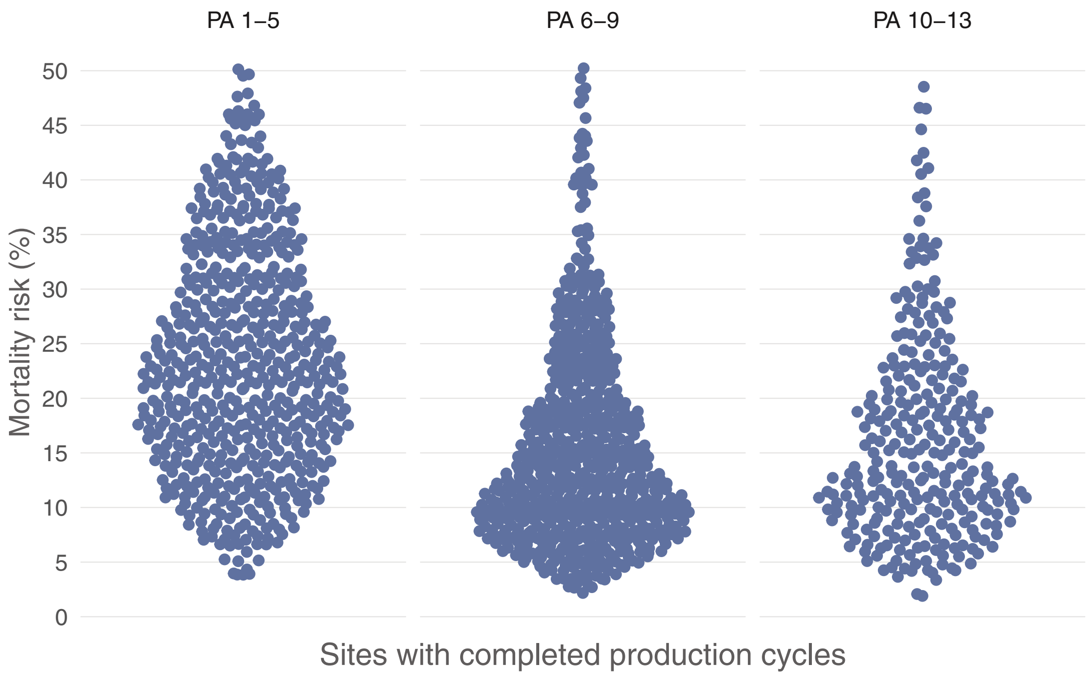


Figure 2.3.3 Total mortality risk throughout production cycles (%) for sites with salmon for 12 months or more at sea in the period 2019–2023, divided into groups of production areas. Approximately 20% of the completed production cycles were shorter than 12 months and were therefore excluded. Areas in the three figures with high density of dots (width of the dot cloud) show clustering of sites with similar production cycle mortality. Sites with mortality assessed to be extreme values are excluded from the figure. Extreme values were defined as observations exceeding the third quartile + 1.5 times the interquartile range (IQR), where IQR is the difference between the third and first quartile. Extreme values constituted less than 3% of the completed production cycles during the period.

Cause-specific classification of dead farmed Atlantic salmon

The Norwegian Veterinary Institute (NVI) is engaged in a collaborative effort with Sjømat Norge (the Norwegian Seafood Federation) and AquaCloud (NCE Seafood Innovation). The aim of the project is to implement and digitally report and share standardized causes of death at marine sites with salmonids. A database called "Fish health database" has been established, where producers, based on voluntary participation, report daily mortality data into the standardized coded format. Currently, there is restricted sharing of this data, meaning that the fish farmers only can view their own data, in addition to summarized descriptive statistics at regional level. Sharing and organizing information on salmon mortality and its potential causes, could enable farmers to gain a deeper understanding of the factors affecting salmonid health, facilitating a more coordinated and effective response to common issues.

The NVI's role is to assist in quality and consistency checking of the reported data, , with a focus on assessing the quality development so that the database actually achieves the objective that the "Fish Health Database" should become a good source of information for descriptive epidemiology related to aquaculture in Norway.

As part of this quality assurance, NVI is providing summary reports. With the consent of the data users (Sjømat Norge and AquaCloud), on behalf of the data owners (the participating companies), year-end reports can be published in the annual Fish Health Report. In this year's report, we first provide a summary of the level of participation among sites in this initiative followed by an overview of causes of death across three geographical areas (PA 1–4, PA 5–9 and PA 10–13). The number of participating companies has shown a significant increase since 2016. The number of sites reporting mortality causes has increased more than four times, reaching 355 in 2023, and they now cover approximately 43% of the standing biomass at sea (table 2.4.1).

The classification system developed for attributing causes of death (which can be extended to other types of loss) has a hierarchical structure with three levels (1–3), ranging from broader (main categories) classifications to more detailed ones. Level 1, the main categories, has six classes: Infectious diseases (A), Environmental conditions (B), Injury (trauma) (C), Physiological case (D), Other (E), and Unknown (F). Level 2 provides an intermediate level of detail with 29 mortality classifications, while Level 3, the most detailed, includes 150 mortality classifications (per February 2024). Due to the hierarchical structure, Level 2 and 3 are open for addition of new classes, such as new diseases (under main class A) or new type of

Table 2.4.1 The proportion (%) of sites contributing to the project, biomass (tons) reported at the end of the year, smallest monthly biomass reported, largest monthly biomass reported, in addition to the average monthly biomass reported for each year.

Year	Proportion (%) of sites	Lowest monthly biomass (tons)	Largest monthly biomass (tons)	Average monthly biomass (tons)
2016	9 %	-	-	-
2017	25 %	124 576	225 454	189 400
2018	26 %	107 874	235 039	167 773
2019	26 %	208 775	240 613	223 119
2020	26 %	190 777	263 471	220 751
2021	42 %	388 574	443 001	415 284
2022	44 %	391 952	442 935	418 510
2023	43 %	380 466	437 449	406 130

injuries (under main class C). Note that at Level 3, there are also unspecified classes (i.e., unspecified predator, unspecified injury and so on). Updated classes can be accessed at **https://airtable.com/appmR1vpr9M5UvMSs/shrTyJKqGTPQzZacw/tbl1o8yjrnrw7EtIt?backgroundColor=cyan&viewControls=on** (downloaded in May 2, 2024).

Distribution of major causes of salmon deaths on a national level

The project is in an ongoing process of increasing both the quality of the data recorded, as well as the number of companies that share data. The objective is that the "Fish health database" should become a good source of information for the descriptive epidemiology related to aquaculture in Norway. To achieve this goal, there are two important prerequisites that have not yet been met. One is that the information must represent at least 80% of the population. The second is that routine assessments that are made in connection with collection of dead fish, can be considered uniform and with the most appropriate classification of "cause of death". Since this type of sorting until recently has had no other purpose than to help the individual company with a better overview of own health challenges, there has been less emphasis on standardize the dead fish assessments themselves. Although a standard is established for how mortality are to be recorded digitally, it will take time before the desired standardization of the "diagnosis" at the different farms is achieved. Increased participation helps to increase focus on this and thereby the quality and strength of the data.

In the following, we will present figures we have been able to calculate from the database, based on the quality of the data as of now. It is important to specify that the figures do not indicate the real prevalence of the various categories. At the same time, it is also important to note the importance and potential such a tool has, both for research, but also for the producers themselves to gain a better basis for creating improvements in the future.

Table 2.4.2 provides an overview of the proportion of causes of death within the various categories in level 1. The highest participation of sites was in the period 2021–2023 (> 40 percent at national level), and the distribution of causes of death for these three years are our focus in this report. As can be seen in Table 2.3.1, the major cause of death at national level have changed from “Unknown cause (F)” in 2021 to “Infectious diseases (A)” and “Injuries (Trauma)(C)” in 2023.

Going beyond the level 1 categories in the period 2021–2023, the five most frequently reported level 3 categories under “Infectious Diseases (A)” were skin ulcers (including winter ulcer and Tenacibaculosis), cardiomyopathy syndrome (CMS), bacterial gill disease, pasteurellosis, and heart and skeletal muscle

Table 2.4.2 Overview of the proportion of causes of death within the various categories in level 1 per year, as well as overall for 2019–2023 based on data from the Fish Health Database. *Note: the figures do not indicate the real prevalence of the various categories.

Level 1	2019*	2020*	2021*	2022*	2023*
A Infectious diseases	10,1 %	17,5 %	20,6 %	28,5 %	38,1 %
B Environmental conditions	16,3 %	0,7 %	0,2 %	0,5 %	2 %
C Injury (trauma)	15,5 %	17,2 %	24,5 %	29,5 %	32,9 %
D Physiological case	4,4 %	5,4 %	5,9 %	4,6 %	4,5 %
E Other	2,0 %	2,6 %	3,4 %	2,1 %	2,0 %
F Unknown	51,8 %	56,6 %	45,3 %	34,8 %	19,6 %
Total	100 %	100 %	100 %	100 %	100 %

inflammation (HSMI). The main reported specified causes of deaths in class "environmental Impacts (B)" were Toxic Jellyfish and Nephrocalcinosis. The main reported specified causes of deaths among "Injuries (Trauma) (C)" were handling damage, non-medical treatment, injury (unspecified), Optilicer, and Thermolicer, which are technologies used in the salmon farming industry for controlling sea lice. The main reported specified causes of deaths among "Physiological Causes (D)" were physiological maladaptation, smoltification and sexual maturation. The main reported causes of deaths "Other Causes (E)" were dead before slaughter, vertebral deformity and malformation of head or jaws. The overall findings of this analysis are consistent with results obtained from the annual survey for the Fish Health Reports 2021, 2022 and the current report, where fish health personnel are asked to select the five most important causes of mortality for salmon of on growing sites in their area.

Distribution of major causes of salmon deaths in Groups of Production Areas

Figure 2.4.1 illustrates the distribution of level 1 causes of death within three groups of production areas (PAs), PAs 1–4, PAs 5–9, and PAs 10–13, from 2021 to 2023. Consistent with the national level, in all production area groups, we observed a decrease in the proportion of unknown deaths from 2021 to 2023. This likely indicates improvements in data quality and data registrations, specifically in terms of completeness and consistency that can probably be credited to a calibration period and enhanced training for the fish health personnel responsible for record keeping at the sites. In all groups of production areas, the proportion of "Infectious diseases (A)" as a cause of death has increased throughout the reporting years. In 2023, the main cause of death in PAs 1–4 was due to "Infectious diseases(A)" (47%), in PAs 5–9 it was due to "Injury (trauma)(C)" (39%), and in PAs 10–13, both "Infectious diseases (A)"

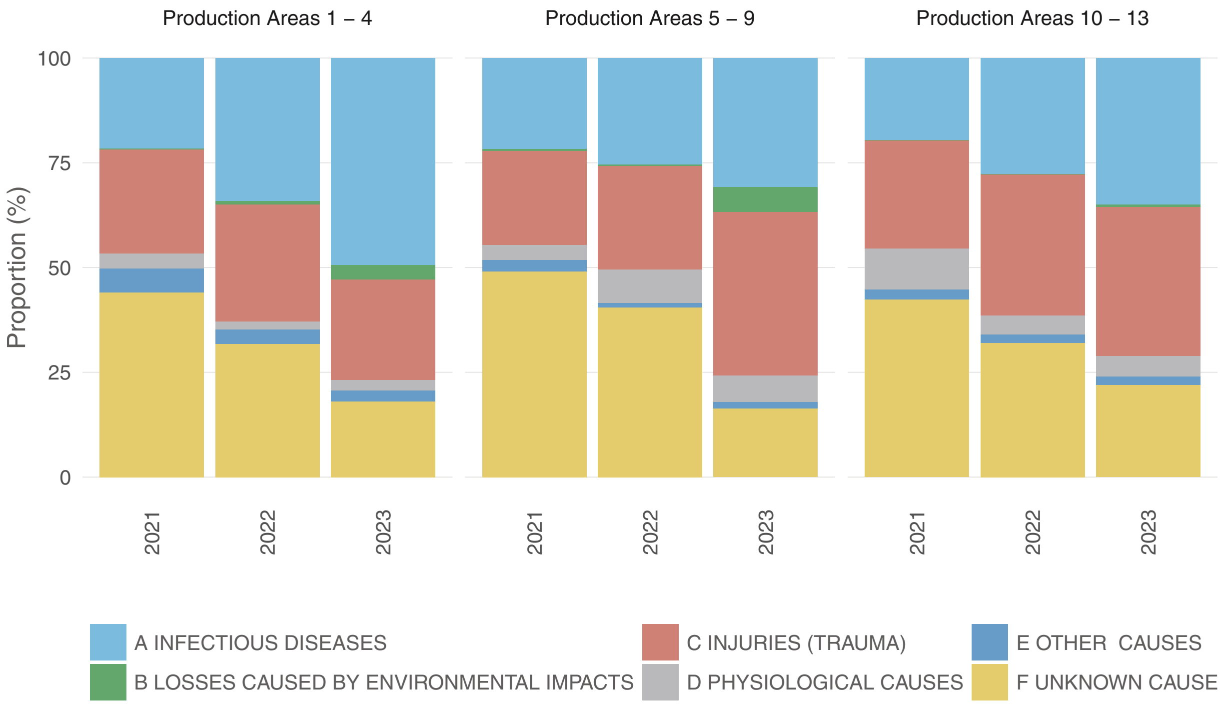


Figure 2.4.1 The proportion of causes of death recorded for farmed Atlantic salmon among level 1 in the time period 2021–2023, divided into three groups of production areas: PAs 1–4, PAs 5–9 and PAs 10–13. For details, please see text. Please note: These are registrations made by companies that share data in the project, and do not indicate the real prevalence at a national level.

and "Injury (Trauma) (C)" shared similarly the main contribution to causes of death (35% and 36%, respectively).

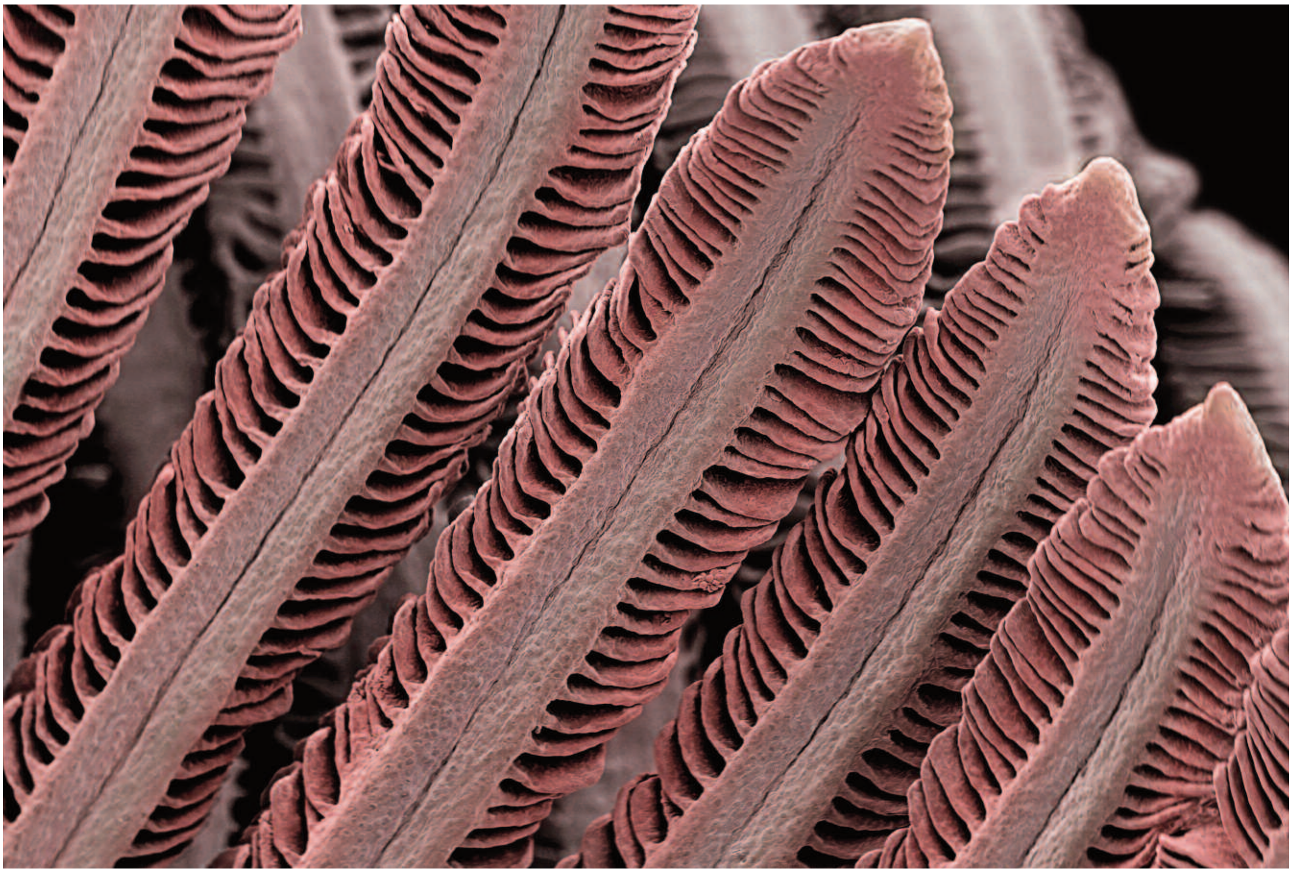
When analyzing the more detailed level 3 classes, among the infectious diseases reports by production areas, pasteurellosis, skin ulcers, and CMS were predominant in PAs 1–4 during 2021 and 2022. Interestingly, pasteurellosis, which was more than one-third of the death causes due to infectious diseases, dropped to approximately 10% in 2023. This decrease corresponds well with the reduced number of cases reported from diagnostic laboratories (a drop from 52 to 27 cases from 2022 to 2023) as well as results from the fish health survey where pasteurellosis was rated much lower as a health issue overall in 2023 (chapter 7.5 Pasteurellosis). For PAs 1–4, it is also worth mentioning the relevant drop of salmon pancreas disease (PD), which was a much more frequent assigned cause of death in 2021 (~12%) and were just over 2% more recently. The figures for PD correspond well to the number of cases reported by the Norwegian Food Safety Authority. Additionally, bacterial gill disease emerged significantly in PAs 1–4, comprising over a quarter of the infectious diseases death causes in 2023. These findings are also well in line with data from the diagnostic laboratories and how fish health personnel in this area graded different health issues in the annual survey. In the other production areas (5–9 and 10–13), skin ulcers was the primary infectious disease concern, showing an increasing trend that reached almost half of the reporting death causes in PAs 5–9 and two-thirds in PAs 10–13. Other causes of death noteworthy in PAs 5–9 (range: 9–23%, depending on the disease) include CMS, HSMI and bacterial gill disease; the latter was more relevant in 2023. In PAs 10–13, HSMI and Parvicapsulosis were common diseases reported causing the deaths. However, caution is advised as high proportion of the records in the most northern areas (PAs 10–13) were assigned to unspecified infectious disease in 2021 and 2022.

Deaths classified as "Environmental Conditions (B)" notably increased in 2023, especially in PAs 5–9 and PAs 10–13. This surge was mainly due to the jellyfish attacks in November–December 2023, making jellyfish in total contributing 1.7% to the total reported deaths in participating sites of all areas. Reporting of deaths caused by jellyfish attacks in the PAs 5–9 and PAs 10–13 were 97% and 89% within the total "Environmental conditions (B)" deaths for these areas, respectively. This corresponded to almost 60% of all the year's "Environmental Conditions (B)" deaths. The remaining deaths in 2023 due to environmental conditions in PAs 1–4 were mostly unspecified and we are unable to draw conclusions about it. Jellyfish attacks have been reported in PAs 1–4 between 2021 and 2023; however, the most commonly reported specific environmental cause there was nephrocalcinosis.

The proportion of deaths classified as "Injury (trauma) (C)" has been quite stable in the last three years in PAs 1–4 and PAs 10–13. In PAs 5–9, there was a marked increase in the proportion of deaths classified as trauma in 2023. Trauma due to handling (unspecified) has the largest increase in 2023 in this area, and this mortality class has the highest proportion (37.9%) on a national level in 2023 among "Injury (trauma) (C)". Additionally, in 2023, "unspecified predator" among "Injury (trauma (C)" classifications contributed notably higher (1.4% of salmon deaths among the participating sites) than in the preceding years (2019-2022). The potential inclusion of some jellyfish cases under this class might also be related to the data reporting quality and consistency.

Classifications of deaths as "Physiological causes (D)" has also been quite stable on a national level in the last years, proportion of deaths ranging from 4.5% (2023) to 5.9% (2021). Unspecific physiological maladaptation and smoltification issues were the causes with highest proportion in PAs 5–9 (37.2% and 38.6%, respectively) and PAs 10–13 (54.1% and 45.1 %, respectively) in 2023, whereas in PAs 1–4, sexual maturation and unspecific physiological maladaptation has the highest proportions (42.9% and 28.9%, respectively) registered among the physiological causes.

Within the "Unknown causes (F)", complex gill disease (CGD) with unknown cause is reported. Over the last three years (2021–2023), this CGD classification occurred mainly in PAs 1–4 and PAs 5–9; in the latter areas, it surged to almost 20% in 2023 out of the total "Unknown causes (F)". This is similar to the trend observed for bacterial gill disease, but it could be related to other potential etiological factors, such as parasites, viruses, zooplankton, algae, toxins, etc., and which were not assigned to any of the more specific classifications.



Salmon gill magnified 300 times. (Scanning electron microscope, colour manipulated). Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

Ref.:

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3 Fish health economics

By Cecilie Sviland Walde and Bård Misund

Economics is the study of production, consumption and distribution of goods and services, as well as the management of resources, seen from the point of view of society and producers. Animal health refers to the physiological, behavioural and mental state of animals, and is a central element of animal welfare (Chapter 5 Fish welfare). Maintaining good animal health involves preventing and treating disease, ensuring good nutrition and adapted living conditions, and addressing other factors that may affect animal welfare. Animal health economics involves giving animal health and welfare a distinct place in the economy.

In essence, animal health economics is about how companies and society, under limited resources, can make and make decisions to ensure good animal health.

The health of farmed fish can have a significant effect on production levels, consumption and distribution of aquaculture products. Firstly, disease will of course have negative consequences for the fish themselves. The biological costs of disease and other health-related problems include reduced growth, downgrading of harvest quality and, ultimately, death, which will have an effect on production, consumption and management of resources through less efficient production, less food, poor use of resources, as well as potentially reduced demand and trade restrictions. Pathogens in farmed fish can infect wild fish, and implementation of control measures to prevent or limit disease can have a negative effect on other species or the farmed fish. Animal health economics in its broadest form (i.e. economics) is therefore not only about corporate profitability and unit production costs, but also how poor animal health affects society. Below some examples on how disease and control of disease can affect economic conditions for the individual fish farmer, for an area and for society as a whole are highlighted.

3.1 Social consequences

The economic consequences of disease and poor fish health can be considerable, both for fish farmers and society. For individual fish farmers, impaired fish health has direct economic consequences through lost income as a result of mortality, reduced growth and downgrading, as well as increased costs for preventive measures, treatment and possibly extended production time. These higher costs may nevertheless be lower than the economic gain provided by increased production intensity. It is therefore not certain that a fish farmer will lose in total even if the biological costs increase, which can provide financial incentives for increased production.

In many cases, however, it is obvious that ensuring good animal health by preventing the introduction and spread of infectious agents is profitable. Several examples document that infectious diseases can have serious animal welfare consequences leading to substantial economic losses for both fish farmers and society. In the 1970s, 1980s and 1990s, infectious bacterial diseases such as vibriosis, cold water vibriosis and furunculosis caused high mortality and widespread use of antibiotics. Fortunately, effective vaccines against these diseases eventually became available, limiting the biological losses caused by the diseases. However, the widespread use of antibiotics gave the industry a negative reputation that lasted for several decades after the use of antibiotics had been greatly reduced.

The most dramatic examples of disease having enormous economic consequences are the outbreaks of infectious salmon anaemia (ISA) in Chile 2007-2009 and the Faroe Islands 2003-2006. In both countries, ISA led to the near collapse of industry. In Chile, production fell by 64 per cent from 2008 to 2010. In addition, the number of salmon smolts released to sea was reduced by 80 per cent from 2007-2009. The direct and indirect loss of production led to a prolonged economic crisis, affecting both individuals and local communities, as well as the supplier industry. According to a spokesperson for the Chilean salmon industry, the loss was around USD 2 billion in 2010, and 40 percent of workers lost their jobs. In the Faroe Islands, production fell by almost 75 per cent between 2003 and 2006 following the ISA outbreak. It took about 10 years for production to return to 2003 levels.

In Norway, similar examples can be found, notably pancreatic disease (PD), which was introduced to Norway in the late 1980s. For many years, the number of annual outbreaks was relatively low, before the disease began to spread both north and south of the main outbreak area in Hordaland County. In 2010, a new virus variant (SAV2) was introduced in Central Norway, where it took root.

In 2013, an average PD outbreak was estimated to cost around 55.4 million Norwegian kroner per farm, equivalent to 74.8 million in 2023. During 2014-2020, the number of new PD outbreaks each year was around 140-170. For the industry as a whole, this rate corresponds to an annual cost of PD of between NOK 10-12 billion. Currently, only PA1 and the areas from PA7 northwards are free of PD, although there have been some detections further north – most recently in PA8 in the autumn of 2023.

The probability of an epidemic of a serious infectious disease may be perceived to be small, and the measures to prevent the onset of the disease can be expensive. However, research also shows that the risk of extreme events is often underestimated. Furthermore, experience from Norway and other aquaculture production countries shows that infectious fish disease epidemics can have major consequences for fish health and welfare, as well as economic consequences for companies and society. If the disease takes root, the consequences can be even greater. It is therefore important that risk assessments have solid scientific foundations and that health economic calculations are supported by good epidemiological studies. Consequently, economic calculations can highlight the monetary consequences of epidemics as well as diseases becoming endemic, which in turn can be compared with the investment costs for biosecurity measures and preparedness.

3.2 Costs and benefits of various biosecurity measures

Several different biosecurity measures can be used to prevent the introduction and limit the spread of infection (Chapter 4 Biosecurity). One of the most pervasive measures is mandatory immediate harvesting following detection of the ISA and PD in areas where these are declared free of these diseases. For a production site, the economic consequences of harvesting may be high, and the producer in question may therefore consider whether it is profitable to continue production despite proven disease, which is something that can for instance depend on when in the production cycle the disease strikes. For instance, it has been shown that it is profitable for the farmer to harvest fish immediately rather than go through a PD outbreak if the size of the fish is larger than 3.2 kg. However, for a larger geographical production area, the consequence of not harvesting is an increased risk of other facilities becoming infected. These are sites that would normally continue their production without disease being transmitted from the site with a PD outbreak.

Several factors influence the cost and benefit of immediate harvesting as a strategy at the site, larger regional and the national levels. These include the consequences for fish health, at which stage in the production cycle the disease outbreak occurs, the effect of immediate harvesting for preventing new outbreaks, the market price of salmon, etc. All of these factors are attached with uncertainty. The consequences of immediate harvesting for the individual facility and for the area as a whole are thus complex. The cost of doing nothing must be compared to the cost of doing something. The alternatives being considered will be different for the different plants and change over time. Strategies that are expensive in the short term may be profitable over the long run, and decisions that are expensive for the individual site may be profitable for a larger geographical production area. Assessments of the costs and benefits of measures, therefore, cannot be restricted to simply assessing the impact on the individual plant or to the individual production cycle.

3.3 The free-rider problem

An aspect that needs to be taken into account is if the same production site takes the brunt of the stamping out strategy by repeatedly carrying out immediate harvesting, accruing costs that are not shared by the other farms that get the benefit of the strategy. An example would be facilities that operate in the periphery zone between endemic and non-endemic areas. These facilities could end up keeping down disease pressure for an entire area by taking the cost of repeated harvests and increased biosecurity requirements. In economic theory, this is called the free-rider problem, where several producers or consumers enjoy a public good without paying for it. Lack of disease is such a public good. The fear of being exploited by free riders can destroy the willingness to cooperate.

3.4 How to calculate health economics in aquaculture?

The examples above shed light on complex situations, where economic decision theory can help support rational choices, both for fish farmers, managers and politicians.

Considerations such as profitability, the health and welfare of farmed salmon and wild salmon, as well as negative environmental impacts do not always pull in the same direction and can lead to conflicting objectives. One particular choice can come at the expense of choosing something else. A choice between different alternative courses of action means that something must be discarded. This concept, opportunity cost, is essential part of economic decision theory. When something is prioritized over anything else, this has a consequence that must be considered and taken into account. Once the decision has been made it will have financial consequences, which can be calculated either as a pure cost estimate, or weighted against the benefits.

Assessments of fish health economics can provide information on how such problems should be solved, for example by shedding light on the economic burden of disease, and the cost-benefit of various measures to eradicate, limit or prevent disease. Cost estimates can be useful to shed light on the scope of a problem and to help prioritize efforts.

Little is known about the financial burden of various diseases in farmed salmon in Norway today. The companies do not report fish health costs in neither their quarterly nor annual accounts. Since the beginning of the 1980s, the Directorate of Fisheries' profitability survey has collected accounting and production data from fish farming companies, and the survey provides a good indication of the level and changes in production costs. Since 2015, this overview has also included the item 'health costs' (Table 3.4.1). The reported health costs (part of the item 'other operating expenses') have steadily increased since 2015, but the reasons for the increase are not given, nor which costs are included in 'health costs'. There is reason to believe that the item includes direct health costs such as costs of preventive work (vaccines) and treatment costs (medicines and delousing equipment), while the biological costs of mortality, reduced growth, poor feed utilisation (increased feed factor) and reduced harvest quality are not captured in this accounting item. It is reasonable to believe that the biological costs are greater than the stated ‘health’ costs. Biological costs are difficult to calculate, but can be estimated numerically under given assumptions. Table 3.4.2 shows estimates of the total fish health costs for the companies.

Table 3.4.1. Reported fish health expenses. Source: Norwegian Directorate of Fisheries’ aquaculture profitability survey.

Year	Reported health expenses (NOK/kg, nominal)	Estimated total reported health expenses for the industry (bln. NOK, nominal)
2015	1.83	2.68
2016	2,02	2.84
2017	2.25	3.25
2018	1.59	2.22
2019	2.21	3.14
2020	2.61	3.92
2021	2.49	3.97
2022	2.66	4.39

As well diseases having private costs for aquaculture companies, there are also some social costs for society. Companies will not include these social costs in their financial accounts. Such costs are called negative externalities, leading to market failure when the price of the product does not take into account the actual costs of production (private and social). Examples of social costs are negative impact on the environment through use of treatment chemicals, increased infection pressure on wild stocks, poor utilisation of resources, or that people are upset by media reports about poor fish welfare in aquaculture. The latter can lead to people buying less farmed fish, which in turn can lead to reduced demand and, in isolation, lower market prices. In the longer term, reduced fish health may lead to the authorities setting stricter requirements for what is considered acceptable fish welfare through, for example, stricter standards, lower production capacity and taxes, which in turn may increase companies' costs. In addition, society incurs costs in the form of monitoring and management of fish health, including funding for research activities.

3.5 Animal health economics in a local and global perspective

The companies will be subject to society's requirements and expectations, which is often referred to as the companies' social license to operate. This license can provide useful guidelines for changes in the industry's regulatory framework. There is an increasing focus on sustainability in society, a driving force which is increasingly also being operationalized through new regulations and requirements for information. The EU recently introduced a Corporate Sustainability Reporting Directive (CSRD), which is being rolled out in member states and in Norway through new laws and regulations and accounting standards (European Sustainability Reporting Standards, ESRS). Under the ESRS standards companies covered by the CSRD must report on both the companies' impact on society and the environment and how sustainability requirements will affect their profitability and development in the short, medium and longer term, a perspective which is also called the double materiality principle. Animal welfare is a potential factor that can be included in companies' long-term reporting.

Increasing human population growth and centralization have led to more efficient and intensive livestock production. In many societies, the production of animals for food is more or less invisible to the population, and the products are often largely processed after ending up in stores. Productivity improvements have also resulted in a smaller proportion of the population being involved in livestock production as compared to earlier times. This development also applies to salmon farming, where production takes place in closed-containment systems on land and in sea cages out of sight for the vast majority of the population. This has likely led to a distinction between humans and production animals, and where the value of a production animal is largely dictated by buyer demand and the animal husbandry (supply). As we (consumers) become better informed and obtain

Table 3.4.2. Estimated total fish health expenses in 2022 (NOK/kg whole fish equivalent, WFE)

Cost element	Typical cost set-up	GBADs set-up
Economic feed conversion rate	1.27	1.00
Smolt cost	5.09	4.00
Feed cost	21.63	17.04
Wages	3.54	2.79
Depreciation	3.06	2.41
Direct fish health cost	2.66	2.09
Biological cost	0	11.77
Other operating expenses	9.11	7.17
Harvesting cost	4.67	4.67
Capital costs	10.26	8.08
Sum production costs	60.02	60.02

increased knowledge about the health and welfare of farmed animals, attitudes, values and preferences in society change. In other words, when humans care more about animal welfare, the animal's well-being gains an increased economic value. There are major differences in how consumers value good animal welfare. Some consumers value good animal welfare and are willing to pay for it, while other consumers will be more focused on what the animal product costs to buy in stores. However, the economic consequences of poor animal welfare not only affects those who buy farmed animal products. Conceptually, animal welfare can be perceived as a public good, and thus has an economic value, and where negative media reports about fish welfare in aquaculture may also have a cost for those consumers who do not buy farmed fish. However, calculations of such economic effects are very complicated to carry out in practice.

Some studies of disease costs at company level exist, particularly related to PD, ISA and salmon lice, both in Norway and in other production countries. For example, it has been documented that salmon lice, and especially treatment for salmon lice, entail significant costs for aquaculture companies, and that the costs have increased, particularly following increased use of non-medicinal salmon lice treatment methods. Currently, we know even less of what diseases other than PD, ISA, and salmon lice costs the industry. This applies in particular to non-notifiable diseases, which are considered to have even greater consequences for lost fish growth, increased mortality and reduced fish welfare. This makes it difficult to rank the economic significance of the various diseases and thus also prioritize efforts. Another problem is that bioeconomic studies typically are not directly comparable. In general, there is a need for economic assessments of animal disease burden to be standardized.

An initiative called "Global burden of animal diseases" (GBADs), started by the World Organization for Animal Health (WOAH), has developed a standardized framework for calculating the total burden of animal diseases. This framework is closely related to the way the global burden of disease in humans is calculated. The framework has gained increasing acceptance, and the goal is to implement this also for calculating the disease burden in Norwegian aquaculture. To achieve this goal, information is needed on a number of factors related to the biomass of fish produced, farmed species, production systems, and the extent and effects of the diseases. Much of this information is collected in during the preparation of the Fish Health Report. In addition, information is needed on prices, costs and expenses for preventive measures and treatment, such as the purchase of vaccines and medicines, as well as investments in, for example, delousing equipment. Having this information allows for comparing actual production with the amounts of fish that could have been produced either in a "utopian" world without disease or against a baseline scenario. In this way the gap caused by disease and other health problems can be identified. Next, this gap can be attributed to different categories such as disease, comorbidities, nutrition and injuries. In practice, a disease-free condition in fish farming is almost impossible, but it is nevertheless a relevant benchmark for comparison (baseline) when pricing the total burden of disease. This approach is very similar to what is referred to as the biological production loss model in Arnfinn Aunsmo's doctoral thesis "Health related losses in sea farmed Atlantic salmon- quantification, risk factors and economic impact" in 2009 (Figure 3.5.1).

Preparing an ideal or utopian production estimate requires access to adequate good quality data. Lacking this data one needs to resort to more indirect approaches. One such approach, which can be used in aquaculture, is to use economic feed factor as an indicator to capture the effects of disease on growth and mortality. Such a method will unfortunately also introduce some level of measurement errors in that it captures factors that are not due to poor fish welfare, such as feed waste and effects of changes in feed composition.

The biological costs of mortality, reduced growth, increased susceptibility to disease and impaired harvest quality are often difficult to calculate. The reason is that it can often be difficult to isolate the negative effects of the individual disease and thus also calculate the costs. For example, in the case of increased fish mortality following delousing – did the fish die from the delousing treatment, or other underlying diseases such as CMS or gill disease? Such types of calculations require good epidemiological studies, which in turn are often very data intensive. In addition, it requires standardized ways of categorizing the effects of various diseases across companies and traceability of the fish groups. Currently, such data is not public or readily available, and often only available to the individual companies. Publicly available data on diseases are limited to salmon lice counts, salmon lice treatments and some notifiable

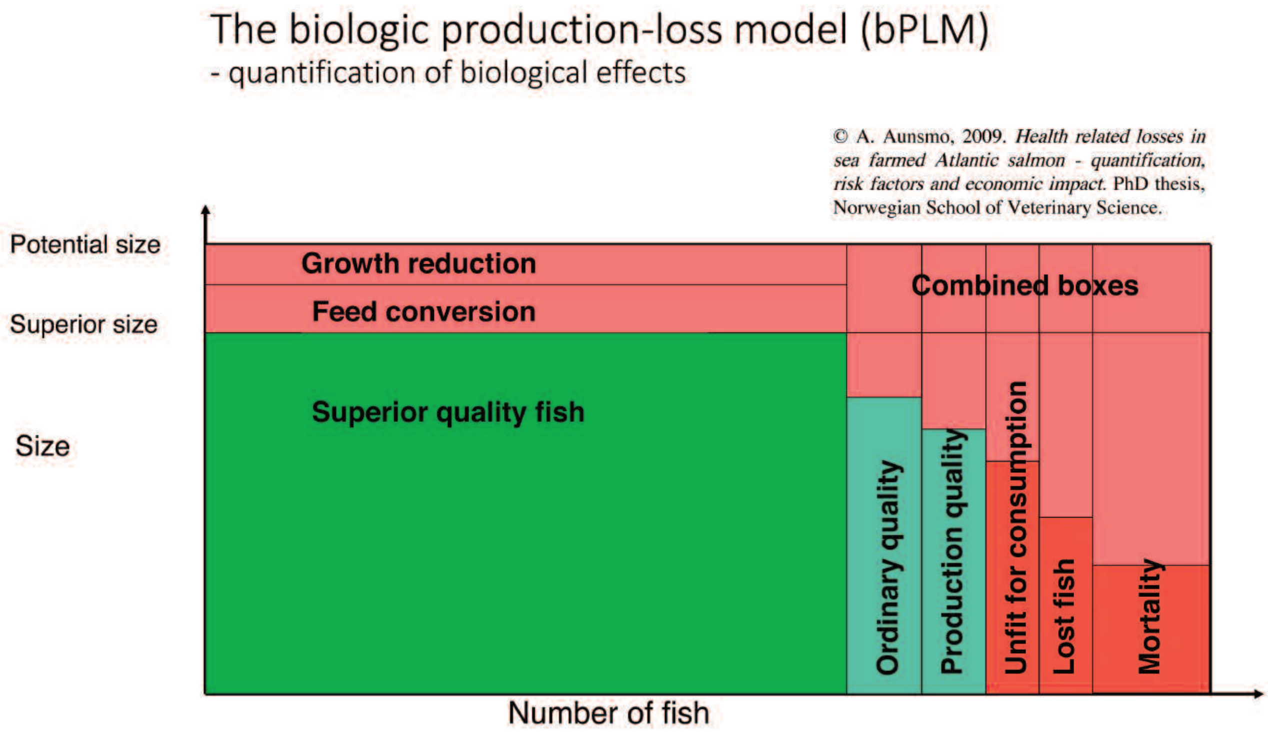


Figure 3.5.1. Biological production loss model. This describes a framework for the biomass potential in salmon aquaculture. Both produced biomass and biological losses can be categorized and quantified using this framework. Dark red colour indicates lost biomass, light red colour the unrealised potential production. The light green coloured area denotes reduced quality of produced biomass, and dark green produced biomass of superior quality. The figure is collected from Arnfinn Aunsmo's PhD dissertation "Health related losses in sea farmed Atlantic salmon- quantification, risk factors and economic impact", 2008, p. 36.

diseases such as PD and ISA. Health registrations in aquaculture under the auspices of NMBU is ongoing, working on a list for standardized categorization of causes of mortality, and monitoring and reporting of several of the non-notifiable diseases are fundamental for calculating the financial burden of diseases in Norwegian aquaculture and for prioritizing research and control measures.

3.6 Health economics as part of a decision-making basis

Successful management of aquaculture activities requires clear goals. Which of the following objectives should the companies strive towards – profitability, sustainability or animal welfare – is a key discussion to be had. Economic decision theory can help support rational choices, so that resources are managed efficiently. However, it is important to remember that economic calculations are a support for a making decision, not the final answer. Prioritization is also about assessing ethical requirements and goals. For example, it may turn out that some diseases at a general level do not have large economic consequences. However, it may be that for the fish that are affected, the disease has a very serious welfare consequence. Disease can also have a substantial financial impact on the affected business or for a small local community that is dependent on the business. In such cases, purely business calculations seen from the perspective of the individual firm may be insufficient.

The production of animals entails a special responsibility to safeguard the welfare of animals. This is an ethical goal that every pet owner can and should be guided by. One important goal is to ensure the best possible animal health with the means available. There are other additional goals that companies must strive towards, such as economic profitability, sustainable food production, efficient use of resources, environmental impacts, and societal acceptance. Companies create important values such as jobs, and in the case of fish farming, healthy food for a growing population. Aquaculture companies, like any other business, must be profitable in order to survive, but how they create their profitability is increasingly also an important factor.

4 Biosafety

By Ingunn Sommerset, Kathrine Nilsen, Sonal Patel, Kari Olli Helgesen, Trishang Udhwani, Kristoffer Vale Nielsen, Torfinn Moldal, Åse Helen Garseth og Taran Skjerdal

4.1 Biosafety - understanding and practical meaning in aquaculture

Biosafety has been included in "Norsk Standard" (Norway's member of ISO and CEN) NS 9417:2022 and is defined as the following: "The sum of operational- and physical measures with the intent of limiting the risk of disease introduction, -development and spread to, from and within an animal population, facility, zone, segment, transportation unit or any other venue, property or place." Biosafety in aquaculture is not limited to within and between farming operations, but involve several stakeholders, including end consumers and protective interests of wild fish. Stakeholders therefore can and should engage with the biosafety work within the industry.

The animal health law published in 2022 also applies to aquaculture animals, where preventive measures are central. All approved aquaculture facilities must have a biosafety plan, which contains justified descriptions on how the facility works to prevent, limit and fight infection. The Norwegian Food Safety Authorities, NFSA, published a guide on biosafety planning in aquaculture in December 2023. The NFSA's guide explain the purpose of the plan, how to prepare, improve and use the plan, but also to support NFSA in approvals of facilities, revisions and inspections of facilities. Initially the guide states: "Fish diseases spread multiple ways that requires different preventative measures. To make an effective biosafety plan which considers each individual facility, good knowledge of relevant diseases is required". NFSA's guide show several examples on how infections spread and suggested biosafety measures. The guide does not include protective measures against salmon lice which is covered in separate regulations.

The industry also put biosafety high on the agenda in 2023. By identifying important drivers for infections during the sea phase of salmon production, the Norwegian seafood federation ("SjømatNorge") published the leaflet "Best practice for biosafety and disease control". It states the goal for the biosafety work in the aquaculture industry and describes a number of risk-reducing measures in salmon production from broodfish and eggs, smolt production, production in the sea phase and safe transportation and slaughter. Implementation of these biosecurity measures depends on active collaboration by the industry, but also to some extent involvement of the regulators.

To establish effective routines for biosafety, scientific knowledge about the different infectious agents present in a population is required; occurrence, changes over time and the possibility for discovering new ones. Biosafety in the industry is therefore in demand of data- and information sharing, access to relevant material and openness. A trusting joint effort is necessary if the industry is to reach its goal to limit and fight the spread of disease. NVI's task is to confirm suspected listed diseases and advise NFSA on matters of infectious emergencies. Fragmented and contained/restricted information sharing, complicates the authority's ability of preparedness. The Norwegian fish health report is important as a counterbalance to privatization of animal health information, providing a solid knowledge base for an annual status of known diseases in the Norwegian aquaculture industry. Discovering emerging diseases at an early stage is however still a challenge.

4.2 Sources and routes of infection

An infectious agent can be a virus, bacteria, fungus or parasite that cause an infectious disease. For some well-known fish diseases in Norwegian aquaculture the source of infection is known. For example, the main source of infection for pancreas disease (PD) is the infected farmed salmon itself. For other diseases, like Pasteurellosis, the source is unknown. However, even if the primary source and route is unknown, different risk factors for infection can be known. The infectious route can be passive, meaning the agent enters a facility through the water. Alternatively, it can be active, meaning the infection occurs through contact with infected equipment, infected roe, or infected fish. Through the more active route of infection, diseases can be spread over larger geographical areas than through a passive route with water currents.

Sources and routes of infection in land-based aquaculture

There is generally good understanding of the main transmission routes into land-based facilities. While previously fry and smolt-production was the only land-based production, in recent years land based post-smolt and ongrowing farming facilities have been established. New methods for water treatment are implemented, many without appropriate scientifically established methods for monitoring the hygienic quality and public regulations struggle to keep up. Both disease outbreaks and serious welfare incidents occur in land-based facilities. The main transmission routes into the facility are normally through intake water and through the intake of infected roe/fish. Vertical transmission from infected broodstock to the next generation via roe or milt is called true vertical transmission (the pathogen is inside the roe grain), while roe can also be contaminated on the outside from infected parent fish or other sources. Vertical transmission is a known transmission route for diseases such as bacterial kidney disease (BKD) and the viral disease infectious pancreatic necrosis (IPN). Good hygiene and regulation-required disinfection of roe reduce the risk of infection.

To reduce the risk of infection through intake water, there is a requirement for disinfection of water for aquaculture facilities involved in hatching and production of salmonid fish and other freshwater fish, if the freshwater source is exposed to migration of anadromous fish or if seawater is used. Both the method and technical equipment for water disinfection must be approved, and supervision shall be conducted according to the "Regulation for disinfection of water, aquaculture" (FOR-1997-02-20-192). The regulation also includes requirements for disinfection of wastewater from slaughterhouses and from land-based fish facilities approved for experimental infection trials. The NSFA has identified a need for revisions to adapt the regulation to the current situation, as the production of farmed fish on land has become much larger and more complex than when the regulations were established.

Fortunately, the questionnaire answered by fish-health specialists and inspectors from NFSA shows that infectious diseases is rated in the lower part amongst the most important issues for salmon hatchery production (Appendix A1). In hatchery production of rainbow trout, the viral disease IPN is ranked as one of the top roblems causing mortality (Appendix A2). For cleaner-fish (lumpfish and wrasse) hatchery production with intake of seawater, infectious diseases are still problematic (Appendix D1, E1 and chapter 12 “Health of cleaner-fish"). Whether this caused by of pathogens in inlet water (FOR-1997-02-20-192 does not include requirements for disinfection of seawater for marine fish production) or introduction of infected roe or fry, is unknown.

Sources and routes of infection in classic sea-based fish farming

Through the classic open sea-farm production systems, typically in net pens, the fish will constantly be exposed to infectious agents and harmful substances (like algae or jellyfish) carried with the ocean currents. Infections can be transmitted internally from sick fish in neighbouring net pens, or from infected external neighbouring farms. Infection can also occur due to close encounters between cohabitating salmon and cleaner fish, or from a source in the environment – like wild fish, sea birds or sea mammals.

Another important risk factor for infection during sea-based fish farming is linked to active transmission of disease whereby fish (smolt or post-smolt) carrying diseases are transferred from land-based, closed or semi-closed production facilities to open net pens in classic sea-based fish farming. Infection can also occur through contact with contaminated equipment or boats, such as wellboats, delousing barges, net cleaning equipment, loading hoses, tanks and tubs and more.

Diseased and dead fish is also an important biosecurity risk. Dead fish and other biological waste classified to carry a biological hazard must be kept hygienically separate from live fish at the facility. Dead fish shalle be cleared out from the cage on a daily basis and ensiled at a pH level lower than 4 in closed containers. The fish farm must have a plan on how to handle large amounts of dead fish in case of emergency, including boats, and how to handle infectious biomaterial.

4.3 Coordinated fallowing and area planning

For a sea-based facility with broodstock or fish for consumption, there is a requirement for a two-month minimum fallowing period of the site after the end of production and before the introduction of new fish. The NFSA may impose a longer fallowing period if deemed appropriate for infection control purposes, and request coordinated fallowing of multiple sites. There are requirements for environmental monitoring of the seabed within the facility zone, but there is no equivalent requirement for monitoring of pathogens in the environment following outbreaks of serious diseases. Most sea-based facilities do not collect waste such as fish excrement and feed residues. For certain serious diseases, such as PD (Pancreas Disease), it is known that the virus is shed through the excrement of infected salmon. It is not known how quickly the PD virus is broken down in fish excrement and therefore how long it will pose an infectious hazard in the environment. A modelling study on the spread of PD within and between Norwegian sea-based aquaculture facilities did show an increased risk of infection on previously infected sites, but that this risk was moderate. The model, based on real PD detections, also showed that the main source of PD infection in a farm was infected neighbouring facilities, accounting for 88 percent of the cases. Whether a facility became infected from its neighbour or not, depended on the sea distance between the facilities and the number of fish in the facilities. Rapid slaughter and coordinated fallowing within defined infection zones has also been shown to significantly reduce the risk of PD spreading.

Many pathogenic bacteria and parasites are naturally present in the environment. Salmon lice and the amoeba *Paramoeba perurans*, which causes AGD, can both passively be transferred through moving water masses, although with some very short distance self-movement. *Moritella viscosa* and *Tenacibaculum* species, which cause classical and atypical winter ulcers respectively, are also naturally present in the environment, likely as decomposing organisms on the seabed. These naturally occurring parasites and microorganisms cannot be completely eradicated through fallowing, as the potential source of infection is naturally present in the environment.

The production areas (Norwegian “produksjonsområder” short “PO”) established in 2017 were created to regulate the production capacity for profitable and sustainable development of aquaculture with salmon, trout, and rainbow trout. The delineation of the 13 areas was mainly based on natural geographical boundaries for water contact, and the production capacity in each area is regulated based on the impact of salmon lice on wild salmonids. There is no requirement for coordinated fallowing within these POs. Apart from the boundaries between the PD zone (endemic PD) and the monitoring zones for PD (PD-free), there is no agreed-upon national or regional area structure that cuts off transmission pathways through firebreaks or coordinated stocking and fallowing strategy. However, local agreements on coordinated fallowing along the coast are made, one example of this is the "Aquaculture Working Group" where salmon and rainbow trout farmers in Nordmøre and Sør-Trøndelag cooperate. The group is coordinated by the fish health service “Åkerblå” and has entered into a binding biosafety agreement that includes zone structure and firebreaks. There is likely a significant untapped potential in transitioning to a better zone structure for traditional sea-based aquaculture facilities, where the areas are reset between each production cycle. A recently started FHF-funded research project called "Optimization of site use and area organization for increased biosafety (OptiLok)" will utilize knowledge of various pathogens and hydrodynamics, as well as epidemiological models, to calculate water contact between individual sites. The aim is to be able to recommend an optimal area organization to reduce the likelihood of waterborne transmission between fish farming sites.

4.4 Vaccination as a biosafety measure

Effective vaccines against important bacterial diseases have historically contributed, and continue to contribute, to keeping antibiotic use in Norwegian aquaculture at very low levels compared to other countries and other livestock. Vaccination of fish is currently regulated by the Food Act (§ 19), the Aquaculture Operations Regulations (§§ 11 and 28), and the Animal Disease Control Regulations §§ 5-9. The regulations describe in general terms the obligation to implement relevant infection prevention measures, including vaccination. Vaccination is considered a very important infection prevention measure. For salmonids, effective vaccines are available against many diseases, but for less commercially significant aquaculture species such as cod, halibut, and various species of farmed cleaner fish, research and development work is still required to establish effective vaccines. This may be one of the reasons why 53 out of 77 antibiotic prescriptions for farmed fish in 2023 were for marine species (Chapter 7.9 Sensitivity to antibacterial agents and antibiotic consumption). Where approved vaccines with marketing authorization are not available, or those offered are shown to be ineffective, autogenous vaccines may be relevant. Autogenous vaccines are based on an infectious agent isolated from one or more fish, which belongs to the same "epidemiological unit." Permission must be sought in each case before use (exemption from approval), and the manufacturer must be approved by the Directorate for Medical Products. According to figures from one producer, approximately 30 million doses of an autogenous vaccine against disease caused by Pasteurella and approximately 10 million doses of an autogenous vaccine against winter ulcer disease caused by M. viscosa were sold in 2023. The latter can no longer be prescribed since a new winter ulcer vaccine was granted marketing authorization in May 2023 (see below). Autogenous vaccines are also available against disease caused by Yersinia. For cod, either 3- or 4-component (multivalent) vaccines are used.

It is common to vaccinate salmonids when in the hatchery production phase (freshwater) to immunize them against important infectious diseases encountered during the sea phase. Figure 4.4.1 shows the number of doses (in millions) of various categories of vaccines with marketing authorization for Atlantic salmon and rainbow trout that were requisitioned for hatcheries from 2020 to 2023. The data are obtained from the Norwegian Food Safety Authority's Veterinary Medicinal Products Register (VetReg) as of January 17, 2024, and are limited to injectable vaccines. The most common general vaccination of Atlantic salmon consists of a multivalent injection vaccine containing five bacterial antigens and a viral antigen aimed to provide protection against IPN, referred to as "General/IPN" in Figure 4.4. The five bacterial components include *Aeromonas salmonicida* subsp. *salmonicida, Vibrio anguillarum* serotype O1 and O2a, *Vibrio salmonicida,* and *Moritella viscosa*. General vaccination without IPN, referred to as "General" in Figure 4.4, is the most commonly used for rainbow trout, but in 2023 there was a noticeable increase in the number of doses allocated to Atlantic salmon. There are also multivalent vaccines that include inactivated virus antigens that protect against ISA or PD. However, the most common way to vaccinate against PD is to administer the PD vaccine separately, either in the form of a DNA vaccine (injected into muscle) or an inactivated PD virus vaccine (injected into the abdomen). The PD vaccine is administered simultaneously with the general vaccine. PD vaccines were not requisitioned for rainbow trout during the period 2020 - 2023, even though this species can also contract PD and shed infectious virus. Vaccination against PD is discussed more specifically in Chapter 6.1 Pancreatic Disease (PD).

Vaccination against ISA has become more common in recent years, especially in Northern Norway where there were significant challenges associated with ISA until 2021. There is also an increasing interest in vaccination in Western Norway, which makes sense in light of the outbreaks and suspected cases that occurred in this area in 2023. Vaccination can reduce disease impact and virus shedding, however there are several examples of ISA detections at sites with vaccinated fish.

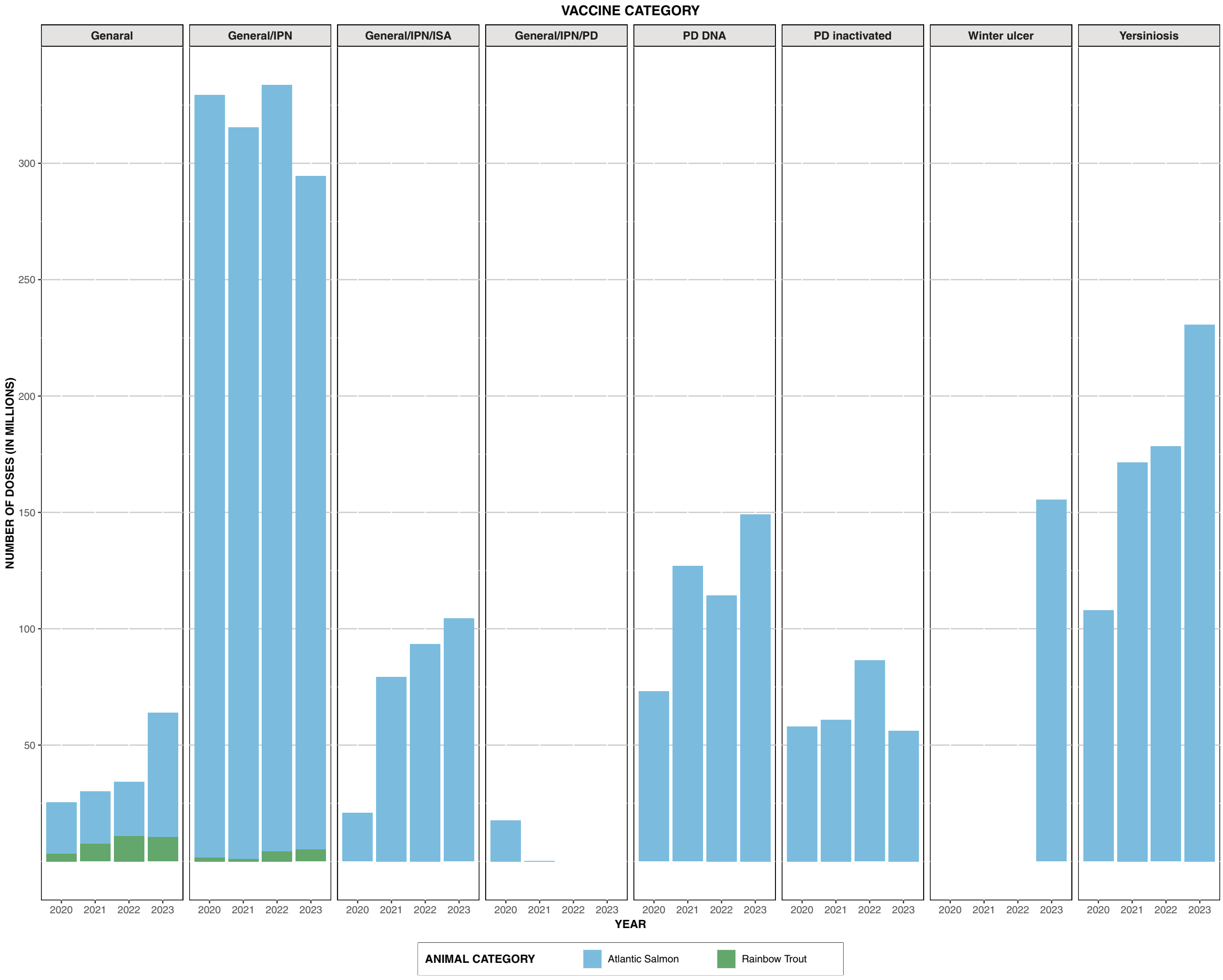


Figure 4.4.1 number of injection-based vaccine doses delivered to smolt facilities, 2020 to 2023, split into the following categories: General (containing furunculosis, cold-water vibriosis, vibriosis, and for some winter-ulcer components), general/IPN (as previously plus infectious pancreatic necrosis), general/IPN/ISA (general plus IPN plus infectious salmon anemia), general/IPN/PD (general plus IPN plus inactivated PD vaccine), PD_DNA (DNA vaccine against pancreas disease), PD-inactivated (inactivated PD component), winter-ulcer, and yersiniosis. The categories are further divided into vaccines intended for salmon (blue) and for rainbow trout (green). Data is sourced from the Norwegian Food Safety Authority's Veterinary Medicines Register (VetReg), downloaded on 17.01.2024. Bath vaccines are not included.

There is a significant increase in the use of injectable vaccines against yersiniosis from 2020 to 2023. According to VetReg, approximately 230 million Atlantic salmon were injected with a yersiniosis vaccine in 2023, while approximately 447 million Atlantic salmon were injected with one of the three general vaccines with or without a virus component (general, general/IPN, or general/IPN/ISA). This means that slightly more than 50 percent of all vaccinated Atlantic salmon were also vaccinated against yersiniosis, and this figure excludes any potential bath vaccination figures. The high vaccine coverage corresponds to the increase in reported cases of *Y. ruckeri* infections over the last years. It also imply that the industry has increasingly applied vaccination as a disease prevention measure in 2023, see also Chapter 7.6 Yersiniosis. In May 2023, a new vaccine against winter ulcer disease was introduced to the market: a single-component vaccine containing the so-called ‘variant’ *Moritella viscosa* antigen. During 2023, approximately 155 million doses of this vaccine (referred to as "Winter ulcer disease" in Figure 4.4) were requisitioned. The new vaccine is administered simultaneously with the general vaccine, which contains the ‘classic’ variant of *M. viscosa*. Winter ulcer disease has been an increasing problem in farmed Atlantic salmon during the sea phase in recent years, and it has been discussed whether the new variant of *M. viscosa* is to be blamed and whether the classic vaccines give cross-protection or not. The potential effect of the new vaccine on the winter ulcer situation is expected to be evaluated during 2024 (Chapter 7.4 Winter ulcer disease).

Although the number of requisitioned vaccine doses of the different vaccines provides some indication of the expected cost-benefit ratio, the actual vaccine efficacy in the field is more challenging to quantify. VetReg data only contain information about which hatchery site the vaccine is requisitioned for and not the sea site where the vaccinated fish are transferred. To measure the efficacy of vaccination as a biosafety measure, information about vaccination status needs to be available per sea site, and preferably per production unit, at the cage level. Currently, such a public registry does not exist.

In the Fish health report survey, we have asked fish health personnel having experience with vaccination to answer questions regarding efficacy and side effects. In the 2023 survey, the following question was asked: "Have you experienced clinical outbreaks of the following diseases despite the fish being vaccinated against these diseases?" Specific diseases mentioned were ISA, PD, IPN, winter ulcer, yersiniosis, pasteurellosis, and "others." There were five response options for each disease: 1) "Yes", 2) "Yes, but to a lesser extent than in unvaccinated fish", 3) "No", 4) "Not vaccinated against", and 5) "Don't know". The responses were distributed as shown in Table 4.4.1.

The responses indicate that the abovementioned vaccines are perceived to provide varying degrees of protection against the diseases they are intended to protect against. The vaccination against winter ulcer disease is perceived to have the poorest efficacy, with 43 out of 55 respondents (74%) reportingclinical outbreaks despite vaccination in 2023. For the other vaccines, better protection against clinical outbreaks is reported. For example, for yersiniosis, only 5 out of 41 respondents (12%) report clinical outbreaks in vaccinated stocks.

Out of a total of 30 free-text responses regarding vaccine efficacy, vaccination against winter ulcer disease was mentioned in 21 responses, pasteurellosis in seven responses, PD in six, yersiniosis in four, IPN in four,

Table 4.4.1 Summary of responses to the question: "Have you experienced clinical outbreaks of the following diseases despite the fish being vaccinated against these diseases?". Listed are the number of respondents who answered the question with the various response options, for each of the diseases ISA, PD, IPN, Winter ulcer (*Moritella viscosa*), Yersiniosis (*Yersinia ruckeri*), Pasteurellosis, and "Others". Numbers in parentheses represent the same number but as a percentage of the total number of respondents.

Disease	ISA	PD	IPN	Winter ulcer	Yersiniosis	Pasteurellosis	Others
Yes	1 (2 %)	2 (4 %)	12 (22 %)	37 (64 %)	2 (4 %)	1 (2 %)	2 (5 %)
Yes, but to a lesser degree compared to unvaccinated	2 (4 %)	16 (29 %)	6 (11 %)	6 (10 %)	3 (6 %)	8 (15 %)	1 (2 %)
No	29 (56 %)	21 (38 %)	32 (59 %)	7 (12 %)	32 (63 %)	17 (33 %)	23 (53 %)
Not vaccinated against	19 (37 %)	14 (25 %)	1 (2 %)	3 (5 %)	10 (20 %)	21 (40 %)	9 (21 %)
Don't know	1 (2 %)	2 (4 %)	3 (6 %)	5 (9 %)	4 (8 %)	5 (10 %)	8 (19 %)
Number of answers (respondents)	52	55	54	58	51	52	43

vibriosis in two, and one response mentioned atypical furunculosis (post-smolt). In the responses discussing poor vaccine efficacy against winter ulcer disease, several mentioned that this could be due to outbreaks of a different variant of *M. viscosa* than that used in the vaccine. In 2022 several fish farmers tested the new winter ulcer vaccine containing the "variant *M. viscosa*" as part of a clinical field trial. Some of these sites claim to observe an improved vaccine efficacy against winter ulcer disease already. As mentioned above, a relatively large number of Atlantic salmon were vaccinated with the new winter ulcer vaccine in 2023, making it easier to assess the efficacy in the field next year.

The general oil-based vaccines against bacterial diseases for Atlantic salmon and rainbow trout, except for winter ulcer disease the last years, have provided a high level of protection against the development of clinical outbreaks and have significantly contributed to reducing transmission pressure in Norwegian aquaculture. Historically, it has been more challenging to develop vaccines with good efficacy against viral diseases such as IPN, ISA, and PD. Although there is evidence suggesting that the new virus vaccines have better efficacy than previous formulations, none of them provide sterile immunity. This means that vaccinated individuals can still be infected and shed infectious virus, albeit to a lesser extent than unvaccinated infected fish. Therefore, it is essential to combine several biosafety measures, with vaccination being one of several important measures. The vast majority of vaccines with marketing authorization for Atlantic salmon in Norway are documented to provide active immunisation which leads to reduced clinical symptoms and severity, including mortality of the respective diseases the vaccines are targeted against. This has important welfare implications for the fish but can also pose challenges if the monitoring of serious infectious diseases is based on clinical signs. This has been, and continues to be, a relevant topic for discussion regarding the control of ISA (category C disease) and for PD (category F disease) outside endemic zones.

4.5 Other biosafety measures

Biosafety measures encompasses everything from essential general prevention – breeding, genetics, a good living environment, and proper nutrition to provide a strong starting point for the development of healthy and resilient individuals. Screening of roe, broodstock, and fry to detect pathogens and potential exclusion of groups before transfer/release or use are important infection-reducing measures. Thorough health checks performed by qualified fish health personnel, early detection of signs of illness, daily monitoring of mortality, appetite, and behaviour are important for implementing effective containment measures during disease outbreaks. For example, destruction or early slaughter to prevent further spread or forced area fallowing at sea during ISA outbreaks, or disinfection of land facilities/parts of land facilities during disease outbreaks. Overall, there are many measures of varying complexity that are interconnected to collectively provide good biosafety.

Genetic selection and screening of broodstock and roe/spleen

Breeding forms a strong foundation for today's farmed fish, and a significant portion of this work involves selection for resistance to various diseases. A successful example of this is the discovery of a genetic marker correlated with resistance to IPN, and the development of so-called IPN QTL roe. Although this does not provide complete resistance to IPN, the use of QTL roe has resulted in a significant decrease in the number of IPN cases in Atlantic salmon from 2015/2016 and has remained stable to this day.

To prevent the spread of infection from broodstock to offspring through vertical transmission of pathogens, health checks and screening of broodstock, milt, and roe are important measures. The industry has previously gained control over diseases such as bacterial kidney disease (BKD) by screening and excluding positive individuals from production. During commercial production of broodstock/roe and milt, there is a unique opportunity to conduct extensive disease mapping because all broodstock that die within the nine months preceding stripping must be autopsied if the cause of death is not accidental. It is also regulated by law that all broodstock from which roe is to be delivered must be euthanized and examined before the roe can be marketed. Rainbow trout can be stripped twice. In addition to selecting the correct fish and screening eggs, milt, and broodstock, disinfection of the fertilized eggs is also carried out. The aquaculture industry has well-established procedures for these fundamental biosafety measures, and there are generally few problems with diseases in fry, which suggests that the infection-reducing measures at this production stage are effective.

Measures for vessels

Wellboats and transport represent a significant risk of infection - both for known and unknown pathogens. However, there is little concrete knowledge about this route of transmission in the industry, and there is insufficient documentation on best practices to prevent this route of transmission. Nevertheless, there are legally mandated measures in certain situations, and it can be said that the norm is to wash and disinfect vessels between assignments.

Washing and disinfection are important infection prevention measures, but doing so to a level deemed acceptable is very demanding. A modern well boat often has complex delousing systems and sorting functions, several closed pipe systems, and different filters, which means that both automatic washing systems and manual labour must be used to get the job done, which can take several hours. Thorough cleaning is a prerequisite for disinfection to work as intended.

Measures such as control of cleaning, vessel quarantining, as well as washing and disinfection during launching, allow vessels to take on assignments along the entire coast, yet there are still several others that work exclusively in selected areas - which is also a good measure to limit the spread of infection from one zone to another. Inspections conducted by veterinarians or fish health biologists, colloquially known as veterinary inspections, are important measures to ensure adequate implementation and detection of deficiencies. However, the inspection of cleaning performed lacks a standard/established method with descriptions or requirements, and any veterinarian or fish health biologist can conduct such an inspection based on their own assessment. Typically, a combination of visual impression is used in consultation with a somewhat more objective measuring instrument such as an ATP meter. Veterinary inspections are used in cases where it is a legal requirement by the Norwegian Food Safety Authority, but they are also used in cases of the breeders' own wishes, requirements, or procedures.

Vessel quarantining is regulated by the transportation regulation “Forskrift om transport av akvakulturdyr”(Nor). If well boats used for the transport or handling offish farmed in sea are to be used for the transport of smolts (farmed on land), and/or if they are to move from assignments in PD endemic areas to new assignments outside the PD zone, there is a requirement for quarantining. The quarantine period is set at a minimum of 48 hours after cleaning is certified by a veterinarian or fish health biologist. The requirement for vessel quarantine is intended to prevent infection. However, if a vessel is not adequately washed and disinfected, it cannot be guaranteed that all pathogens will die out after 48 hours without host contact. Nevertheless, the quarantine requirement may have an effect, as the cost of a well boat being non-functional for 48 hours is high, and the quarantine requirement may provide incentives to stay within a defined area or on a specific type of assignment to avoid downtime.

Measures for Recirculating Aquaculture Systems (RAS)

Good design with established physical barriers between sections and different infection zones plays a crucial role in avoiding or reducing the spread of infection within a facility. This applies to all facilities regardless of technologies used.

In recent years, there has been an increase in the use of RAS in land-based facilities. The water must undergo biological treatment to remove toxic nitrogenous waste products from the fish's metabolism before returning to the fish tanks. Various types of biofilters are used, with the most common being moving bed (MBBR) or fixed bed (FBBR). These have a large surface area with biofilms containing bacteria that contribute to the nitrification (detoxification) of the water. It takes time to achieve the desired composition of the microbial community in the biofilter. This means that many operators do not want to remove mature biofilters for cleaning and disinfection between fish groups and fish generations. Thus, complete fallowing of the facility between fish generations is not achieved. There has been speculation about whether pathogenic pathogens could persist unnoticed in biofilters. The Norwegian Food Safety Authority has warned that it may be necessary to inactivate all microorganisms in the biofilter between generations due to the presence of, for example, high levels of ISAV HPR-0. Several research projects are currently underway to study the risk of infection in RAS.

When infectious agents and fish diseases are detected in a fish farming facility that recirculates water either fully or partially, the infectious agent will also circulate with the water, thereby having several opportunities to encounter a susceptible host. During disease outbreaks, the infectious agent can become concentrated in the production water and in the wastewater.The Norwegian Veterinary Institute has recently raised concerns about the potential biosecurity risks in outlet water from RAS facilities. To reduce contamination of downstream water sources, there should therefore be requirements for the wastewater to be directed to a separate disinfection loop before discharge. Collected sludge should also be secured against runoff.

There is significant variation between RAS facilities, and in older facilities straightforward access for cleaning and disinfection, as well as keeping fish groups physically separated may be difficult. It is essential to allocate enough time to carry out fallowing periods, routine cleaning and disinfection, and necessary measures in the event of infection of a fish group. It is also crucial to remove all escaped fish, often referred to as "escapees", as they can pose a source of infection. Although there are knowledge gaps regarding factors affecting infectious agents and potential survival in RAS, as well as which methods and protocols are effective, most operators are working systematically to maintain and improve biosafety in such systems.

4.6 Current Examples of Biosafety Failures

Bacterial Kidney Disease Outbreak

After several years with few (0-3) cases of BKD per year, BKD was recorded in multiple locations in production areas PO4 and PO6 in 2023. The primary sources of infection for the outbreaks are unknown, and it is also unclear if there is an epidemiological connection between the outbreaks in PO4 and PO6. As Renibacterium salmoninarum is considered poorly contagious via waterborne transmission in the sea, the disease has been managed by quarantining sea sites without stampling out. However, an important lesson from the BKD outbreak in Mid-Norway is that one should not underestimate the importance of so-called vector-borne transmission. The way sea sites are operated today provides extensive contact between different geographical areas, companies, and sites through shared use of well boats, delousing vessels, and service boats. Initially, the BKD outbreak in PO6 only affected one aquaculture company, and there were early suspicions of pathogen spread from a site in Hitra in Trøndelag to sites in Nordmøre via the same well boat used for both harvesting and delousing with freshwater in November and December 2022, despite approved and certified disinfection. Several inherent characteristics of *R. salmoninarum* have made the outbreak particularly challenging and complex. The bacterium is naturally slow growing, and it can take a long time from the fish are infected until they show clinical signs and further until the entire fish group is infected. The prevalence in an infected population will therefore be low for a significant period. The bacterium can also have an uneven distribution in kidney tissue in infected fish, making it challenging to detect using PCR early in the infection phase because only a relatively small amount of tissue is examined. In some of the cases from 2023, the bacterium was detected on growth media several weeks after the same fish was negative by PCR analysis. Previously, it has been shown that sampling from four instead of one location in the kidney from the same fish increased the likelihood of detecting the infection. Together, these characteristics makes early detection of infection in the population challenging and thus pose a significant disadvantage in today's operating structure.

ISA Situation

In 2023, ISA was confirmed at 18 sites, with the majority of cases occurring in PO2 and PO3. Although several sites are located close to each other, phylogenetic analyses based on sequences for segment 5 and segment 6 indicate that there have been no extensive local epidemics with the same virus variant. Several outbreaks in the sea in PO2 could be linked to a post-smolt facility where ISAV HPR-0 was detected, and which had supplied fish to the relevant sites. For three ISA cases in Hardangerfjorden (PO3), sequencing indicated that the virus strains were identical, but simultaneously identical or closely related to viruses at two sites in PO4 in autumn 2022. Epidemiological mapping showed that a well boat that had been to the two sites with ISA in PO4 in autumn 2022 had also visited the site in Hardanger that was first diagnosed with ISA in 2023. An outbreak at a site in PO7 could be linked to ISAV HPR-0 detected at the smolt facility that had supplied smolt to the relevant sea site.

Pathogenic ISA virus (ISAV HPR-Δ) develops from non-virulent ISAV HPR0, with the latter causing a transient infection without clinical signs. This makes it challenging to actively monitor ISAV HPR-0 infection as a risk factor for ISAV HPR-Δ and ISA disease development. ISAV HPR-Δ can also be present as a sub-clinical infection in a facility for a significant period before fish with typical clinical signs are observed. This shows that apparently healthy fish can also be carriers of the virus, and that biosafety measures must be included in all operations involving contact with farmed Atlantic salmon and movements from one site to another. Successful control of ISA requires early detection of the disease and prompt removal of infected fish to prevent further spread. This has also been the Norwegian Food Safety Authority's control strategy in recent years and is likely a key reason as to why there has been no extensive horizontal spread with regional epidemics of ISA.

The ISA situation is discussed in Chapter 6.2 Infectious Salmon Anemia (ISA), and several important biosafety aspects of last year's detections and suspicions are addressed in the chapter under "Assessment of the ISA Situation."

PD in Norland (PA8)

After several years without cases of PD north of the PD zone, PD caused by SAV2 was detected at four sites in PO8 in 2023 (Chapter 6.1 Pancreas Disease (PD)). How the infection was initially introduced is unknown, and PD was detected at the four sites between September and December 2023. However, it is unlikely that the PD virus has been introduced from the endemic PD zone with northward water currents, as the geographical distance is large. The infection is likely to have been actively introduced via boat traffic. All the known infected facilities were emptied of fish within the deadlines set by the Norwegian Food Safety Authority, and mapping of potential transmission routes is ongoing in collaboration with industry stakeholders and regulatory support.

4.7 Food Safety

It is not known that infectious diseases in Norwegian farmed fish can be zoonotic, i.e., causing disease in other mammals or humans. However, food, especially raw and smoked fish products, can be contaminated with microorganisms that can cause disease in humans.

The bacterium *Listeria monocytogenes* can cause the disease listeriosis in both animals and humans. The bacterium is naturally found in the environment, including water, soil, vegetation, and in wild animals and livestock as well as in food processing facilities. It can multiply effectively at refrigeration temperatures, and raw fish has been shown to be a good medium.

It has been known from EFSA reports that fish and fish products are contaminated with *L. monocytogenes* at least five times more often than meat and cheese products. However, until a few years ago, there were few human cases of listeriosis outbreaks traced back to fish from marine environments. Three possible explanations were that the serotypes of *L. monocytogenes* in freshly slaughtered fish were less virulent than those in meat and cheese, possibly because they were adapted to colder temperatures, that the types that house strains in smokehouses were also low-virulent, and finally, that listeriosis cases related to fish products occure but as sporadic cases rather than outbreaks. Although the two former hypotheses have not been directly disproven in recent years, they are less accepted than before, as whole genome sequencing has indicated unprocessed fish as a possible source of Listeria infections via smoked and cured products.

Outbreaks of listeriosis associated with cold-smoked fish are now reported every year. In 2022 and 2023, there were outbreaks in Norway involving smoked salmon and trout. Despite the time gap, the same genetic sequence of Listeria strains was present both years. In Sweden, there was an outbreak in 2023 involving smoked fish where the raw material was Norwegian salmon while the smokehouse was in Sweden. The outbreak lasted several months, and Listeria with the same genetic sequence was found both in products from the smokehouse in Sweden and from the raw material supplier in Norway. In other countries, there have been reported outbreaks of listeriosis over many years with patients in several countries involving smoked fish as the likely source of infection. Common to these outbreaks is that the smokehouse or another link in the chain has handled fish from many suppliers, or that the products have been distributed to many countries.

Salmon and trout from the Norwegian aquaculture industry have been suspected as the source of several international outbreaks, even though the smoking and curing steps have occurred in other countries. The links have been made partly because of tracebility data showing that Norwegian fish has been sold to the processing plants that the outbreaks are traced back to, and partly because DNA sequences of Listeria strains from Norwegian farmed fish have been published and therefore been accessible for outbreak investigation already before an epidemiological link between fish and patient has been suggested.
The discovery that smoked and cured fish may be the cause of more listeriosis cases than previously thought is based on comparing DNA sequences from illness cases from many years. This is a fundamentally different way of defining outbreaks than before. The classical definition of foodborne outbreaks is that there should be a clustering of cases within a defined period, typically a few months. Scattered cases over time have been considered sporadic cases and therefore not investigated. One reason why individual cases have not been investigated is that it is more important to prevent new cases of illness than to clarify each individual case. Before whole-genome sequencing was used, coincidence in time and geography was the signals that there was a connection between cases that could lead to even more cases if the source was not found. With the introduction of whole-genome sequencing, connections are found in other ways, and underlying causes can be sought in a different way. One outcome of this change is that foods such as smoked fish and raw materials for smoked fish are given greater attention than before as possible sources of listeriosis.

Even before whole-genome sequencing was used, smoked and cured fish were classified as high-risk products. This was because both types of products are ready-to-eat products with long enough shelf life and good enough growth opportunities for Listeria that the bacterium can be present in high concentrations, especially in the second half of the storage time and even when stored in a broken cold chain. Dose-response models have indicated that the risk of illness in susceptible consumers increases significantly when the concentration is over 1000 colony-forming units per gram of food, assuming a portion size of 100 g. Susceptible consumers are children, elderly, pregnant women, and immunocompromised individuals (referred to as YOPI in English). For the less susceptible part of the population, the risk of illness increases at concentrations that are about 100 times higher. Today's regulations includes a maximum limit of 100 colony-forming *L. monocytogenes* per gram of ready-to-eat product throughout the storage period. This is to prevent foods on the market, which are not heat-treated by the consumer, from having so much *Listeria* that the risk of illness increases. For producers of ready-to-eat food, there are specific guidelines on what to do to ensure that the limit is held. These are storage studies where the amount of *Listeria* that can grow during the storage period in the product is investigated, combined with analyses of products to verify this. In addition, HACCP and internal control procedures are designed to prevent high concentrations of *Listeria*.

The Food Act was developed several decades ago. It was expected that the number of cases of listeriosis would be reduced after the introduction of this, but the number has been constant or rising. There has also been greater consumption of ready-to-eat foods during this period, so it is possible that the law has worked as intended, but that the infection pressure has increased. In recent decades, there have been outbreaks with other foods than those previously considered high-risk products, such as ice cream, frozen corn, caramel apples, sandwiches with complex fillings, to name a few. This, along with indications that smoked and cured fish are causing more cases of illness than previously thought, has led to a reassessment of the risk assessments of Listeria in foods. In 2022, FAO and WHO began work on developing new risk models for several types of foods, including a thorough revision of the risk model for smoked and cured fish. This model includes all steps back to live fish, with an emphasis on contamination, growth, and decontamination (killing) of *Listeria* at each step. The model is also designed to account for the fact that the sequence types of *Listeria* found in the sea and slaughterhouse may be different from those found later in the chain, so that the probability of illness in consumers can be calculated based on where *Listeria* enters and how virulent the strains are. The description of the model is expected to be published in 2024.

Photo: Rudolf Svensen

5. Fish Welfare

By Kristine Gismervik, Kristoffer Vale Nielsen, Kristin Bjørklund, Magnus N. Osnes, Siri Gåsnes, Leif C. Stige, Lars Qviller, Lisa Furnesvik, Ewa Harasimczuk

The Norwegian Animal Welfare Act (AWA) promotes the intrinsic value of animals and grants them the right to an environment and treatment that ensures good welfare throughout their life cycle. The law applies equally to all fish in aquaculture, including lumpfish and wrasse species used as cleaner fish to remove sea lice from salmon. Fishing and capture of fish must be performed in a proper way according to animal welfare (AWA §20).

Animal welfare can be understood based on 1) the biological function of the animal, with good health and normal development, 2) the animal's own perceived situation with an emphasis on emotions such as security, fear, and pain, and 3) the most natural life possible. Animal welfare can be defined by combining the two questions on the left in Figure 5.1, by considering “an animal's individual mental and physical state while coping with its environment," or by using the definition "Quality of life as perceived by the animal itself." A broad approach is important when measuring animal welfare. Since fish cannot express what they experience and feel, welfare indicators are used to obtain information of the likely perceived quality of life of fish, see subsection 5.1 Welfare Indicators. Good health is a prerequisite for good welfare. Both the intensity and duration of pain and discomfort are important when assessing animal welfare. Survival in itself is no guarantee of good welfare. In practice, fish welfare will be influenced by a combination of various factors such as disease, environmental conditions, nutrition, and management practices including handling.

It is important to realise that attitudes and language used in legislation and everyday language contribute to increasing awareness that fish are animals, have intrinsic value, and can experience both good and poor welfare. There are examples of wording in regulations concerning fish containing fewer positive welfare expectations compared to regulations for terrestrial animals, see the Fish Health Report 2022, subsection 4.2. Even though the Animal Welfare Act applies equally, such differences can affect how the regulations are interpreted.

The Office of the Auditor General issued "Document 3:12 (2022-2023) Government's work on fish health and fish welfare in the aquaculture industry" in 2023. This criticized the authorities for not having implemented measures sufficient to reduce diseases and poor fish

What is animal welfare?		
Are the animals healthy? Do they have what they want?		*Quality of life as perceived by the animal itself.*
Dawkins, M.S. (2021)	Figure from Gismervik et al. (2020), definition adjusted from Broom (1986). NRC (2005) from UMB/NMBU have similar definition.	Bracke et al. (1999) FISHWELL; Noble et al. (2018)

Figure 5.1 Three common definitions of animal welfare (in italics) including references. A broad approach to the concept of animal welfare is important, including the normal understandings such as biological function, animals' own experience and a natural life.

welfare in the aquaculture industry. It pointed out that the permit system is fragmented, that risk management requirements in aquaculture operations are too vague, that the Norwegian Food Safety Authority needs to further develop its risk-based supervision and better follow up new technology and the impact of operating methods on fish welfare. Furthermore, there is a need for better cooperation on regulations, data management, reporting requirements and supervision between agencies such as the Norwegian Food Safety Authority and the Norwegian Directorate of Fisheries. It is further stated that the Ministry of Trade, Industry, and Fisheries has not implemented sufficient measures to reduce disease challenges.

It has been over 20 years since the last parliamentary white paper on animal welfare, and a new animal welfare white paper is planned released in 2024. In this context, it is important to ensure that the knowledge base is updated and that the attitudes society holds towards animal welfare are reflected in regulations, management, and in spesific action plans to improve the welfare of fish and other animals. In 2024, a new aquaculture white paper is also planned, which will address the permit system for aquaculture. It is important that this is adapted and enables the objectives of the animal welfare white paper so that the growth focus of industrial policy is changed and balanced towards better safeguarding animal welfare. A comprehensive governmental management approach focusing on the concretization of welfare, health, and environmental goals in the aquaculture industry is necessary to reduce mortality and improve welfare, and measurable improvements should be expected within a few years. Fish health personnel, research institutions, and the public authorities have a special responsibility to work towards better fish welfare, disseminate knowledge, and promote positive attitudes towards fish, both in the industry and in the general population. In the work on the new animal welfare white paper, it is important to emphasize AWA § 3, which states that animals have intrinsic value regardless of their utility value for humans.

5.1 Welfare indicators

Welfare indicators are defined in the LAKSVEL-protocol as all parameters that can be measured or observed and provide information about the well-being of the animals. Welfare indicators can be divided into either environmentally-based, where parameters such as water quality or resource availability in the environment are measured, and animal-based, where parameters related to the fish itself is/are measured. Animal-based indicators can be group-based, such as mortality or schooling behaviour, and individual-based, such as scoring external damage to the fish. Good welfare indicators should be easy to measure and interpret. Part of the challenge in developing welfare indicators is having enough knowledge about biological variation, threshold values and identification of parameters suitable for indication that the fish experience their own welfare as good. Good fish welfare is more than the absence of poor welfare. The ethical norm for acceptable welfare evolves as we gain more knowledge and better assessment methods of how the fish are doing.

Behaviour is a welfare indicator that can provide early warning of health and welfare status and is therefore interesting to use more extensively in the field. Behaviour can be quantified by counting how many times the animal exhibits a certain type of behaviour in a given period. In contrast, in a qualitative behavioural assessment (QBA), focus is placed on the expressive manner in which the animal execute the behaviours. This method was developed to more consider the animal’s perspective regarding emotions and welfare, and is one of the few scientific methods that assesses positive emotional states in animals. In other species, QBA is a well-integrated tool, but its application within aquaculture remains largely unexplored. Wiese et al. (2023) showed in their study that qualitative behavioural analysis was a sensitive method for detecting changes in the characteristics of salmon after a presumed stressful tank experiment. The article demonstrates that QBA can be a potential welfare indicator. For commercially scaled farming, this is particularly interesting regarding the development of indicators for positive behaviour, known as positive welfare indicators.

Camera technology can identify individual fish, and standard welfare indicators such as LAKSVEL can be used to score the injuries and defects. The disadvantages of camera-based image solutions may include only one side of the fish being evaluated, image quality affecting the assessments and gills (hidden under the opercula) being difficult to assess. Other limitations may include light conditions or particles in the water. Video analysis of behaviour patterns, such as respiratory rate based on opercula movements or mouth opening, can be an alternative method to assess behaviour and stress levels in fish.

By linking camera surveillance and other technologies to machine learning, information on welfare indicators can be generated from a large number of fish without handling. Avoiding stressful crowding, handling, and anesthesia is a good initiative for welfare. At the population level hydro-acoustic technology provides information on behaviour, e.g. in movement patterns and appetite. Technological development is significant, and good tools can be developed in the future to contribute to a better overall assessment of health and welfare conditions.

Results from the annual survey among fish health personnel indicate that camera technology is currently used to a limited extent. In response to the question of whether camera technology is used for welfare scoring, 99 respondents provided answers. Only three percent stated that camera technology is used to a large extent. Identical numbers (48.5 percent) responded that camera technology is used to a limited extent for welfare scoring as those who answered that the camera is not used for welfare scoring. Of the 51 respondents who had experience with welfare scoring using cameras, 75 percent stated that the camera provided a better overview. Six percent believed that the camera did not provide a better overview, and 20 percent answered "don't know."

Welfare indicators can be used at different levels in today's aquaculture industry. At the site level, they can be used to evaluate a disease or welfare situation, such as winter-ulcers, or as an aid to decision-making before handling operations. At the company level, welfare indicators can be used as the basis for strategic decisions on how different sites can be operated, such as determining the appropriate number of fish for each site or the timing of smolt transfer. Finally, public management can use welfare indicators for targeted measures either regarding a welfare situation at an aquaculture site or as a framework for regulating the aquaculture industry, see chapter 5.2.

Mortality is the crudest, but most commonly used welfare indicator. Categorization of probable cause of death, together with welfare indicators measuring the condition of live fish, provide valuable information about fish welfare. The Norwegian Standard, NS 9417:2022, specifies the following main categories of cause of death and loss: "A: Infectious Diseases," "B: Environmental Conditions," "C: Injuries and Trauma," "D: Physiological Causes," "E: Other Causes," and "F: Undetermined." The categories A – E are further divided into various subcategories with specification of the cause of death. Use of this standard and sharing of mortality data is voluntary, via the industry initiative AquaCloud. Further information on categorization and available data for 2023 is described in Chapter 2, subsection 2.4 Cause-specific mortality for salmon farming.

Until we have a unified reporting system for welfare indicators and mortality classification, the national survey among fish health personnel can be used as an indicator of the health situation in the aquaculture industry. For national ranking of health problems in farmed salmon in the different production areas (PA), see Appendices A–C. Various diseases and welfare problems vary with geography in the sea phase of salmon farming, see Figures 5.1.1 a)-c). The figures must be interpreted cautiously, partly due to some replies to the survey being duplicated as respondents could not be placed in specified production areas. The figures illustrate that

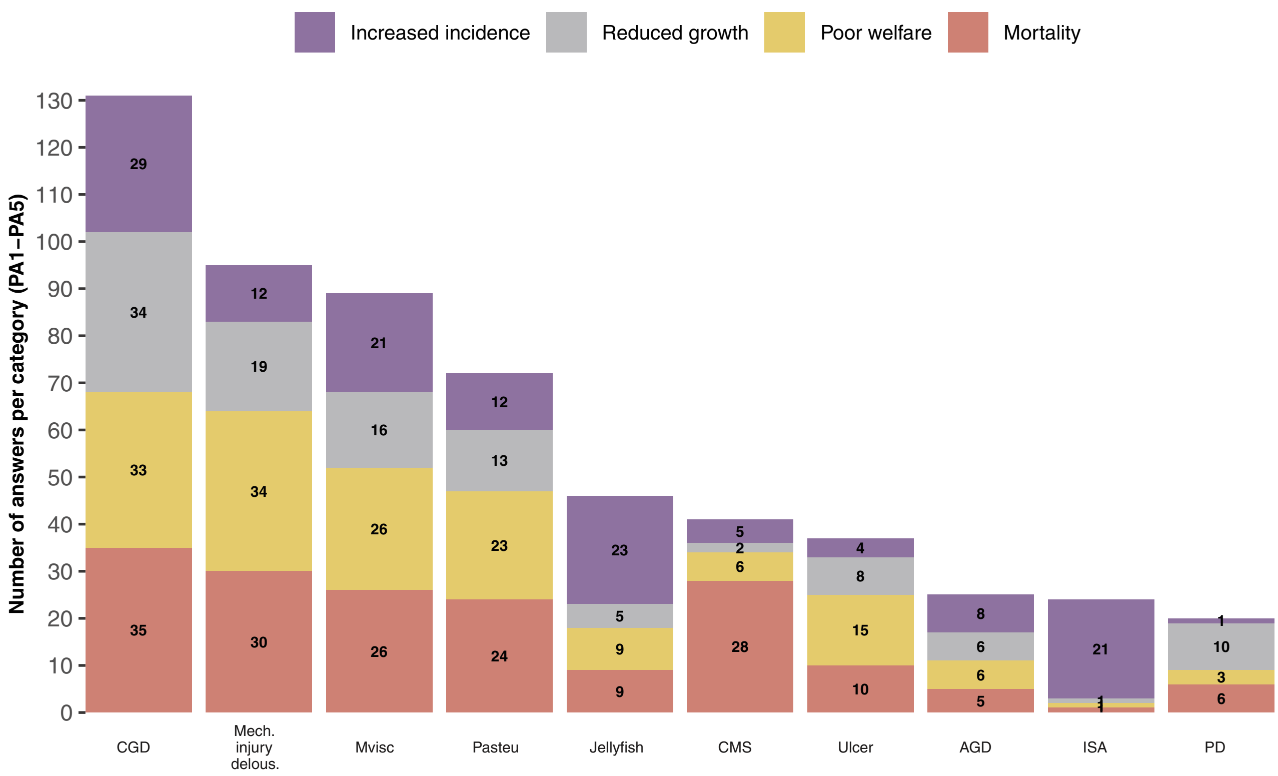


Figure 5.1.1 a) The ten diseases and welfare issues in ongrowing salmon farms that received the most crosses per combined production area; PA1-PA5 (N=43). N= number of respondents, i.e. fish health personnel and inspectors of the Norwegian Food Safety Authority. See Appendix B1 for an explanation of abbreviations for each disease/problem on the x-axis, as well as the overview for the whole country.

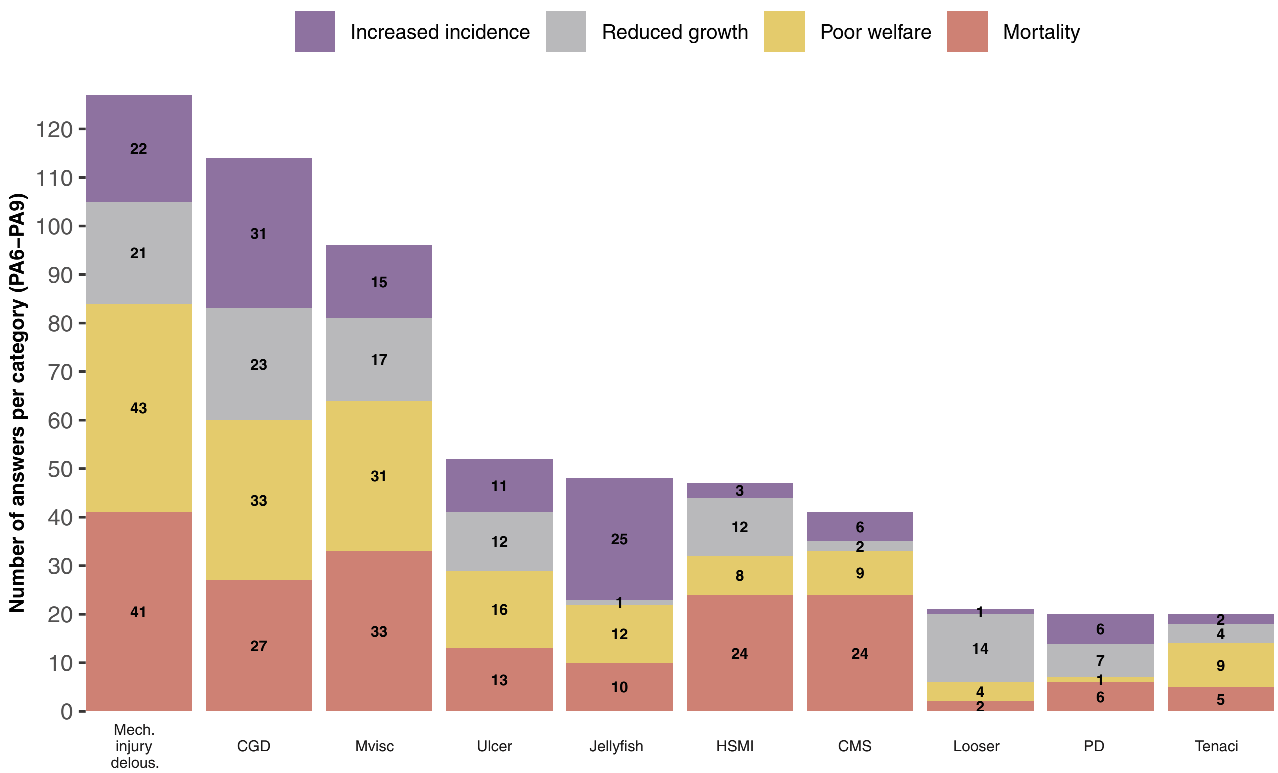


Figure 5.1.1 b) The ten diseases and welfare issues in ongrowing salmon farms that received the most votes per combined production area; PA6-PA9 (N=49).

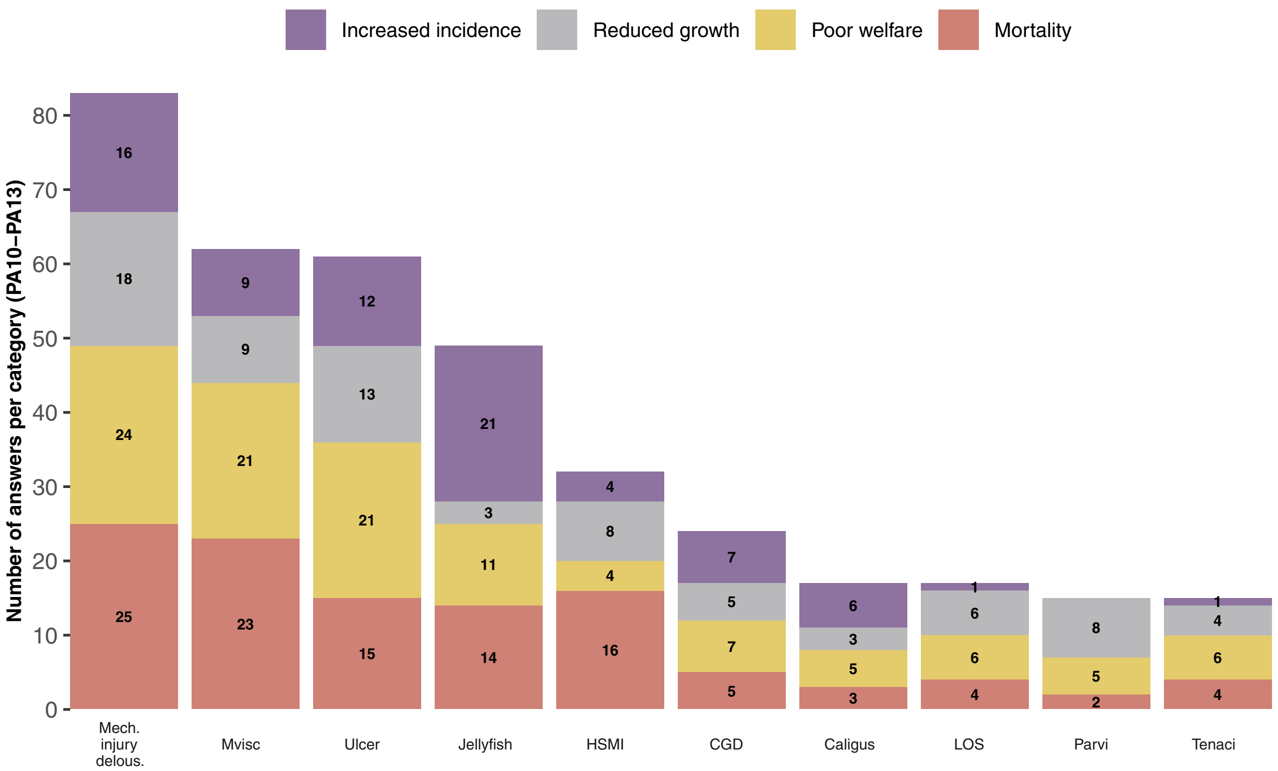


Figure 5.1.1 c) The ten diseases and welfare issues in ongrowing salmon farms that received the most votes per combined production area; PA10-PA13 (N=28).

diseases and welfare problems that are prominent in some areas are not as significant in others.

Non-notifiable disease are considered most important in relation to reduced welfare and mortality in the various areas. However, notifiable ISA is increasing in incidence in PA1-PA5. Pasteurellosis is a problem in the southernmost areas, while parvicapsulosis and sea lice are reported from the northernmost areas. Gill disease is considered the main cause of mortality in PA1-PA5, and also highly relevant in Mid-Norway. All areas consider mechanical damage associated with delousing treatment as the main factor for reduced welfare. Also, ulcers caused by *Moritella viscosa* are considered a major challenge in all regions. The combination of gill disease, mechanical damage from delousing treatment, and bacterial infection pressure has a negative impact on fish welfare. Skin lesions are reported as a significant factor for mortality and welfare in all areas, but are most prominent in the northernmost areas. In 2023, string jellyfish (*Apolemia uvaria*) have been a challenge in several areas, resulting in early slaughter of entire sites. All regions report challenges related to jellyfish in this year's survey, whereas in 2022, such challenges were only reported from Northern Norway. See Chapter 5.7 regarding notifications related to welfare-related incidents and Chapter 10.7 Algae, jellyfish and fish health.

5.2 Fish Welfare and Health in Regulations and public Management

To address the challenges related to health and welfare in the aquaculture industry, a common understanding of the issues is necessary. Figure 5.2.1 illustrates the epidemiological triangle where the relationships between agent, host, and environment influence development of disease. Preventive health work through use of veterinary/biological expertise in decision-making is essential. This can help implement measures against individual factors and reduce disease to a minimum. Focus on biosecurity can reduce the risk of infection, i.e., the presence of disease-causing agents. Production measures can improve the environmental conditions under which fish are kept, including access to sufficient water of good quality. Breeding, balanced nutritional status, and vaccination are examples of factors that affect the fish's ability to resist disease. In technology development, it is important to focus on solutions that involve minimal handling, minimize stress to fish, and rapid removal of dead/dying fish, which reduces infection pressure and improves welfare. When regulations and public management are to be created or changed, it is important that they contribute to reducing the risk of disease and that the impact of new technology, welfare, and health development can be measured.

Governmental-based Operational Welfare Indicators (GOWI)

The Norwegian Veterinary Institute shall contribute to increased knowledge of welfare indicators meeting the needs of the fish. This requires improved data quality and data flow, which in processed form provides better national overview for public management, research, and industry. There is great potential for more systematic use of reports made to the authorities as governmental-based operational welfare indicators (GOWIs). By compiling statistics of, for example, mortality/emergency slaughter, disease cases, delousing operations, use of cleaner fish, welfare incidents, slaughter quality, regulatory violations, ensilage, and experimental animal

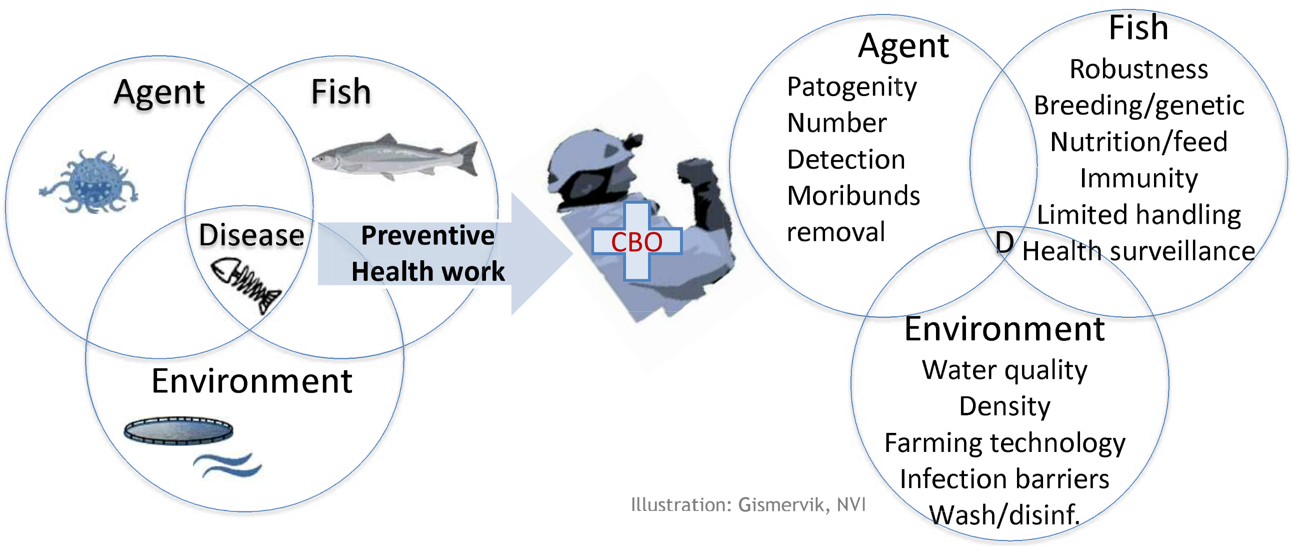


Figure 5.2.1 Disease prevention is important in all industrial livestock production, but particularly in fish farming where waterborne infection can be spread to a large number of animals without individual treatment options. Preventive health work is about ensuring robust animals with good immune status, an optimal environment adapted to the species and life stages and the absence of pathogens, here illustrated by a reduction in the space for disease (D) on the right side of the figure.

reporting, a better knowledge base is obtained to set limits for biological impact on fish and identify specific management goals for further development. Such limits can be used both to develop appropriate regulations and public supervision. The Office of the Auditor General reviewed health and welfare in the aquaculture industry in 2023 and concluded, among other things, that risk-based supervision must be further developed. The Office of the Auditor General further points out that few specific requirements for risk management weakens the Norwegian Food Safety Authority's ability to follow up fish health and welfare in the aquaculture industry. Effective enforcement of a functional regulatory framework requires clear requirements for risk management.

For this year's fish health report, we have investigated how welfare indicators such as mortality, slaughter quality, and lice treatments can be combined in a GOWI framework. The work with GOWIs shows that there is significant variation between individual sites and geographical areas, indicating potential for improvement. Regarding slaughter quality at a site, it can be summarized by looking at the proportion of fish classified as ‘superior quality’. The superior proportion are fish without major wounds, injuries, or other defects leading to downgrading, see subsection 5.8 Slaughter and slaughter data. For salmon in the sea phase, we have, in the period 2021 – 2023, looked at the relationship between cumulative mortality for completed production cycles and superior proportion at slaughter. At an overarching level, there seems to be a relationship between low cumulative mortality (below five percent) and a superior proportion above 90 percent. For mortality over five percent, there is large variation in superior proportion, and possible relationships in the data should be further investigated.

Fish Welfare in the Legal System

The Norwegian Animal Welfare Act applies to fish. However, there are few cases of poor fish welfare that have reached the legal system in Norway, as production animals or as pets. In comparison, there is an increasing number of cases involving terrestrial animals in which the Norwegian Food Safety Authority and/or the police have involved the Norwegian Veterinary Institute for pathological examinations or as experts in animal welfare in criminal cases. The increase may be due to establishment of an animal police department, where animal welfare cases are prioritised. The Norwegian Veterinary Institute has reviewed cases from the legal system concerning fish welfare and sees in several cases a need to increase knowledge about fish as sentient beings and attitudes improved regarding the intrinsic value of fish (Animal Welfare Act § 3). In a judgment regarding the euthanasia of aquarium fish with chlorine (TOIN-2022-127517), the court emphasized that fish have a less developed sensory system than mammals and that inhumane euthanasia of fish cannot be compared to mammals. This does not reflect updated knowledge about fish's ability to feel pain and stress.

None of the judgments we have examined have resulted in prohibition of activities covered by the Animal Welfare Act (cf. § 33), which is used to prevent future animal suffering. In terrestrial livestock farming, the Norwegian Food Safety Authority uses this paragraph as a tool. Similar administrative measures are rare within the aquaculture industry but are now being considered as a tool for aquaculture sites that over time do not operate in a medically and ethically responsible manner. Regardless of the species, such follow-up unfortunately entails time-consuming administrative work.

According to the Animal Welfare Act, animals should be protected from "unnecessary suffering." In the judgment on exceeding the louse limit of 2019 (TFOSN-2019-9268), the court considered that "(...) the result may be that one, among other things based on considerations of economy and tradition, considers a husbandry or an action as legal, even though its propriety may be debated. Examples of this are the extent of disease accepted in fish farming." Now, attitudes related to health and welfare in the aquaculture industry are changing, as evidenced, for example, by the Consumer Council's proposal in the autumn of 2023 for disease labelling of fish and the media's interest in fish welfare.

The threshold for "unnecessary suffering" changes as knowledge about animals increases, and it is important that the legal system picks up on this. Ghost fishing, where cod nets were left unattended for four months and a large number of fish, crabs, and porpoises were found dead, has recently been brought to court. The judgment sent an important message that ghost fishing is a serious violation of the Animal Welfare Act and that failure to tend nets should be punished with imprisonment. The responsible officer for animal welfare crime at the Economic Crime Unit has emphasized that the police, prosecution, and court rarely possess veterinary or other animal-related expertise and rely on such assistance.

Animal Welfare Report

In 2024, the animal welfare report will be presented to Parliament. The Norwegian Veterinary Institute, along with the Institute of Marine Research, the Norwegian Food Safety Authority, and the Norwegian Directorate of Fisheries, have been appointed by the Ministry of Trade, Industry, and Fisheries to participate in a reference group on aquatic animals considering the animal welfare report. The Norwegian Veterinary Institute believes it is important that the animal welfare report recognizes the challenges related to health and welfare in Norwegian fish farming. Overall welfare goals should be set that encompass all species in fish farming, including cleaner fish. Examples of mortality limits for Atlantic salmon are given in the SALMONWEL standard (FHF 901554). Other goals may include slaughter quality and maximum number of non-medicinal delousing treatments. Good animal welfare should be economically rewarding, and to stimulate this, incentive schemes that encourage better fish welfare can be introduced. The aquaculture industry is undergoing rapid technological development. As further explained in subsection 5.4 Operations and Methods and 5.7 Salmon Lice, there are still challenges with methods, technology, and operations. Welfare goals should be introduced for technological innovation and development. Fulfilment of welfare goals for technologies should be clarified in evaluations, and knowledge should be shared and maintained at a scientific level. In 2024, work on a new Aquaculture Report will begin. This report will review the entire aquaculture licensing system and build on the report from the Aquaculture Committee. The goal of the Aquaculture Report is to establish a more comprehensive system that ensures sustainable development and contributes to creating value along the coast (regjeringen.no). The Aquaculture Report should be viewed in conjunction with the Animal Welfare Report and the feedback provided in connection with the Aquaculture Committee's report (NOU 2023:23 Comprehensive management of aquaculture for sustainable value creation). The Norwegian Veterinary Institute's proposals for measures contributing to better welfare of farmed fish are listed in Table 5.2.1. It is important that the animal welfare report is followed up with specific action plans and resources to make the necessary animal welfare improvements, so that welfare is ensured before further growth in accordance with the Animal Welfare Act.

The Annual Survey

In this year's survey among fish health personnel, there were 60 free-text responses under "additional comments on the fish health and welfare situation in the Norwegian aquaculture industry." Of these, 1/3 (20 respondents) described the need for incentives to improve the welfare situation in the Norwegian aquaculture industry. Several believed that mortality levels should be included as a parameter in regulation of further growth. Fifteen respondents believed that the industry must gain control over biological challenges before further growth can occur, or that the intensity and/or biomass must be reduced, meaning that welfare must be ensured before growth.

Tabell 5.2.1: Important areas of measures for improving the animal welfare in the farmed fish industry

Areas of measures	Measures
1. Reporting to public management	Fish-ID, for tracking groups through the complete production chain. Mandatory reporting of of non-listed disease (G- list). Reporting appropriate welfare indicators. Data sharing from technological development, and between public authorites.
2. Permit system	Production permit calculated based on the number of individuals in addition to MTB. Welfare aims in the permit system, e.g.: requirement for maximum mortality at sea site level when purchasing production capacity, and max. 2 non-medicinal delousing. Remove exceptional growth in its current form from the Traffic Light System. A site structure that is suitable for ensuring biosecurity in all PAs/regions.
3. Site level	Welfare aims fulfillment and real risk-reducing measures as part of approval of the operating plan. Reduction in biomass/number of fish if the limits for acceptable mortality are exceeded or the aims are not reached within the deadline. Animal welfare program with the use of appropriate welfare indicators. E.g. limit for acceptable mortality for all fish species (like LAKSVEL).
4. Technology and operations	Specific welfare goals in technical innovation and development, including minimum requirements before commercialization. Requirements for documentation and sharing.
5. Knowledge and public management	Further development and use of GOWIs. Establish 3R-center: Collect and make available knowledge to replace and find alternatives to the use of research animals, and to ensure unnecessary repetition of animal experiments.

5.3 Welfare Consequences of the Traffic Light System

The Traffic Light System in the aquaculture industry was established to provide predictable and sustainable growth. The only sustainability indicator to date is mortality in outwardly migrating wild salmon smolts due to salmon lice infestation. See Table 5.3.1 and further discussion of the Traffic Light System in Chapter 10.4 Salmon Lice and Sustainability. From a welfare perspective, the current operation of the Traffic Light System is problematic. Unless there is a large-scale transition to farming technologies resulting in minimal or no lice emission, the industry in all areas will gradually transition from green to yellow, implying national 10-30 percent lice-induced mortality in wild salmon smolts. For wild salmon, this entails significant welfare consequences. The same applies to wild sea trout, which tend to reside more stationary and closer to the fjords than wild salmon, and are significantly affected by salmon lice (Chapter 10.4 Salmon Lice and Sustainability). For farmed fish, high lice pressure still results in significant welfare consequences, primarily due to non-medicinal delousing methods with a lot of handling, as discussed in subsection 5.7 Welfare Challenges Associated with Salmon Lice Treatments. For a summary of traffic light colours and trends in treatment weeks for salmon lice, both medicinal and non-medicinal, as well as biomass per production area, see Figure 5.3.1.

As the figure illustrates, areas with the highest biomass of farmed fish also have the most delousing per facility, resulting in negative welfare consequences. For instance, research conducted by The Norwegian Veterinary Institute has shown that non-medicinal methods lead to five to six times higher mortality rates post-treatment compared to medicinal delousing, as well as reduced growth compared to medicinal delousing.

§ 12 of the Production Area regulation allows for exceptional growth. Operators applying for and granted capacity expansion are exempt from capacity reduction in red areas or allowed growth in yellow areas. The conditions for exceptional growth include, among other things, that the site has fewer than 0.1 adult female lice per fish between weeks 13 and 39, and that only one medicinal treatment against salmon lice has been carried out during the last production cycle (FOR-2017-01-16-61). Exceptional growth was originally intended for introduction of new farming methods/technologies that could demonstrate less parasite and disease spread (Report No. 16 to the Storting (2014-2015)), but until now, has not been practiced as such. The Norwegian Veterinary Institute supports the proposal to remove exceptional growth as currently practiced, as also recommended in the Report No. 23 to the Storting (2023) Comprehensive Management of Aquaculture for Sustainable Value Creation.

Sites granted exceptional growth have not until now had limitations placed on the number of permitted non-medicinal delousing treatments. Analyses of sea sites granted exceptional growth in 2023 showed that several had a high number of weeks with non-medicinal delousing, with some having up to 14 weeks in a year (Figure 5.3.2). This can partly be due to that the treatments happened over many weeks if single cage treatments were prominent. However, 60 sites granted exceptional growth in 2023 reported 68 welfare incidents the previous year, most of which were related to non-medicinal delousing. Several sites granted exceptional growth also had high mortality rates in the last production cycle (Figure 5.3.3). Note that the mortality on sites granted exceptional growth is not different from other sites in the same area. Nevertheless, Figure 5.3.3 illustrates that poor animal welfare, in which up to half of the fish may have died during the qualification period, does not prevent the granting of exceptional growth in production areas where production should otherwise be reduced.

To avoid rewarding poor welfare with growth or exceptional growth, it would be appropriate to set requirements for health and welfare parameters including survival, at the site level before allocation. Exceptional growth can also be limited to farming methods associated with reduced disease spread and lice emissions. Limiting the number of medicinal delousing

Table 5.3.1 Traffic Light System

Facts on the traffic light system in the aquaculture industry

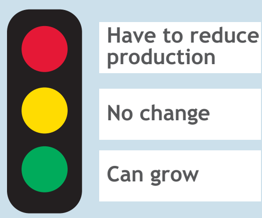
Goal: provide predictable and sustainable growth.
Sustainability indicator: Mortality of outward-migrating wild salmon smolts due to salmon lice infection.

Production areas where wild salmon smolt:

- have under 10 percent lice-induced mortality are defined as low-risk areas
- 10-30 percent mortality are defined as moderate-risk areas
- Over 30 percent mortality are defined as high-risk areas.

Appointed expert group: evaluates lice-induced mortality every year.

Ministry of Trade, Industry and Fisheries (NFD): awards every second year the traffic light colour for each production area, based on the expert group’s assessment, the steering group's recommendations, and other relevant societal factors.



treatments is crucial, as they pose a significant risk to fish welfare. Sites applying for exceptional growth in 2025 will be required to have a maximum of six non-medicinal delousings (FOR-2017-01-16-61, § 12 pkt.b.4.). It is positive to introduce requirements that reduce the risk of the Traffic Light System contributing to poor fish welfare. However, the requirement for six non-medicinal delousing treatments on the same fish group lacks scientific welfare documentation. The requirement that farming methods, equipment, and technical solutions used for animals are suitable for ensuring the welfare of the animals applies to both the farmersand the technical producer/retailer (Animal Welfare Act § 8). This requirement is further described in the Aquaculture Operations Regulation § 20, where it is specified that "methods, installations, and equipment can only be used in an aquaculture facility when the consequences for fish welfare are documented." Furthermore, "testing shall be conducted according to scientific principles and shall document the welfare consequences of the method in the specific context of its use." Unlike other laws, the Norwegian Animal Welfare Act does not have its own dispensation provision, meaning the possibility of exception from the regulations does not exist. Acceptance of as many delousing treatments as specified in a regulation like the Production Area Regulation can thus contribute to violations of regulations. The Norwegian Food Safety Authority recommended a limit of up to two non-medicinal delousing treatments in its consultation response to the regulation. Welfare clearance of sites, such as requirements for survival (for both salmon and any cleaner fish), restrictions on the use of non-medicinal delousing including requirements for welfare documentation, assessment of reportable welfare incidents, and assessment of slaughter quality before growth, can strengthen the Traffic Light System and promote ethical value creation with sustainability.

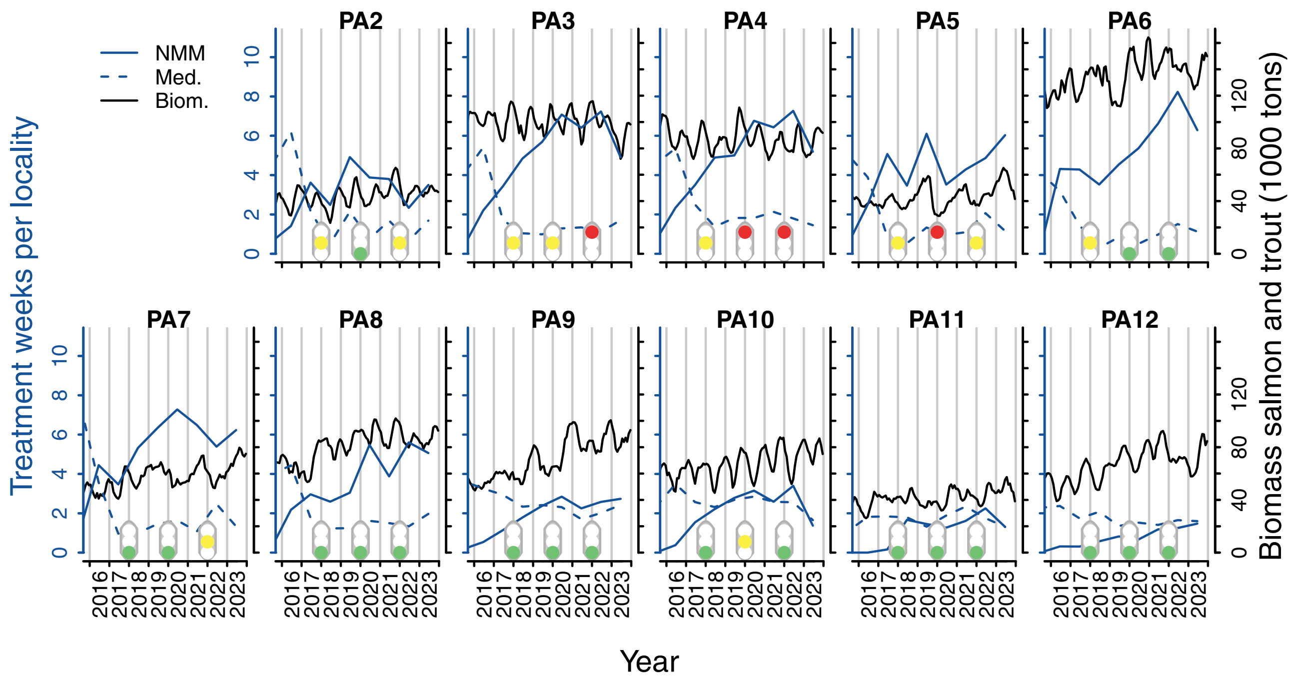


Figure 5.3.1 Chronological trends in salmon lice treatments and biomass of farmed fish in each production area (PA) from 2016 to 2023. The blue solid lines show the number of weeks of non-medicinal delousing (NMM) reported to the Norwegian Food Safety Authority (data from BarentsWatch), and the blue dashed lines show weeks of medicinal treatment (Med.). The black lines show biomass (Biom.) of salmon and rainbow trout in marine farms reported to the Directorate of Fisheries. The traffic lights show which production areas were given a green, yellow or red light by the Government in the Traffic Light System. Red lights for PA3 and PA4 in the first period are shown as yellow, as the red light did not lead to a reduction in the permitted production capacity in the first year. PA1 and PA13 are not shown because there were few farms in operation.

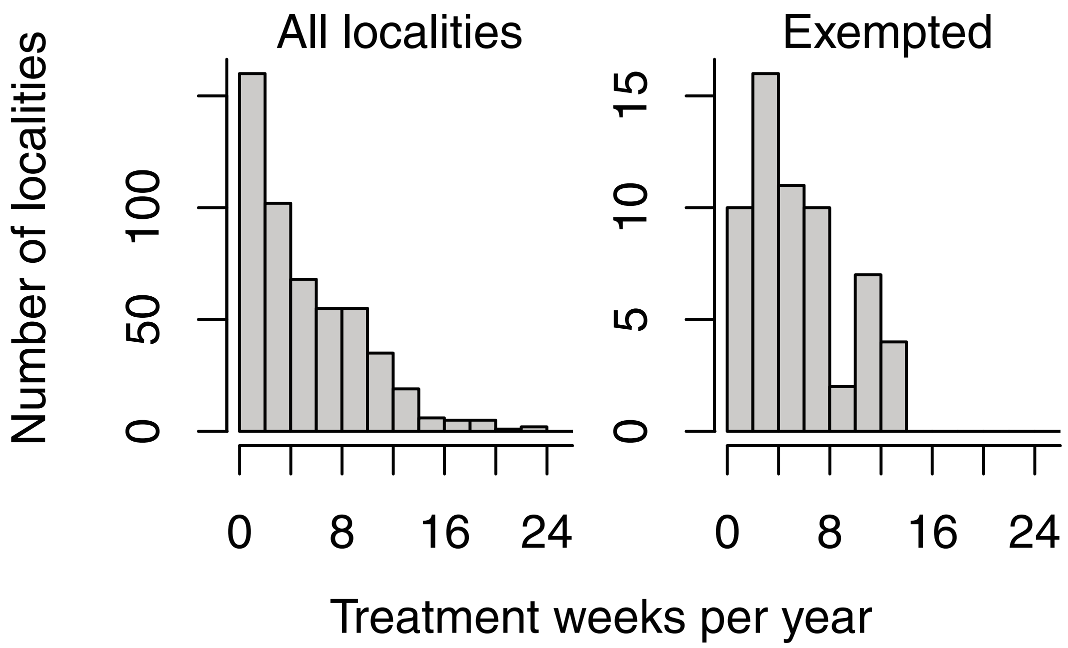


Figure 5.3.2 Total number of treatment weeks per year for all farms (figure on the left) compared with farms that were allocated exceptional growth in 2023 (figure on the right). The x-axis shows the number of weeks of non-medicinal delousing reported to the Norwegian Food Safety Authority per year, and the y-axis the number of farms. Only farms in PA3 and PA4 are included, since most of the farms that received exceptional growth are located there. The period is the last completed production cycle before the application deadline for exceptional growth (August 2023) for farms with exceptional growth and comparable calendar years for all locations (2021-2022).

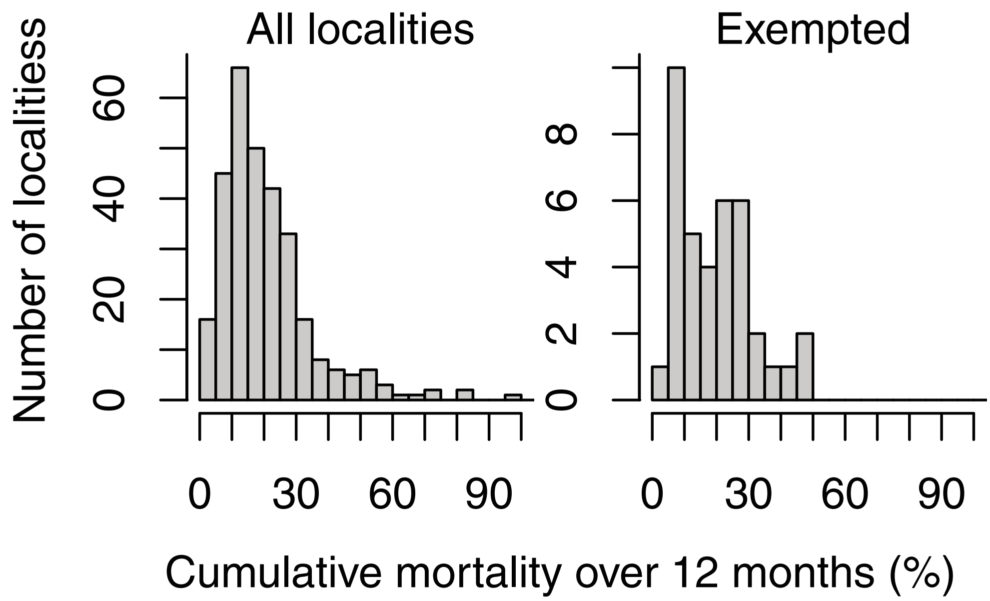


Figure 5.3.3. Mortality in all localities in PA3 and PA4 compared with localities that were allocated exceptional growth in 2023 in the same areas (figure on the right). Mortality is defined here as cumulative mortality over the last 12 months of the qualification period for farms with exceptional growth, or the mortality over the last 12 months of production for other sites. The X-axis represents mortality, while the Y-axis represents the number of farms.

5.4 Operation and methods

The Animal Welfare Act grants farmed fish the right to good welfare and imposes requirements on the owner regarding welfare during operation of a fish farming facility (Table 5.4.1). Regulations are implemented through a range of directives, guidelines, and communication channels, as well as through supervisory visits. The intentions of the regulations are good and aim to shape attitudes. However, if interpreted strictly, there is often considerable disparity between the regulations and the practical realities within the aquaculture sector.

In the Norwegian Food Safety Authority's guidelines on fish welfare during development and use of methods, equipment, and technology in aquaculture, "methods" are defined as: "Operational methods, equipment, installations, technical solutions, etc., used on aquatic animals." Common to methods used on fish is that their suitability should be evaluated based on the welfare of the fish (Table 5.4.1). The suitability of new methods must be documented before use. If a method is to be used under varied conditions, testing and documentation should also reflect this. Testing and documentation with many variables are both very time- and resource-consuming, and the results may not reflect the actual need. The aquaculture industry farms fish under varying conditions; environmental factors such as water temperature vary, as do the size, health status, and species-specific needs of the fish. These conditions can affect how suitable a method is for safeguarding the welfare of the fish. The conditions surrounding the planned use may differ from that documented as welfare-sound. Whether the method can be used or not becomes a balance between welfare risk and consequences, and in practice, economics and other aspects may also influence the assessment. A lot of knowledge is generated through trial and error, but unfortunately, experiences of this kind rarely result in updated documentation relating to the suitability of the method.

In recent years, the Norwegian Food Safety Authority

Table 5.4.1 Quotes from the Animal Welfare Act related to farm operation.

Quotes from the Animal Welfare Act regarding good welfare and requirements for the animal owner about operational conditions	Legal basis
“Animals have an intrinsic value which is irrespective of the usable value they may have for man. Animals shall be treated well and be protected from danger of unnecessary stress and strains.”	§ 3. General requirement regarding the treatment of animals
“The animal keeper shall ensure that animals are looked after by appropriately competent personnel.”	§ 6. Competence and responsibility
“The animal keeper shall ensure that industrial methods, equipment and technical solutions which are applied to animals are suitable for the purpose of ensuring the animals’ welfare.”	§ 8. Industrial methods, equipment and technical solutions
“The animal keeper shall ensure that animals are kept in an environment which is consistent with good welfare, and which meets the animals’ needs which are specific for both the species and the individual. The environment shall give the animals opportunity to carry out stimulating activities, movement, rest and other natural behaviour. The animals’ living environment shall stimulate good health and condition, and contribute to safety and well-being.“	§ 23. The animals’ environment
The animal keeper shall ensure that the animal receives good supervision and care, including securing that: *a. feed, pastures and water are of good quality, satisfy the animal’s need for nutrition and fluids, and stimulate good health and welfare.* *b. animals are protected from injury, disease, parasites and other dangers. Sick and injured animals shall be given appropriate treatment and be euthanised if necessary,* *c. spreading of infectious disease is limited*	§ 24. Attention, care and feeding

(Mattilsynet) has had a dedicated method/technology group that has worked specifically on welfare documentation and technology. However, within the deadline for the Fish Health Report, it was not possible to obtain statistics on testing of new technologies from the Norwegian Food Safety Authority (as per § 20 of the Aquaculture Operation Regulations, “Akvakulturdriftsforskriften”). This is because the group was disbanded in 2023, and the further working format is currently not clarified.

The report from the Norwegian Office of the Auditor General (Riksrevisjonen) in 2023, entitled "Government's Work on Fish Health and Welfare in the Aquaculture Industry. Document 3:12 (2022-2023)," states that there has been widespread adoption of technologies and production methods that compromise fish welfare. In other words, it is observed that the industry's willingness to take risks is too high in relation to fish welfare. The Office of the Auditor General further writes that the Norwegian Food Safety Authority (Mattilsynet) receives little information both on specific risk assessments related to disease and welfare and on planned mitigating measures. They also note that the impact of new technologies and operational methods on fish welfare needs to be monitored more closely. In 2022, the EU's animal health legislation introduced stricter requirements for biosecurity plans. Increased focus on preventive measures may hopefully also have a positive effect on risk assessments, thereby reducing the willingness to take risks regarding poor fish welfare.

Much good work is being done in the industry, research institutions, and public management with the goal of improving welfare. However, the production methods and scale of the industry are fundamentally flawed in relation to biology, so the small advances made are not visible in the broader context. If the aquaculture industry is to achieve significantly improved fish welfare, reduced mortality, and sustainable production, the industry must make radical changes in many areas of operation and methodology. New technology and methods must be adopted and operated according to the fish's needs.

The Annual Survey

This year's survey received a large number of free-text responses linking welfare issues to the operation of fish farming facilities and/or applied methods. The cause of a

Table 5.4.2 Thematic causes of welfare problems as reported in free-text fields in the Norwegian Veterinary Institute's survey to fish health personnel, inspectors, and advisers at the Norwegian Food Safety Authority (Mattilsynet) in 2023.

Cause of Welfare Problems	Comments
Equipment failure	Including equipment not suited to current operations.
Water quality	Poor/reduced water quality. Often related to equipment and/or operations, usually concurrently reported in one or both of these.
Human error	Lack of routines, knowledge gaps, attitudes, insufficient resources/prioritization/effort.
Operations and production	Handling, operational intensity, and site structure. Production methods assessed as unsuitable under given circumstances. Operational incidents often involve a human factor, but this is not automatically reported in this category.
Documentation	Inadequate documentation of equipment in use and other knowledge needs.
Biosecurity	Need for increased focus on disease transmission risk.
Disease/health/deformities	Specific disorders are mentioned.
Other	Welfare-related issues not fitting into other categories

welfare problem is often complex and can be challenging to identify. A free-text response may thus be subject to uncertainty due to the complexity of the matter and the often brief description. The fact that the survey covers many different topics also contributed to the challenging summarization, and the results can only be interpreted as possible trends.

The survey consisted of a total of 21 questions where respondents had the opportunity to use free-text responses. The 112 respondents provided a total of 475 free-text responses. The responses were classified categorically based on the theme and cause of the welfare problem (Table 5.4.2). A response could be categorized into several different themes depending on its content. For example, a response addressing poor water quality could simultaneously address the cause, which was inadequate equipment for water treatment.

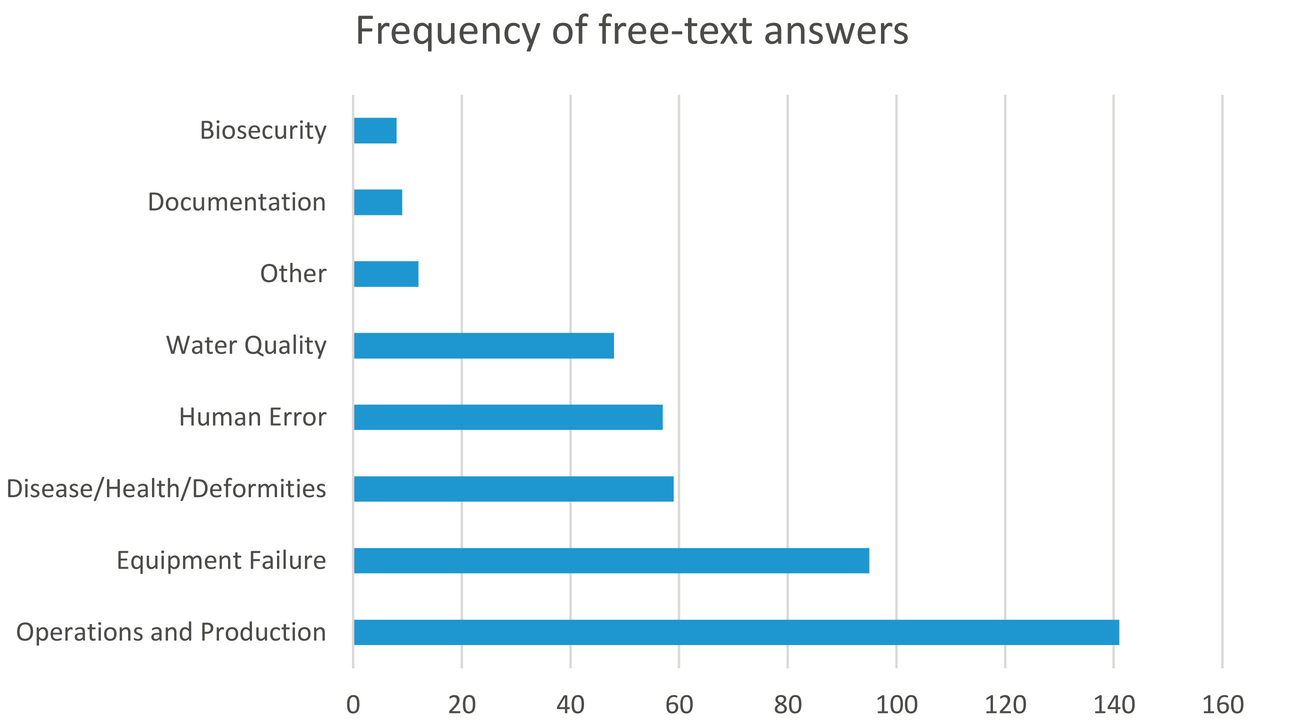


Figure 5.4.1 Frequency of causes for reduced animal welfare in farmed fish after categorization of free text responses (N=258) in the Norwegian Veterinary Institute's 2023 survey.

5.5 Experimental fish in 2022

Norway is one of the countries in Europe that use the most experimental animals, approximately 18 percent of the total number. In 2022, Norway used over 1.4 million experimental animals, of which 95 percent were fish (Table 5.5.1). Atlantic salmon accounted for 80 percent of the total number. The number of large-scale experiments in the aquaculture industry varies from year to year. In 2022, nearly 600,000 fewer experimental animals were utilised compared to 2021, mainly due to a reduction in the number of Atlantic salmon used. For example, in 2016, 10.6 million salmon were used in two large delousing trials. The large number of experimental animals used is mainly due to the significant health, welfare, and environmental challenges faced by the aquaculture industry as well as extensive and internationally leading technological development within the industry. Despite significant health and welfare challenges involving cleaner fish, see section 5.10 Cleaner Fish, there is a significant decrease in the number of lumpfish and various wrasse species used as experimental animals.

The criteria for what counts as an animal experiment is the same in Norway as in the EU, and are the same for fish as for other animals: "A procedure which imposes on an animal a strain at least equivalent to an injection". Experiments are divided into four severity categories i.e. terminal, mild, moderate or severe. Experiments conducted exclusively under general anesthesia, where the animal is not expected to regain consciousness, are classified as "terminal." Experiments causing brief mild pain, fear, or other stress are classified as "mild" Experiments causing brief moderate pain, fear, or other stress are defined as "moderate". While "severe" experiments cause severe pain, fear, other stress, or prolonged moderate pain, fear, or other stress. There is a requirement that severe experiments are evaluated afterward. The evaluation is published on the Norwegian Food Safety Authority's website. From autumn 2023, the summary of animal experiments from FOTS applications submitted to the Norwegian Food Safety Authority will be published in the EU database ALURES (Animal Use Reporting - EU System).

Table 5.5.1 Number and distribution of experimental animal use in Norway, from the Norwegian Food Safety Authority's annual reports on the use of experimental animals. The annual report (Food Safety Authority, use of animals in experiments) for 2023 is not available, therefore figures for 2022 are used.

Species	2020	2021	2022
Zebrafish (*Danio rerio*)	38 867	29 574	24 813
Total number of fish excluding zebrafish (Pisces)	(1 313 565)	(1 903 937)	(1 312 835)
Atlantic salmon (*Salmo salar*)	840 678	1 697 816	1 091 533
Trout (*Salmo trutta*)	23 123	71 602	54 188
Rainbow trout (*Oncorhynchus mykiss*)	9510	4877	21 333
Lumpfish (*Cyclopterus lumpus*)	161 368	24 634	4666
Ballan wrasse (*Labrus bergylta*)	81 305	11 576	996
Goldsinny wrasse (*Ctenolabrus rupestris*)	1150	1108	442
Corkwing wrasse (*Symphodus melops*)	2046	2206	1427
Herring (*Clupea harengus*)	38 983	28 102	66 512
Mackerel (*Scomber combrus*)	48 970	49 173	50 488
Halibut (*Hippoglossus hippoglossus*)	934	4872	8 105
Cod (*Gadus morhua*)	101 434	4118	6 602
Other fish	4064	3 853	6 543
Total of all experimental animals	**1 422 04**	**2 008 597**	**1 414 737**

There is great variation in how much stress and/or pain the fish are exposed to in different trials. Batch testing of vaccines, which involves infection experiments and induction of disease, is often highly stressful. With financial support from the Norwegian Animal Protection Alliance, Norecopa analyzed the use of experimental animals in Norway from 2018 to 2021. The work has been updated with data for 2022 and shows, among other things, a significant increase in the number of experimental fish in the “moderate” category compared to mild category in 2021 and 2022 (Figure 5.5.1).

Of the nearly 1.1 million salmon used in experiments in 2022, 73 percent were used in applied research and 20 percent were used for conservation of species (Figure 5.5.2). Whether marking of fish is defined as an experiment or not is situation dependent. For example, marking of wild fish (also in live gene banks) is defined as an experiment, while marking of farmed fish as part of breeding work is exempt. This partially explains the large proportion of experimental fish used for preservation of species. Ninety-nine percent of experiments in preservation of species are classified as "mild”.

Legislation on the use of experimental animals promotes the principle of the three R’s: i.e. “Replacement, Reduction, and Refinement". Norway is committed to reduce and ultimately replace animal experiments according to the EU's Directive on the Protection of Animals Used for Scientific Purposes. There are political discussions about establishing offshore aquaculture, and there is an increase in the production of farmed cod. Such conditions may lead to a need for knowledge and an increase in the number of experimental animals rather than the desired reduction. Animal experiments that cannot currently be replaced with alternative methods should be reduced in scope and improved so that the burden is in the mildest possible category. In addition, it must be ensured that the experiments are relevant, reliable, and reproducible. Despite our high and increasing consumption of experimental animals, including land animals, Norway still lacks a national 3R center. In contrasts with our Scandinavian neighbors and several other countries in Europe. The establishment of such a center can promote research into alternatives to animal experiments and ensure that knowledge about animal experiments is disseminated. Better knowledge sharing, including negative results, can prevent unnecessary repetition of animal experiments. This will also benefit animal experiment management.

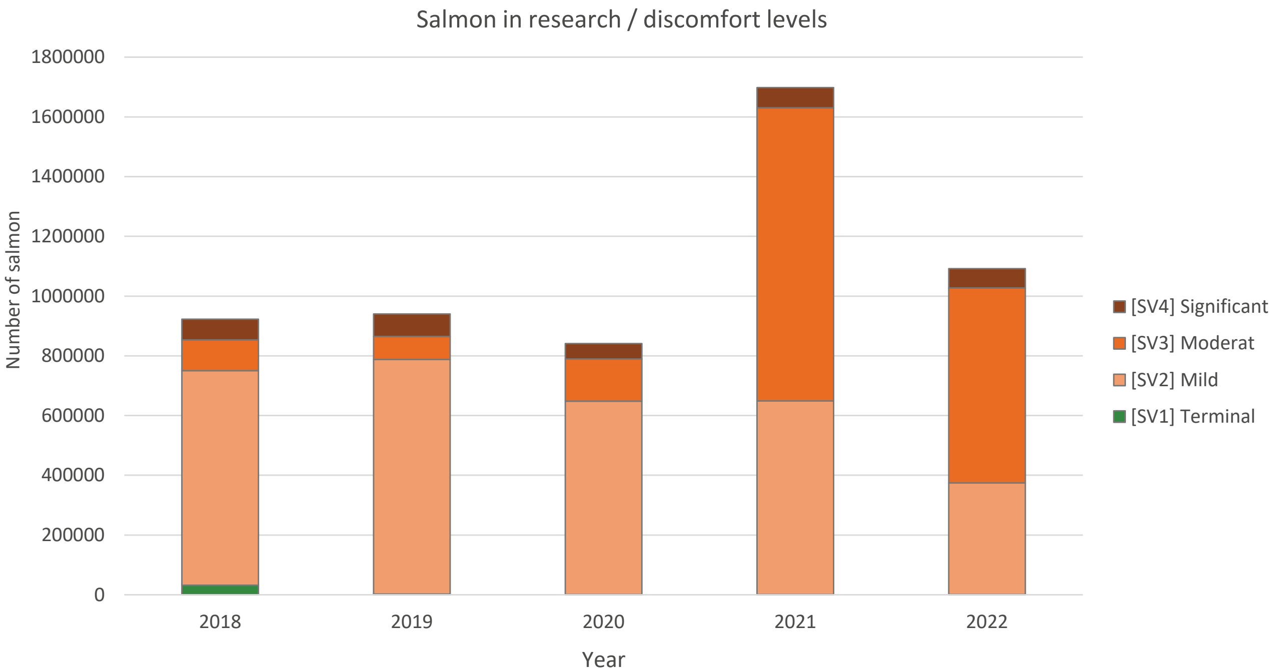


Figure 5.5.1 Number of Atlantic salmon that have been used in trials divided into the four discomfort levels, terminal, mild, moderate and significant from 2018 to 2022 (data 2018-2021: Champetier A & Smith A, Norsk veterinærtidsskrift 5-2023, data 2022: Norecopa, unpublished).

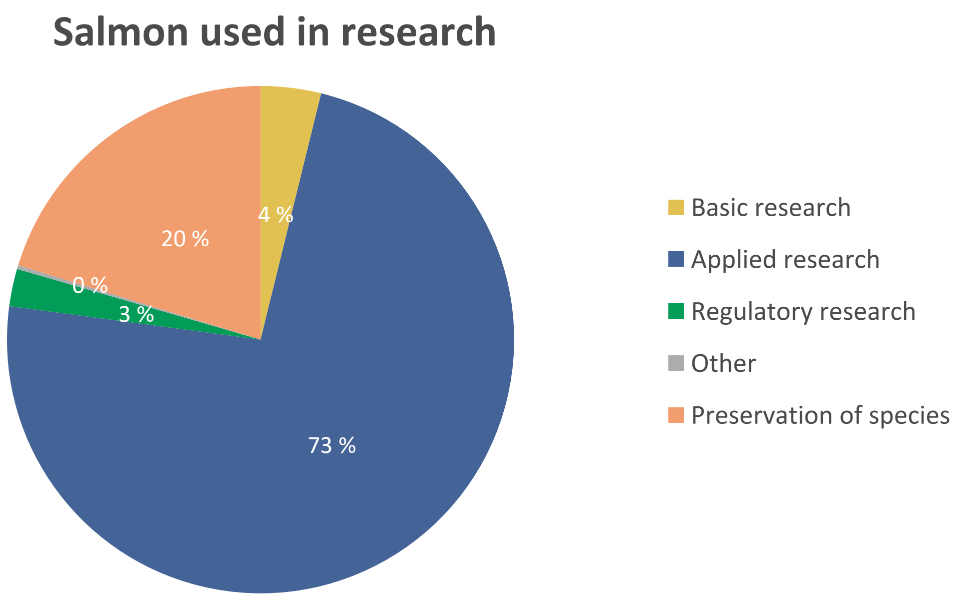


Figure 5.5.2 Percent-wise distribution of the type of experiment salmon have been used in resesarch for 2022. Data from the Norwegian Food Safety Authority, compiled by the Norwegian Veterinary Institute

5.6 Welfare challenges in juvenile salmonid production

The first phase of the production of salmon and rainbow trout takes place in freshwater. In freshwater farms for salmonid fish, fertilized eggs hatch and develop into yolk sac fry, proceed through first-feeding and further develop from fry to parr before undergoing a physiological adaptation to seawater, becoming smolts. The juvenile phase is largely influenced by the environment and the surroundings the fish inhabit. Environmental parameters during the freshwater phase significantly impact the salmon's subsequent life in the marine phase, and there is still a great need for knowledge on how farming conditions provided to the fish in the early stages affect it both in the short and long term.

The water temperature the fish are exposed to is crucial for their development. Experiments conducted in the nineties showed that the temperature during the egg phase should not exceed 8°C, as the incubation temperature of salmon eggs affects both heart and skeletal development. Recent research also indicates differences in the development of muscle fibres in salmon incubated at 4°C and 8°C from fertilization, which may affect growth and development in the marine phase as well. There is increased focus on heart health in farmed salmon, as abnormal heart shape and viral infections attacking the heart have a major impact on disease and mortality in the marine phase. Both PMCV (Piscint myocarditis virus), causing CMS and PRV (Piscine orthoreovirus), causing HSMI (heart and skeletal muscle inflammation), can be detected in freshwater farms. Less intensive production at lower temperatures in the juvenile phase has been shown from field experience to be beneficial for rearing a robust smolt. A robust smolt that can handle the transition to the sea is important. In the marine phase, fish encounter more pathogens than in freshwater, and often face tough handling, especially in connection with treatment against sea lice, see subsection 5.7 Sea Lice and Treatment.

In addition to temperature, other water quality parameters will also affect the welfare and health of the smolt. Chapter 10.5 Water Quality discusses the welfare consequences of reduced water quality in the smolt phase. Nephrocalcinosis and Hemorrhagic Smolt Syndrome (HSS) are the two diseases reported to have the greatest significance in the smolt phase, and both are associated with suboptimal environmental conditions. A study in Mid-Norway identified the addition of seawater in the freshwater phase as a risk factor for developing nephrocalcinosis (Klykken et al., 2023). Additionally, situations where sudden changes in water quality and osmoregulatory stress in vulnerable production phases increase the risk of developing nephrocalcinosis. In the

FHF project STONEHUNT, led by the Norwegian Veterinary Institute, a clear correlation was found between exposure to increased CO_2 levels and the development of nephrocalcinosis, regardless of salinity. HSS is most often seen in the period before transfer to seawater and is characterized by bleeding in many organs. Chapters 10.3 Nephrocalcinosis and 10.4 HSS discuss various aspects of these important production-related, non-infectious diseases in the smolt phase. Understanding why they occur and how they can be prevented will lead to a significant improvement in smolt welfare.

In the Norwegian Veterinary Institute's survey, fish health personnel and inspectors from the Norwegian Food Safety Authority were asked to indicate the conditions they believed had the greatest negative impact on mortality, reduced growth, welfare, and whether the occurrence is increasing in juvenile production of salmon and rainbow trout. As in previous years, the greatest challenges are related to non-infectious diseases and suboptimal production conditions (Appendix A1). Compared to previous years, water quality seems to have had an increased focus as a cause of problems in the smolt phase in 2023, otherwise the ranking of various health problems is relatively stable.

In 2023, 37.7 million salmon and 2.4 million rainbow trout above three grams from freshwater farms in Norway were reported as dead to the Norwegian Food Safety Authority. For salmon, there has been a steady increase in mortality over the past ten years, with a peak in 2019. Official statistics on the number of sold smolt from the Norwegian Directorate of Fisheries also show an increase in the same period, except for 2023 (see Chapter 2 Mortality, Table 2.2.1). Therefore, the increase in mortality from 2022 to 2023 cannot be explained by an increase in the number of smolt sold.

The number of welfare-related incidents reported to the Norwegian Food Safety Authority from freshwater farms saw a decrease in 2023 for the first time in several years, dropping from 228 cases in 2022 to 198 cases in 2023 (Table 5.6.1). Since 2022, the Norwegian Food Safety Authority has initiated a systematic prioritization for following up on incident reports. A large proportion of the freshwater farms incidents in 2023, like in 2022, were assessed as serious and requiring follow-up. Therefore, it is important to identify the causes of such incidents for prevention purposes. By reviewing free-text fields associated with reporting to the Norwegian Food Safety Authority in 2023, the Norwegian Veterinary Institute has examined the underlying causes of incidents in the

Table 5.6.1 Number of reported welfare incidents to the Norwegian Food Safety Authority based on incident type in the years 2018-2023. The reports concern juvenile salmonids. Data from the Norwegian Food Safety Authority are indicated as registered in their electronic reporting system (MATS). Differences in numbers from the Fish Health Report 2022 are due to updated figures from the Norwegian Food Safety Authority.

Welfare-related incidents from freshwater farms						
Cause	2018	2019	2020	2021	2022	2023
Other	26 (45%)	46 (47%)	84 (52%)	112 (55%)	104 (46%)	89 (45%)
Unexplained mortality	27 (47%)	46 (47%)	50 (31%)	51 (25%)	77 (34%)	67 (34%)
Pumping	1 (2%)	2 (2%)	13 (8%)	23 (11%)	20 (9%)	21 (11%)
Vaccination	2 (3%)	3 (3%)	12 (7%)	17 (8%)	20 (9%)	17 (9%)
Natural forces	1 (2%)	-	3 (2%)	1 (0,5%)	2 (1%)	3 (2%)
Fire	-	1 (1%)	-		1 (0,4%)	
Counting	1 (2%)	-	-		4 (2%)	1 (0,5%)
Total	58	98	162	204	228	198

largest category "other" (Figure 5.6.1). The categorization is based on what has been reported as causal factors, often with very limited free-text information. Furthermore, professional judgment has been applied, and the categorization must be interpreted as possible trends. A reported incident was often categorized into multiple risk factors, illustrating complex causal relationships. Most often, it involves human error, water quality, and equipment failure, closely followed by disease/parasites, often in various combinations of the categories. In addition, there are few but severe incidents involving failures in chemical use resulting in toxic damage/death, and some incidents related to fish handling. Of a total of 89 reports of "other". Figure 5.6.1 is based on 81 reports. The difference is due to the exclusion of reports without specified causes and misclassifications.

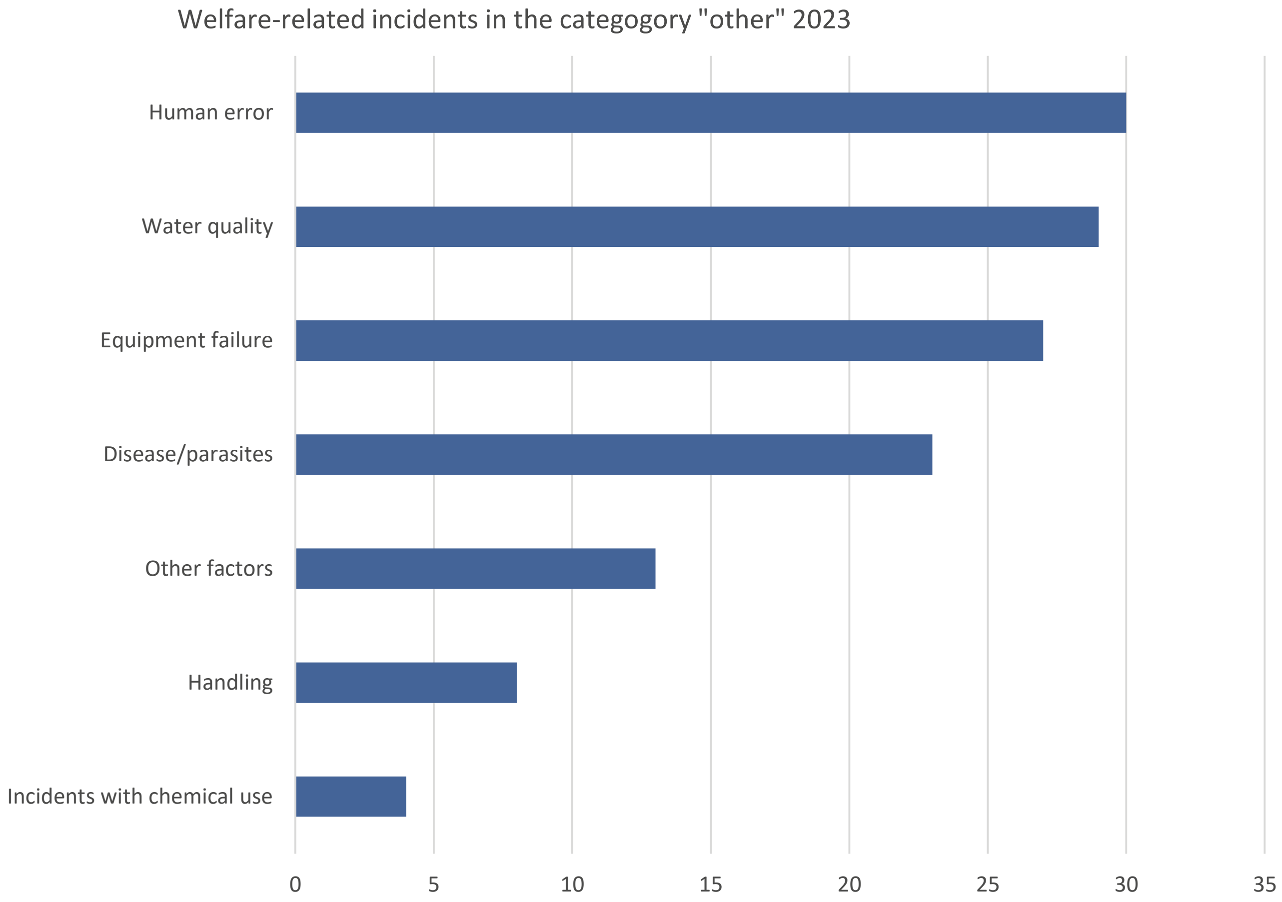


Figure 5.6.1 Thematic risk factors based on free-text fields for 81 welfare incidents in juvenile salmonids reported as "other" to the Norwegian Food Safety Authority in 2023. The categorization is based on professional judgment of limited free-text information and must therefore be interpreted solely as potential trends. A reported incident was often categorized into multiple risk factors, illustrating complex causal relationships.

5.7 Salmon Lice and Treatment

Control of salmon lice have traditionally relied on the use of medications. Widespread resistance to the available drugs has led to the development and extensive use of other delousing methods as well as increased focus on prevention. Prevention can include both operational measures at individual sites, such as shielding technologies, and collaboration between multiple actors (zoning operations). Both continuous delousing methods such as cleaner fish and laser, and delousing with non-medicinal methods are used. The non-medicinal, labour-intensive methods pose significant welfare challenges, and mechanical damage during delousing is reported by fish health personnel as the most important welfare challenge in the last six years, including 2023 (Appendices B1 and B2). If the salmon are sick or weakened by infections, they cannot withstand additional handling.

Non-medicinal methods (also called IMM in Norwegian) are mainly based on three different principles; thermal (warm water), mechanical (water-based flushing and brushing) and use of fresh water. In last year's fish health report, it was clear that methods combining two principles are increasingly being used. This year, it is reported that combination methods have become relatively common, and triple methods are reported.

A common factor for non-medicinal delousing is that the

Figure 5.7.1 Skin damage from lice flushing. Photo: Norwegian Veterinary Institute

fish must be crowded before being pumped into the delousing systems. This in itself has proven to be a major welfare risk. Thermal and mechanical treatment, treatment with freshwater, as well as combinations of these, involve a lot of handling and a number of situations where stress, risk of mechanical damage to gills, fins, eyes, skin, etc., will occur (Figure 5.7.1). In addition, harmful changes in water quality such as a decrease in oxygen saturation or gas supersaturation and isolated incidents with residues of detergents in wells have been reported (Chapter 10.5 Water Quality). Non-medicinal methods are less effective than medication, and the effect on sessile lice is generally low. During periods of high infection pressure, more frequent handling is often carried out. There is little documentation related to the fish's recovery time and wound healing. Thermal delousing is controversial, as the water temperatures used have been shown to be painful

Tabel 5.7.1. Welfare consequences in salmon exposed to warm water in controlled trials.

Findings	The fish/trial	References
Behaviour consistent with pain at water temperatures of 28°C and higher. The fish dies/is dying after a few minutes, faster at higher temperatures Details: Panic behaviour, increased swimming speed, collision with tank wall, splashing at surface, muscular spasm, head shaking (the latter also seen at 24-26°C)	Tank test, salmon post smolt approx. 234 g. At 34°C, human endpoint* was reached in just under 120 sec. *Humane endpoint: Loss of balance, the fish lays on its side in the 2nd sec, assessed as dying and euthanized	Nilsson et. al., 2019
Salmon suffered acute tissue damage in the gills, eyes, brain and possibly the nasal cavity and thymus	Tank test, salmon post smolt approx. 234 g. after exposure water temperatures 34-38 °C for 72-140 sec.	Gismervik et. al., 2019
Strong behavioural reaction/panic behaviour despite sedation. Significantly increased mild fin damage	Salmon approx. 1137 g, exposed to 34 °C for 30 sec. in a soft bag, laboratory test	Moltumyr et. al., 2021
Increased incidence/severity of various injuries, reduced growth. Strong behavioural response to the treatment. Long-term effects	Salmon approx. 1.4 kg, exposed twice to 34 °C water for 30 sec. with 23-24 day intervals, laboratory tests	Moltumyr et.al., 2022
Increased mortality, gill damage, altered gene expression. Increased number of gill pathogens	Field trial, salmon (approx. 2 kg) Exposed to 34°C water for 28 sec.	Østevik et al., 2022
Increasing mortality, panic reactions, and eye injuries with rising temperature. Clear behavioural changes at 27 °C despite low Δt. Lesser behavioural changes in subsequent treatments compared to the initial one.	Salmon, 2 kg, four treatment groups exposed to two treatments at 27, 30, or 33 °C, and one group at 14 °C for 30 seconds at four-week intervals, laboratory experiment.	Bui et al., 2022
All treatments had a negative effect on welfare, but fish exposed to 34 °C had relatively worse welfare, manifested by a higher prevalence of injuries, reduced growth, and condition factor. Sedation prior to treatment mitigated the negative welfare impact.	Salmon, average weight 1.1 kg at the first treatment round and 1.6 - 4.2 kg at the second, exposed to 28 °C and 34 °C, alone and in combination with mechanical and freshwater treatment, laboratory experiment. Half of the combination methods involved the use of sedation.	Thomphson et al., 2023

for fish (see overview in Table 5.7.1). Recent research shows that the effectiveness, i.e., reduction of lice, of thermal delousing is low at 28 °C compared to 34 °C (Thompson, 2023). Thermal delousing at 34°C had a higher prevalence of injuries and reduced growth and condition factor than other treatment principles. The effectiveness of thermal delousing is highest at temperatures that also negatively affect fish welfare the most, makes this delousing principle difficult to use in practice. Documentation on welfare is still lacking, but the ban announced by the Norwegian Food Safety Authority has not been implemented. The conclusion from the report in 2015 issued by the Norwegian Veterinary Institute is no longer documentation that the method is welfare-approved. This has also recently been clarified by one of the researchers behind the report (interview on Dagsrevyen February 6, 2024).

The Norwegian Food Safety Authority issued guidelines in 2022 on the use of veterinary personnel and non-medicinal delousing. The guidelines describe responsibilities, assistant practices and specifies the duty to report incidents that lead to poor welfare. It is important that the welfare-related incidents contain sufficient information so that experiences can be shared for preventive measures. There is now a systematization of the reports underway, and the Norwegian Veterinary Institute is involved in further knowledge gathering around these incidents.

In 2023, there is a decrease in non-medicinal delousing methods compared to the previous three years. There is a reduction in all non-medicinal methods as single principles in 2023 compared to previous years. Table 9.1.2 in Chapter 9.1 Salmon Lice - *Lepeophtheirus salmonis*, shows reported combinations for the same site in the same week. Not all are real combination methods, for example, one may have deloused one pen with thermal and another pen with mechanical treatment in the same week. Most combination treatments and triple treatments are increasing. Especially freshwater combined with thermal has increased since 2022. In 2023, mechanical methods are the most used single principle. In Table 9.1.2, Optiflush is listed as a mechanical method unless otherwise is specified. The Norwegian Veterinary Institute acknowledges that this sprayer is frequently utilized alongside other treatment methods, particularly thermal treatment. Consequently, certain combinations of thermal and Optiflush may have been classified under mechanical treatment. Thermal delousing is still widely used as a single treatment and in combination with other principles.

Different methods are used per PA, illustrated in Figure 5.7.2. In PA4 and PA3, thermal treatment is still widely used, although there is a decrease from 2022. In PA6 mechanical delousing is widely used. In PA5, there is a significant increase in combination methods in the form of freshwater and thermal. Additionally, in PA7, a combination of treatment methods is identified, where freshwater and mechanical principles are merged. As mentioned earlier, there has been a total decrease in the number of treatment weeks in 2023, and the decrease has been greatest in PA3, PA4, PA6, PA10 and PA11. The reasons can be many and complex and it remains uncertain whether this trend persist in 2024. Increased effectiveness of other preventive methods may be part of the explanation, increased use of lice lasers in PA10 is mentioned in the free-text field of the survey as a reason for reduced need for delousing. The effect of combination methods is discussed in a separate section. Earlier slaughter due to detection of listed diseases (ISA and BKD), as well as jellyfish attacks, may also have had an effect on the lice situation locally. PA6 reported sustention of low action limits during summer of 2023 (Barbo Klakegg, lice conference 2024). Overall, the use of imidacloprid has been somewhat reduced in 2023, but strategic use of an effective drug can also affect the lice pressure in an area (Chapter 9.1 Salmon Lice - *Lepeophtheirus salmonis*).

It is mandatory to report serious welfare incidents to the Norwegian Food Safety Authority. The seriousness and extent of reported incidents vary, and different

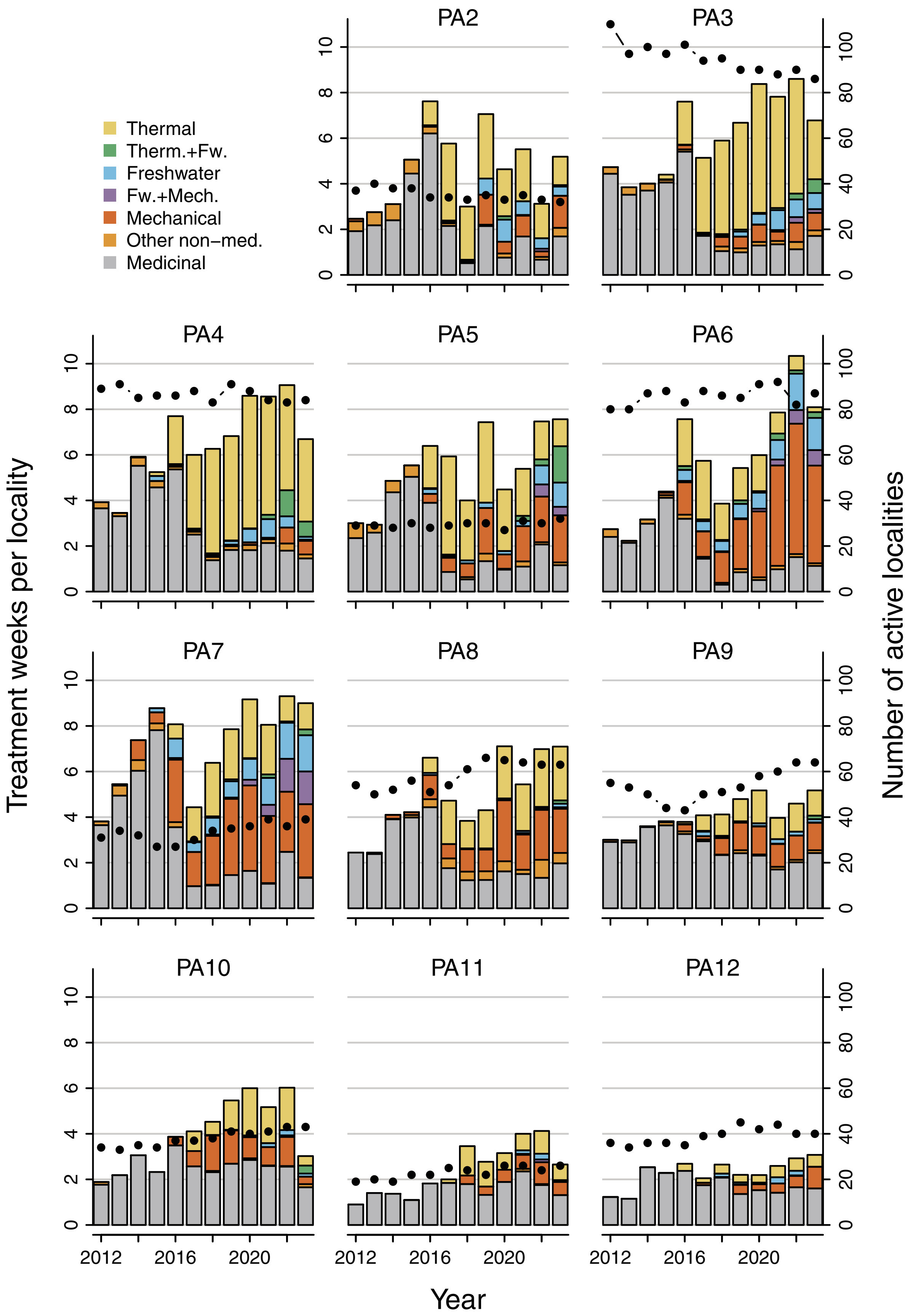


Figure 5.7.2 Trends in the number of treatment weeks per farm in the various production areas (PA). The columns show the number of weeks of treatment for different delousing methods, including medicinal delousing (scale on the left y-axis). The number of active farms per PA is indicated by black dots (right axis). PA1 and PA13 are omitted due to few active farms.

companies may have different thresholds for reporting. The summary does not specify fish species, and while reports primarily involve salmon, cleaner-fish are also included. In 2023, the Norwegian Food Safety Authority received 1419 notifications related to welfare incidents in ongrowing and broodstock farms (Table 5.7.2), which is a reduction compared to previous years. The reduction in non-medicinal delousing in 2023 may have affected the reporting of fewer welfare incidents. In addition, the Norwegian Food Safety Authority has provided more guidance on how to understand the reporting requirement, where it appears what can be comprehended as conditions that have resulted in serious welfare consequences for the fish. The new Animal Health Law (AHL) from the EU was implemented in Norway in 2022. The introduction also led to changes in the health regulations for fish, while the regulations related to animal welfare and reporting obligation remain unchanged. AHL allow a delay in reporting of abnormal unexplained mortality for 14 days to assess the causal factors. However, according to aquaculture management regulations § 14, the Norwegian Food Safety Authority must be notified immediately of conditions that have led to serious welfare consequences for the fish, including disease, injury, or failure. Due to the regulatory changes, it cannot be ruled out that misunderstandings have arisen, leading to unreported serious welfare incidents where the cause is known.

On collection of statistics for 2023 from the Norwegian Food Safety Authority, a major adjustment to the 2022 statistics were made (49 notifications were added). The reason was delayed reporting/missing updates. The table overview is based on the year of the event, not the reporting year. An event reported in 2023 from 2021 is not included in the table update, as errors in the year cannot be ruled out.

Of the reported incidents in 2023, 482 (34 percent) were related to non-medicinal delousing, continuing the trend

Tabel 5.7.2 The distribution of welfare-related incidents reported to the Norwegian Food Safety Authority based on incident type. Data from the Norwegian Food Safety Authority as registered in their electronic reporting system (MATS), applicable to ongrowing/broodstock fish.

Number reported welfare related incidents ongrowing/broodstock fish	2018	2019	2020	2021	2022*	2023
Non-medicinal delousing with handling	629 (61%)	906 (61%)	873 (54%)	774 (48%)	770 (42%)	482 (34%)
Undetermined mortality	196 (19%)	251 (17%)	282 (17%)	270 (17%)	336 (18%)	264 (19%)
Other	112 (11%)	178 (12%)	312 (19%)	384 (24%)	461 (25%)	419 (30%)
Handling	40 (4%)	60 (4%)	78 (5%)	71 (4%)	96 (5%)	87 (6%)
Medicinal delousing with handling	40 (4%)	55 (4%)	19 (1%)	38 (2%)	91 (5%)	73 (5%)
Grading/pumping	7 (1%)	18 (1%)	16 (1%)	15 (1%)	14 (1%)	14 (1%)
Natural forces	0	9 (1%)	25 (2%)	23 (1%)	33 (2%)	9 (1%)
Medicinal delousing without handling	9 (1%)	9 (1%)	6 (0%)	10 (1%)	7 (0%)	7 (0%)
Non-medicinal delousing without handling	3 (0%)	3 (0%)	9 (1%)	31 (2%)	18 (1%)	6 (0%)
Jellyfish			3 (0%)		4 (0%)	57 (4%)
Reduced susceptibility/resistence	1 (0%)	0	0	1 (0%)	0	1 (0%)
Total	**1037**	**1489**	**1623**	**1617**	**1830**	**1419**

* Minor changes from the Fish Health Report 2022 are due to delayed reporting/updated figures.

of a reduction in the proportion of incidents related to non-medicinal delousing. However, there seems to be a trend where incidents categorized as "other" are increasing, and this requires further investigation. To implement measures and preventive treatment, it is necessary to investigate the causal factors in welfare incidents. By categorizing free text from 2023, the causes of welfare incidents related to non-medicinal delousing with handling are elaborated upon eight categories (Table 5.7.3). Underlying disease and crowding/handling are mainly cited as reasons for the welfare incident occurring. Followed by injuries occurring during treatment. Wounds following treatment are included in this category. Gill bleeding is categorized as an injury during treatment, although it cannot be ruled out that underlying disease may also contribute to this cause.

Several of the categories may partly overlap, e.g., both weather/currents, equipment failure, and human error may cause injuries or mortality during crowding or handling. In cases where multiple factors are described as the cause of the welfare incident, this has been listed in multiple categories. Therefore, a report may be categorized under multiple causes. As the last column shows, several reports cannot be categorized, illustrating the importance of further work on causal factors and detailed reporting.

By analysing the mortality rates at specific sites in relation to the type of incident, we can determine which incidents pose a heightened risk of severe welfare consequences in terms of fatal outcome (Figure 5.7.3). As the figure shows, there is high mortality associated with

Table 5.7.3: Categorization of welfare incidents with non-medicinal delousing for ongrowing/broodstock fish, where it was possible to gather information about the cause of the incident from free text. "All methods" is a count without considering whether the type of treatment principle was specified. This category thus contains more incidents than all other specified treatment principles combined. Thermal refers to Termolicer and Optilicer, which use hot water. Mechanical involves water flushing, possibly combined with brushes, such as Hydrolicer, Flatsetsund flusher, Skamik, and Optiflush. Freshwater refers to freshwater used alone. Combination methods include free text entries such as freshwater + Termolicer, Termolicer + Hydrolicer, Freshwell, combination treatment, and combination method.

Method	Cat.1	Cat.2	Cat.3	Cat.4	Cat 5.	Cat.6	Cat.7	Cat.8	Not categorizable
	Disease, underlying	Crowding/ Handling	Water quality	Human error	Equipment failure	Weather/ Currents	Injuries including gill bleeding and wounds	Other (jellyfish)	
All methods	68	68	16	4	6	12	35	15 (11)	224
Thermal	19	19	2	0	1	3	7	1 (1)	38
Mechanical	11	11	2	0	2	2	4	1 (1)	50
Freshwater	0	0	4	1	1	1	1	2 (1)	10
Combination methods	12	12	0	0	0	1	8	3 (3)	50

many incident reports, especially in the categories of "Other," "Non-medicinal delousing with handling," and "Unclarified mortality." Six outliers have been removed for better readability of the figure, three of which had 45 percent mortality each and were related to jellyfish attacks and unclarified death, one related to natural forces (33 percent mortality), and two are listed as "other" (42 and 49 percent mortality, respectively). There is also a relatively high mortality associated with medicinal delousing with handling. One possible explanation for this phenomenon could be that medication treatment is administered to frail fish, which are at a heightened risk of experiencing decreased welfare and increased mortality due to the handling process. Among the welfare incidents, there were 57 reports of jellyfish attacks in 2023, and here too there is partly significant mortality associated with these incidents (see also Chapter 2 Production and Mortality and Chapter 10.7 Algae and Jellyfish). The percentage mortality, as indicated in Figure 5.7.3, must be considered a probable underestimate. Incidents that, for example, concern one or a few cages will be underestimated since the calculation is done at the farm level. In addition, mortality is calculated in the month of

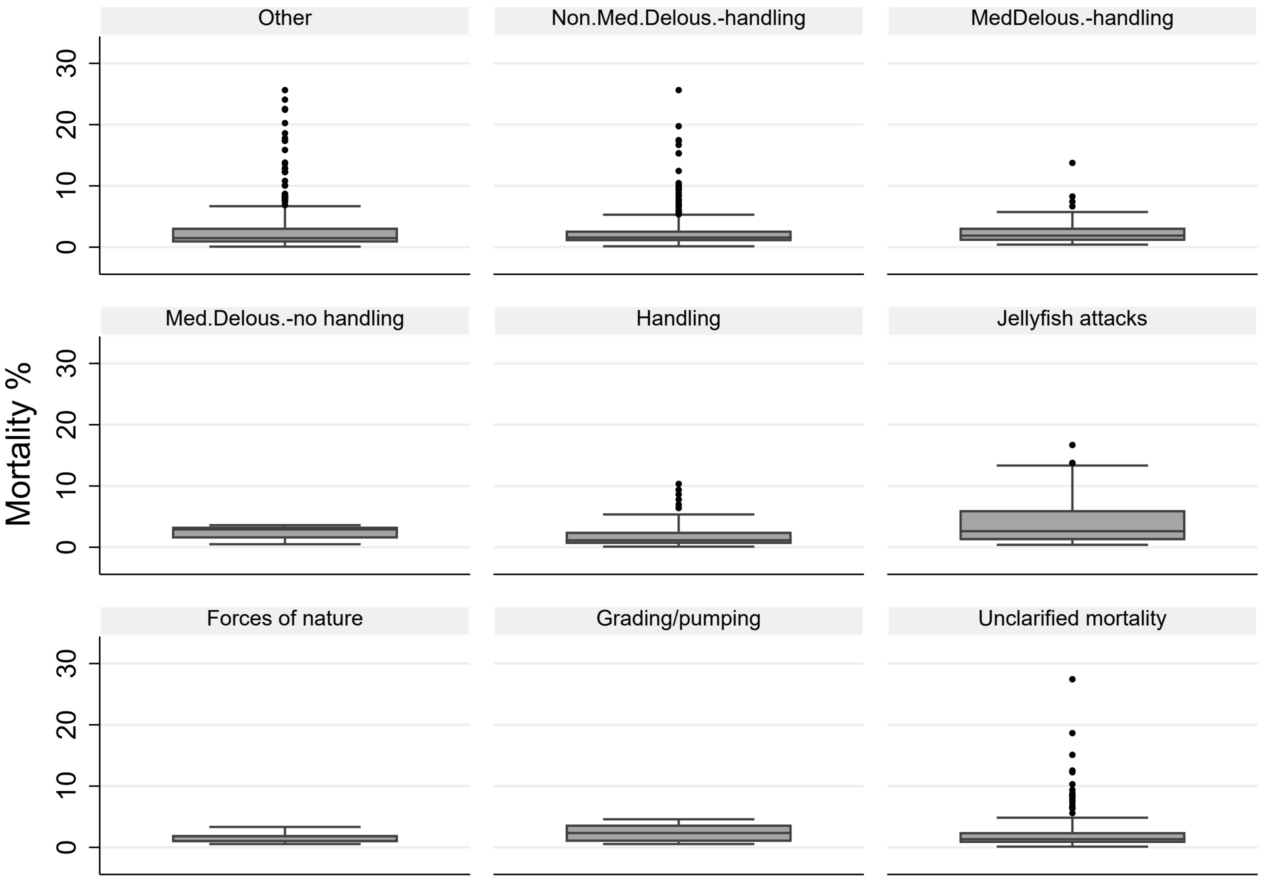


Figure 5.7.3 Overview of mortality (%) based on incident type as reported in MATS to the Norwegian Food Safety Authority for ongrowing and broodstock fish. Data are shown as boxplots of mortalities in the month the event occurred. N=1327 reports, after excluding reports due to incomplete data, including the removal of two outliers of 33 and 49% to improve readability of the figure.

the event itself, so that events that occur at the very end of the month will represent an underreporting of mortality associated with the event in question. Reports where mortality could not be linked, as well as obvious errors in reporting, were removed. Despite the underestimation, the calculated mortality associated with various events is high. The Norwegian Food Safety Authority is developing the reporting on welfare incidents. The Norwegian Veterinary Institute will contribute to mapping causal factors and possible preventive measures.

The Annual Survey

Knowledge about negative welfare impacts of non-medicinal delousing is increasing, in terms of both injury frequency, mortality, and other welfare measures. There is no public scientific welfare documentation on repeated non-medicinal delousing (cf. requirements in aquaculture management regulations § 20). Increasing use of combination methods makes the situation more complex. In this year's survey, it is stated that triple principles of treatment is also used. There is a lack of knowledge of how frequent delousing and combination methods affect skin and mucous layers as well as gills. Problems with complex gill diseases have been increasing in recent years. In the survey, "Mechanical damage related to delousing" is again ranked at the top as a cause of reduced welfare in both ongrowing and broodstock salmon and rainbow trout, as well as an important cause of reduced welfare in cleaner fish (Appendices B1, B2, C1, C2, D2, and E2).

From 2020, several producers have introduced an "emergency culling practice", in which an emergency slaughter boat is kept in readiness for the culling of injured fish following delousing. In this year's survey, respondents were asked if the practice of using an emergency slaughter boat is also used for daily mortality. Out of 80 respondents, 59 percent answered that this is never or very rarely used, 6 percent answered "rarely", 16 percent "sometimes," and 8 percent answered "often." Respondents who indicate that emergency slaughter boat is used in connection with daily mortality mainly belong to PA3-PA6.

In the survey, there were 60 free-text responses under "additional comments on fish health and welfare situation in the Norwegian aquaculture industry." Of these, five respondents expressed concern about the use of emergency slaughter boats and that the practice contributes to masking the real mortality rate. It is important that the use of these boats does not the willingness to risk treatment of weak fish. It is also important that fish slaughtered in this way are registered and reported, so that the fish welfare consequences of different delousing methods can be evaluated.

A total of 81 respondents shared their experiences of welfare with various delousing methods in this year’s survey. Compared to the 2022 survey, there was a continued trend of more respondents having experience with combination methods. In 2023, 41 percent had experience with Optiflush compared to 25 percent in 2022, and 28 percent had experience with Freshwell compared to 21 percent in 2022. The proportion of respondents with experience with freshwater also increased (78 percent compared to 63 percent in 2022). There was a relatively stable proportion of respondents with experience with Termolicer, Optilicer, and FLS. However, there was a reduced proportion of respondents with experience with Hydrolicer (49 percent in 2023 compared to 66 percent in 2022) and Skamik (26 percent in 2023 compared to 43 percent in 2022). Furthermore, a smaller percentage of respondents chose "other" (13.6 percent compared to 24 percent). In the free-text field "other" category was described as various combination methods such as Freshterm (freshwater and Termolicer), freshwater + Hydrolicer, and Optiflush + thermal.

The effectiveness of non-medicinal delousing in removing salmon lice can depend on many factors. Examples include pressure, temperature, treatment time, crowding. However, the effectiveness of treatment can also be compromised if lice populations develop tolerance to the treatments due to selection pressure. Respondents were asked if they had seen any changes in the delousing effectiveness of non-medicinal treatments. Of 77 respondents, 77 percent reported no change in effectiveness, 13 percent reported reduced effectiveness, and 10 percent reported increased effectiveness. Of the 29 free-text responses received, ten reported increased effectiveness and/or welfare when using freshwater in combination with other methods. Three respondents suspected reduced effectiveness with freshwater, three respondents believed there was reduced effectiveness with thermal treatment or that treatment water needed to be at higher temperatures than before. One respondent suspected a reduction in delousing effectiveness with flushing. One reported reduced effectiveness for a combination method. Three respondents reported reduced effectiveness with the use of medications. One respondent believed there is more caution now, with less increase in pressure or temperature, which could result in slightly lower effectiveness than before when using non-medicinal treatment. Another respondent believed that the increasing incidence of gill disorders has increased the mortality rate during delousing.

Regarding delousing with hot water, 37 percent of respondents stated that the most commonly used treatment temperature was 31-32 °C. 27 percent said 29-30 °C and 16 percent said 33-34 °C. The highest temperature reported for delousing with heated water varied from 28-34 °C. Of 54 respondents, 54 percent reported that the highest temperature was 34 °C (ranging from 33.5-34.0), a decrease from 71 percent in 2022. The highest treatment temperature was used when the sea temperature was between 6-17 °C. 51 respondents reported that the lowest treatment temperature used varied from 23-32 °C, and 55 percent reported that the lowest treatment temperature was 28 °C or higher. The sea temperature when using the lowest treatment temperature ranged from 5-17 °C.

In the survey, fish health personnel were also asked if there had been a change in the severity of external injuries associated with non-medicinal delousing in 2023 compared to 2022. 46 percent reported no change, 13 percent reported improvement, 6 percent reported

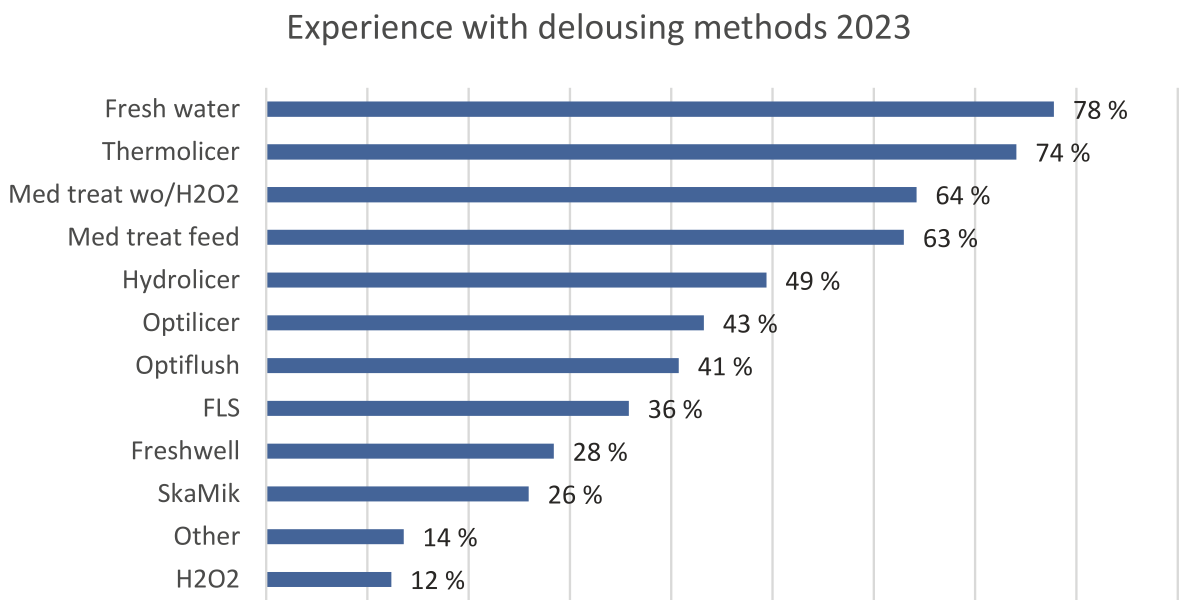


Figure 5.7.4 Overview of the delousing methods fish health personnel in the survey had experience with in 2023 (N=81)

worsening, while 35 percent answered "don't know" (N=80).

This year's survey also included questions about the frequency of injuries and increased mortality associated with the use of Optiflush and Freshwell. Optiflush is initially a freshwater flushing unit, but it is often used in combination with other principles. The manufacturer mentions that Optiflush can be used in combination with thermal delousing. Initially, our interest was in the combination of thermal and flushing treatments, but this aspect should have been explicitly clarified in the survey. Many respondents stated in the free-text field that Optiflush was only used with thermal delousing. All responses are included, but there is uncertainty about whether the responses are based on Optiflush used alone or in combination with thermal or other treatment principles. Figure 5.7.5 compares various welfare parameters evaluated when using Freshwell and Optiflush, with the reservations indicated above. Note that the number of respondents familiar with the methods is low, so results must be interpreted with caution.

There were 29 comments received where injuries and mortality with different treatment methods were elaborated on. Eight respondents mentioned that combination treatment (double treatment) seems more gentle for the fish. Six respondents wrote that they only had experience with Optiflush used with Termolicer and not as a standalone treatment, making it difficult to assess alone; one respondent wrote that Optiflush was used with thermal and/or freshwater treatment. Two respondents mentioned that the "FLS delouser" is considered gentle. Two respondents mentioned that Freshwell is not used at falling temperatures, so there is little wound development observed. Some mentioned that injuries after treatment could be related to vessel design, technical failures, inexperienced crew, and that mortality after treatment could be related to underlying disease.

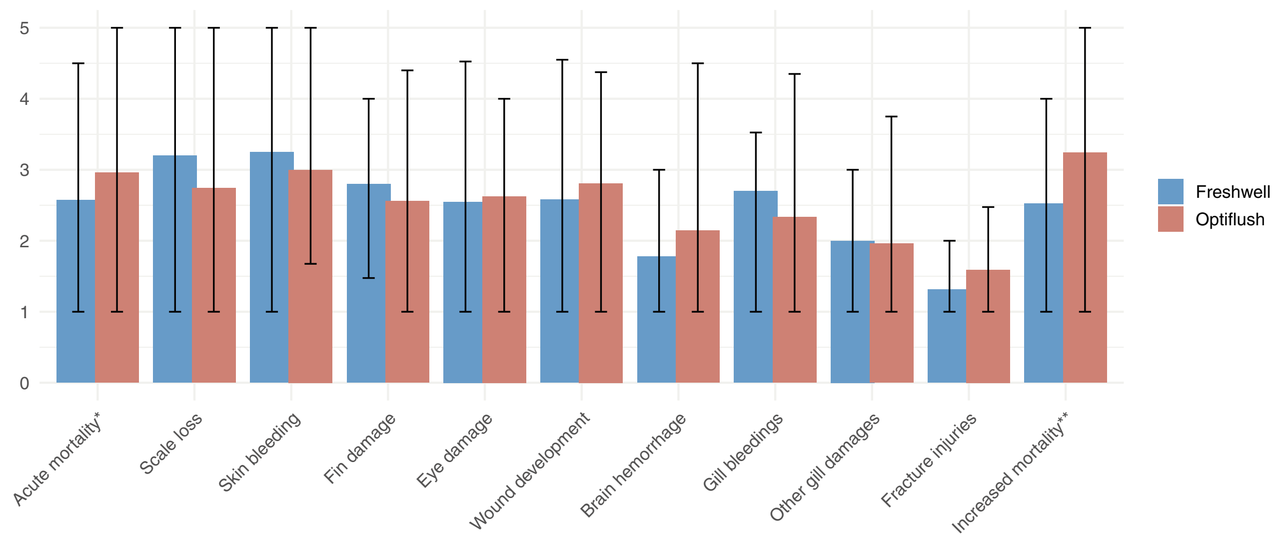


Figure 5.7.5 Average frequency of injuries or mortality associated with Freshwell (N=22) and Optiflush (N=29), with error bars indicating the 95% interquantile range. Frequency is graded on a scale from 1 (never seen/very rarely) to 5 (seen in almost all fish). For the two questions about mortality, answer option 5 corresponds to almost all delousing. Increased acute mortality is defined as more than 0.2 percent in the first 3 days following delousing, while increased death refers to mortality up to 2 weeks after treatment (compared to the level the week before treatment, and beyond the acute mortality period).

5.8 Slaughter and slaughter data

All slaughtering of animals involves the risk of suffering, and there is a requirement for livestock and farmed fish to be stunned before killing. Slaughtering of farmed fish is largely automated. The likelihood of fish experiencing injury, pain, stress, and other distresses is influenced not only by the effectiveness of stunning but also by prior handling. Both crowding, pumping, possible live chilling, time out of water, and the design of pipes and channels are significant factors.

The stunning methods permitted for salmonid fish are electricity and percussive stunning, or a combination of these. Stunning should render the fish unconscious and therefore unable to experience discomfort during bleeding and exsanguination. The fish should remain unconscious until it dies from blood loss. Research shows that both methods can work satisfactorily in relation to fish welfare, provided that the systems are used and maintained as intended. For percussive stunning, it is essential that the fish is struck with sufficient force in the correct location, on the skull slightly behind the eyes. The blow should result in a severe concussion and preferably bleeding in the posterior/lower area of the cranium where the blood vessels enter. For effective stunning in percussive stunning machines, the fish must be of reasonably similar size and head shape, and be correctly oriented. During electric stunning, the current must not pass until the fish's head is inside the stunner. Electric shocks that hit the body before brain function is disrupted are painful. In electric stunning, the current intensity through the brain must be sufficient to cause immediate unconsciousness. If the current intensity is too low, it may take longer for the fish to become unconscious, or worst-case scenario, only the musculature is immobilized, causing the fish to lie still without being unconscious. Visual assessment of stunning quality can be challenging. Electric stunning is often reversible and short-lived, so it is crucial that the fish are bled immediately after stunning. Cutting one side of the gill arches results in slower exsanguination than if both sides of the gill arches are cut.

The considerations for product quality and fish welfare often coincide at the slaughterhouse. Fish that are stressed before slaughter enter rigor mortis more quickly after slaughter and develop a harder rigor, compared to less stressed fish. This reduces the possibility of pre-rigor filleting. Additionally, the final pH in the fillet becomes higher, which reduces shelf life.

It can be beneficial for fish welfare if slaughter takes place on a boat directly from the pen, provided that stunning and slaughter are performed satisfactorily. With the use of a slaughter boat, fish are pumped directly from the aquaculture pen, stunned, and bled on board, then transported to shore for further processing. This avoids the welfare consequences of loading and unloading live fish on a well-boat, transportation to the slaughterhouse, and potentially storage in a waiting pen followed by pumping at the slaughterhouse. However, in 2023, there were examples of dying and dead fish being slaughtered on slaughter boats. Such practices are problematic both in terms of food safety and slaughter quality. From an infection perspective, it is crucial that diseased fish are dealt with promptly as rapid slaughter reduces/prevents the spread of infection. Practices that promote live storage or failure to request rapid removal and slaughter where the fish are not suitable for human consumption, increase the risk of poor welfare and further spread of infection.

The requirement for good welfare at slaughter applies to all fish, including fish that are rejected for human consumption. This can include cleaner fish, bycatch such as small cod, as well as salmonids that are to be discarded. These fish have the same entitlement to welfare-conscious handling and slaughter as fish with economic value.

The final report from the Norwegian Food Safety Authority's inspection campaign "Approvals, Fish Health, and Animal Welfare at Fish Slaughterhouses 2022" was published on December 1, 2023. In this campaign, inspections were conducted at 28 fish slaughterhouses, representing approximately half of the country's fish slaughterhouses. The Norwegian Food Safety Authority uncovered several deviations, most of which have been subsequently rectified. The majority of deviations were found in small to medium-sized slaughterhouses, with few or no deviations found in large slaughterhouses.

Regarding the topic of fish welfare, there were deviations related to stunning and slaughter, including (quote): "equipment not adjusted to fish size, fish head not entering first into the stunner, incorrect blow/voltage, inadequate post-stunning control/back-up, ensuring no signs of life in the bleeding tank or on the conveyor belt before processing" (Norwegian Food Safety Authority's final report from the inspection campaign "Approvals, Fish Health, and Animal Welfare at Fish Slaughterhouses 2022").

In this year's survey, 30 respondents indicated that they had conducted inspections at or worked with slaughterhouses in 2023. Most of them (20 of 30) had inspections at only one slaughterhouse, six respondents had experience with two facilities, two with three, one with four, and one with five facilities. When asked, "Have you conducted inspections or had experience with slaughter boats in 2023?" 31 individuals answered "yes" while 81 individuals answered "no."

The respondents were asked to assess the stunning quality of electrical and percussive stunning. Approximately half of the 30 respondents to each question answered either "Don't know" or "No experience." The reason for the relatively low response rate to these questions is unknown, but it may be due to factors such as respondents other than those overseeing welfare at slaughterhouses answering, or it could reflect the difficulty in assessing stunning quality. Of the 15 respondents who answered the question about electrical stunning and the 12 who answered the question about percussive stunning, one-third reported that more than 99 percent of the fish were satisfactorily stunned (Figure 5.8.1), while the rest experienced lower reliability. This response indicates a deterioration compared to the results for the same question in 2021. In 2021, 50 percent of respondents reported that more than 99 percent of the fish were well stunned with both methods. Whether this result reflects a real change or other factors is uncertain. Respondents indicate in free-text responses that assessing the effectiveness of electrical stunning is difficult, especially for species other than salmon. The machines are adapted for salmon and generally work well for this species, but problems quickly arise when used on other species. It is also highlighted that there is generally a lack of knowledge and follow-up. Regarding percussive stunning, free-text responses address problems related to varying fish size. Especially small fish and deformed fish have an increased risk of inadequate stunning when using percussive stunning machines. Fish orientation is a theme concerning both stunning methods.

In response to the question about whether backup

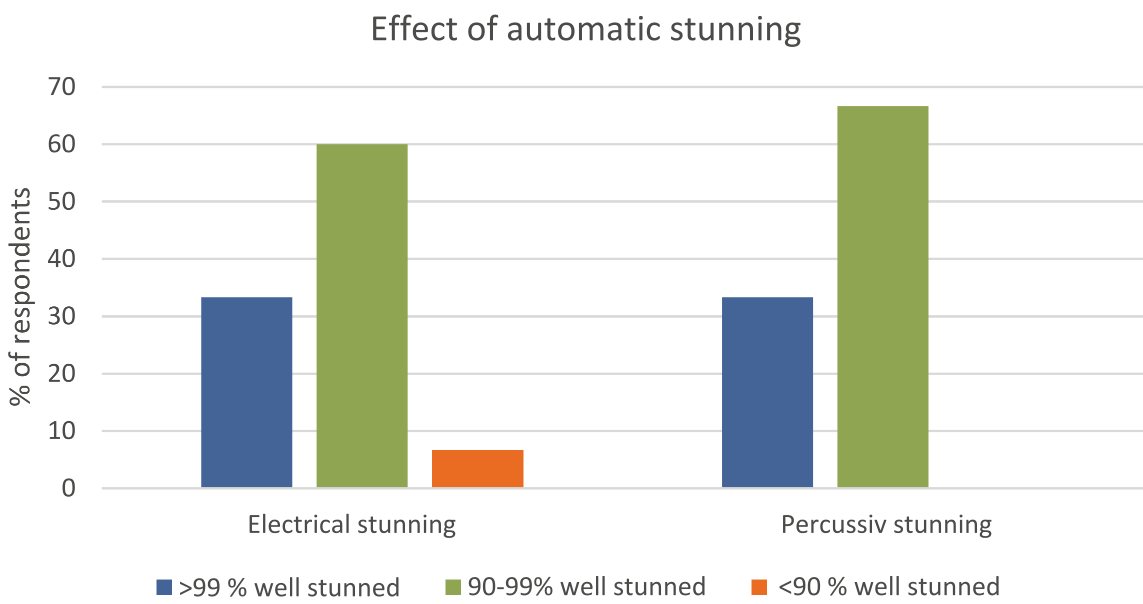


Figure 5.8.1. The diagram illustrates the respondents' assessment of the percentage of fish that are well stunned after stunning with the methods of electricity and percussion. The number of respondents was 15 for electric stunning and 12 for percussion stunning.

systems for stunning work satisfactorily, i.e., in case the fish is not stunned by the first stunning method, eight respondents answered "yes" (29 percent), three answered "no" (11 percent), and 17 answered "don't know" (61 percent). This represents a decrease in the proportion of respondents answering "yes" from 48 percent in 2021, which was the last time this question was asked. At the same time, the proportion of respondents answering "don't know" increased by approximately the same amount.

Fifteen respondents had experience with automatic bleeding systems, of which 11 respondents (73 percent) reported that it works satisfactorily, and four (27 percent) reported that it does not work satisfactorily. None reported that automatic bleeding "works very well." In comparison, the Fish Health Report 2021 stated: Fifteen respondents had experience with automatic bleeding systems, of which 40 percent believed it worked very well, 33 percent satisfactorily, while 27 percent often observed failed-cutting. Thus, concerning automatic bleeding, there seems to be a shift from 2021 to 2023 towards poorer fish welfare or a more negative perception of fish welfare at the slaughterhouses. An alternative interpretation could be that there are no signs of improvements since 2021.

Other comments (free-text responses) regarding welfare challenges for salmon in slaughterhouses or slaughter boats indicate that there is insufficient documentation of equipment in relation to fish welfare. Concerns are also expressed regarding the consequences for fish welfare due to the increasing slaughter of sick and small fish, particularly because the equipment is not tailored to small fish. Lack of competence and/or lack of focus on attitudes towards fish welfare at slaughterhouses are mentioned. Problematic oxygen conditions in storage pens are also mentioned.

Regarding whether stunning and slaughter of cleaner fish at slaughterhouses provide satisfactory fish welfare, 12 out of 27 responded "Don't know" (44 percent), nine responded "No" (33 percent), and six responded "Yes" (22 percent). In the follow-up question answered by eight respondents, various issues were mentioned: 1) lumpfish attach themselves in various places and can end up in the salmon stunner due to their body shape, 2) staff shortages, 3) insufficient competence and human error, 4) inadequate stunning and bleeding of cleaner fish, 5) insufficient removal of cleaner fish prior to slaughter results in a lot of cleaner fish at the slaughterhouse, 6) insufficient documentation of equipment used on cleaner fish, 7) improvement in stunning and slaughtering of cleaner fish in recent years..

The last question concerned experiences regarding the Norwegian Food Safety Authority's supervision campaign in 2022 on animal welfare at slaughterhouses. Four respondents stated that they had experienced improvements in animal welfare following the campaign. Five responded that they had not experienced improvements, ten responded that they did not know if there had been improvements, and nine responded that they did not have experience with the campaign.

The deviations uncovered in the Norwegian Food Safety Authority's campaign share many similarities with the findings in this year's survey. Since inspections were only carried out at half of the slaughterhouses in the campaign and a significant number of deviations were identified, there is reason to believe that there is still a need for increased focus on improving fish welfare in slaughterhouses not included in the campaign. Given that a typical batch of slaughtered fish consists of varying sizes, morphologies, and sometimes even different species, ensuring welfare-compliant stunning and slaughter of all individuals may seem challenging. Therefore, robust backup systems and a commitment to stunning and slaughtering all fish are all the more important.

Slaughter data

After slaughter, the harvested fish are often sorted into quality categories such as superior, ordinary, and production grade. Additionally, when slaughtering a batch of fish, there is typically a fraction of the fish that are not suitable for processing and are therefore discarded (known as "discard"). The utilization of these different quality grades can vary among slaughterhouses or processing vessels. There can be various reasons for downgrading a fish, including sexual maturation, wounds, injuries, and deformities. A common characteristic among a significant portion of the fish that are downgraded is that they have experienced a period of compromised welfare prior to slaughter.

The "superior fraction" is a commonly used parameter in the industry to describe the quality of a batch of fish after slaughter from pens or facilities. Typically, the superior fraction is expressed as a percentage of the total quantity slaughtered, calculated based on weight. The superior fraction represents the fish in the best quality class, i.e., the portion of fish that have not been downgraded. From a welfare perspective, the superior fraction should be calculated based on the number of fish rather than their weight. This is because the individual weights of an average superior fish are likely to be higher than those of an average downgraded fish from the same batch. Consequently, a superior fraction based on weight will often be higher than a superior fraction based on the number of fish in the same batch.

Norwegian fish slaughterhouses and slaughter boats submit slaughter reports to the Norwegian Food Safety Authority. The slaughter data includes information on the species of fish and the quantity slaughtered (dressed weight), as well as the quantities of fish in the different quality classes. Additionally, for each slaughter report, the main reason for downgrading to the "production" category and the primary reason for discarding to the "discard" category are provided.

The Norwegian Veterinary Institute has been granted access to the dataset containing slaughter data from 2023, focusing only on salmon and rainbow trout. Slaughter reports with obvious errors and duplicate entries were removed. Reports labeled as trout from sea locations were combined with rainbow trout, as both are assumed to represent rainbow trout. After data cleaning, the dataset comprised 5610 rows of slaughter reports (fish of the same species, from the same site, and slaughtered at the same slaughterhouse/boat). These data represent 102 percent of the salmon and 98 percent of the rainbow trout slaughtered in Norway in 2023 (according to statistics published by the Norwegian Directorate of Fisheries, updated January 22, 2024, when adjusted for gutting loss (added 12.5 percent for salmon and 13.5 percent for rainbow trout to dressed weight)). Therefore, there may still be some minor duplicates or errors that were not detected during data cleaning. The data are summarized in Table 5.8.1.

In each slaughter report, the “main reason for downgrading” of fish to “production” class is indicated. The choice of reason is predefined with four different options: “Defects”, “Sexual maturation”, “Clinical disease”, and “Wound/injury”. It is only possible to specify one reason per slaughter report."

"The most common choice for the “main reason for downgrading to production” in 2023 was the category “wound/injury” for salmon, while for rainbow trout, it was the category “defects” (Figure 5.8.2). “Wound/injury” was rarely chosen for rainbow trout, and

Table 5.8.1. Overview of slaughter data for 2023 as reported from slaughterhouses/boats to the Norwegian Food Safety Authority. Number of slaughter reports, total volume slaughtered (gutted weight), and quantity classified as superior, ordinary, production, and discard.

	Salmon	Rainbow trout
Number of slaughter reports	4 965	645
Total slaughter, tons	1 383 768	70 365
Total superior, tons	1 162 494	62 895
Total ordinary, tons	16 990	2 286
Total production, tons	196 709	5 070
Total discard, tons	7 575	114
"Percentage of superior out of total (weight)"	84,0 %	89,4 %

“Clinical disease” is generally infrequently used. There is a somewhat similar pattern in the choice of the main downgrading reason in the years 2021-23 for both salmon and rainbow trout.

"When it comes to fish that are not slaughtered but sorted into the category “discard”, the main reason for this is also indicated in the slaughter report. The same categories are used for discarded fish as for production fish, but in addition, the category “Self-dead” is an option. For both salmon and rainbow trout, the most common category is “Defects”, see Fig. 5.8.3.

According to the Norwegian Directorate of Fisheries' “Loss (wastage) statistics” as of February 8, 2024, there were 3.366 million salmon and 130,000 rainbow trout discarded in 2023.

The percentage of superior quality (%) for salmon slaughtered in the various production areas (PA) in 2023 is shown in Figure 5.8.4. Due to few sites in PA1 and PA13, PA1 and PA2 are combined and PA12 and PA13 are combined. The figure shows the percentage distribution of the main reasons for downgrading, calculated based on the weight volume of fish. There is variation in the superior percentage between production areas. PA5 and PA7 are the highest at 89 percent superior, while PA3 (79 percent) and PA12-PA13 (78 percent) are the lowest in terms of percentage superior (shown as dots in Figure 5.8.4). The “injury/damage” is the most important reason for downgrading nationwide, but in the southwest, the “defects” option is also frequently chosen. “Sexual maturation” seems to have the greatest relative importance in PA1/PA2 and in PA5. “Clinical disease” has limited use, mostly in PA PA12/PA13. Similar figures have not been prepared for rainbow trout, as the production of this species is significantly smaller and the number of producers is few in the various production areas.

When the slaughter reports are organized chronologically, it is observed that both the slaughter volume and the percentage of superior quality vary with the season (Figure 5.8.5). In the first half of the year, the weekly slaughter volume was approximately 20-25 thousand tons, and the percentage of superior quality was mostly in the range of 70 to 80 percent. In the second half of the year, the weekly slaughter volume increased to approximately 30-35 thousand tons, and the percentage of superior quality increased to around 90 percent.

In the dataset, there are figures from the slaughter of salmon and rainbow trout from a total of 614 different aquaculture sites. By summing up the slaughter reports for each site, a total superior percentage was calculated. This then expresses the average of all fish slaughtered in the period for each site. The average superior percentage for the 614 sites was 83 percent (the 25th percentile was 77 percent, the median was 88 percent, and the 75th percentile was 92 percent). Figure 5.8.6 shows the number of sites with superior percentages within different percentile intervals.

"The reporting of slaughter data provides large enough datasets to discern overarching trends between species, years, and production areas. In assessment of slaughter data as an indicator of fish welfare, it is important to understand both strengths and weaknesses. At the site and pen level, the proportion classified as downgraded and discarded, as well as the reasons for this, provide valuable information about welfare at the end of production. Weaknesses may include variation in the use of different quality classes, with the “ordinary” class apparently not being used at some slaughter sites. In some slaughter reports, discards are not specified. Another weakness is that only one downgrading reason can be reported per week, which provides an oversimplified picture of the actual situation, as it must be assumed that the situation is often more complex. As mentioned earlier, it would be a valuable addition if the number of fish were added to the dataset. Slaughter data can be used in conjunction with other data such as FOVI scores (Chapter 5.2 Fish Welfare and Health in Regulations and Management) to examine overarching trends and measure changes in fish welfare."

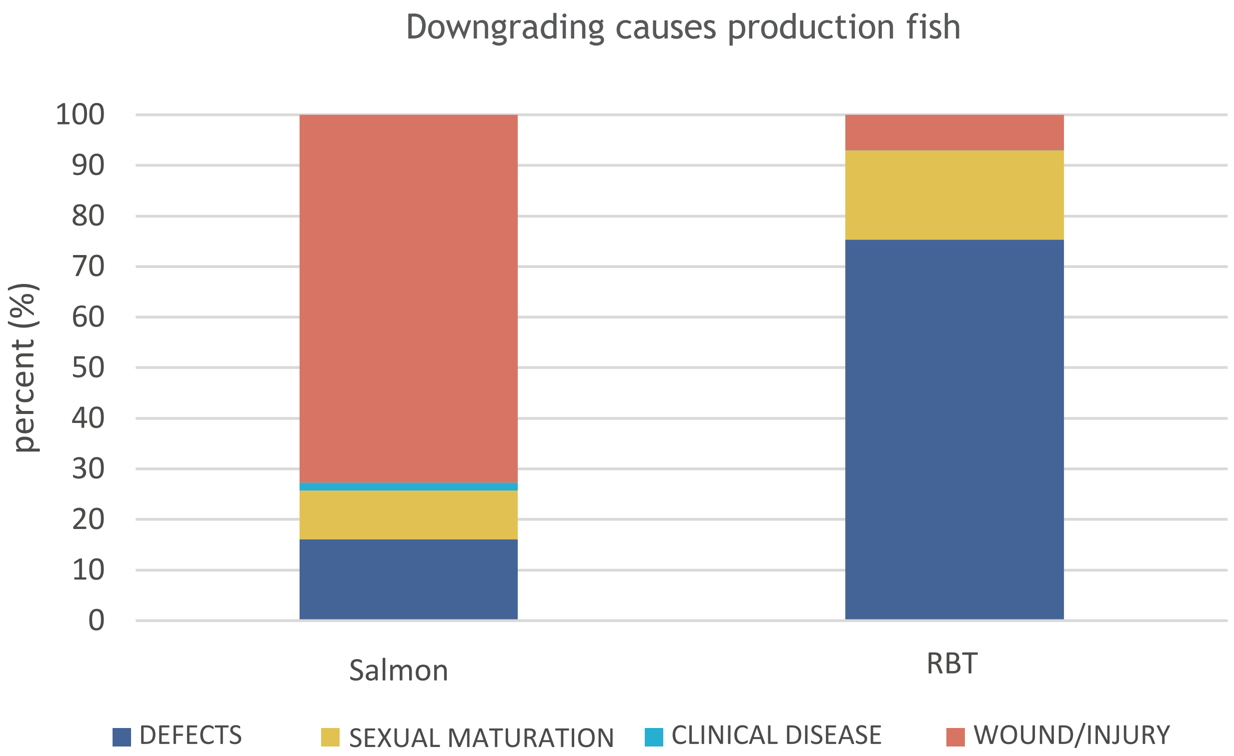


Figure 5.8.2. Proportion of production fish (weight), salmon and rainbow trout (RBT), where the categories "defects," "sexual maturation," "clinical disease," and "wounds/injuries" were chosen as the primary reason for downgrading.

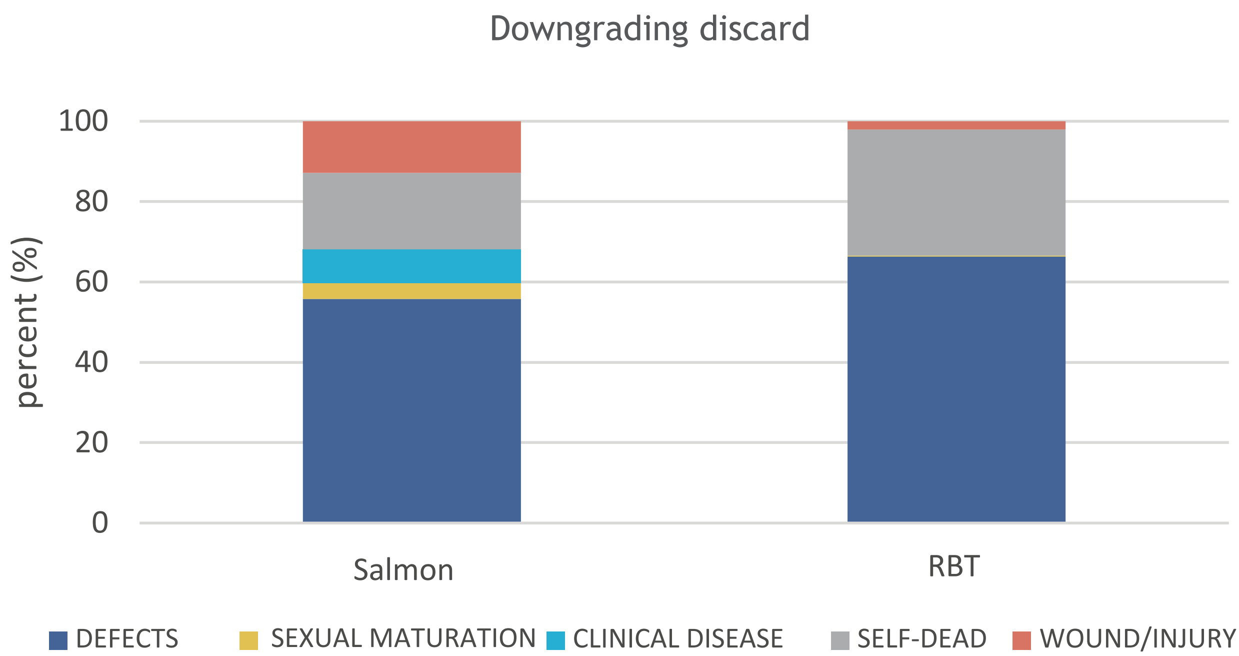


Figure 5.8.3 Percentage of discard fish, salmon and rainbow trout (RBT), where the categories "defects", "sexual maturation", "clinical disease", "self-dead", and "wound/injury" were chosen as the main reasons for downgrading.

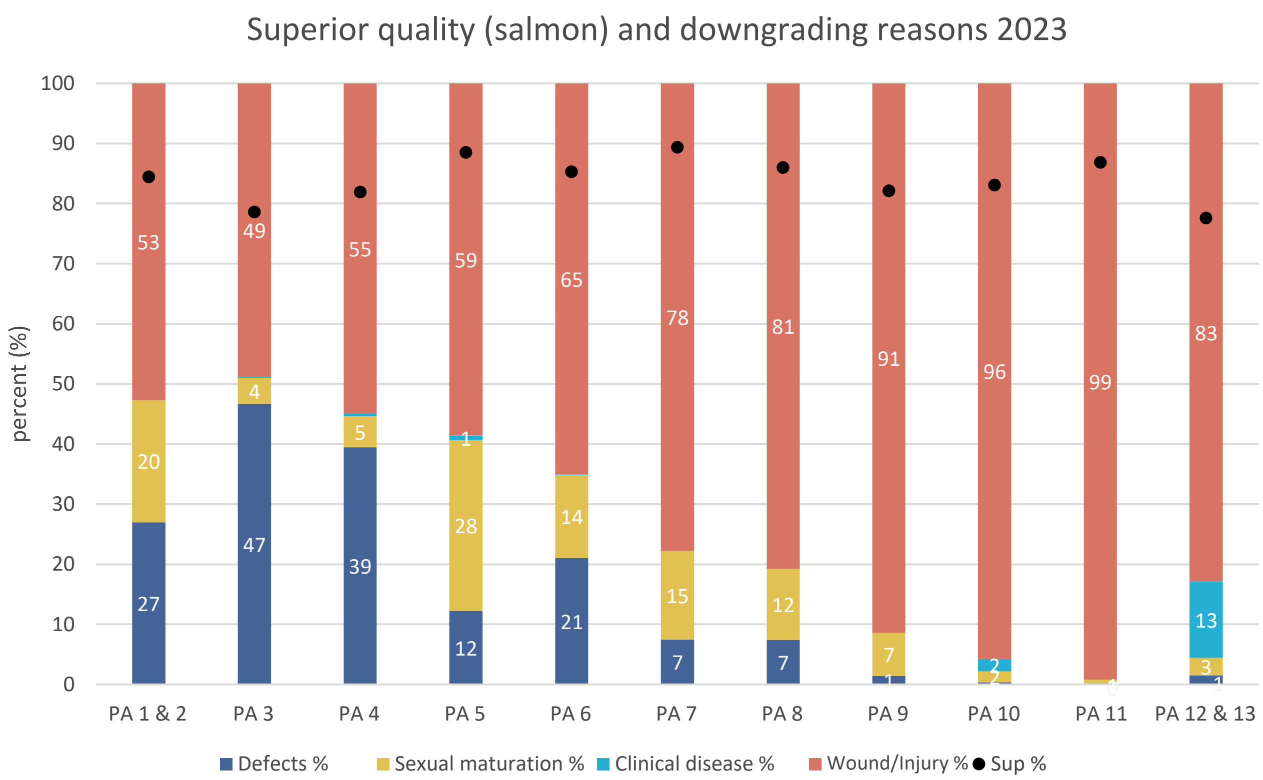


Figure 5.8.4. Superior quality (%) per production area in 2023, as a percentage of total slaughtered volume (salmon) shown as "dot", and distribution (%) of main downgrading reasons shown in different column colors. Data from PA1 and PA2 are combined, and the same applies to data from PA12 and PA13.

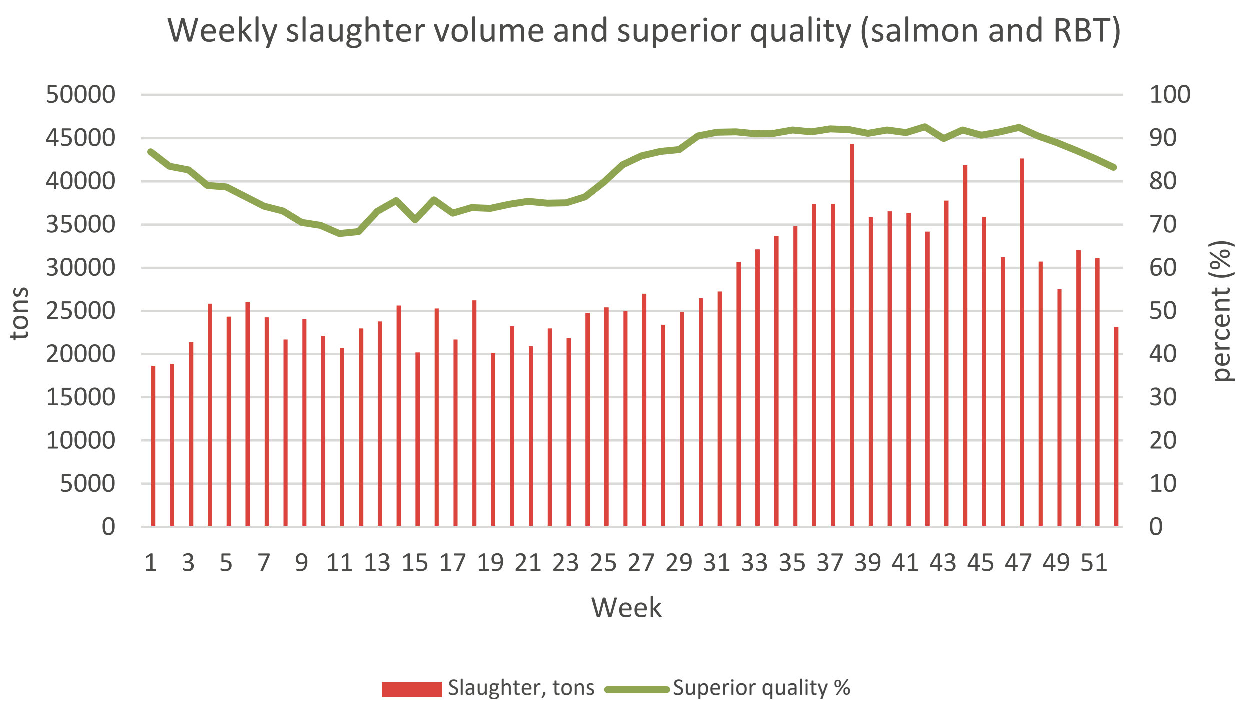


Figure 5.8.5. Weekly slaughter volume in tons and superior quality (%) in 2023 combined for salmon and rainbow trout.

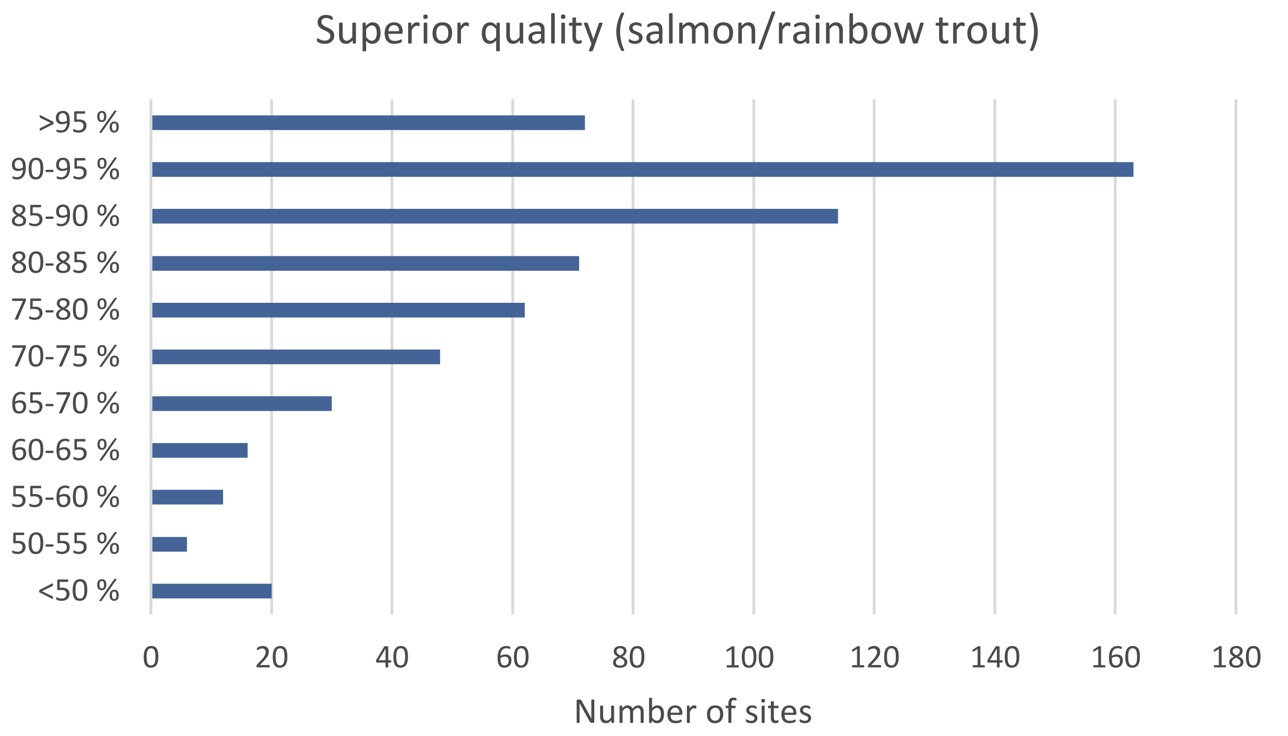


Figure 5.8.6. Number of sites with superior quality (%) within various percentage intervals, after slaughter of salmon and/or rainbow trout. Total number of sites in the dataset (N = 614).

5.9 Feed and feeding

The feeding method and the amount of feed affect fish welfare, among other things, by influencing the behaviour of the fish. For example, suboptimal feeding or provision of insufficient feed can lead to a competitive situation among the fish. Aggressive behaviour, in turn, leads to fish being injured, with fins, gill covers, and eyes often being vulnerable in such situations. Overfeeding can negatively impact water quality and is also an unsustainable waste of feed.

Fasting of fish is routinely done before transport and handling. Such cessation of feeding does not result in aggression in the same way as insufficient feeding over an extended period. Fasting is done to empty the fish's intestine and reduce its metabolism. This contributes to better water quality and reduces the fish's oxygen consumption, making it better able to tolerate handling. Additionally, there are quality and hygiene reasons for fasting before slaughter. Recent research on post-smolt Atlantic salmon has not been able to demonstrate negative welfare effects of withholding feed for periods of four to eight weeks.

Proper nutrition is essential for normal development and growth in all animals. Nutritional needs change throughout the lifecycle, and there may also be individual differences. Commercial feed is tailored to the nutritional needs of the majority of fish within an age group. There are rarely significant safety margins when it comes to costly feed ingredients. Changes in raw material prices or environmental considerations can lead to changes in feed composition. This must be carefully monitored both in the short and long term to avoid adverse effects on health and welfare. Since the 1990s, there have been significant changes in the types of raw materials and the proportion of different ingredients used in standard feed for salmon and rainbow trout. The amount of fishmeal and fish oil has been greatly reduced in line with an increase in content of vegetable ingredients.

In addition to standard feed, suppliers of feed for farmed fish often offer a wide range of so-called health feeds. These types of feeds are marketed for example, to have effects against gill problems, lice, wounds, heart disorders, and more. There is limited access to documentation on the actual effectiveness of these feed types, but there is some evidence indicating positive effects. If a health feed is to have a good effect on fish with an infectious disease, it must be assumed that the overarching mechanism is that the feed provides nutrients that the fish does not have sufficient stores of, to fight against the agent.

In the Norwegian aquaculture industry, some health problems of a complex nature have shown an increasing trend in recent years. It is reasonable to suspect that inadequate nutrition may be part of the overall picture. For the farmer, it is important to assess whether the fish have access to a sufficient amount of essential nutrients to cope with the sometimes significant challenges they are exposed to.

The Annual Survey

Among the free-text responses in this year's survey, several respondents describe suboptimal feeding of cleaner fish in pens. Specifically, insufficient distribution of feed is mentioned, and feeding near hiding places was suggested. On the positive side, good experiences are

5.10 Cleaner-fish

Cleaner-fish are lumpfish and various wrasse species that are used as part of the control strategy against salmon lice. In 2023, according to the Norwegian Directorate of Fisheries (data as of 20.02.2024), approximately 33.9 million cleaner-fish were used. This is the fourth year in a row that a decrease in the number is recorded, corresponding to a decrease of 2.47 million cleaner-fish from the previous year. Since the peak year of 2019, there has been a decrease of 44.5 percent (Figure 5.10.1). The number of sites for salmon and trout that have reported using cleaner-fish has decreased from 444 in 2019 to 253 sites in 2023. This accounts for approximately 29 percent of active production sites in 2023. The use of cleaner fish in PA9 has almost ended. The registered reduction over the past four years reflects the views of fish health personnel that cleaner-fish are used to a lesser extent than previously or that their use is in the process of being phased out due to health and welfare challenges. Another reason for the decline may be due to the Norwegian Food Safety Authority's clarification of § 28 of the operation of aquaculture facilities regulation, which states the requirement to fish out cleaner-fish prior to delousing. Last year, the Norwegian Veterinary Institute gained access to data from the Norwegian Directorate of Fisheries where fish farmers themselves reported the release of cleaner-fish and the number of fish registered as dead. Errors in registration were discovered and corrected, so some of the decrease may also be due to corrections in reporting to the Norwegian Directorate of Fisheries.

Of the wrasse species, corkwing wrasse, ballan wrasse and goldsinny wrasse, are used to control salmon lice. Only ballan wrasse are farmed. Ballan wrasse are difficult to farm, partly because they have small larvae that require live food. The live feed currently used is likely suboptimal and may negatively affect the development of larva, in terms of deformities and early death. Skeletal deformities in farmed ballan wrasse are common and are believed to affect both their welfare and efficacy as delousers. The other wrasse species, as well as some ballan wrasse, are wild-caught. The catch quota is 18 million wrasse, and fishing is distributed across three geographical areas: Southern Norway, Western Norway, and north of 62°N. In addition, wrasse are also imported from Sweden. The majority of wrasse released in farms are caught locally, but transport over longer distances also occurs. It has been shown that the Skagerrak population of corkwing wrasse in PA6-PO7 is genetically affected due to escapes (Norwegian Fish Farming Risk Report 2023). The significance of the depletion of wrasse populations and their removal from the local capture area ecosystem is unknown, but fishing has been regulated by quotas since 2018.

Almost all lumpfish used are farmed and account for over 50 percent of the total number of cleaner-fish released.

Despite a significant decline in farmed lumpfish in recent years, it remains one of Norway's most farmed species in terms of numbers. The advantages of farmed cleaner-fish is lower risk of disease transmission, more stable quality, and reduced risk of overexploitation of wild stocks. Unfortunately, there are few available vaccines for farmed cleaner-fish, and there is also a demand for vaccines with better efficacy.

It is known that reporting mortality rates per species of cleaner-fish is challenging. Cleaner fish figures, including mortality rates reported to the Norwegian Directorate of Fisheries, were shared with the Norwegian Veterinary Institute for last year's report (2022), but due to changes in the data transfer method and the need for quality assurance, the figures for 2023 will be published later.

The cleaner-fish natural habitat differs considerably from the environment in the cages used in salmon farming. The Atlantic salmon is an athletic fish with high swimming capacity, while both lumpfish and ballan wrasse have poorer swimming capacity. Therefore, they will not thrive in locations with moderate to strong currents. Locations with strong currents and weather exposure are therefore a major challenge. In the survey, it is also mentioned this year that it is necessary to assess whether the environmental conditions in individual locations are suitable for cleaner-fish. From previous surveys, it is known that cleaner-fish are used in locations with strong currents, even though fish farmers and fish health personnel believe that they cannot tolerate it. Consideration of the environmental conditions at the location is highlighted by several respondents as a concrete measure that can improve the welfare of cleaner-fish. In addition, lumpfish poorly tolerate high sea temperatures, and summer temperatures in Southern Norway pose an additional challenge. Although lumpfish are usually released at lower temperatures, in 2022 as in 2023, lumpfish were still released in the summer months in Southern Norway. This practice causes a high risk of infectious diseases and reduced welfare for lumpfish. On the other hand, wrasse are more tolerant of high water

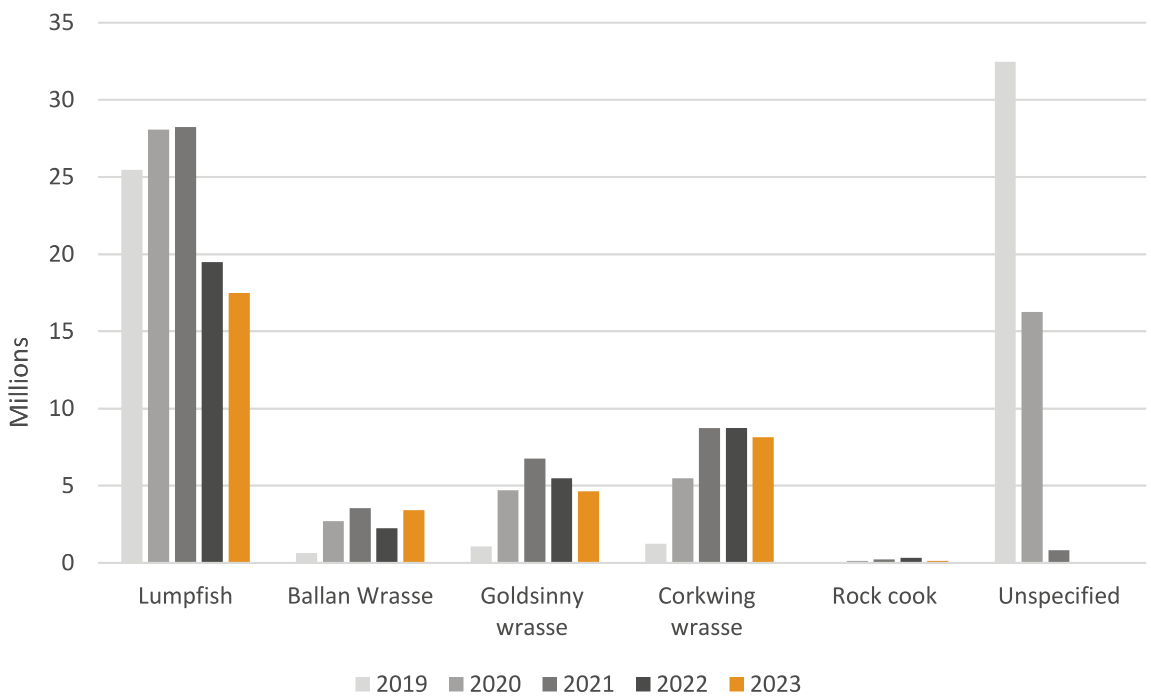


Figure 5.10.1 Use of lumpfish and wrasse in net pens with salmonid fish from 2019 to 2023 (Norwegian Directorate of Fisheries, figures as of January 22, 2023).

temperatures and have low activity at 5-10 °C. It is therefore positive that releases do not occur in the northern production areas (PA7-PA13).

It is uncertain to what extent salmon and cleaner fish meet in the pen, as there are large water volumes and the species have different environmental preferences. In addition, there is uncertainty about the cleaner-fish's effectiveness in delousing. Several fish farmers claim to have success with cleaner-fish. However, published studies from experiments on a smaller scale show that the effectiveness of cleaner-fish is variable, and the best effect is observed in tank experiments on land. In studies from the Institute of Marine Research with data from the entire industry, only limited utility value is observed. Fish health personnel are also asked this year about the perceived effect of lumpfish, farmed ballan wrasse, and wild-caught wrasse against lice (Figure 5.10.2). For lumpfish, about one percent report good effect, 43 percent do not know. For each of the categories "little/no effect," "postponed delousing by about a month," and "avoided 1-2 delousings per sea-cycle," respectively, 12 and 26 percent experience this. For farmed ballan wrasse and wild-caught wrasse, over 60 percent answer "do not know," while three percent say they have a good effect. The proportion stating "do not know," as well as low figures for good effect, illustrate the significant uncertainty regarding the effectiveness of cleaner-fish in 2023 and 2022.

Vaccination of farmed cleaner-fish, provision of suitable shelters, suitable feed and feeding strategies are measures used to improve their welfare. Nevertheless, mortality remains persistently unacceptably high, and welfare and disease challenges are significant (Chapter 12 The Health Situation for Cleaner Fish). It is likely that cleaner-fish do not have the ability to either adapt to or master salmon farming conditions.

In this year's survey, respondents were asked to assess the conditions that have the greatest negative impact on mortality, reduced growth, and welfare, as well as

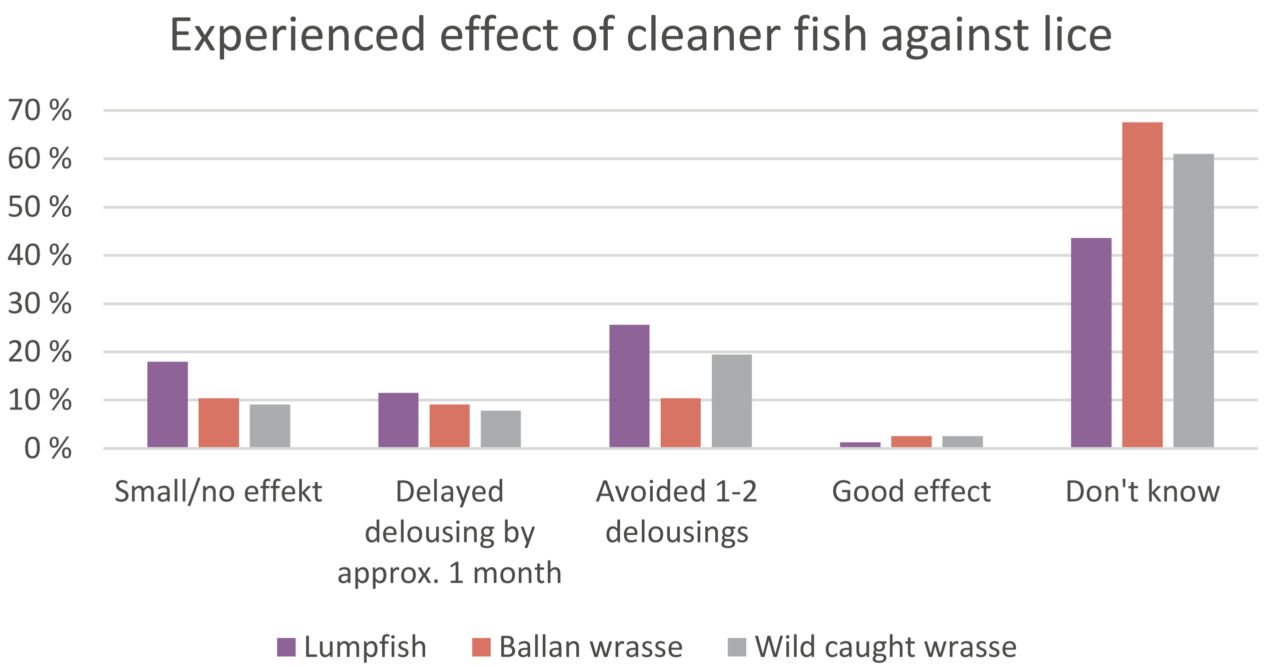


Figure 5.10.2 Fish health personnel experiences of the delousing effect of lumpfish, farmed ballan wrasse and wildcaught wrasse on a scale from little/no effect to good/significant effect and don't know. N=78 for lumpfish and N=77 for farmed ballan wrasse and wild-caught wrasse.

increased occurrence in the hatchery for lumpfish and wrasse. As in previous years, fin damage and suboptimal care scored highest, followed by unspecified disease (Appendices D1 and E1). This corresponds with comments in the survey where fin damage and suboptimal care are highlighted as challenges in the hatchery. Ballan wrasse with skeletal deformities of the jaw and significant fin damage have reduced welfare, which will affect their ability to eat lice. For wrasse cohabitating with salmon in the farms, handling, atypical furunculosis, and fin damage are mentioned as the main causes of mortality and reduced welfare (Appendix E2). For lumpfish cohabitating with salmon, handling, non-medicinal delousing, and atypical furunculosis are highlighted as the main causes of mortality and reduced welfare (Appendix D2). Handling and non-medicinal delousing are also increasing in frequency. Geographically, respondents for PA1-PA5 mention handling, atypical furunculosis, and fin damage as the main causes of reduced welfare and mortality (Figure 5.10.3a). For PA6-PA8, handling, non-medicinal delousing, and suboptimal care are listed as the causes of mortality and reduced welfare (Figure 5.10.3b). For PA10-PA13, lesions and non-medicinal delousing are perceived as the main causes of mortality and reduced welfare (Figure 5.10.3c). Handling and non-medicinal delousing are also increasing in frequency. New this year is that handling is highlighted as the main cause of mortality and reduced welfare nationwide, which can be seen in connection with the increased focus on fishing out cleaner-fish prior to delousing, due to the Norwegian Food Safety Authority's clarification of the requirement to fish out cleaner-fish.

When commenting on the general health situation for cleaner-fish, 49 comments were received. Fish health personnel are critical of current practices this year as well. Most of the comments are about the reduced or discontinued use of cleaner fish and the need for it to end. It is mentioned by several that there is increased focus on fishing out cleaner fish ahead of delousing and that significant resources are spent on this. Furthermore, it is commented that it is challenging and that there are not good enough methods, contributing to poor health and welfare. One comment mentions that cleaner fish have good health and effectiveness. Fishing out and removing lumpfish with increasing temperatures and upon detection of disease is also mentioned.

When commenting about specific measures that can improve the welfare of cleaner fish, 51 comments were received, of which 11 mention discontinuation of cleaner fish use. Other measures highlighted include better sorting before sea transfer based on fin status and care. Better adjustments in the farms such as type and quantity of feed, feeding strategy such as active feeding in shelters, better and sufficient shelters. Good fishing out prior to delousing/work operations is also mentioned. There is also a need to consider cleaner-fish during net cleaning. Many of the same comments are highlighted in the comments concerning what can degrade the welfare of cleaner-fish. Here, 42 comments were received. Several respondents highlight operational conditions. In the hatchery, issues such as lack of shelters, high density, poor water quality, lack of sorting before sea transfer, especially regarding fin status, are mentioned. Regarding conditions at sea, it corresponds with the comments regarding measures leading to improvement in welfare.

For the question about experiences with discontinuing cleaner fish farming, there were 17 responses, most of which are positive about discontinuation. As for the reasons for discontinuation, among other things, unsuitable environmental conditions at the site, difficulties in ensuring the welfare of cleaner fish, and stricter requirements from regulatory authorities are mentioned. It is also highlighted that discontinuation has contributed to improved attitudes among personnel and that it is easier to implement measures and treatments at the right time when cleaner fish are not considered. Several also mention this year that cleaner fish have been replaced with lice lasers.

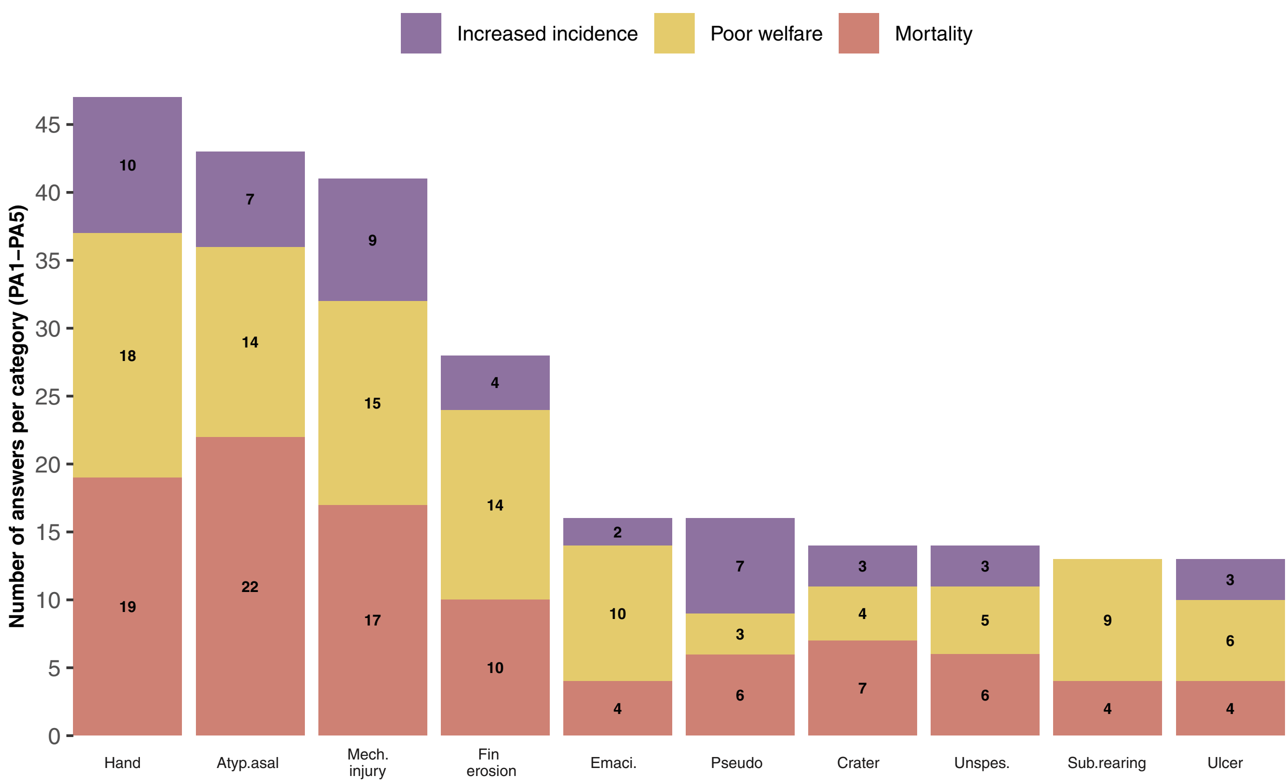


Figure 5.10.3 a) Fish health personnel and inspectors of the Norwegian Food Safety Authority have ranked the three most important causes of mortality, welfare, and increasing incidence in lumpfish held in cages with salmonid fish in PA1-PA5 (N=37).

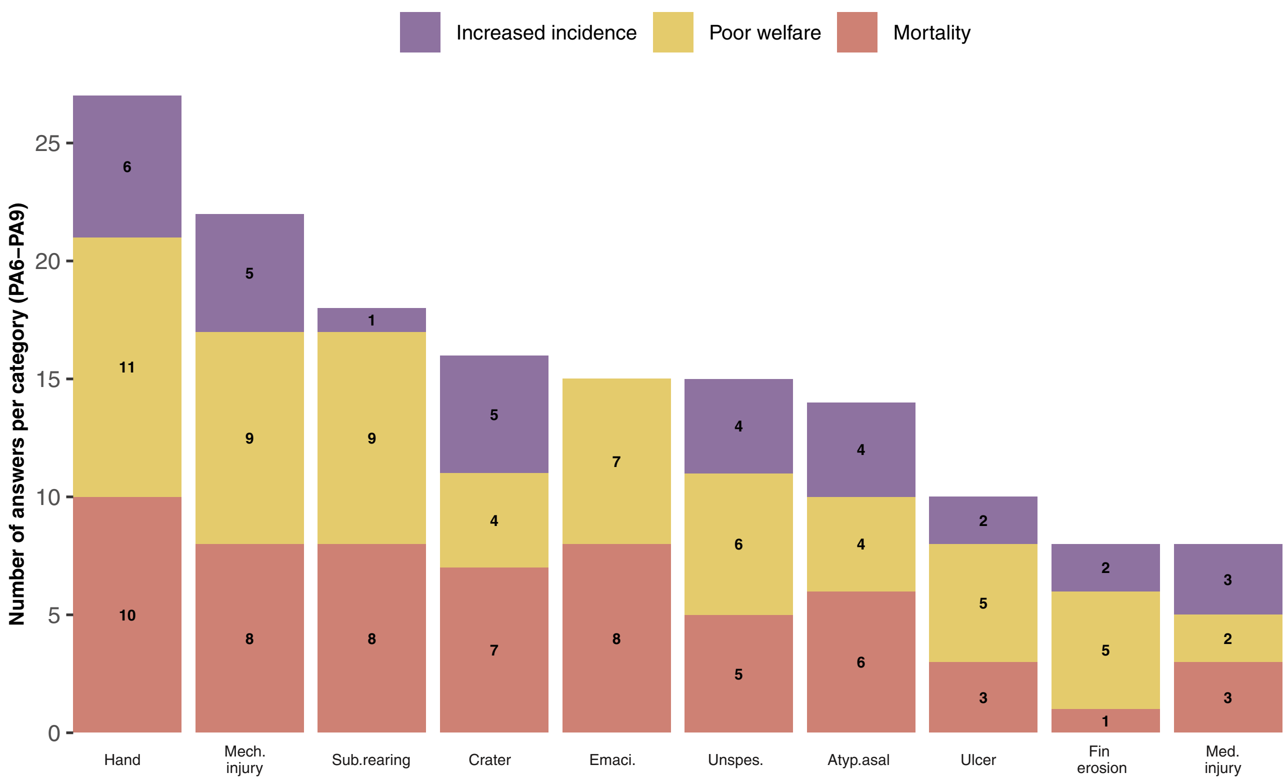


Figure 5.10.3 b) The respondents (N) have ranked the three most important causes of mortality, welfare, and increasing issues in lumpfish held in cages with salmonid fish in PA6-PA9 (N=24).

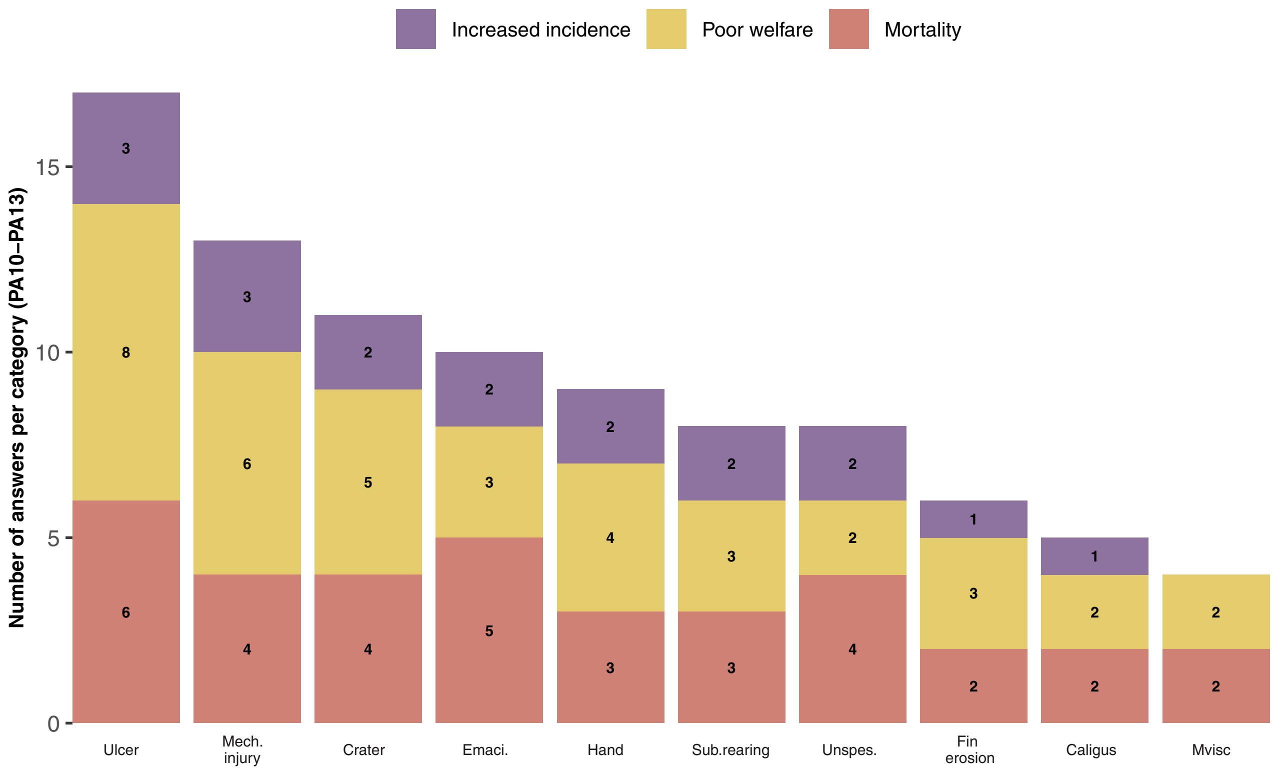


Figure 5.10.3 c) The respondents (N) have ranked the three most important causes of mortality, welfare, and increasing issues in lumpfish held in cages with salmonid fish in PA10-PA13 (N=14).

As in previous years, respondents were asked if the mortality of cleaner-fish after stocking in sea cages with salmonids was approximately the same level, higher or lower, or if they did not know. Also in 2023, there is a disturbingly high percentage answering "do not know"; 48 and 55 percent for lumpfish and wrasse, respectively. The high percentage answering "do not know" shows that it is difficult for fish health personnel to have a good overview of cleaner-fish mortality in the farms and thus be able to measure the effect of any measures to improve survival and welfare.

5.11 Overall Assessment of fish welfare in 2023

The welfare challenges highlighted in this and previous editions of the Fish Health Report indicate that it is necessary for improvement of animal welfare in the aquaculture industry. This cannot be achieved solely through individual case supervision by the Norwegian Food Safety Authority or through the use of the legal system. Structural changes in the licensing system are necessary to improve fish welfare. In the Traffic Light System, there is a need for a change in how growth exceptions are practiced, including clearing sites with welfare in mind before growth. In such clearance, both mortality, the number of non-medicinal delousing, care of cleaner-fish, reported welfare incidents, and slaughter quality can be used as concretization of welfare goals. It is important to set overarching welfare goals, an example of which could be maximum percent mortality for salmon in the sea phase, with less than five percent suggested as a goal to strive towards. Governmental-based welfare indicators, known as GOWIs, can be used to measure and steer that the development is heading in the right direction. Steering towards good welfare and low mortality through a GOWI framework consisting, for example, of also the number of non-medicinal delousing known to negatively affect fish, and slaughter quality can contribute to better product handling and ethical value creation. Welfare indicators must be more used, including changed fish behavior as valuable early warning signs. To operationalize the use of welfare indicators, various camera technologies and sensors can be used to obtain information about a larger quantity of fish, but it is still used to a limited extent for welfare scoring, for example.

At an overarching level, many of the welfare problems in the industry are related to operations, the methods used, and human factors. The farmer has the responsibility to adapt operations and methods to the needs of the fish, and here the survey identifies significant potential for improvement. Also within the theme of fish nutrition, new research indicates that Norwegian standard feed does not always contain sufficient important nutrients to meet the fish's needs in a sometimes very demanding everyday life. Farmers should be aware of this so that the fish are ensured a feed tailored to their specific needs.

The entire life cycle of salmon must be considered holistically when assessing welfare and mortality. The juvenile phase must not become too intensive, for example by using too high density or temperature, as intensive production likely affects the smolt's robustness after seawater transfer. Regulatory reporting, especially in the juvenile phase, still has great potential for improvement: Currently, fish groups cannot be followed from hatching to slaughter, and it is not possible to calculate mortality for the entire life cycle, something the Fish Health Report has pointed out since 2019. To be able to implement targeted measures based on where the biggest challenges lie in production, the use of both standardized causes of mortality, welfare indicators, and systematic disease registrations must increase. In 2023 is the first year the number of reported welfare incidents from juvenile production has decreased or leveled off, but a large proportion is still very serious. Most incidences are categorized as "other" and "unresolved mortality." Based on classification of stated free text, the Norwegian Veterinary Institute has examined causal relationships in the "other" category. Thematically, it concerns human error, water quality, and equipment failure, closely followed by disease/parasites, often in various combinations of the categories. In addition, there are few but serious incidents related to chemical use resulting in toxic damage/death and some incidents related to fish transfers.

For farmed fish in the sea phase, the number of delousing, as well as the methods used, remains a major welfare problem, both for salmon and cleaner-fish. This year's survey shows that combination methods have become relatively common, and there are also reports of triple methods. In 2023, there is a reduction in the number of non-medicinal delousing weeks, from 3145 weeks in 2022 to 2609 weeks in 2023. Pure thermal delousing is no longer the most used method, while there are indications that thermal delousing in combination with freshwater has increased significantly. Experience has shown that mechanical delousing machines have caused scale loss, and the fish will be particularly vulnerable to winter ulcers if treated at cold water temperatures. Winter ulcers rank high as a cause of reduced welfare and mortality in farmed atlantic salmon in the sea phase in this year's survey, which is supported by the high number of sites diagnosed with winter ulcers in 2023 (Chapter 7.4 Winter Sores). Experience shows that fish that are pre-stressed, for example due to poor gill health or circulatory disturbances, tolerate treatment very poorly. This is also shown by a closer thematic review of causal relationships in reported welfare incidents for ongrowing fish and broodstock regarding non-medicinal delousing with handling. With access to an expanded list of national disease reports, for example through listing in category G, better overviews of causal relationships could be obtained.

Overall, the Norwegian Food Safety Authority received 1419 reports of welfare incidents concerning ongrowing fish and broodstock in 2023, a reduction from 1830 reports in 2022. This may partly be due to fewer delousing weeks in 2023 compared to the previous year, but other factors may also play a role such as changes in reporting practices/guidance and improvement in implementation or risk assessments of delousing. Thermal delousing alone is also used less frequently. It remains to be seen if the trend where the proportion of reports related to non-medicinal delousing continues to decrease. Further systematic work on welfare incidents and knowledge gathering initiated here may provide better answers in the years to come.

It is important that the practice of using slaughter boats on the pen edge during delousing for emergency slaughter of stressed fish does not increase the risk willingness for delousing. In addition, the number of fish slaughtered in this way should be reported and made available to increase the knowledge base around delousing operations. This year's survey reveals that more are starting to use slaughter boats to handle daily mortality, a practice that can camouflage mortality depending on how it is reported.

This year's survey indicates no significant progress in terms of fish welfare at slaughterhouses. There are still challenges related to stunning and slaughter. Some of the challenges can be attributed to conditions in the industry which sometimes deliver a lot of fish that deviates from what the equipment at the slaughterhouses is designed for. The slaughter quality for salmon was on average poorer in 2023 than it was in both 2021 and 2022. The main reason for downgrading was the category "injury/wound," representing fish that likely lived with reduced welfare for shorter or longer periods prior to slaughter. The slaughter quality for rainbow trout is on average better than for salmon, and it also seems to have a positive trend since 2021. There is a large variation throughout the year in how much fish is downgraded at slaughter, with the lowest superior proportion in slaughtering conducted in the first half of the year. This may be related to low water temperatures in the latter part of the sea production period and increased risk of wound problems. Also at the site level, there is a large variation in the proportion of fish graded as superior quality at slaughter. On average, one Norwegian sea site facility delivered slaughter fish with a superior proportion of 83 percent in 2023, meaning that around 17 percent of the fish by weight were downgraded. An expansion with the number of fish in slaughter reports would be valuable, especially in relation to using this type of data as a welfare indicator.

It is the fourth year in a row that there has been a decrease in the use of cleaner-fish. There have also been more comments this year stating that there are no plans to use cleaner fish in 2024, indicating a further reduction next year. For cleaner-fish still in the industry, there are still significant welfare challenges that can be attributed to them having poor conditions to cope with life in the farm with salmonids. Handling of cleaner-fish is highlighted as the main cause of their mortality and reduced welfare this year. This is likely related to the regulatory requirement for fishing out cleaner-fish prior to delousing. Health and welfare challenges for cleaner-fish in the sea phase with salmon are considered significant. There is still great uncertainty regarding cleaner-fish ability to eat lice (delousing effect), and a lack of overview of mortality.

It is important to take a holistic approach to fish welfare. For example, when it comes to fish used as experimental animals. Here, both the number of fish and their load in various experiments coincide with the challenges of the aquaculture industry. As of 2022, which is the latest statistics, 95 percent of experimental animals in Norway were fish, primarily salmon. It is important that results from animal experiments are made available, among other things, because dissemination can prevent unnecessary repetition of experiments. Fish health personnel are engaged drivers for both fish health, welfare, and general biosecurity, and various challenges are reported in the different production areas. Through collaboration with industry professionals, better public management systems should be built to facilitate that good health and welfare are most profitable. Industry development should be based on good health and welfare, for both farmed fish, wild fish, cleaner-fish, and experimental fish. The new white paper on animal welfare expected in 2024 will hopefully contribute to welfare-wise good choices for all the above-mentioned categories. For farmed fish, it is important to introduce larger changes into the licensing system to promote welfare and find good indicators to achieve welfare goals.

Cod farm. Photo: Hanne Nilsen, Norvegian Veterinary Institute

6 Viral diseases of farmed salmonids

By Torfinn Moldal

Infectious salmon anemia (ISA) was confirmed at 18 sites in 2023. Additionally, there were suspicions of ISA at five sites, all of which were emptied of fish by the end of last year. A significant portion of last year's confirmed outbreaks and suspicions were on the west coast of Norway. ISA was confirmed at one land-based facility with broodstock, while the remaining outbreaks were at sea sites. There are several cases of likely transmission from nearby sites, but there were no extensive epidemics or spread of infection caused by the same virus variant in 2023. In one instance, transmission may have occurred via wellboat, and several outbreaks can be linked to detections of ISAV HPR0 at the smolt facility or post-smolt facility that had supplied fish to the outbreak sites.

On a national level, there has been a pleasing decline in cases of pancreas disease (PD) in recent years, and in 2023, there has been a further reduction with a total of 58 cases, compared to 98 cases in 2022. However, four PD outbreaks caused by salmonid alphavirus 2 (SAV2) on the Helgeland coast last autumn are serious. It is not known how the infection was introduced to Helgeland. Rapid emptying of the PD sites has presumably prevented further spread of the infection.

In 2023, cardiomyopathy syndrome (CMS) was detected on approximately the same number of sites as in 2022, while heart and skeletal muscle inflammation (HSMI) were detected on roughly the same number of sites as in 2021 after an apparent decline in 2022. This suggests that various measures to prevent HSMI have not yielded measurable results overall. CMS and HSMI are among the most frequently detected diseases in salmon during the grow-out phase and are associated with high mortality in connection with sea lice treatment. For infectious pancreatic necrosis (IPN), the situation is stable with low incidence.

Salmon Gill Pox Virus (SGPV) was detected at 124 facilities last year. In approximately half of the cases, virus detection was associated with clinical disease or pathological changes in the gills. In the survey, the significance of SGPV is judged to be low compared to other health issues in all stages of production, including mortality, welfare, and reduced growth.

Infectious hematopoietic necrosis (IHN) was once again detected in Denmark in 2023. Monitoring of pink salmon caught in rivers in county Finnmark in the north of Norway, brown trout and rainbow trout from freshwater sites in southeastern Norway, as well as Atlantic salmon, rainbow trout, and lumpfish from marine sites, revealed neither IHN virus nor viral hemorrhagic septicemia virus (VHSV) last year. Given the consequences of an outbreak of IHN or VHS, it is important to monitor farmed fish in Norway so that infected fish can be quickly removed.

Table 6.1 Number of sites with salmonid fish diagnosed with viral diseases in the period 2014-2023. *For the period 2014-2019, the number of sites with CMS, HSMI, and IPN is based on samples sent to the Norwegian Veterinary Institute, while data made available from aquaculture companies through private laboratories are included in the count since 2020 (see Chapter 1 Statistical basis for the report).

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
ISA	10	15	12	14	13	10	23	25	15	18
PD	142	137	138	176	163	152	158	100	98	58
CMS	107	105	90	100	101	82	154*	155*	131*	129*
HSMI	181	135	101	93	104	79	161*	188*	147*	184*
IPN	48	30	27	23	19	23	22*	20*	12*	12*

6.1 Pancreas disease (PD)

By Hilde Sindre, Anne Berit Olsen and Hege Løkslett

The Disease

Pancreas disease (PD) is a serious contagious viral disease in farmed salmonids at sea, and is caused by salmonid alphavirus (SAV). Diseased fish display extensive pancreatic pathology and inflammation in the heart and skeletal musculature.

At present, there are two PD epidemics in Norway. The genotype SAV3 is widespread on the western coast after gradual transmission from the initial hotspot in areas around Bergen in 2003-2004. After introduction in 2010 of a new genotype, marine SAV2, PD caused by this genotype has spread rapidly in Mid-Norway. Most cases of PD caused by SAV3 are detected in the South-western and Western part of Norway south of Stadt, while most cases of PD caused by SAV2 are registered in North-western and Mid-Norway, north of Hustadvika in Møre og Romsdal.

The mortality caused by PD varies from low to moderate, but high mortality is observed in some cases. Generally, the field mortality caused by SAV2 is lower than for SAV3. Infection with SAV2 leads to low feed conversion and development of runted fish. Extended production times due to persistent reduced appetite, and losses due to reduced market quality are commonly experienced.

Disease control

PD is a notifiable disease (category F) in Norway. From 2014, infection with salmonid alphavirus (SAV) has also been on the World Organisation for Animal Health (WOAH, founded as OIE) list of infectious fish diseases. Consequently, countries with a documented free status can refuse to import salmonids from SAV-affected areas in Norway.

In order to control and reduce the spread of the disease in Norway, PD has been regulated through legislation since 2007.The most recent national legislation from 2017, (2017-08-29 no. 1318), defines a continuous PD zone from Jæren in the South to Skjemta in Flatanger in Mid-Norway. The rest of the Norwegian coast is defined as two PD-free surveillance zones on both sides of the PD zone, stretching to Sweden and Russia, respectively. The main objectives of the legislation against PD are to reduce the negative effects of the disease in the PD zone, to prevent PD from establishing in the surveillance zones and to limit the prevalence of both SAV3 and SAV2.

The main reservoir for salmonid alphavirus is infected farmed salmonids. From 2017, intensive screening, defined through the PD legislation, has resulted in early virus detection and consequently an increased opportunity to reduce the spread of the virus and the disease. The legislation specifies mandatory monthly samples from 20 fish from all marine sites holding salmonid fish and other sites utilizing untreated seawater. All samples are screened for the presence of SAV by PCR, and positives are reported to the Food Safety Authorities.

Increased focus on coordinated fallowing and biosecurity measures regarding transport of both smolt and fish for slaughtering are important to reduce virus spread. Control of intake of seawater for the production of post-smolt in the PD zone is also an important measure. From 1 January 2021, the Food Safety Authorities has implemented requirement for treatment of transport water both inside and outside of the PD zone. To prevent spread of SAV and PD in the PD-free surveillance zones, rapid harvesting/removal of diseased fish populations within surveillance zones is favorable.

Several commercial vaccines against PD are available, and vaccination is commonly used in the SAV3 zone on the Western coast (PA2-PA5). In Trøndelag, PD vaccination has been less frequent, but the last years a substantial increase in ordered PD-vaccine doses in PA6 has been registered (figure 6.1.1). In §7 in the PD-legislation from 2017, mandatory vaccination was required for all salmonids destined for sea water production sites and brood fish sites in an area from Taskneset to Langøya (PA6 and PA7), however this requirement was withdrawn with no time frame for implementation.

The effect of vaccination against PD has been debated. However, studies have shown that the vaccines may reduce the severity of the disease, and some of the vaccines have been documented to reduce the negative effect on feed conversion and lower the mortality following SAV infection. In addition, vaccination may contribute to lowering the level of virus shedded into the water. As the effect of vaccination is closely connected to infection pressure, implementation of other biosecurity measures is important to achieve a good protective effect (Chapter 4.4 Vaccination as a biosafety measure).

The Norwegian Veterinary Institute (NVI) is both international and national reference laboratory for SAV. When PD is suspected, samples shall be sent to NVI for verification of diagnosis. NVI cooperates with the Food Safety Authorities regarding monitoring of PD, and data are published in interactive maps (BarentsWatch).

More information about PD (in Norwegian), can be found at the following site: **https://www.vetinst.no/sykdom-og-agens/pankreassykdom-pd**

The Health Situation in 2023

Official data

In 2023, 58 new cases of PD were registered (25 SAV2 and 33 SAV3), with seven cases in rainbow trout (SAV3) (figure 6.1.2). The number of cases is significantly reduced from 2022, with 98 cases, and even more compared to 2020, with 158 cases. There is a reduction in cases caused both by SAV2 (figure 6.1.3) and SAV3 (figure 6.1.4). In 2023, there were no infections with both SAV2 and SAV3 at the same site, but for the first time since 2017, PD was detected north of Trøndelag, in the PD free zone.

The control area to prevent, decrease and control PD with SAV2 in Stad, Kinn and Bremanger municipalities in Vestland county has been removed. A new restriction zone for PD has been implemented in Alstadhaug, Vefsn, Dønna, Herøy, Vega, Brønnøy og Vevelstad municipalities, connected to the detection of PD caused by SAV2 on four sites at the coast of Helgeland (PA8) autumn 2023 (FOR-2023-10-04-1564).

Statistics and diagnosis

The number of PD-cases for tables and figures in the report includes sites which based on the criteria in the legislation, either had a suspicion of or where PD was confirmed in 2022.These data are based on the Food Safety Authorities reports in the PD/ISA-portal, an internal notification portal operated by the NVI. This database is the source for various interactive maps, including the Fish health application in Barentswatch. Sites with suspicion of or confirmed PD from 2022 are not included in the data for PD for 2023. Consequently, the number of infected sites within the PD zone is higher than the reported number, as infected fish from 2022 may remain at sea in the following year. This also applies for areas without new detections in 2023.

Suspicion of PD may be based on clinical signs, histopathological finding, PCR, isolation of virus in cell culture or detection of antibodies against SAV in serum/plasma. A PD diagnosis is in most cases based on detection of SAV by PCR and typical histopathological findings in the same fish. In addition, the genotype of the virus will be routinely determined. If fish with suspected or confirmed PD is moved to another site, this site automatically also receives the same status of suspected or confirmed PD, without any new analysis of samples.

SAV2

There was a marked reduction in the number of new SAV2-cases, from 49 in 2022 to 25 in 2023. The detection peaks were in February and October/November (figure 6.1.5). PA6, Nordmøre and Sør-Trøndelag, remains the main area for SAV2 with 21 of the 25 cases. There was no new detections in PA5 or further south, in PA7 nor PA9-PA12. In contrast, four new cases of SAV2 were detected in PA8, outside the endemic zone and in a production area without any detections of PD since 2017 (figure 6.1.2).

SAV3

PD caused by SAV3 is mainly detected in PA2-PA4, covering Ryfylke to Stadt, in the southern part of the PD zone. In this area, the positive trend with a reduction in the number of PD cases has continued in 2023, although there is some variation between different production areas. In 2023, 33 new cases of PD (SAV3) were detected, compared to 49 in 2022 and 121 back in 2017. For SAV3, a peak in the number of cases has typically been observed in June/July. In 2023, peaks were observed both in July and September (figure 6.1.6). No new detections of SAV3

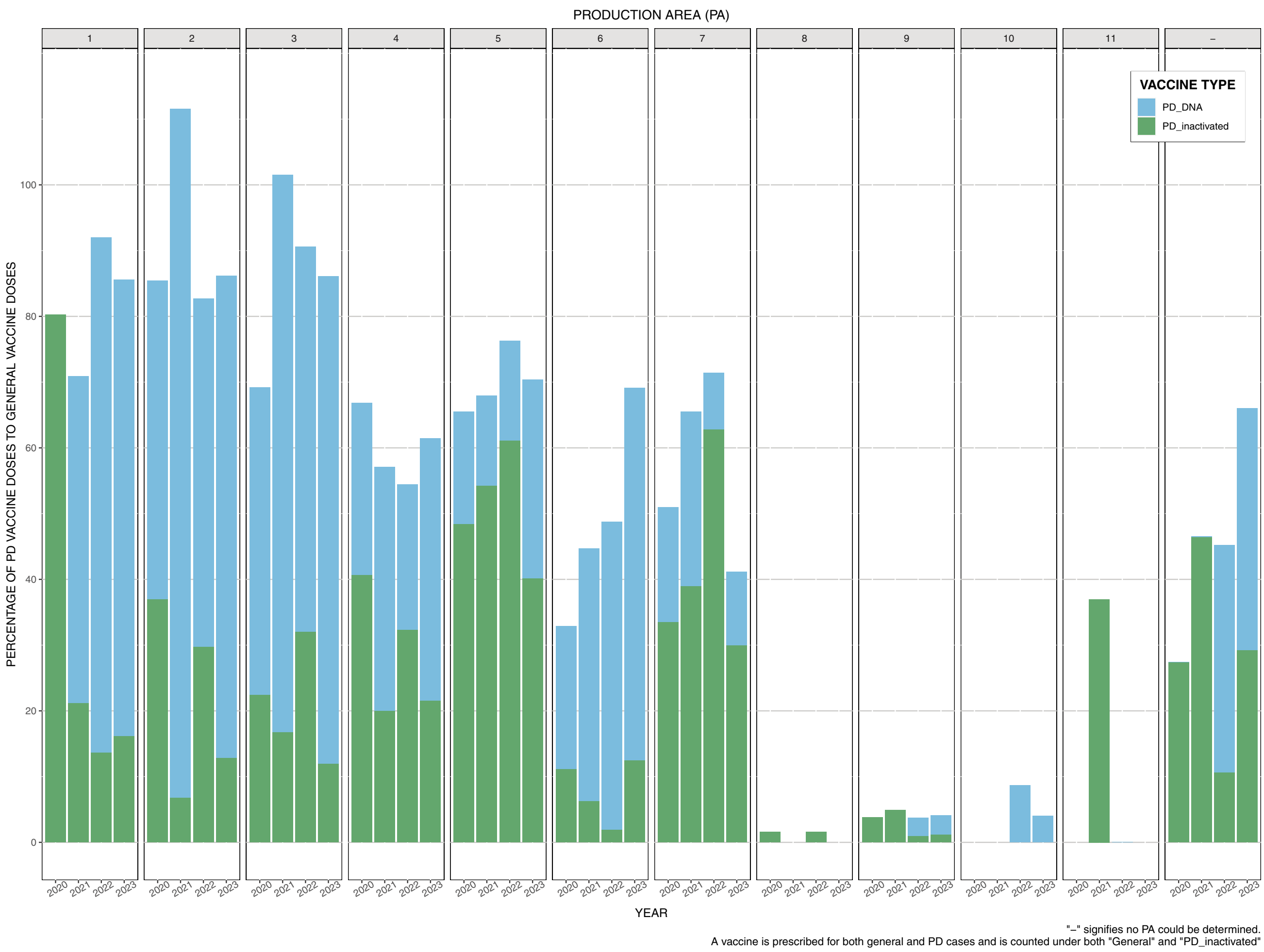


Figure 6.1.1 Pancreas disease (PD) injection-vaccine doses given as percent of "general" vaccine doses dispensed by pharmacies to hatcheries from 2020 to 2023, subdivided by the production area (PA) where the hatcheries are located. "-" means that no PA could be determined. The PD-vaccines were split into two groups, based on how they were manufactured: PD_DNA (in blue) is DNA-vaccines, while PD_inactivated (in green) is traditional, inactivated vaccines. Vaccines against furunculosis, cold water vibriosis and vibriosis were considered as general vaccines. Some of the general vaccines also contain components against other diseases. One of them also contains a PD-component. The doses of this vaccine are therefore included in two groups: PD_inactivated and general. The data originates from the Norwegian Food Safety Authorities' Veterinary prescription registry (VetReg), downloaded 17.01.2024. Only salmon are reported vaccinated against PD. Bath vaccines are not included. Illustration: Trishang Udhwani, Norwegian Veterinary Institute

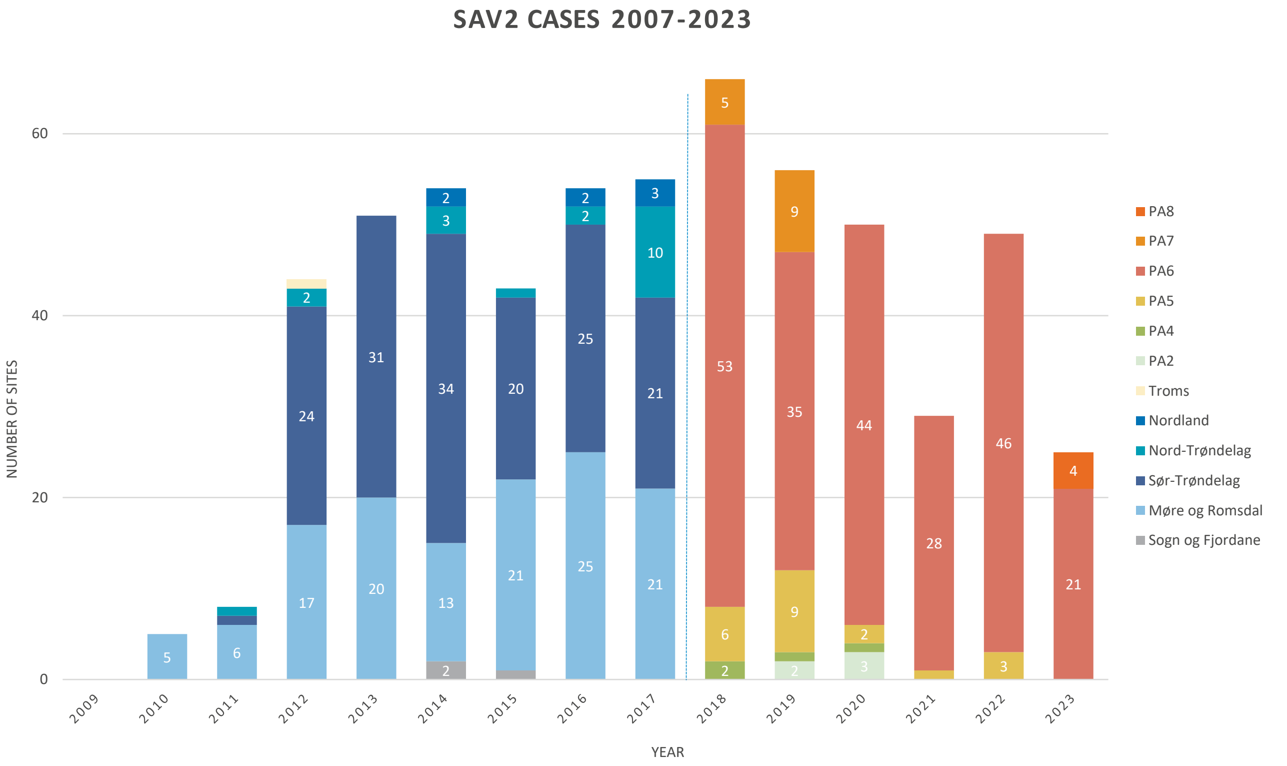


Figure 6.1.2 Distribution of the number of new SAV2 cases per county (2007-2017) and per production area (PA) (2018-2023). Areas without SAV2-cases are not included in the figure.

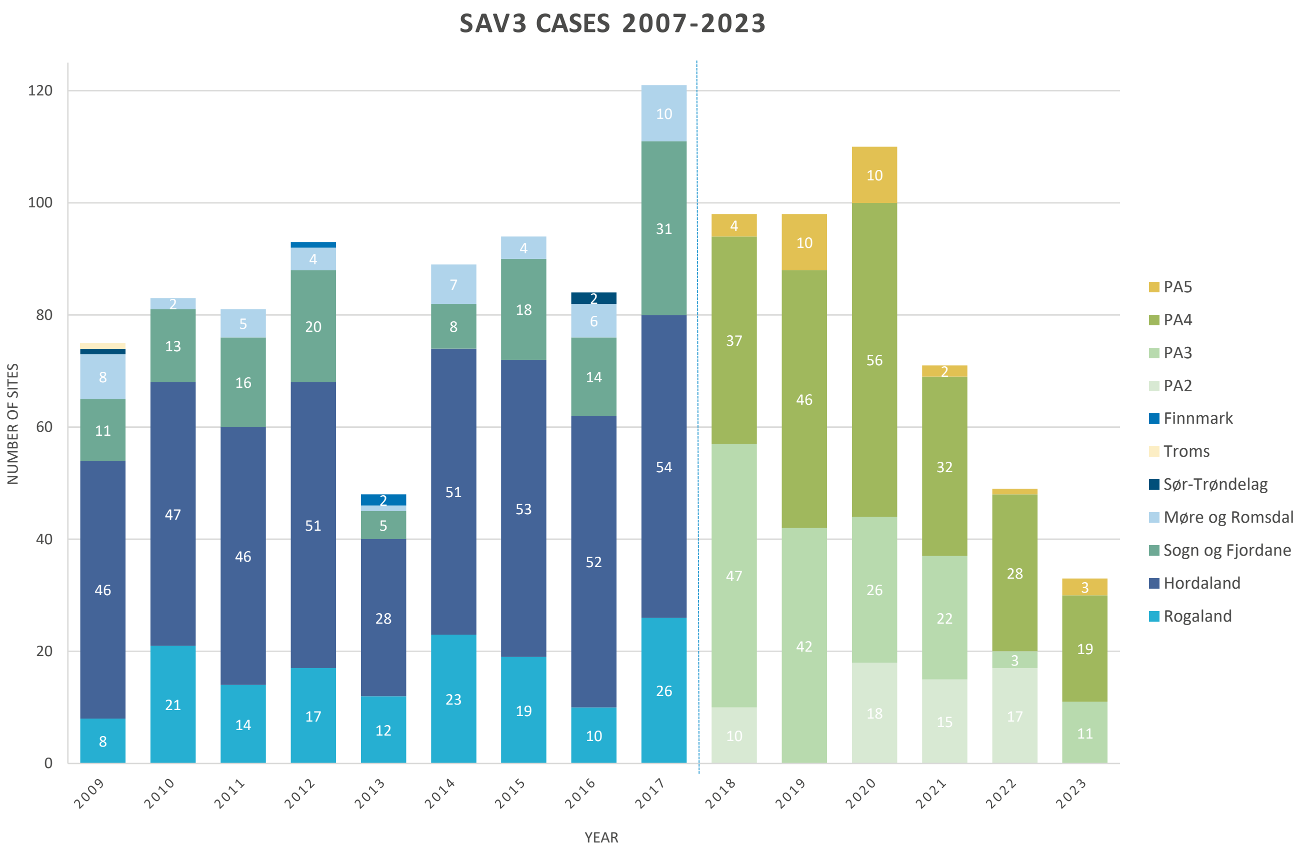


Figure 6.1.3 Distribution of the number of new SAV3 cases per county (2007-2017) and per production area (PA) (2018-2023). Areas without SAV2-cases are not included in the figure.

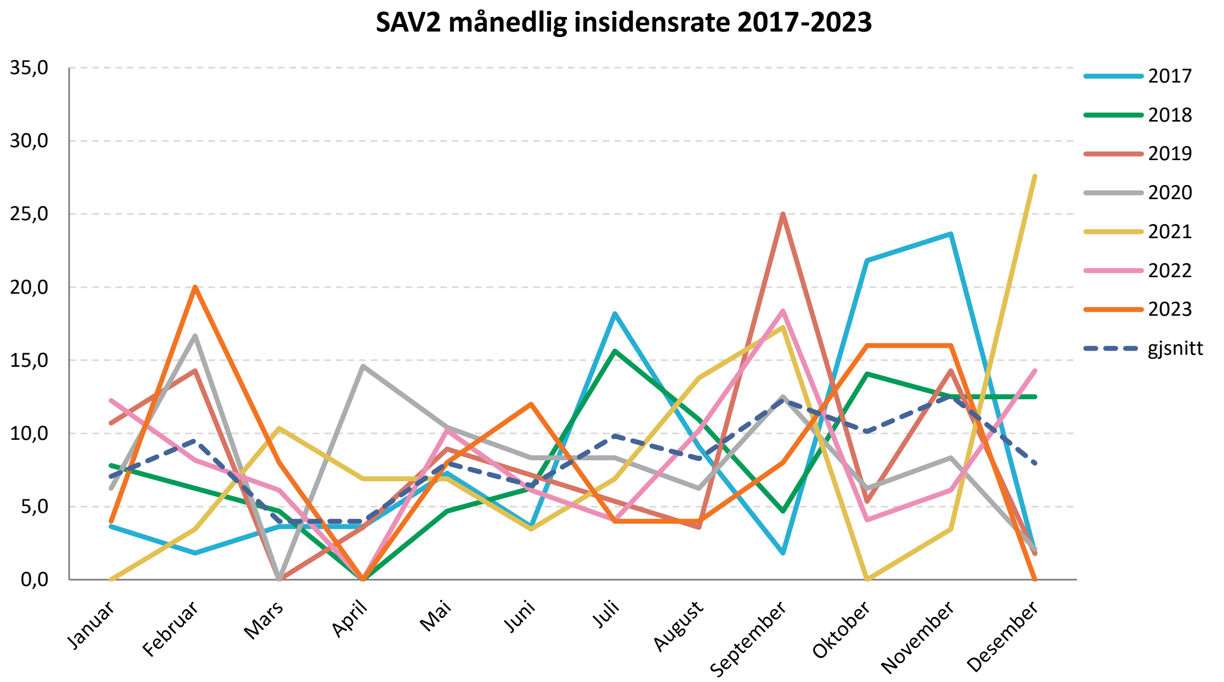


Figure 6.1.4 Monthly incidence rate for SAV2 from 2017 to 2023. The incidence rate for each month is calculated by dividing the number of cases for the specific month with the number of total cases each year, and multiplying with hundred.

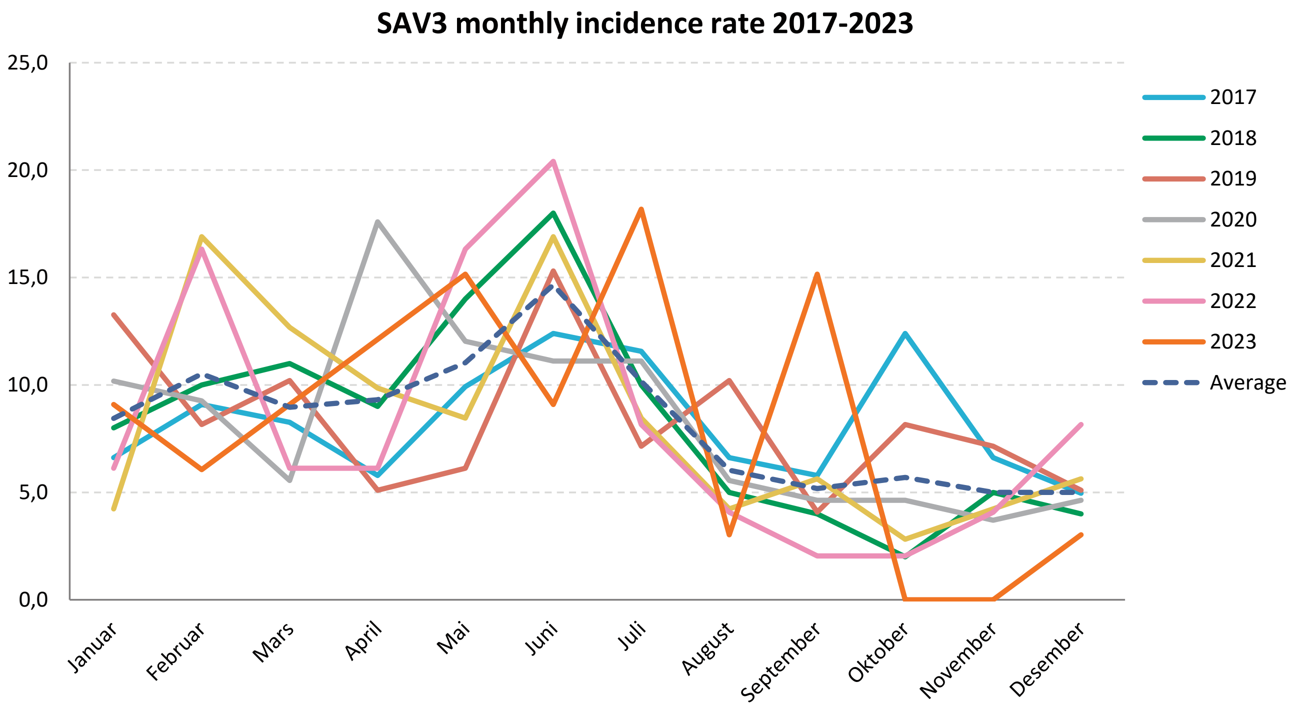


Figure 6.1.5 Monthly incidence rate for SAV3 from 2017 to 2023. The incidence rate for each month is calculated by dividing the number of cases for the specific month with the number of total cases each year, and multiplying with hundred.

were made in PA2 in 2023, compared to 17 in 2023. In PA3 there was an increase from only three cases in 2022 to 11 in 2023, while PA4 had a reduction from 28 in 2022 to 19 in 2023. In PA5 (Stadt to Hustadvika) the number of detections remains low, with three cases in 2023 compared to one case in 2022. SAV3 was not detected north of the SAV3-endemisk area, in PA6 to PA13, Nordmøre to Øst-Finnmark (figure 6.1.1).

The Annual Survey

Many respondents still considered PD as an important viral disease in marine finishing sites for both Atlantic salmon and rainbow trout (Appendix B1 and B2), but the disease is considered less important in later years. Low feed conversion is still reported as the main challenge connected to the disease. Seventy percent of the respondents (39 of 55) reported experience with vaccination of fish against PD. Of these, 54 percent (21 of 39) reports no observed PD following vaccination, and 41 percent (16 of 39) reports less severe disease than in unvaccinated fish. Five percent (2 of 39) reports no observed improvement. Like for 2022, some of the respondents report milder disease development following vaccinaton with DNA vaccine.

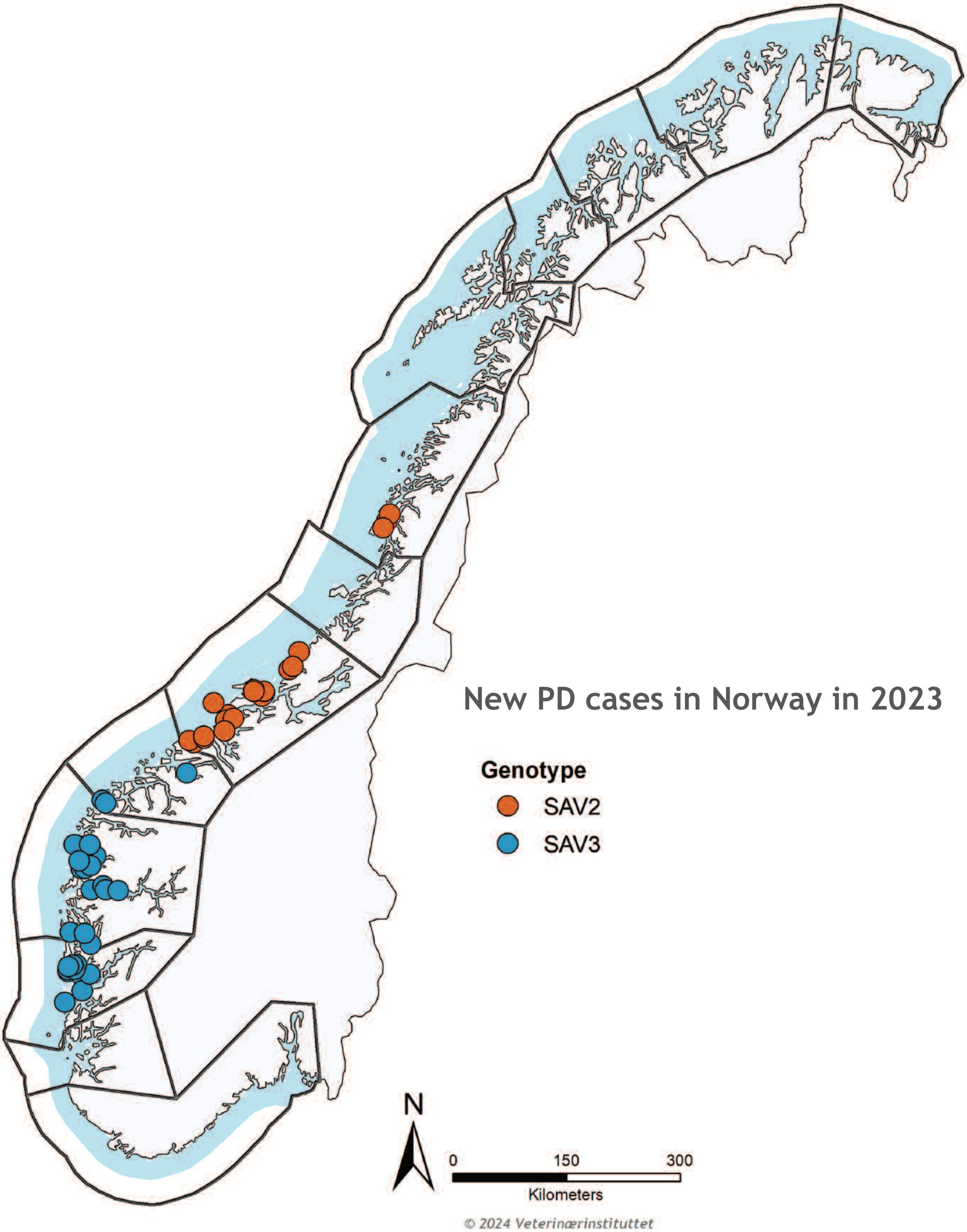
Evaluation of the PD situation

The number of PD cases have had positive declining trend in the last few years. However, the disease continues to be a challenge for the aquaculture industry, connected to health and welfare challenges for the fish, and increased production costs. Fish may be infected with SAV for some time before visible disease is observed (preclinical disease). Consequently, frequent screening for SAV is important to detect infections early. Low prevalence of PD or individuals with very low viral louds may lead to missed detection on a site. As development of PD is stress-related, a sub-clinical infection may therefore develop into a serious outbreak in connection to handling of the fish, for instance when treated for sea lice. SAV can spread directly in seawater, or by transport of fish for slaughtering or moving of infected fish between sites.

An examination of the weight at the time of PD diagnosis, showed that for over 50 percent of the cases in salmon the fish was 2.5 kg or above (up to 6 kg). This may indicate that a major part of the fish probably handles the balance between infection pressure and disease resistance over a long period before developing disease, and may be a positive indicator for limited infection pressure. As also seen previously, there were a few exceptions, with PD reported on small fish down to 200 gram and also virus detection on fish down to 50 g (both vaccinated and unvaccinated). In these cases, the infection pressure may have been substantially higher. For rainbow trout the median weight at diagnosis was 3.5 kg (0.7–4.8 kg).

For the first time in this year's report, data on ordered vaccines for Atlantic salmon and rainbow trout from 2020-2023 were collected from the Food Safety Authorities VetReg database (Chapter 4.4 Vaccination as a biosafety measure). For PD vaccines, the numbers are presented in two groups, DNA vaccine and inactivated virus vaccine. VetReg only contains information regarding the hatchery and fish species the vaccine has been ordered for, and these hatcheries may supply fish to sites in several production areas. However, an increased use of PD-vaccinated smolt in PA6, as indicated in figure 6.1.1 , is also supported by information from the aquaculture industry in this area. Calculation of PD vaccination degree, i.e. how large proportion of the vaccinated fish population which is also receiving PD vaccination, indicates that the coverage is largest (> 80 percent) in PA1, PA2 and PA3. I PA4 – PA7 the coverage varies between approx. 40 to 70 percent. As the number for PA2 and PA3 in some instances reach over 100 percent PD vaccine coverage, some caution should still be taking in interpreting these data. It is also notable that although rainbow trout is a susceptible species for SAV and develops PD, no vaccine doses has been reported for use in rainbow trout in the specified period.

When the northern boundary for the PD zone was moved further north in 2017, some incidences of PD were detected in an area close to Buholmråsa in Trøndelag, previously PD free. In 2023, PD caused by SAV2 was detected in PA8, further north from the PD zone border. The source of this introduction is still unknown. The Food Safety Authorities have implemented a restriction zone covering the area around these detected cases, with the goal to prevent further spread of PD in this area and to neighboring areas and hopefully remove PD. Through earlier experiences, we known that PD can be combatted in specific areas with strict biosecurity measures and good cooperation within the aquaculture industry and between the industry and the authorities, and hopefully this is also successful for this local epidemic.



Figur 6.1.6 Map of new PD cases in Norway in 2023 divided into the genotypes SAV2 and SAV3. Illustration: Attila Tarpai, Veterinærinstituttet

6.2 Infectious salmon anaemia (ISA)

By Torfinn Moldal, Hege Løkslett, Johanna Hol Fosse, and Ole Bendik Dale

The disease

Infectious salmon anemia (ISA) is a serious viral disease caused by virulent (disease-causing) strains of infectious salmon anemia virus (ISAV). Natural outbreaks of ISA have only been detected in farmed Atlantic salmon, but both rainbow trout and brown trout are susceptible to the infection. The virus initially infects the surface of the fish (gills and skin), before spreading to the circulatory system. Examination of dead fish typically reveals pale gills, suggestive of severe anaemia (reduced red blood cell numbers), as well as clinical signs compatible with vascular and circulatory dysfunction, such as free abdominal fluid, oedema, necrotic lesions, and haemorrhages in eyes, skin, and internal organs (Figure 6.2.1).

ISAV may be present on a farm for a considerable period of time before characteristic clinical and pathological signs of the disease and increased mortality become evident. Sometimes, a relatively small proportion of the fish is infected and develops the disease. Accordingly, the daily mortality rate in affected pens will be low, often in the region of 0.5-1‰. In such cases, the detection of virus can be challenging, and it may be necessary to examine a large number of fish by PCR to detect infection.

There is a distinction between non-virulent ISA-virus (ISAV HPR0) and virulent ISA-virus (ISAV HPRΔ). ISAV HPRΔ develops from ISAV HPR0 by changes in two viral surface proteins. Partial deletion of the genetic material encoding the hyper-variable region (HPR) of the viral haemagglutinin esterase, in combination with changes near the F protein cleavage site, appear to make it easier for the virus to invade the host cell. However, the outcome of infection is not solely determined by the properties of the virus. The resilience of the fish and various environmental factors also play a role.

ISAV HPR0 is widespread, and transient infections with ISAV HPR0 occur in both broodfish and production fish on smolt farms and ongrowing sites. A peer-reviewed study from the Faeroe Islands describes so-called «house strains» of ISAV HPR0 in freshwater smolt farms. The same article shows that ISAV HPR0 strains detected in the smolt farms were not closely related to the virus variants found in brood stock, suggesting that true vertical transmission of ISAV HPR0 through roe does not occur frequently. Data from Norwegian smolt farms suggest that ISAV HPR0 can persist in the same location for years and contribute to subsequent outbreaks in ongrowing sites.

Over the past decade, ISA has been confirmed in two smolt farms. Both had supplied smolt to several ongrowing sites where ISA was also confirmed. In both cases, the ISA-virus on the smolt farm was identical or closely related to the virus found on the respective ongrowing site. During the same period, ISAV HPR0 was detected in around ten smolt farms that had supplied smolt to one or more ongrowing sites with ISA outbreaks. Here too, the ISA-viruses that caused the outbreaks were identical or closely related to the ISAV HPR0 detected on the smolt farm from which the fish originated.

Our knowledge about the relationship between ISAV HPR0 and the development of ISA has many gaps, both when it comes to reservoirs of infection, how frequently ISAV HPR0 develops into ISAV HPRΔ, and the factors that drive such transitions. Nevertheless, epidemiological data suggest that a proportion of ISAV HPR0 infections results in the emergence of novel ISAV HPRΔ. When isolated ISA outbreaks occur, the development of novel ISAV HPRΔ from ISAV HPR0 is the most likely reason. Such transitions have been documented in the field, and isolated ISA outbreaks can be connected to insufficient biosecurity measures, such as inadequate infection barriers between different production stages and stress.

Disease control

ISAV HPRΔ is notifiable in Norway and the EU (category C+D+E), while infection with ISAV (both ISAV HPRΔ and HPR0) is notifiable to the World Animal Health Organisation. ISA outbreaks are regulated by strict measures. Typically, a restricted zone (earlier referred to as a control area) is defined around a site where ISA has been confirmed. The restricted zone includes a protection zone (earlier referred to as an eradication zone) in the area closest to the affected site (typically 5-10 km radius), surrounded by a surveillance zone. In conjunction with the recent EU Animal Health Law, Norway is currently developing a new control and eradication plan for ISAV.

For more information about ISA, (in Norwegian): see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/infeksios-lakseanemi-ila

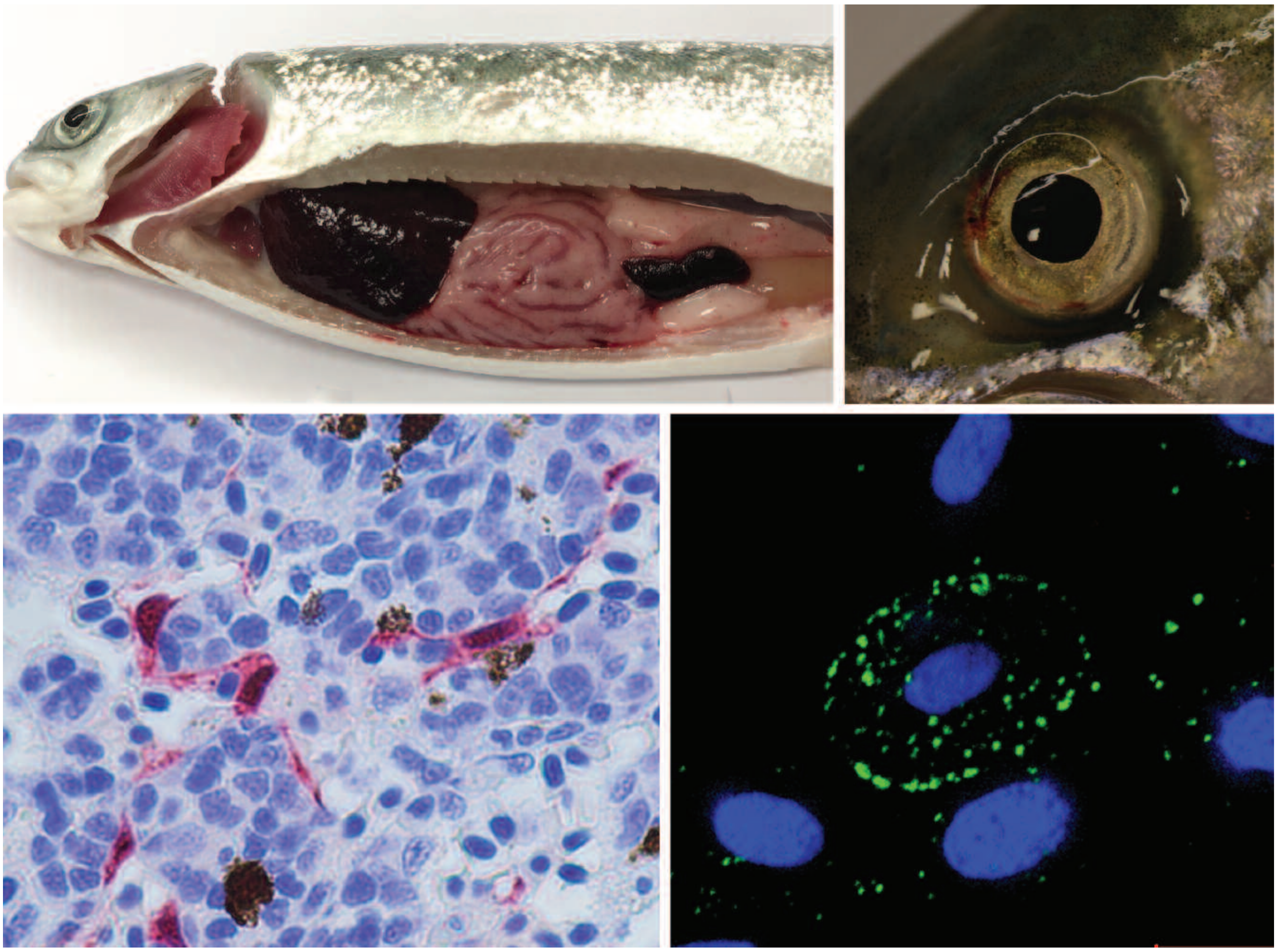


Figure 6.2.1 Infectious salmon anaemia (ISA) causes clinical signs like pale gills, dark liver, and pin point bleeds in internal organs and eye (top row). The ISA virus replicates in the inner cellular layer of salmon blood vessels (lower left panel, the virus is labelled red by immunohistochemical staining). When the virus is released to the blood, it attaches to the surface of salmon red blood cells (lower right panel, the virus is labelled green by immunofluorescent staining). Photo: Frieda Betty Ploss, Adriana Magalhães Santos Andresen and Johanna Hol Fosse.

The Health Situation in 2023

Official data

In 2023, ISA outbreaks were confirmed at a total of 18 sites, including five in PA2, six in PA3, one in PA4, one in PA5, two in PA6, two in PA7, and one in PA12 (Figure 6.2.2). One of the confirmed outbreaks in PA2 was recorded as a suspicion in the autumn of 2022, while the remaining outbreaks confirmed in 2023 followed suspicions that arose the same year. Five suspected cases of ISA in 2023 remained unconfirmed at the end of the year. PA3 had two unconfirmed suspicions, while PA4, PA6, and PA12 had one unconfirmed suspicion each. The suspicion in PA6 concerned a site operated in conjunction with a site where ISA was confirmed, while the other suspicions were based on the detection of virulent ISA virus. All sites with unconfirmed suspicions were emptied of fish by the end of the year.

The Annual Survey

The results from this year's survey show that a relatively high number of respondents perceive ISA as an increasing problem on salmon ongrowing sites in 2023 (Appendix B1).

Figure 6.2.2 Geographic distribution of sites with confirmed and suspected infectious salmon anaemia (ISA) in Norway in 2023. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

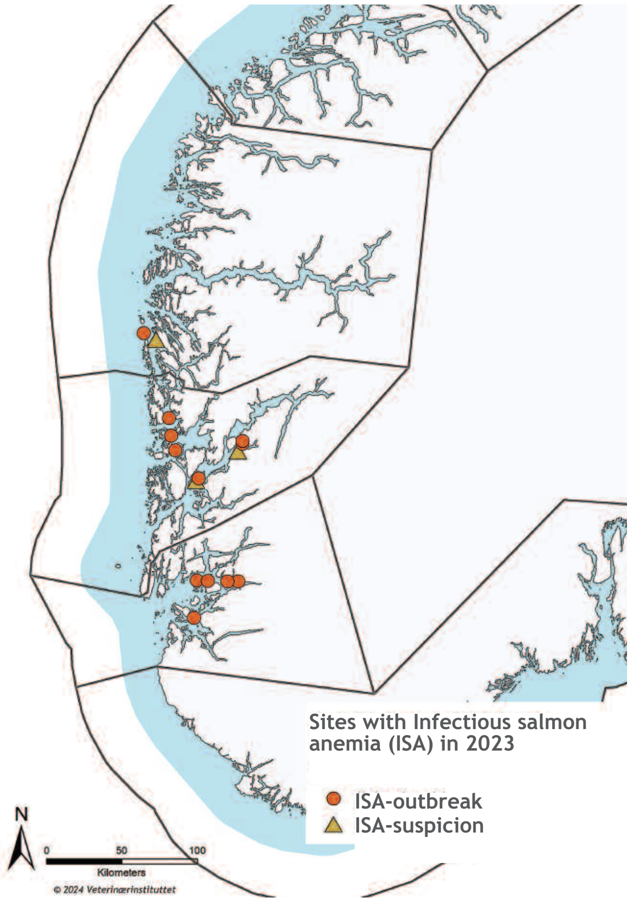


Figure 6.2.3 Geographic distribution of sites with confirmed and suspected infectious salmon anaemia (ISA) in PA2-PA4 in 2023.

On the other hand, only a few think that ISA causes increased mortality or reduced growth and welfare among the ongrowers. Three out of 47 respondents consider ISAV HPR0 an increasing problem in salmon smolt farms (Appendix A1). ISA and ISAV HPR0 are not considered a significant problem in salmon broodfish farms (Appendix C1).

Evaluation of the ISA situation

A significant proportion of confirmed ISA outbreaks and suspicions in 2023 occurred in Vestlandet region (Figure 6.2.3). ISA was confirmed in one freshwater broodfish farm in PA2, while the remaining outbreaks occurred in seawater farms. Eleven sites were covered by existing restriction zone regulations at the time of ISA suspicion. On average, the fish had been in the sea for one year when the suspicion of ISA arose. At one site where ISA was confirmed, the fish had been vaccinated against ISA.

Between 2013 and 2022, an average of nearly 15 ISA outbreaks were confirmed each year (Figure 6.2.4). This means the number of confirmed outbreaks in 2023 is somewhat above the average for the previous decade and approximately twice that of the government's long-term goal that less than one percent of active sites should test positive for ISA each year. The geographical distribution of confirmed ISA cases in Norway over the past five years is shown in Figure 6.2.5. In the last two years, noticeably fewer outbreaks have occurred in the northernmost production areas, compared to the previous two years. Implementation of control measures and increased vaccination against ISA are possible explanations.

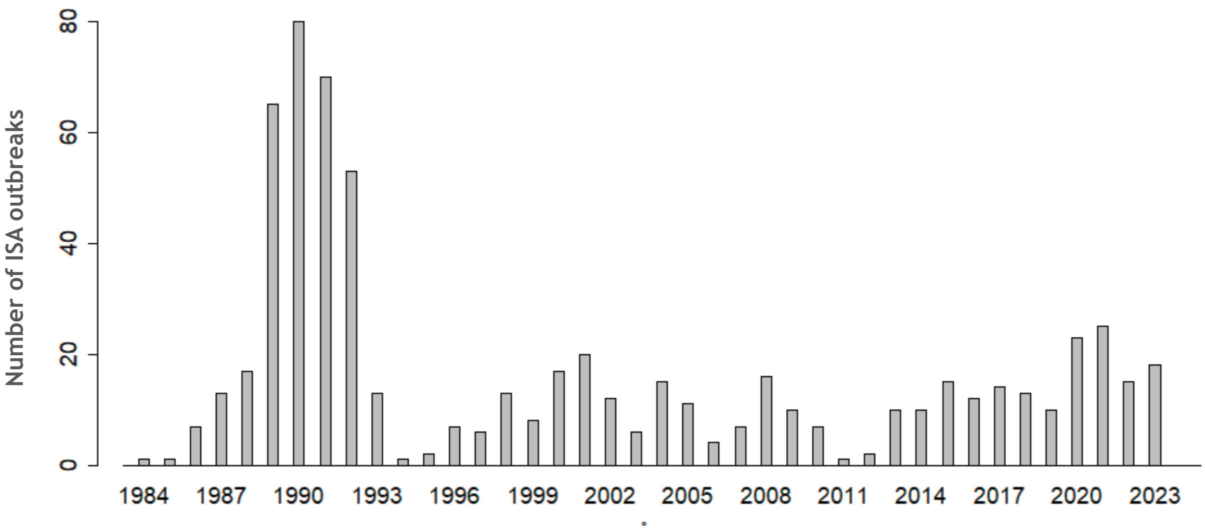


Figure 6.2.4 Annual confirmed infectious salmon anaemia (ISA) outbreaks in Norway from 1984 to 2023.

In PA2, all sea sites where ISA was confirmed had received fish from a smolt farm where ISAV HPR0 is detected. Two of the sites had also received fish from other smolt farms. Family tree analyses based on segment 5 and segment 6 sequences show that the viruses detected at two of the sea sites are identical or closely related to the ISAV HPR0 detected at the smolt farm. At one of these sea sites, ISAV HPRΔ was detected in samples taken less than two weeks after stocking. Despite close monitoring, no ISAV HPRΔ was revealed on the smolt farm that supplied the fish. The virus detected at one of the other sea sites with ISA in PA2 is more closely related to ISAV HPR0 detected at a smolt farm in the same area in 2022. The viruses detected at the broodstock facility and the last sea site with ISA in PA2 are identical.

In PA3 and PA4, several virus variants were detected at the sites with confirmed or suspected ISA. At three sites in Sunn- and Midthordaland region, the detected virus variants were closely related both to each other and to virus detected on another site in the same region in 2021. However, the viruses detected in 2023 have a different HPR deletion than those detected in 2021, and the deletions are not compatible. This implies that multiple independent deletions have occurred, suggesting a common origin rather than horisontal transmission, further supported by the distance in time.

The viruses detected at three sites in Hardanger are identical to each other and identical or closely related to viruses detected at two sites in PA4 in the late autumn of 2022. A wellboat that visited these two PA4 sites on several occasions in the autumn of 2022, also visited the first site where ISA was confirmed in Hardanger in 2023 during the same period.

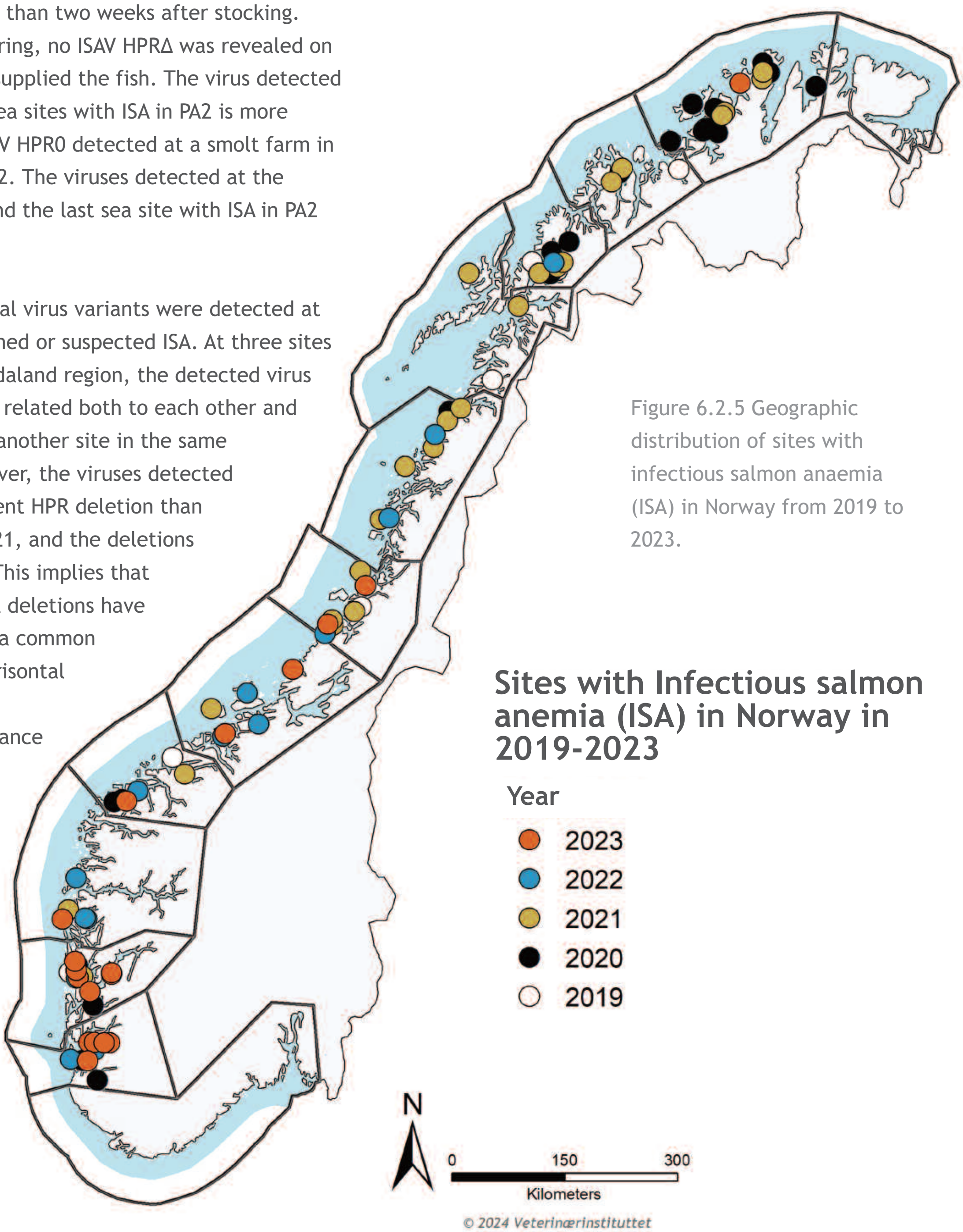


Figure 6.2.5 Geographic distribution of sites with infectious salmon anaemia (ISA) in Norway from 2019 to 2023.

Viruses detected at two sites in Sunnhordaland and one site in Nordhordaland in 2023 are closely related to virus detected at a site in Nordhordaland in 2022. The latter site had been emptied of fish before stocking of the PA4 site where ISA was confirmed last year, and viruses detected at the sites in Sunnhordland have different and incompatible deletions to that detected in Nordhordaland. For the sites in PA4 with unconfirmed suspicion in 2023, it has not been possible to obtain virus sequences for family tree investigation.

Virus detected at the site where ISA was confirmed in PA5 is closely related to virus detected at a nearby site in the late summer of 2022. Fish were present at both sites from the summer of 2022 until autumn the same year. Viruses detected at the site where ISA was confirmed in PA6 and one of the sites in PA7 are not closely related to any virus detected in recent years. Virus detected at the other site in PA7 is closely related to ISAV HPR0 detected at the hatchery that had supplied the smolt to the site. Virus detected at the site where ISA was confirmed in PA12 is not closely related to any virus detected in recent years. At the site in PA12 with the unconfirmed ISA suspicion, the detected virus was closely related to ISA virus detected at a site in the same production area in 2020.

In summary, there have been no extensive epidemics or transmission caused by the same virus variant in 2023. The most notable features are relatively few outbreaks in the north and many outbreaks and suspicions on the West Coast. In one case, transmission may have occurred by boat, and several outbreaks at sea sites can be linked to the hatchery or post-smolt facility that supplied fish to the respective sites. There are several instances of likely transmission from nearby sites, while detection of closely related viruses with different, incompatible HPR deletions or in fish groups that have not been in the sea at the same time suggest a common origin rather than horizontal transmission.

In line with the Norwegian Veterinary Institute's obligations as an international and national reference laboratory for ISA, quality-assured virus sequences for segment 5 and segment 6 detected in connection with outbreaks, suspicions, and surveillance are published in a public international database (GenBank). The sequences are named based on geographical origin and year of detection, as well as the Norwegian Veterinary Institute journal number. Additionally, site number, site name, date of sampling, and species are reported.

Since autumn 2015, systematic monitoring has been conducted in restriction zones (previously control areas) established in response to ISA outbreaks. This monitoring involves monthly inspections and samplings to detect ISA at the earliest possible stage. Since 2019, ISAV HPR0 in hatcheries has been mapped in a program where around half of Norwegian hatcheries are tested for ISA virus through one sampling every other year. In 2023, ISAV HPR0 was detected in six out of 75 hatcheries in the monitoring program (8 percent). Corresponding figures for 2019, 2020, 2021, and 2022 were 7 percent (five out of 74), 14 percent (six out of 42), 10 percent (eight out of 78), and 11.5 percent (nine out of 78) positive hatcheries, respectively. The actual number of ISAV HPR0 positive hatcheries is probably considerably higher, given that ISAV HPR0 causes a short-lived and transient infection in individual fish, that the facilities were only tested at a single time point, and that samples were only obtained from fish in a proportion of the tanks at each hatchery. Final figures and assessments will be published in the report from the monitoring program for ISAV HPR0 in Norwegian hatcheries 2023.

As of today, the Norwegian Veterinary Institute does not have a comprehensive overview of detections of ISAV HPR0. Based on data from private laboratories shared by aquaculture companies and the Norwegian Veterinary Institute's own investigations, ISAV HPR0 has been detected at a total of 61 sites in 2023 (Figure 6.2.6).

Successful control of ISA requires early detection of the disease and prompt removal of infected fish to prevent further spread. Prevention, however, is better than control. It is likely that the presence of ISAV HPR0 is a significant risk factor for ISA outbreaks. Increased knowledge about reservoirs for ISAV HPR0 and the drivers behind the transition from ISAV HPR0 to ISAV HPRΔ will be important for designing better control strategies against ISA in the future.

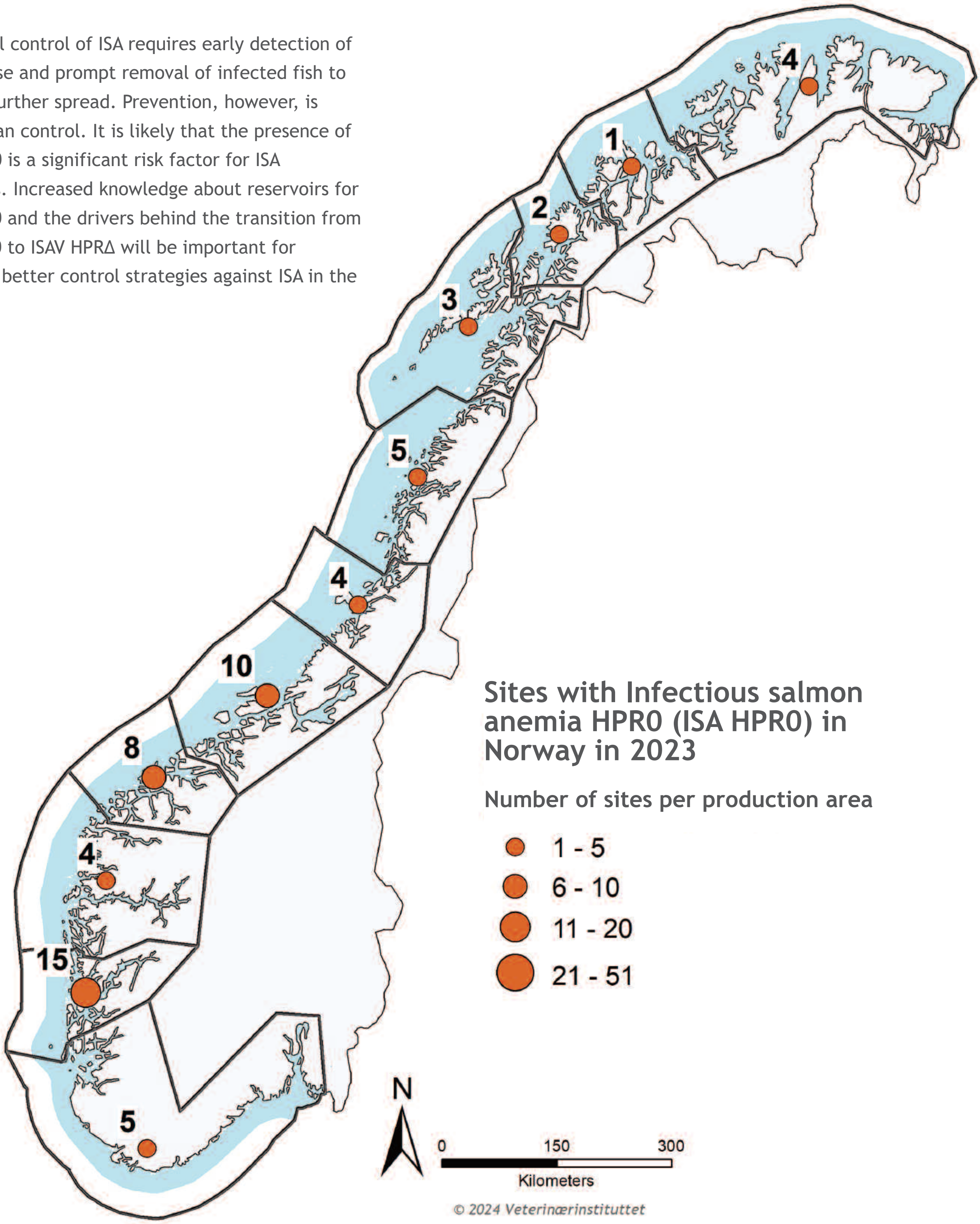


Figure 6.2.6 Sites where ISAV HPR0 has been detected in 2023 per production area. Because of the low number of locations, PA1 and PA2 are shown together. The same applies to PA12 and PA13. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

6.3 Infectious pancreatic necrosis (IPN)

By Irene Ørpetveit og Geir Bornø

The Disease

Infectious pancreatic necrosis (IPN) is a viral disease primarily associated with farmed salmonids. The IPN virus belongs to the genus *Aquabirnaviridae* in the family *Birnaviridae*. A significant proportion of IPN infected fish develop a lifelong, persistent infection. Juvenile fish and post-smolts appear to be the most susceptible age groups. Mortality varies between negligible and up to 90 percent dependent on virus strain, fish genetics, fish physiological stages and other environmental or production related parameters.

Disease control

There are no public control measures against IPN in Norway, and the disease is not notifiable. For the industry, biosafety measures to prevent infection during the hatchery phase is important. A strong genetic marker for resistance to IPN enables selective breeding of salmon and rainbow trout (qTL roe) with a high degree of IPN resistance. This type of roe is now widespread in Norway. Eradication of 'house strains' of IPN virus has also contributed to the favorable IPN situation. A large proportion of fish are vaccinated against IPN-virus, but the protective effect is uncertain, compared to other preventive measures.

For more information about IPN, see the fact sheet: **https://www.vetinst.no/sykdom-og-agens/infeksi%C3%B8s-pankreasnekrose-ipn**

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and other laboratories

Compiled data from the Norwegian Veterinary Institute and the private laboratories (Chapter 1 Statistical basis for the report) show that in 2023, IPN was detected at elleven sites with salmon and one site with rainbow trout. This is similar to previous years. Of the elleven salmon sites, five sites - two hatchery sites and three sea sites – were diagnosed at the NVI. IPN has been detected along most of the coast (Figure 6.3.1), and distributed as follows, with the number of positive locations in parentheses: PA3 (2), PA6 (1), PA8 (1), PA9 (3), PA10 (3), PA10 (1) og PA12 and PA13 (1). From surveys based solely on agent detection (mainly analyzed by real-time RT-PCR), IPN virus has been detected on 38 sites with salmon and five with rainbow trout. This is almost twice as many as in 2022, when IPN virus was detected at a total of 23 sites. For sites with only detection of IPN virus in 2023, only three cases were reported to have clinical significance, 15 reported that the IPN virus detection was without clinical significance, and 14 respondents had not answered.

The Annual Survey

Despite extensive use of QTL stocks and vaccination, IPN is ranged relatively high with regards to increasing incidence in salmon in hatchery sites, and it was ticked by 14 out of 47 respondents. Reduced growth was ticked by eight out of 54 respondents, reduced welfare by six out of 59 respondents and mortality by ten out of 59 respondents. For rainbow trout in hatchery sites, mortality was ticked by seven out of twelve respondents, reduced growth by two out of elleven, reduced welfare by four out of elleven, and three out of seven regards IPN as an increasing problem (Appendices A1 and A2). For salmon and rainbow trout in sea sites and broodstock sites, IPN is ranked relatively low (Appendices B1,B2, C1 and C2). IPN is not reported as a particular problem, as seen in the free input filed, neither in the hatchery phase or the sea phase.

Evaluation of the IPN situation

It is disturbing that breeders experience outbreaks in IPN QTL fish, but it is positive that the number of recorded outbreaks remains at a relatively stable, low level, keeping in mind that IPN used to be one of the most common cause of disease and mortality in farmed salmonids. The Norwegian Veterinary Institute receives IPN virus samples from some outbreaks each year in order to study the virus isolates monitor the situation. The importance of this work was emphasized in 2023, with the detection of a genetic variant different from what has been observed in the latest years.

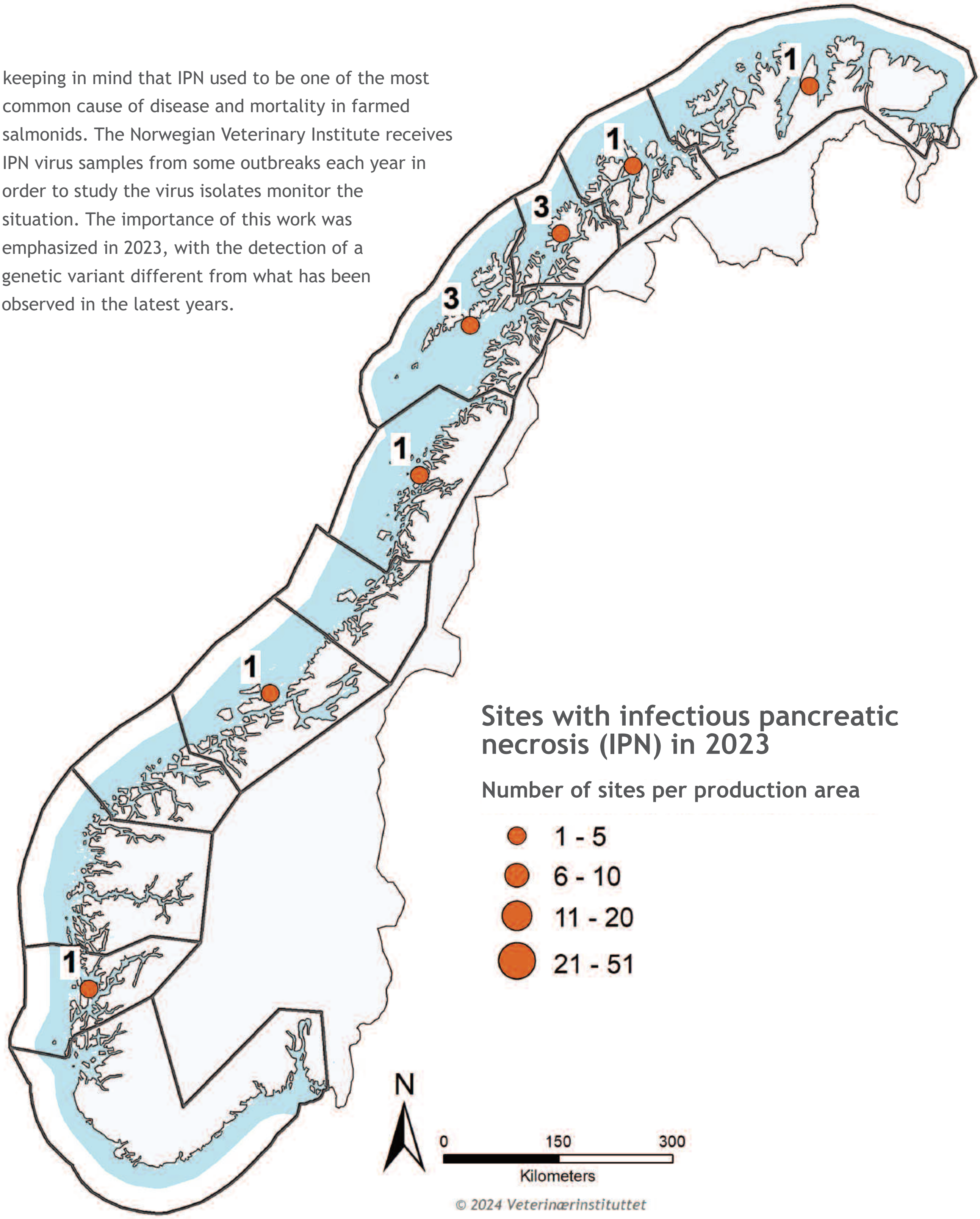


Figure 6.3.1 Distribution of registered IPN outbreaks in Norway 2023.

6.4 Heart and skeletal muscle inflammation (HSMI) in Atlantic salmon and HSMI-like disease in rainbow trout

By Anne Berit Olsen and Maria K. Dahle

The disease

Heart and skeletal muscle inflammation (HSMI) in Atlantic salmon and HSMI-like disease in rainbow trout are caused by two related genetic variants of *Piscine orthoreovirus* (PRV); PRV-1 causes disease in Atlantic salmon, and PRV-3 causes disease in rainbow trout.

HSMI was first described in Atlantic salmon in Norway in 1999, and has since become one of the most prevalent viral diseases in farmed Atlantic salmon in sea water. HSMI outbreaks are most prevalent after sea transfer, but can also occur in juveniles in fresh water. After PRV infection the salmonids gradually develop an inflammatory reaction in the heart, and the clinical disease outbreak is linked to the degree of heart inflammation. During disease outbreaks, it is common to also find inflammation in red skeletal muscle. The course of the disease usually lasts for several weeks, and leads to a variable degree of mortality, from very low up to 20 %. The most serious losses are often seen in relation to crowding and handling. Salmon dying from HSMI are usually found to have extensive circulatory disturbances (Figure 6.4.1).

HSMI-like disease in Norwegian farmed rainbow trout was first described in 2013. Disease outbreaks occurred in hatcheries and in sea farms with fish originating from affected hatcheries. Diseased rainbow trout were very pale due to serious anaemia, which is not seen in Atlantic salmon with HSMI.

Piscine orthoreovirus was identified in heart tissue from Atlantic salmon suffering from HSMI in 2010 (PRV-1) and experimentally confirmed as the causative agent of HSMI in 2017. In rainbow trout a different genotype of PRV was described in 2015 (PRV-3), and experimentally proven to be the causative agent of HSMI-like disease in 2019. PRV-1 from Atlantic salmon and PRV-3 from rainbow trout have a genetic similarity of 90 percent. The two genetic variants can to some degree cross infect between the fish species, but have not been demonstrated to cause disease in the opposite host.

All genetic variants of PRV infect red blood cells of salmonids, and the virus most likely spreads with the blood cells to organs, including the heart tissue. PRV-1 can be detected in most blood-filled organs from soon after infection until long after recovering from HSMI, often until slaughter. This carrier state is commonly without any clinical signs, but an association of PRV with black spots (melanization) in muscle tissue, a quality issue for salmon filets producers, has been reported. PRV has been proposed to increase the problem of muscle melanization.

In rainbow trout, PRV-3 is usually eradicated some time after infection and disease. The level of PRV in the heart of both species is at its highest prior to the onset of tissue inflammation. When cytotoxic immune cells are recruited to the heart, infected cardiomyocytes are killed in order to control the infection.

Experimental studies have demonstrated that salmon with HSMI are sensitive to the low oxygen saturation levels that may occur upon crowding, typical at transport or well boat treatments. Heart inflammation may itself lead to heart failure under stress, and the reduced haemoglobin levels observed in PRV infected red blood cells may play an additional role. During a «fight or flight»-response induced by crowding, the need for oxygen increases above the availability. Stress also inhibits immune responses, and allows the virus to disseminate more efficiently in the body. Such additive effects may increase the disease concequences.

Prevalence

PRV-1 is a very prevalent virus in Norwegian Atlantic salmon aquaculture, and most farmed salmon are considered infected some time during the life cycle. Wild Atlantic salmon can also be infected with PRV-1, but no development of HSMI has been reported in the wild population. In the last decade, many different genetic variants of PRV-1 have been described in Norwegian salmon farms, and experimental trials with PRV-1 variants have demonstrated that they differ in the ability to cause disease. PRV-1 is strongly associated with HSMI also in Scottish, Irish and Chilean aquaculture, whereas Canadian aquaculture reports less HSMI in PRV-1 infected Atlantic salmon. This has been partly explained by different geographical presence of virulent genetic variants of PRV-1.

PRV-3 has since 2017 been associated with disease in rainbow trout in Denmark, and shown to be a common infectious agent in rainbow trout aquaculture in many European countries. According to genetic analyses, the PRV-3 variants found in central Europe belong to a different subgroup than Norwegian PRV-3. PRV-3 is also found in wild brown trout in Europe and farmed coho salmon in Chile. It is important to show caution in international fish trade to avoid spread of virulent viruses.

Disease control

Norway has no official eradication strategy for HSMI, and the disease has not been notifiable since 2014. The background for this is the high prevalence of PRV-1 in farmed salmon in Norway, and that virus detection in many cases is not associated with clinical disease or mortality. PRV-3 mediated HSMI-like disease in rainbow trout is also not notifiable.

Currently, no vaccine against PRV and HSMI is available on the market, although experimental vaccine trials have shown efficacy against HSMI. Treatment of HSMI with anti-inflammatory feed ingredients has been reported, and HSMI resistant salmon breeds have been a focus for research in recent years. So far these efforts have not led to reduction in the total number of HSMI outbreaks and mortality.

The health state of salmon is important for HSMI development, and disease and mortality can be triggered under stressful conditions. HSMI related mortality can be reduced if stressful handling procedures can be avoided in the peak phase of infection and disease.

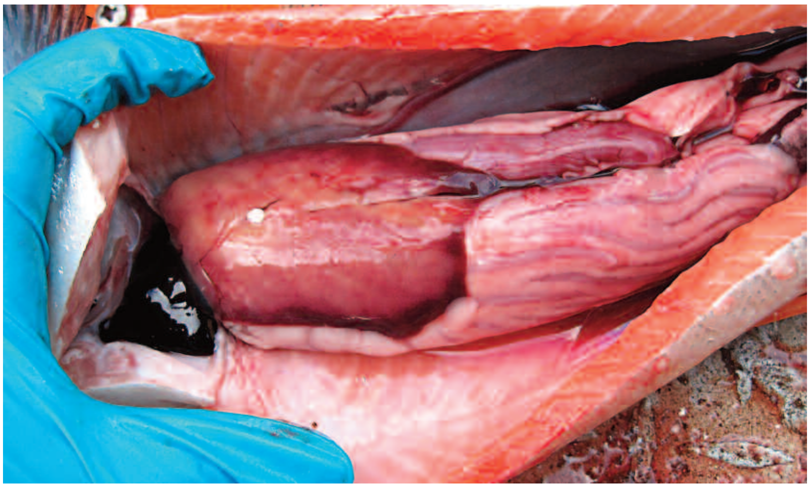


Fig 6.4.1: Atlantic salmon with heart and skeletal muscle inflammation (HSMI) showing intraperitoneal fluid, a fibrin layer on the liver and bleeding to the heart cavity. Photo: Labora

The primary reservoir of PRV-1 is infected farmed Atlantic salmon both in the sea and in infected hatcheries. Virus infected fish from hatcheries may lead to outbreaks after sea transfer, a period when salmon are less immunological resistant. Also for PRV-3 in rainbow trout, virus from infected hatcheries can lead to outbreaks in the sea. For this reason, controlling the infection status in hatcheries is important for reducing outbreaks and mortality after sea transfer.

Some hatcheries have regular PRV infections, and some aquaculture companies aim to eradicate PRV from their facilities. PRV is an uncoated virus (no lipid membrane), and is not as easily inactivated as a membrane coated virus. Regular cleaning and disinfection procedures may not be sufficient for PRV. PRV tolerates high temperatures and UV treatment, but not very acidic or alkaline pH. Intake of sea water has been associated with increased risk of PRV infection, despite UV treatment of the water.

More information on HSMI and HSMI-like disease can be found on this fact sheet:
https://www.vetinst.no/sykdom-og-agens/hjerte-og-skjelettmuskelbetennelse-hsmb

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

HSMI in farmed Atlantic salmon was diagnosed at 184 localities in 2023, primarily in the sea grow-out phase (Fig. 6.4.2). This number is based in diagnostics at the Norwegian Veterinary Institute (NVI) and private diagnostic laboratories (Chapter 1, Data). As seen in previous years, most HSMI diagnoses were reported from mid Norway (PA6) and further north, with a clustering in PA6 (51), followed by PA8 (27) and PA9 (25). Many cases of PRV-1 infected salmon with no HSMI diagnosis were also reported, like in previous years. NVI diagnosed HSMI in salmon from 40 g in hatcheries to fish from 130 g to 5-6 kg in sea farms. The median weight of fish with HSMI in sea cages was 2 kg. HSMI was diagnosed at all times of the year, but about 70 % of cases diagnosed by NVI were between July and November, with an additional spring peak in April. As seen in previous years, some of the HSMI cases early after sea transfer had a known PRV diagnosis from the hatcheries.

PRV-3 was diagnosed in rainbow trout at nine localities in 2023, in PA3 and PA4 in south western Norway. The number of cases was in line with 2022 (10). HSMI-like disease was reported from one sea farm (PA4) in 2023, compared to four in 2022 and three in 2021. PRV-3 is to some degree also detected in wild sea trout in Norway (Chapter 11.2 Health situation in wild salmonid broodstock for the Gene bank for wild salmon).

The Annual Survey

According to the annual survey among Norwegian fish health specialists, HSMI was ranked low (13th) among health problems of concern in smolt farms. Among viral diseases in smolt farms, HSMI was ranked second to infectious pancreatic necrosis (IPN) (Appendix A1). In the marine phase, HSMI scored as the seventh most concerning health problem, and the fifth when focusing just on mortality. Among viral diseases, HSMI ranked second to cardiomyopathy syndrome (CMS) in the marine phase (Appendix B1). HSMI is also reported to be an important cause of mortality in salmon broodstock (Appendix C1).
HSMI-like disease in rainbow trout is considered of importance in hatcheries by some respondents, and these respondents associate the disease with mortality and as an emerging problem (Appendix A2). In the marine phase, HSMI-like disease in rainbow trout is listed third among all health problems, also here linked to mortality and considered emerging (Appendix B2).

Evaluation of the 2023 HSMI situation

HSMI on 184 salmon sites in 2023 is close to the occurrence registered in 2021 (188), after somewhat lower numbers recorded in 2022 (147). This indicates that the HSMI situation is stable. The production areas in mid Norway struggled the most with HSMI in 2023, as in previous years. The annual survey supports a stable situation, as no respondents indicated that HSMI was emerging. As in previous years, PRV-1 was often detected in the absence of disease and mortality. This may be due to presence of low virulent genetic variants of PRV-1, or the salmon may have gone through a mild, subclinical course of disease unnoticed, and established a PRV carrier state.

The number of registered sites with PRV-3 infected rainbow trout was similar to 2022, and doubled compared to 2021. The registrations were within the same geographical region, PA3 and PA4 (in 2022 also PA5). Some fish health experts indicated in the survey that HSMI-like disease in rainbow trout was emerging and linked to mortality. Such a development should be noted and monitored. Indications of HSMI-like disease are pale, anaemic fish, and diagnostics should focus on heart histology and detection of PRV-3 in heart or any blood-filled organ.

Salmonid diseases caused by PRV are of concern also internationally, not only limited to HSMI and HSMI-like disease. PRV variants are also reported to cause other clinical manifestations than what we see in Atlantic salmon and rainbow trout in Norway. In Canadian chinook salmon, a genetic variant of PRV-1 is associated with liver necrosis and jaundice, and a genetic variant of PRV-3 in Chile is associated with liver and heart pathology and anaemia in coho salmon. However, there is still a lack of research that confirms the connection between virus and disease findings in these cases. The more distantly related PRV-2 genotype (approx. 80 percent similar to PRV-1) is associated with anaemia in coho salmon in Japan and PRV-3 is associated with HSMI-like disease in rainbow trout in several European countries.

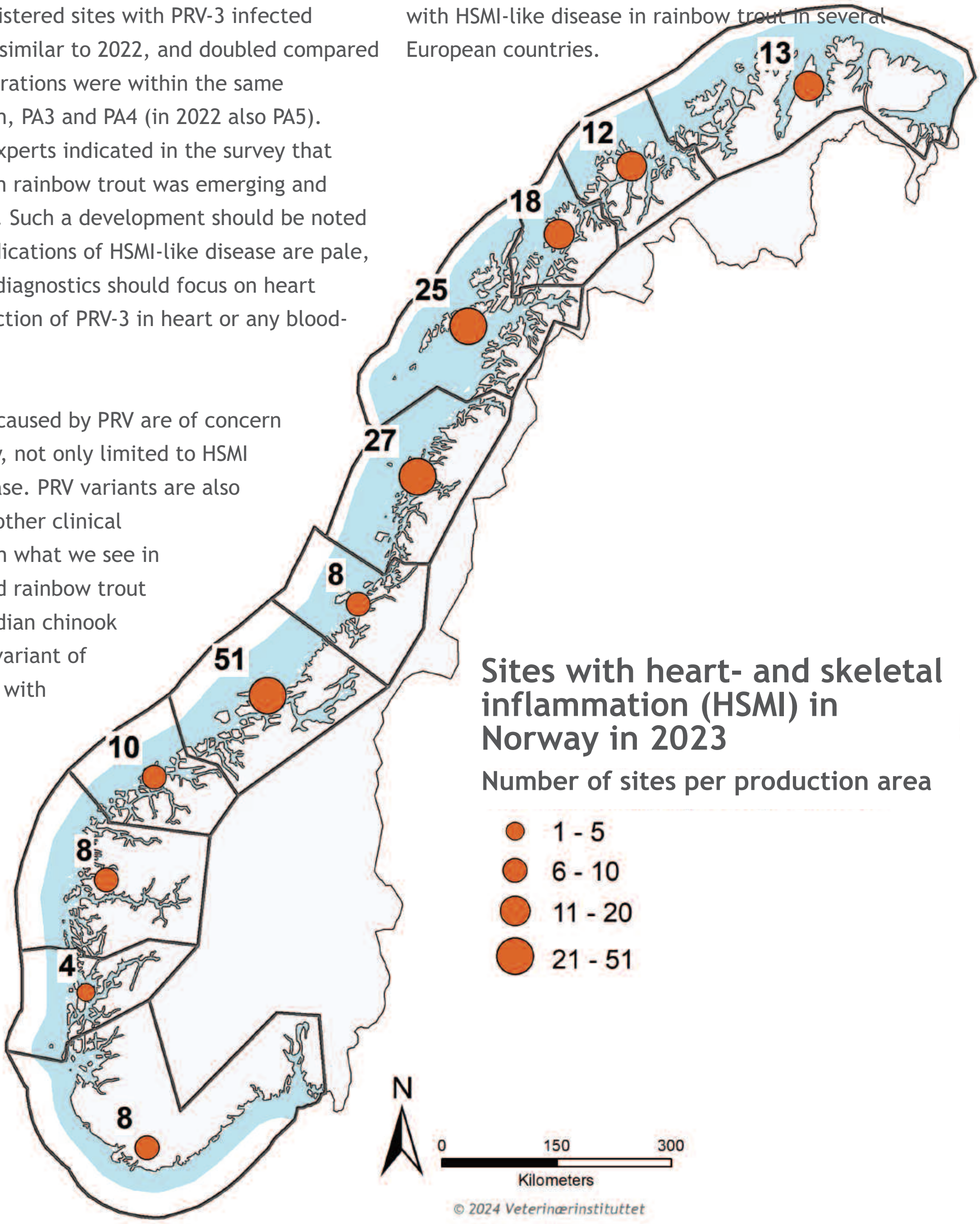


Fig 6.4.2: The number of sites diagnosed with HSMI in 2023 by production areas. Numbers are based on reports from the Norwegian Veterinary Institute and private laboratories. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

6.5 Cardiomyopathy syndrome (CMS)

By Hilde Sindre, Julie Christine Svendsen and Camilla Fritsvold (Patogen)

The Disease

Cardiomyopathy syndrome (CMS) is a serious, infectious myocarditis affecting farmed Atlantic salmon in the marine phase. Since its first description in 1985, the disease is now widespread to all the Norwegian production areas (PAs). CMS is an increasing problem also in other salmon-farming regions on the northern hemisphere, including Scotland and the remaining UK, Ireland and the Faroe islands.

CMS is among the most important challenges and a major contributing factor to losses for the Norwegian salmon farming industry. The annual number of confirmed cases has been consistently high over the last years, and is associated with substantial economic losses. Because CMS tends to affect large salmon close to harvesting, economic losses can be substantial even in cases with relatively modest mortality. CMS related mortality can be low to moderate over a prolonged period, or high in acute outbreaks, often triggered by a stressful event for the fish.

External signs of CMS can be minimal; but exophthalmia (bulging eyes), oedema of the skin scale pockets, and petechiae (pinpoint hemorrhages) on the ventral abdomen are the most typical clinical signs. At autopsy, the most frequent findings include signs of circulatory failure such as ascites and discoloured, mottled liver often covered by fibrinous pseudomembrane layers. In severe cases, a ruptured atrium with large amounts of blood or blood clots around the heart is a common finding (Figure 6.5.1 a and b). Currently, diagnosis of CMS is based on histopathologic findings alone, and confirmed by observations of typical inflammatory changes in the inner, spongious muscle layer of the ventricle and atrium, while the compact cardiac muscle layer of the ventricle wall is relatively unaffected. Some inflammatory reaction, especially in connection with branches of the coronary arteries, may however be observed in pronounced cases also in this part of the heart. In severe cases, the atrial wall may rupture. Cardiac tamponade (fluid accumulation in the pericardial sac) will inhibit the pumping movements of the heart, and in acute cases such as in heart rupture, it can lead to cardiac arrest. Clinically, the disease may resemble pancreas disease (PD), infectious salmon anemia (ISA), and heart and skeletal muscle inflammation (HSMI), but moribund fish are unusual in CMS, and CMS does not cause changes in the exocrine pancreas or skeletal muscle.

The disease is caused by Piscine Myocarditis Virus (PMCV), a relatively simple, totivirus-like non-enveloped, double-stranded RNA virus with a small 6688 base pair genome. Horizontal transmission has been shown. The only known reservoir for infection is the farmed salmon itself, and investigations of wild salmon, wild marine fish and environment samples do not present evidence that they represent a hidden reservoir of significance for PMCV. Some farming sites are more often affected by CMS than others, hence there may be yet unknown reservoirs of PMCV in the environment of the fish, or unidentified factors influencing spread of the infection. Clinical CMS has not been observed in hatcheries, and even though low amounts of PMCV have been reported in fish in the fresh water phase, there is no proof of vertical transmission of the virus. It may take a prolonged time (3-13 months) from detection of the first PMCV-positive fish in a group to the appearance of clinical, histopathological CMS and possibly mortality. In some cases, PMCV is detected relatively early in the sea-phase, without necessarily leading to clinical CMS during the remaining time at sea. In many cases, CMS has a slow spread, both within a cage, a farm and between farms, and transmission does not necessarily follow a logical pattern, as we see for other viral diseases like PD. Within the same production facility, PCMV and/or CMS can be detected in fish in a single or several cages, while neither virus nor disease is detected in cages placed between them.

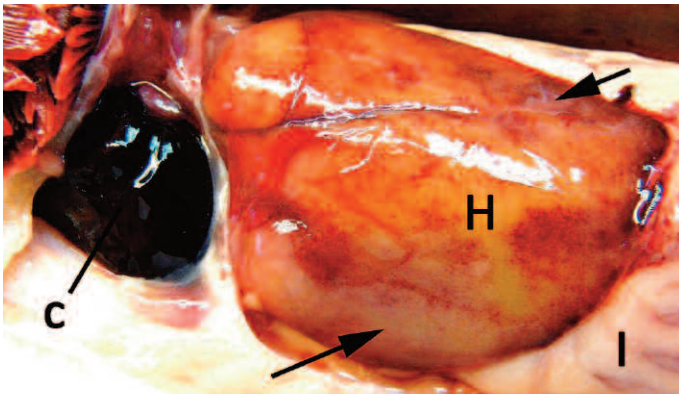
Real-time RT-PCR to detect PMCV is commonly used for screening of facilities without clinical findings, but can also be used to support a histopathological diagnosis. PCR for PMCV is also increasingly used for disease diagnostics as well, and is useful for distinguishing CMS from differential diagnoses in uncharacteristic cases or in mixed infections. Newer in-situ hybridization techniques also look promising in terms of identifying specific pathogens and distinguishing the different inflammatory heart diseases by histological examinations, and are being established for diagnostic use at the Norwegian Veterinary Institute (figure 6.5.2). New research on non-lethal sampling methods such as blood tests and mucous swabs show promising results, and these may be used for PCR detection of PMCV in early stages of infection without clinical signs of CMS, before the typical histopathological changes in the heart can be detected.

There is a general lack of basic knowledge on the virus, infection pathways and development of CMS (pathogenesis). How fish is infected, when virus is shedded, and the factors causing development of clinical disease in fish infected with PMCV, is still unknown. PMCV cannot be propagated in the availablefish cell lines commonly used for fish viruses.

Disease control

CMS is not a notifiable disease in Norway or in the World Organization for Animal Health (WOAH), nor is there a public eradication plan for CMS in Norway. The virus and the disease are present along the entire Norwegian coastline. There are no available vaccines, but research on vaccine development is on-going. The breeding companies have developed, and provide eggs, from QTL-selected salmon strains with increased resistance against CMS. Special feed (functional feed) is also available with the intention of reducing heart damage and mortality in CMS outbreaks.

For information about CMS (in Norwegian), see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/kardiomyopatisyndrom-cms.



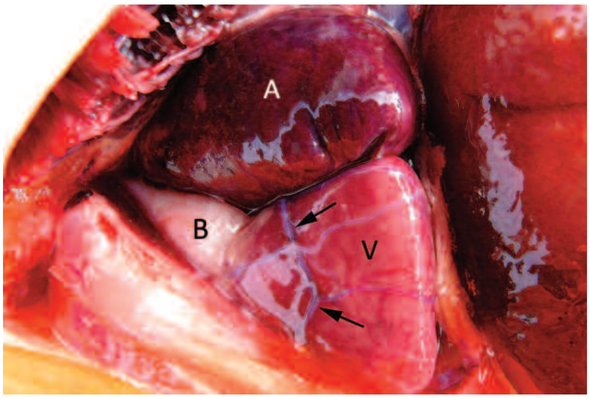


Figure 6.5.1 Cardiomyopathy syndrome (CMS). a) Postmortem findings in fish deceased from CMS: Ruptured heart (C), completely covered by a blood clot filling the heart cavity, liver (H) with multifocal bleeding, discoloration, and fibrin coating (arrows). I = pyloric ceca with adipose tissue and pancreatic tissue. b) Highly dilated, balloon-like atrium (A) in CMS-afflicted fish. B = Bulbus arteriosus, V = heart ventricle, arrows = coronary vessels. Gills to the left, liver to the right of the heart. Photo: Trygve T. Poppe.

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

The figures for 2023 are, as for 2022, based on data from the private laboratories combined with data from Norwegian Veterinary Institute (Chapter 1 Statistical basis for the report). According to these data, CMS was diagnosed at 129 individual sites in 2023, approximately the same number as in 2022 (131 sites). Virus (PMCV) was detected at 144 sites in 2023, an increase from 123 in 2022. The majority of diagnosed CMS cases is still not confirmed by simultaneous detection of PMCV, which is connected to the fact that CMS is a histopatological diagnosis without requirement for confirmed detection of PMCV. Detection of PMCV can be useful additional test, especially in cases with possible co-infections with PRV or SAV. In cases where PMCV was detected without a confirmed CMS diagnosis in 2023, i.e. production sites where only the virus PMCV was detected, clinical disease was registered in 51 percent (40 sites) and 27 percent was reported as clinically healthy, while clinical information was missing for the remaining 23 percent. This may indicate that screening for PMCV in fish stocks with no clinical signs of CMS is frequently performed.

CMS is not a notifiable disease, and consequently it is reasonable to assume that the disease has been, and is, underreported, i.e. self-diagnosis can be perfomed on-site based on the experience of the fish health staff, clinical and necropsy findings, combined with PCR-based PMCV detection. Outbreaks of CMS and CMS-associated mortality lacking histopathologic confirmation, will not be registered as a formal CMS diagnose in the Norwegian Fish Health Report. There is also a risk for inaccurate diagnosing, as other diseases causing circulatory failure, like various variants of HSMB and PD can be missed and/or erroneously interpreted as CMS.

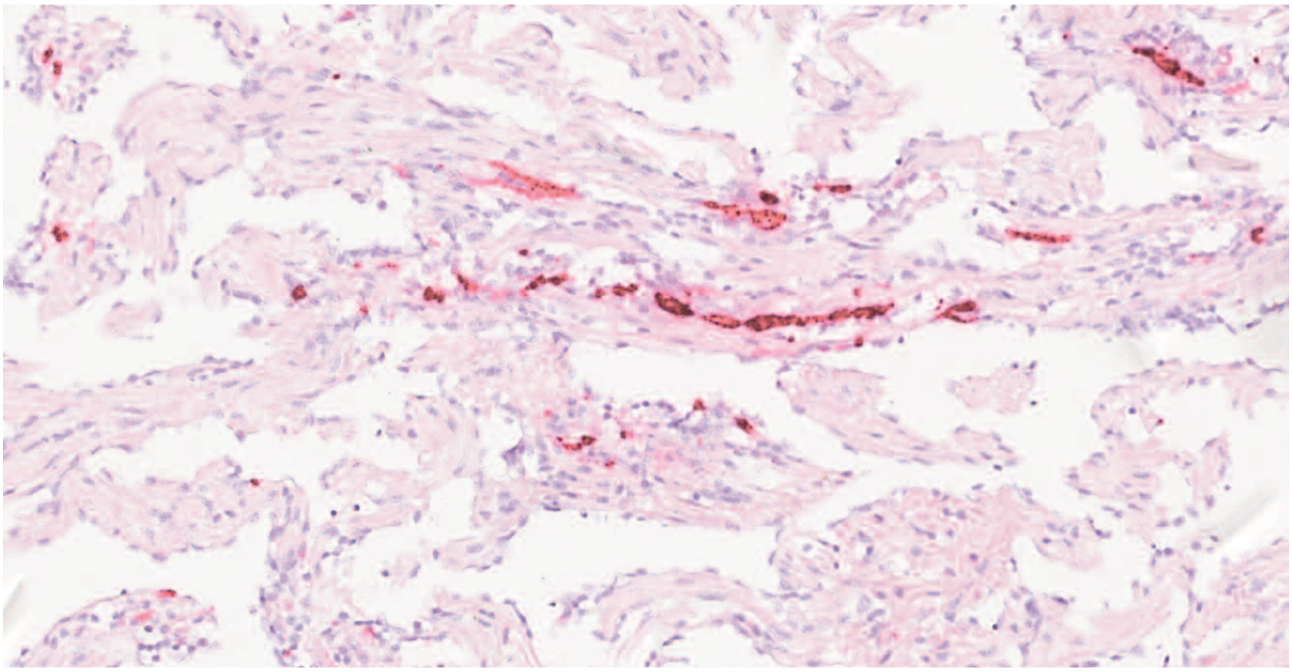


Figure 6.5.2 Detection of PMCV (ORF-1) using RNAscope in situ hybridization in histological tissue sections of the atrium from salmon with CMS (experimental infection). PMCV-specific RNA in areas of inflammation is labeled with dark reddish color. Standard light microscope, 200x magnification. Photo: Camilla Fritsvold, Norwegian Veterinary Institute.

Diagnoses by production areas

The number of confirmed CMS diagnoses for the individual production areas (PAs) is not directly comparable to the numbers from 2020 and earlier, since the basis for the data has expanded from 2021, but differences can serve as an indication for trends over time (Figure 6.5.3.).

The three northernmost production areas (PA11-PA13) had a similar number of cases of CMS as the year before, five diagnosis in 2023, compared to four in 2022. In PA8-PA10, there was a considerable increase, from a total of 18 cases in 2022, to 30 in 2023. In PA7 the number was comparable to last year, with seven cases in2023 and eight in 2022.

PA6 (Nordmøre and Sør-Trøndelag) is historically a hotspot for CMS, and this is also reflected in the data for 2023, with almost 32 percent of all CMS-diagnoses in this production area. The number of cases is similar to last year, with 42 in 2023 and 44 in 2022, respectively, and the increase in cases in this area from earlier years appears to have leveled off.

This is also the trend for Western Norway south of Hustadvika, where the increase in number of CMS-diagnoses finally has stagnated or even declined, with some variation between the different production areas. In PA5, there is an increase in CMS-cases from five in 2022 to eight in 2023, whereas PA4 has a substantial reduction from 19 cases in 2022 to 12 in 2023. In PA3 there is a decline in cases from approximately 30 every year the last four years to 20 in 2023. In PA1 og PA2 the reduction in CMS-diagnoses observed in later years continues, with only five cases in 2023 compared to eight in 2022 and 25 in 2020.

The Annual Survey

The respondents still consider CMS as the most challenging viral disease, but overall, it is perceived as a less significant disease issue than before. However, the disease is ranked as the fourth most important cause of mortality in salmon in ongrowing facilities (Appendix B1). It is not highly ranked in terms of reduced growth in ongrowing facilities, and also a lesser contributor to reduced fish welfare compared to other challenges such as mechanical injuries related to delousing, gill diseases, salmon lice, lice damage, infection with Moritella viscosa, and jellyfish injuries. Furthermore, CMS is not considered an increasing problem, which aligns with the respondents' experiences from 2022.
In salmon broodstock facilities, the disease is still ranked as one of the main causes of mortality (Appendics C1). This is in line with the results from 2021 and 2022. As previous years, the disease also ranks high as a cause of reduced welfare of salmon broodstock, only surpassed by mechanical damages related to delousing and gill disease.

In three of the free text comments for ongrowing fish, the respondents report a decrease in the challenges connected to CMS, compared to earlier years.

Non-medicinal delousing and CMS

The number of non-medicinal treatments against salmon lice remained high in 2023, although a decrease of 17 percent was observed compared to 2022 (Chapter 9.1 Salmon lice). Non-medicinal delousing method presently used in Norway all include some form of crowding, pumping and other stressors for the salmon. Stress has been identified as a risk factor for triggering CMS outbreaks, and the substantial stress induced by delousing may contribute to a transition from a - subclinical PMCV infection to clinical CMS with mortality. Fish with advanced CMS, accompanied by tissue changes especially in the atrium of the heart, will be particularly vulnerable to stress. Furthermore, a group of fish will often present a complex disease picture, such as gill disease combined with HSMB and/or CMS. In such cases, mortality following delousing can sometimes be significant. The occurrence of CMS in smaller fish, which still have a long time left in the sea before they can be harvested, exacerbates and prolongs the issues associated with repeated lice treatments.

Assessment of the CMS situation

The data set used for The Norwegian Fish Health Report 2023 provides a more complete and correct overview of the situation compared to the available data before 2020 (Chapter 1 Statistical basis for the report). Based on the number of CMS diagnoses and the geographical distribution (Figure 6.5.3), the CMS situation in Norway is largely unchanged compared 2022, with 129 cases in 2023. The relatively high number of cases and the negative effects of the disease, connected to mortality and reduced fish welfare, shows that CMS is still a major challenge to the Norwegian aquaculture industry.

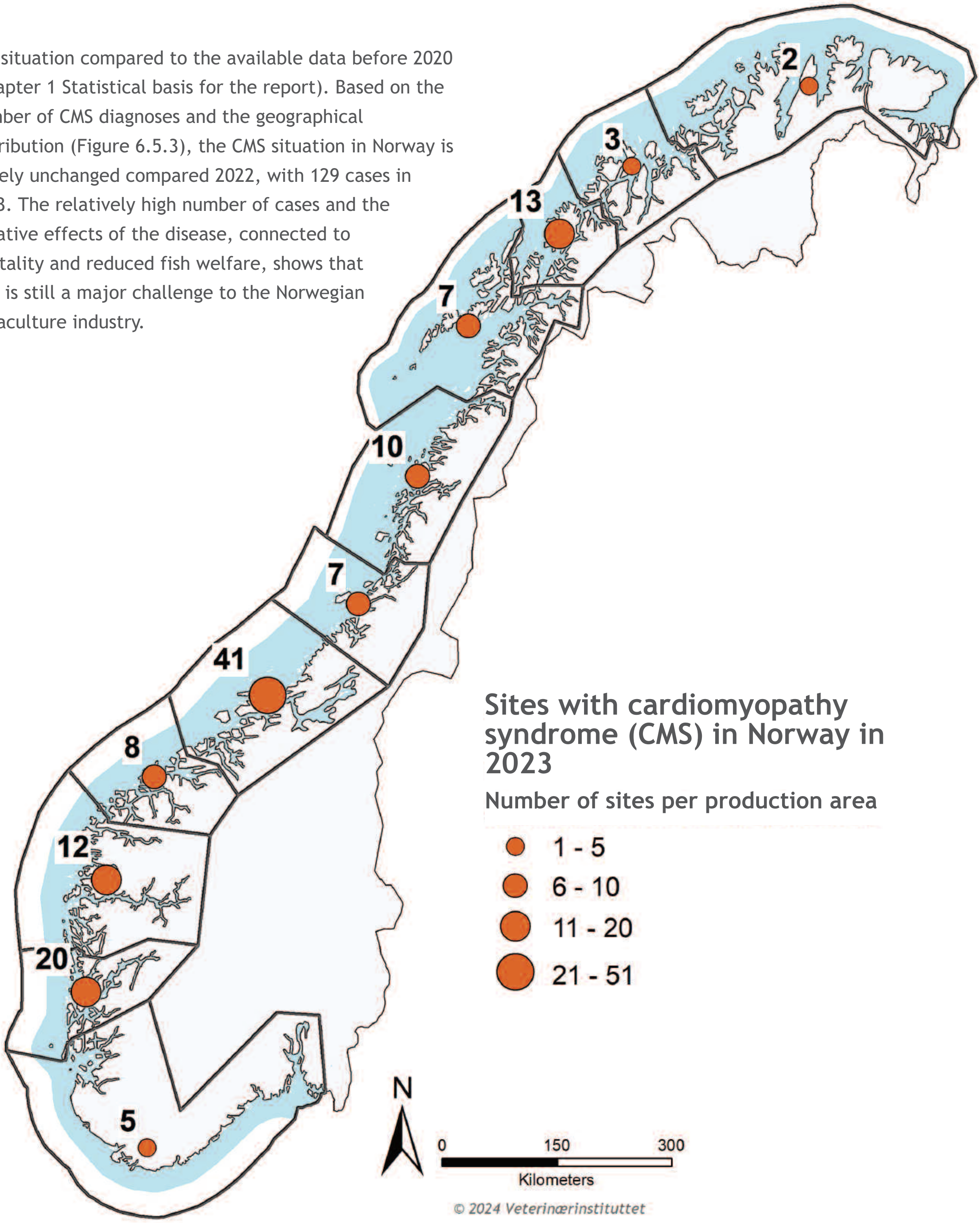


Figure 6.5.3 Number of CMS diagnoses in 2023 distributed across production areas, based on combined data from the Norwegian Veterinary Institute and private laboratories. Few sites in PA1 and PA2 resulted in the merging of these areas. The same applies to PA12 and PA13. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

6.6 Viral haemorrhagic septicemia (VHS)

By Torfinn Moldal and Åse Helen Garseth

The Disease

Viral haemorrhagic septicemia (VHS) is characterised by high mortality, protruding eyes, distended abdomen, bleeding and anaemia (Figure 6.6.1). An abnormal swimming pattern with spiral swimming and «flashing» has also been observed. On *post mortem* examination, swollen kidneys and pale liver with patchy haemorrhages can be observed, and histological investigation typically reveals damage of haematopoietic tissues. The virus that causes VHS belongs to the genus *Novirhabdovirus* within the family *Rhabdoviridae*. It has been identified in about 80 different fish species, both farmed and wild. Outbreaks with high mortality in farmed fish populations are primarily associated with rainbow trout.

Disease Control

Viral hemorrhagic septicemia (VHS) is listed both in Norway and the EU (categories C+D+E), and outbreaks will be combated by destruction of the entire fish population at the infected site («stamping out»). Furthermore, a restriction zone will be established, consisting of a protected zone and a surveillance zone around the site. Vaccination is not considered applicable in Norway.
For more information about VHS (in Norwegian), see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/viral-hemoragisk-septikemi-vhs

The Health Situation in 2023

Official data

In Norway, we have a risk-based surveillance program based on PCR examinations of samples from Atlantic salmon, rainbow trout, and cleaner fish submitted to the Norwegian Veterinary Institute for diagnostic testing. Additionally, brown trout and rainbow trout from freshwater sites, and pink salmon from several rivers in county Finnmark in the north of Norway were included in the surveillance program in 2023. Samples from some fish were also examined with PCR for VHSV based on histological findings. Furthermore, in 2023, no cases of VHS were detected in Norway. The last detection in aquaculture in the country was in rainbow trout in Storfjorden, Sunnmøre, in 2007-2008.

Evaluation of the VHS situation

In 2023, outbreaks of VHS were reported in Italy, Switzerland, Czech Republic, and Germany to the EU's Animal Disease Notification System (ADNS). The detection of VHSV in various species of wrasse in Shetland in 2012 and lumpfish in Iceland in 2015 raises concerns since these fish species are used for biological delousing. The Norwegian Scientific Committee for Food and Environment (VKM) has assessed the risk (probability x consequence) of transmission between wild cleaner fish and farmed fish to be high. Given the potential consequences of an outbreak of VHS, it is important to monitor farmed fish in Norway so that infected fish can be swiftly removed.
Denmark was an endemic area for VHSV for many years, but the virus has not been detected in the country since 2009 following a successful eradication project. In Finland, VHS outbreaks have been detected in connection with production in open sea cages in brackish water and sea, both in Åland and mainland, since the early 2000s. It took a long time for the eradication programs to succeed in Åland, with the last detection in 2012. France presented a plan for VHS eradication in 2017, but there were still two VHS outbreaks in the country in both 2019 and 2020 and one outbreak in 2021.

Figure 6.6.1 VHS in rainbow trout with multiple small haemorrhages. Photo: Ole Bendik Dale, Norwegian Veterinary Institute.

6.7 Infectious haematopoetic necrosis (IHN)

By Torfinn Moldal and Åse Helen Garseth

The Disease

Infectious hematopoietic necrosis (IHN) is a viral disease primarily affecting salmonid fish. The IHN virus, like the VHS virus, belongs to the genus *Novirhabdovirus* in the family *Rhabdoviridae*. Traditionally, fry have been most susceptible, and outbreaks most commonly occur in spring and autumn at temperatures between 8 and 15°C.

Clinically, protruding eyes are often observed, and *post mortem* findings include haemorrhages in internal organs, swollen kidneys, and fluid in the abdominal cavity. Histologically, typical destruction of hematopoietic tissue is seen, and the disease is classified as a hemorrhagic septicemia.

IHN was first isolated from sockeye salmon (*Oncorhynchus nerka*) in a hatchery in the state of Washington, USA, in the 1950s. Since then, the virus has been detected in numerous salmonid species including Atlantic salmon and rainbow trout. High mortality has been reported in Atlantic salmon in the sea in British Columbia. Based on a limited area of the genome, the virus is classified into five genotypes (U, M, L, J, and E) reflecting geographic origin. The genotypes U, M, and L represent the Upper, Middle, and Lower parts of the west coast of North America. In Europe, genotype E originates from North America, while genotype J in Japan has spread across large parts of Asia.

In November 2017, IHNV was detected for the first time in Finland, and the virus was found at a total of six sites with rainbow trout in the following months. The infection was discovered as part of surveillance and was spread from a state-owned broodstock and hatchery facility that had supplied fish to fish farms in the Bothnian Bay. The source of infection is unknown, and the virus did not group with known genotypes nor did it cause disease outbreaks.

In May 2021, IHNV was detected for the first time in Denmark. The virus was of genotype E, and it is believed to have been introduced from Germany. During the summer and early autumn, the virus was detected at a total of eight aquaculture facilities and three recreational fishing facilities ("put and take" lakes). On December 10, 2021, Denmark informed the EU Commission that they are giving up their disease-free status for IHN. In 2022, IHN was detected at an additional ten aquaculture facilities, and last year, IHN was detected at one facility in Denmark.

As a result of fish imports from Denmark, IHN was detected in five facilities in Åland, Finland, from May to October 2021. In the summer of 2022, IHN was again detected at a facility in Åland. The virus was of the same type as the one detected in Åland and Denmark in 2021. The ongoing control program for VHS in Åland has limited the movement of live or unprocessed fish from Åland to VHS-free areas in Finland for over 10 years. Further spread from Åland is therefore considered unlikely.

Disease Control

IHN is listed in both Norway and the EU (categories C+D+E), and outbreaks will be combated by destruction of the entire fish population at the infected site («stamping out»). Furthermore, a restriction zone will be established, consisting of a protected zone and a surveillance zone around the site. Vaccination is not considered applicable in Norway.

For more information about IHN (in Norwegian), see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/infeksi%C3%B8s-hematopoetisk-nekrose-ihn

The Health Situation in 2023

Official data

In Norway, we have a risk-based surveillance program based on PCR examinations of samples from Atlantic salmon, rainbow trout, and cleaner fish submitted to the Norwegian Veterinary Institute for diagnostic testing. Additionally, brown trout and rainbow trout from freshwater sites, and pink salmon from several rivers in county Finnmark in the north of Norway were included in the surveillance program in 2023. Samples from some fish were also examined with PCR for IHNV based on histological findings. IHN has never been detected in Norway.

Evaluation of the IHN situation

IHN occurs endemically in the western parts of the USA and Canada from Alaska in the north to California in the south. The virus has spread to Japan, China, Korea, and Iran, as well as several European countries including Finland and Denmark, as mentioned above. In 2023, besides Denmark, outbreaks of IHN were reported in Italy, Germany, and Austria to the EU's Animal Disease Notification System (ADNS).

The loss of disease-free status in Denmark has significant trade implications for Danish aquaculture producers. Therefore, industry associations for aquaculture facilities have developed a control plan aimed at regaining Denmark's disease-free status. Additionally, Denmark's loss of disease-free status has consequences for Norway as well. When the disease-free status is removed, the restriction zones cease to exist, leading to greater freedom for both fish transportation and recreational fishing within Denmark. This could potentially make the disease situation more difficult to monitor.

Spread is largely associated with the trade of infected eggs and fry from salmonid fish. However, the virus has also been detected in marine species through experimental infection and monitoring of wild populations. These species can thus serve as a reservoir.

The introduction of new species is a potential source of infection. Given the potential consequences of an outbreak of IHN, it is crucial to monitor farmed fish in Norway so that infected fish can be swiftly removed. Furthermore, anyone considering the import of live fish, including rainbow trout from areas officially free of IHN, should conduct a risk assessment in light of the events in Finland and Denmark. The consequence of introduction would be «stamping out» and the risk of spreading to wild fish, potentially leading to Norway becoming part of the permanent distribution area for IHN.

Figure 6.7.1 Fish with circulatory disturbances, haemorrhages and ascites. Macroscopic changes in fish due to IHN can be similar to those observed in ISA. Photo: Kyle Garver, Pacific Biological Station, BC, Canada.

6.8 Salmon Gill Pox Virus

By Mona Gjessing and Ole Bendik Dale

The Disease

Salmon gill pox disease is caused by infection with a large, complex DNA virus called Salmon Gill Pox Virus (SGPV). The disease was discovered in a hatchery with severe, acute mortality. In some tanks, all the fish died within a few days and with very characteristic gill changes with copious amounts of salmon gill pox virus, and no other agents that could explain the gill changes. In such cases a high proportion of the gill pavement cells are infected, and these cells are shed causing the respiratory lamella to collapse preventing the fish from getting oxygen. There is much virus and the diseased fish often have circulatory disturbances and abnormal clumping of red blood cells in addition to the gill changes. When only a small amount of the virus is found, these disease signs is not found.

Sequencing of the virus and development of real-time PCR in 2015 improved diagnostics showed that several other disease manifestations existed. An important finding was that the SGPV is often involved in complex gill disease (Chapter 10.1 Gill health). Detection of SGPV in complex gill disease are more common than the very acute disease outbreaks with extremely high mortality.The salmon gill pox virus has many genes and several that manipulates the host. By mapping gene expression of both the virus and the host through the disease course, SGPV appear to disturb the protective function of the mucus covering the gills and the recruitment of defence cells. This may implicate that the SGPV destroys the gill barrier against infections, both physically and immunologically, thus making the gill more susceptible to other disease-causing agents such as in complex gill disease in both the hatchery phase and the ongrowing phase.

If sea transfer of smolt coincides with an occurrence of salmon pox, the losses can be substantial in the sea. The gene expression study showed that the infection in the gills induced a shift to the ATPase of the freshwater isotype, which could exacerbate the disease outcome at sea transfer.

The SGPV infection can also be found without the development of any apparent disease. Genotyping of isolates from different fish groups in Norway, with different clinical disease history, has so far not indicated that low- or high virulence virus variants exist. Rather, it appears that development of severe disease can be linked to other factors, like stress. This is supported by experimental work, where only salmon treated with the stress hormone cortisol in combination with salmon gill pox virus infection developed the clinical disease. A recent study showed that mediators in the innate immune system in the gills increase during salmon gill pox virus infection, but that the stress hormone cortisol seem to delay this response in the early stages of infection. This demonstrates how important it is to protect the fish from stress.

Infection reservoirs and dissemination

The dissemination routes are not yet known, but the virus typing system MLVA (Multi Locus Variable-number tandem repeat Analysis) can provide this knowledge if applied systematically in outbreaks and linked to other epidemiological information.

As far as we know, only Atlantic salmon become infected with SGPV. In Atlantic salmon from Norway, the Faroe Islands, Scotland and Iceland closely related SGPV have been detected. Isolates from the same country vary less than isolates from different countries. Some fjord systems and hatchery facilities seem to have their own “house strains" over time. It is still unclear if these recurring infections are repeated introductions from the same source, or if one strain can cause persistent infection on site; an important distinction to know for countermeasures.

A somewhat genetically different pox virus has been found in wild Atlantic salmon from the east coast of Canada where no disease problems were reported. In Norway, SGPV occurs among wild Atlantic salmon broodstock, and a few fish that were investigated more closely had typical gill changes for salmon pox, but to a limited extent and apparently without clinical disease. Wild Atlantic salmon can thus be an important reservoir of infection. However, results from examinations of offspring from SGPV infected parents suggest that vertical transmission of salmon gill pox virus is not an important route of infection, while the virus infects very effective horizontally.

Disease control

There is no public control programme for salmon pox in Norway. In the ongoing project funded by the Research Council of Norway, TRACEPOX, thorough cleaning of hatcheries have been found important to keep infection pressure low. Measuring virus levels in water by PCR have been shown to be a good alternative to test fish samples for monitoring outbreaks. Experience from natural outbreaks show that many fish can be spared by not stressing the fish. When an SGPV disease outbreak is suspected in a hatchery, feeding is stopped, oxygen levels raised and all stress avoided to reduce the risk of mass mortality.

The Norwegian Veterinary Institute has followed the SGPV challenges faced by a particular farm over several seasons. Comparing virus isolates over time indicated that the farm was having a “house strain”. In order to remove or reduce infection pressure, new washing and disinfection routines were introduced. This included replacing a neutral disinfectant with an acidic. No SGPV virus were found in samples from the fish at the stages until after vaccination when the same MLVA type as before was found. Suspicion therefore fell on poor cleaning of the grading and vaccination equipment which were not treated with acidic disinfectant for fear of corrosion. The farm has been followed further and, surprisingly, a new type of MLVA was recently identified, suggesting a new introduction to the farm.

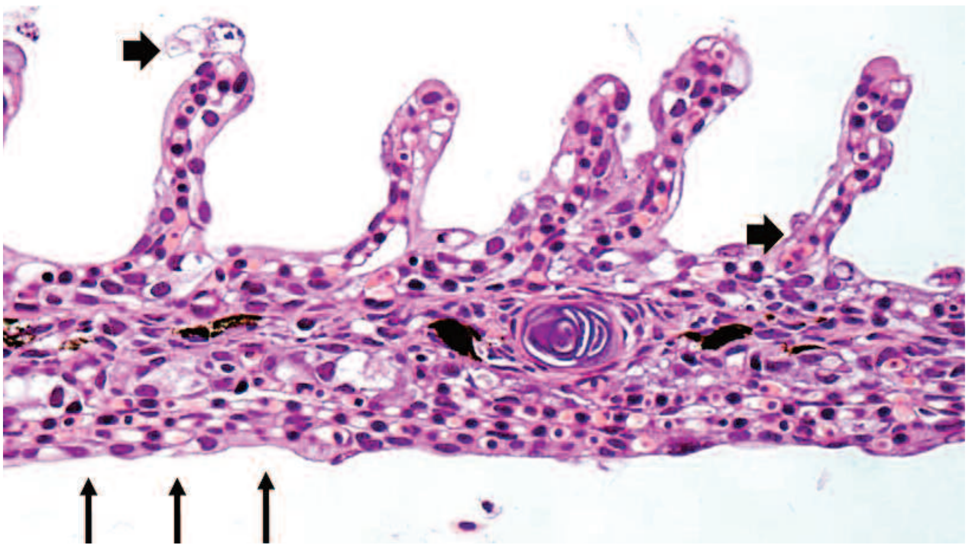


Figure 6.8.1 Histology image of gills infected with SGPV. Thick arrow on top show surface cells on respiratory units that contain much virus, and these cells are about to be shed. Arrows at the bottom show respiratory units that has collapsed leaving no respiratory surface. Photo: M Gjessing, Norwegian Veterinary Institute.

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and other laboratories

In 2023 SGPV was detected at 124 locations. Only two locations were using only freshwater.
In 57 locations the virus was detected in connection wiht clinical disease, and in 6 other locations the virus was found together with histopathological gill changes. I 25 others of the 124 locations it was reported that the fish was clinically healthy, while in 36 locations information on fish health is lacking. About 60% of the detections were in PA1-PA4, 30 percent in PA5-PA7 and 10 percent in PA8-PA13. That means more detections in the south. This may have several explanations, but this is in keeping with the pattern of more gill problems in the Vestlandet region.

Questionnare

In the questionnare the impact of SGPV is rated as small, both in terms of mortality, welfare and reduced growth (Appendix A1, B1 og C1). The responder do not perceive SGPV to be an increasing problem in smolt or ongrowth production, but SGPV is mentioned to of increasing importance in brood fish.

Gill disease is on other hand ranked as very important for mortality, welfare and reduced growth and as a significantly increasing problem. In a number of gill disease cases the SGPV is detected, but its significance is unclear.

Evaluation of the SGPV situation

The major outbreaks causing mass mortality in hatcheries are rare, but the serious consequences for the farms affected makes it worthwhile to map sources of infection to prevent introduction of the virus. As SGPV could be harmful to the disease resistance of
the gills, it is important to find out if the smolt carry the infection from the hatchery and the importance of this for complex gill disease in the sea. Improved knowledge about dissemination and reservoirs of SGPV by using the MLVA tracking tool is important to take appropriate countermeasures. The Norwegian Veterinary Institute encourages fish health services and others who suspect SGPV to submit samples to increase the knowledge needed to improve the gill disease situation.

Interpretation of the laboratory data is complicated as the diagnostics is not standardised and systematically reported. Still the date show a clear south – north gradient, but it is not known if that reflects disease problem related to SGPV in particular. We observe that how the diagnosis of SGPV disease versus testing for the SGPV infection caused is done differently. Routine screening for the infection is done to some extent, but it is often difficult to get an overview of concurrent histological examinations of gill damage and to what degree SGPV is causing the damage. The choice of PCR-method is here important. There is a lack of precision in diagnosing the disease due to SGPV versus the detection of the virus in Norway. Some fish farms routinely screen for the SGPV but it is difficult to get an overview of simultaneous histological gill damage and to what extent SGPV causes the damage. Also the choice of PCR method is important. The method used by NVI detects viral DNA which is related to the amount of virus in the samples. It is observed a strong correlation of clinical disease, disease change and amount of virus in the individual fish. A PCR-method that target virus RNA is detecting transcripts that do not neccesarily correlate to the amount of virus and thus significance for disease.

Infection with SGPV may contribute to complex gill disease together with other agents, but assessing the importance of all agents for the course of the disease requires more than one examination at a given time. It is possible that SGPV is important initially, while other agents become dominant later. To improve investigations of complex gill disease NVI has established an in-situ hybridisation method (ISH) which is very effective in finding both SGPV and related gill changes, also in mixed infections.

For more information about SGPV (in Norwegian), se the fact sheet: **https://www.vetinst.no/sykdom-og-agens/laksepox.**

7. Bacterial diseases of farmed salmonids

By Snorre Gulla

The use of oil-based injection vaccines has for several decades contributed to effective control of multiple serious bacterial diseases among farmed salmonids in Norway, and antibiotic consumption is consequently low. However, some bacterial diseases remain uncontrolled through vaccination and/or the vaccines do not appear to provide full protection. Table 7.1 summarizes detection numbers over recent years, as registered for the most important disease-associated bacteria among salmonids in Norway. For all of the non-notifiable diseases, a varying degree of underreporting should be taken into account. Furthermore, data from private laboratories have only been available for inclusion in the most recent years.

Winter ulcers collectively represent the greatest health- and welfare-challenge in relation to bacterial infection for salmon farmed at sea in Norway, affecting a very large number of sites along the entire coastline every year. Among such cases involving identification of the causative agent(s), various genetic variants of *Moritella viscosa* and/or *Tenacibaculum* spp. are usually detected, often in combination and/or together with other marine bacteria. Winter ulcer is not notifiable and the disease is relatively easily diagnosed on-site, which, together with high scores in the annual survey, may indicate persistent underreporting. Operational procedures that can entail damage to the skin and cause stress, such as physical delousing, may predispose for winter ulcer development. While the majority of Norwegian farmed salmon are vaccinated against *M. viscosa* through multi-component vaccines, it remains to be seen whether the launch and use through 2023 of a new vaccine against a specific variant of the bacterium (Chapter 4 Biosafety, Figure 4.4.1), will help mitigate ulcer problems.

Table 7.1: Number of sites with registered detection, per year, of selected bacteria associated with disease (in parentheses) in salmonids (wild and farmed). Empty cells indicate missing data.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
All fish species												
Aeromonas salmonicida subsp. *salmonicida* (furunculosis)*	0	0	2	3	5	2	3	2	5	5	2	0
Renibacterium salmoninarum (bacterial kidney disease/BKD)*	3	1	0	0	1	1	0	1	1	0	1	12
Rainbow trout												
Flavobacterium psychrophilum (systemic flavobacteriosis)*	5	3	2	3	4	1	4	4	2	1	4	1
Atlantic salmon												
Yersinia ruckeri (yersiniosis)**	16	20	26	34	34	30	20	12	16	19	34	44
Pasteurella spp. (pasteurellosis)**	1	0	0	0	0	0	7	14	57	45	52	27
Mycobacterium spp. (mycobacteriosis)***							3	7	5	5	8	10
Moritella viscosa ('classical' winter ulcer)**										204	296	320
Tenacibaculum spp. (tenacibaculosis/'atypical' winter ulcer)**										159	205	155

*: Notifiable (category F)
**: Includes, as of 2020, also detections made by private laboratories
***: Includes, as of 2023, also detections made by private laboratories

The number of sites with registered detection in salmon of *Yersinia ruckeri*, the causative agent of yersiniosis, continued to increase through 2023, with a majority of occurrences at sea. Some of the detections may represent findings from routine screening without clinical disease, but a very high and rising number of requisitions for the i.p. yersiniosis vaccine, from 2020 to 2023 (Chapter 4 Biosafety, Figure 4.4.1), could indicate significant problems with the disease. However, any effect of increased vaccine coverage is expected to manifest only as vaccinated fish are transferred to sea. It is known that stressful handling etc. may play a role in the development of yersiniosis.

Renibacterium salmoninarum, which causes notifiable bacterial kidney disease (BKD) in salmonids, saw a significant rise in 2023. Primarily, this relates to a series of detections in PA6, where transportation of infected fish and/or the use of wellboats have been suggested as possible routes of transmission. The bacterium can also transmit vertically. There are no effective vaccines or medications available against BKD, making general biosafety measures and screening important tools for combatting the disease.

The pasteurellosis-epidemic that has been ongoing among sea-farmed salmon in Western Norway (PA1-PA5) since 2018 continued also in 2023, albeit with a near halving in the number of sites with registered detection, compared to 2022. The disease is caused by a bacterium currently known as *Pasteurella «atlantica* genomovar *salmonicida*». Frequent co-infections involving other agents, as well as reports of extensive handling, may point to external factors increasing the risk of pasteurellosis outbreaks occurring.

Systemic flavobacteriosis (in rainbow trout) and furunculosis, respectively caused by *Flavobacterium psychrophilum* and *Aeromonas salmonicida* subsp. *salmonicida*, are both notifiable diseases that remain sporadically detected at 0-5 sites annually in Norway. While furunculosis is effectively controlled through vaccination, biosafety measures are central in preventing virulent strains of *F. psychrophilum* from spreading.

Mycobacteriosis, mainly caused by *Mycobacterium salmoniphilum,* has been sporadically detected in Norwegian farmed salmon since 2018, primarily at sea. Data from one private laboratory indicate an increasing number of salmon cases in recent years. A chronic disease development with vague clinical signs is common, and this may contribute to mycobacteriosis being underdiagnosed.

Epitheliocysts on the gills, often associated with *Ca.* Branchiomonas cysticola or other non-culturable bacteria, are among a range of often complex and multifactorial gill disorders of increasing importance in Norwegian salmon farming (Chapter 10.1 Gill Health).

Among other known fish-pathogenic bacteria, with a documented current or previous occurrence in Norway, are *Vibrio anguillarum, Aliivibrio salmonicida*, atypical *Aeromonas salmonicida, Piscirickettsia salmonis, Pseudomonas anguilliseptica*, and *Tenacibaculum maritimum*. Presently however, only sporadic cases are observed in Norwegian farmed salmon, where none of these are perceived as significant problems, for the first two because they are effectively controlled through vaccination.

While various other bacteria are also regularly detected from diseased or dead salmon farmed in Norway, their clinical significance is largely unclear, with a link towards operational and/or environmental challenges often presenting as more plausible. Many of these are naturally occurring environmental bacteria that can assume the role of secondary pathogens in already sick, injured, stressed, or otherwise compromised fish, or act as saprophytes of dead tissue. Relevant genera/species include *Vibrio* spp., *Aliivibrio* spp., *Aeromonas* spp., *Serratia* spp., *Pseudomonas* spp., *Vagococcus salmoninarum*, and *Carnobacterium maltoaromaticum*.

7.1 Flavobacteriosis

By Hanne K. Nilsen

The disease

The bacterium *Flavobacterium psychrophilum* can cause disease in many fish species, in freshwater and brackish water, affecting both fry and larger fish worldwide. Clinical signs vary among fish species and age. In less susceptible species like salmon, the bacterium is associated with external lesions such as fin rot and skin lesions. In more susceptible species like rainbow trout (*Oncorhynchus mykiss*), it can cause severe disease with high mortality, especially in fry. In older fish, symptoms include ulcers (often on the posterior part of the body) and signs of septicaemia such as swollen abdomen with fluid, enlarged spleen, and pale gills. Skeletal deformities with inflammation have been reported after infection. The bacterium is widespread in temperate freshwater and can survive for several weeks in water under laboratory conditions, but the bacterium is primarily associated with diseased fish.

Characterization of the genetic traits of the bacterium shows that there are many different variants (also called sequence types) of *F. psychrophilum*. The MLST (multilocus sequence typing) method requires bacterial cultivation as it relies on assembling DNA sequences from seven different housekeeping genes in each bacterial strain. Some sequence types are associated with severe disease progression and high mortality, while others result in a milder disease course. Laboratory experiments show that certain sequence types may exhibit host specificity, but this is not fully understood. It is also not firmly established whether the ability for vertical transmission varies among different sequence types.

In Norway today, the disease is recognized as a significant cause of mortality and poor welfare in rainbow trout released into brackish water systems and in land-based facilities inland. Previously, the disease has caused high mortality in rainbow trout fry and small fish in several hatcheries in Norway, and it is currently considered a potential threat. It is not uncommon to find the bacterium in lesions and fin rot in salmon (*Salmo salar L.*) and brown trout (*Salmo trutta L.*) in freshwater.

Disease control

F. psychrophilum spreads horizontally from fish to fish, and fish with clinical symptoms can release large numbers of bacteria into the water. It is likely that in some cases, the disease can spread vertically from broodstock to eggs, especially in rainbow trout. Good biosecurity measures such as frequent removal of fish showing signs of disease during outbreaks, washing and disinfection of equipment, as well as disinfection of eggs to reduce possible transmission, are general measures that can prevent the spread and escalation of the disease nationally. It is important to avoid moving infected fish to new areas to prevent spread. Laboratory experiments have shown differences in UV tolerance among different sequence types. *F. psychrophilum* has the ability to form biofilm.

Systemic infection with *F. psychrophilum* in rainbow trout is notifiable and is on the national list of diseases in aquatic animals, category F.

For more information on flavobacteriosis, see fact sheet:
https://www.vetinst.no/sykdom-og-agens/flavobacterium-psychrophilum

Health situation in 2023

Official data

Systemic infection with *F. psychrophilum* was detected in rainbow trout at one hatchery in 2023.

Data from the Norwegian Veterinary Institute

Rainbow Trout

In 2023, systemic infection with *F. psychrophilum* was detected in rainbow trout at one hatchery. There was high mortality in the affected group of fish. Genetic typing identified the variant ST32, a sequence type not previously detected in Norway.

Other Species

In salmon at a rearing facility, *F. psychrophilum* was found in sparse occurrences in several fish over several months. Different sequence types detected were ST23, ST170, ST169, and ST171, indicating that a resident strain of F. psychrophilum was not established in the facility. Sparse findings of *F. psychrophilum* ST170 were also reported in salmon fry with skin lesions and increased mortality at low temperatures. The isolates showed reduced sensitivity to oxolinic acid. In another facility, based on histopathology findings, there was suspicion of infection in lesions in salmon after handling. The sequence types detected in salmon in 2023 have previously been associated with external lesions in brown trout and salmon.

The Annual Survey

Overall, flavobacteriosis was ranked low on the list of diseases perceived as a problem by respondents in 2023. Few respondents ranked the disease as one of the five most important causes of mortality (4 of 59), reduced growth (1 out of 54), or an increasing problem (1 out of 47). None of the respondents perceived the disease as a problem in relation to reduced welfare.

None of the respondents perceived flavobacteriosis as a problem in rainbow trout.

Evaluation of the furunculosis situation

The detection of *F. psychrophilum* at the end of the year in rainbow trout with high mortality is a reminder that the bacterium continues to be a threat in Norwegian aquaculture. In the fjord system where *F. psychrophilum* has been found in recent years, flavobacteriosis was not detected in large rainbow trout in 2023.

For salmon, the submitted material does not provide a comprehensive overview of the situation, but results from diagnostics and the survey show that the disease, as before, can be a challenge in the fry stage.

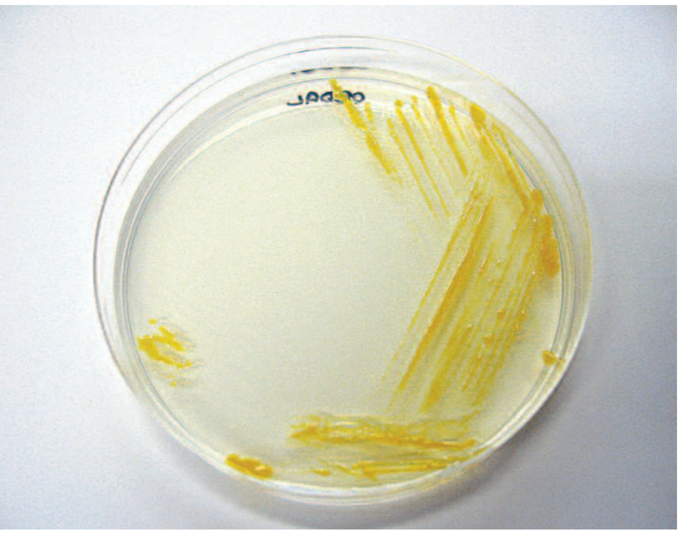


Figure 7.1.1 *Flavobacterium psychrophilum* in Anacker and Ordal medium (AOA). Photo: Hanne Nilsen, Norwegian Veterinary Institute.

7.2 Furunculosis

By Duncan J. Colquhoun

The disease

Classical furunculosis (infection caused by *Aeromonas salmonicida* subsp. *salmonicida*) is an infectious bacterial disease that can cause high mortality in salmonids in both freshwater and seawater. Other fish species such as turbot and lumpfish can occasionally be affected.
A. salmonicida belongs to the family Aeromonadaceae. Five subspecies of the bacterium have been described; salmonicida, achromogenes, masoucida, pectinolytica and smithia. Work conducted at the Norwegian Veterinary Institute has shown that the diversity within the species can be more precisely described by variation in the sequence of the *vapA* gene encoding the A-layer protein, an important virulence gene. Studies at the institute have identified 23 different genetic variants of the bacterium, which in most cases show a high degree of host specificity towards different fish species.
A. salmonicida subsp. *salmonicida* is often referred to as "typical" or "classical" *A. salmonicida*, while all other variants are collectively referred to as "atypical" *A. salmonicida*. The diseases are, therefore, referred to as "classical furunculosis" and "atypical furunculosis". The most common symptoms in larger fish are skin lesions and bloody boils ("furuncles") in the musculature. All *A. salmonicida* variants causing disease in fish are non-motile, short, rod-shaped bacteria. *A. salmonicida* subsp. *salmonicida* produces copious amounts of a brown, water-soluble pigment that can be observed when cultured on media containing the amino acids tyrosine and/or phenylalanine (Figure 7.2.1). Atypical variants typically grow slower, with smaller colonies, and produce less or no pigment. A few non-pigment-producing *A. salmonicida* subsp. *salmonicida* have been recorded. The main route of transmission appears to be horizontal, from fish to fish. In Norway, salmon, brown trout (including sea trout), and Arctic char are most susceptible to infection. Outbreaks of furunculosis in Norway have mainly been associated with sea-based farming and hatcheries using seawater in production, but outbreaks have also been recorded in freshwater without the use of seawater. Rainbow trout are considered more resistant to furunculosis, and the disease has not been detected in farmed rainbow trout in Norway in recent years. Salmonids may be subclinically infected with *A. salmonicida* subsp. *salmonicida* without showing signs of disease. Such "hidden" infections can be difficult to detect, and the disease can develop over time, often after stressful handling, transportation, sorting, etc.

Figure 7.2.1 Atlantic salmon with furunculosis, displaying typical bloody furuncles. Photo: Geir Bornø, Norwegian Veterinary Institute

Disease control

Classical furunculosis is a notifiable disease (List F, national diseases) in Norway. "Atypical furunculosis," i.e. infections caused by other *A. salmonicida* subspecies or strains, are not notifiable.

The implementation of biosecurity measures and vaccination programs in the early 1990s contributed to the fall in number of classical furunculosis cases. Today, the disease is under effective control due to vaccination, but outbreaks in farmed salmon still occur.

For more information on furunculosis, see fact sheet: **https://www.vetinst.no/sykdom-og-agens/furunkulose**

The Health Situation in 2023

Official data

Furunculosis (*A. salmonicida* subsp. *salmonicida*) was not detected in farmed or wild salmonids in 2023.

The Annual Survey

The results reflect that classical furunculosis is an uncommon disease in farmed salmon. Only one of 59 respondents considered the disease a threat in terms of mortality in hatcheries, and one of 47 as a growing problem (Appendix A1). None of the respondents considered the disease a cause of mortality, reduced growth, reduced welfare, or as an increasing problem in market-size salmon (Appendix B1).

Evaluation of the furunculosis situation

Furunculosis in Norwegian salmon farming is under effective control due to extensive use of effective vaccines. However, the continued occurrence of sporadic outbreaks in both wild and farmed salmonids, and the expected increased significance of furunculosis under warmer climates, necessitates continued monitoring of the disease. Vaccination against furunculosis remains a necessary measure.

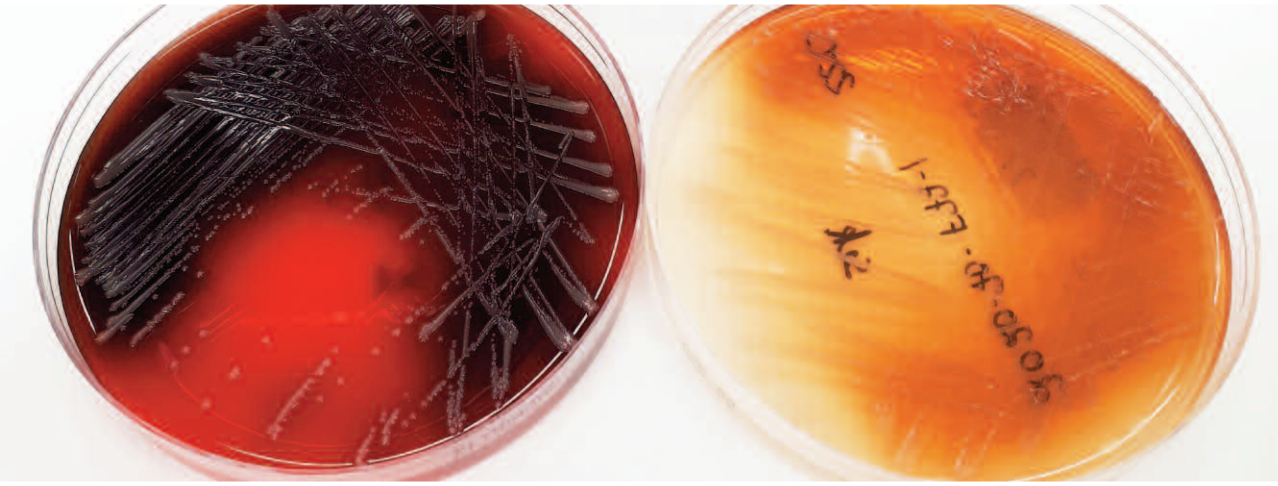


Figure 7.2.2 The furunculosis bacteria *Aeromonas salmonicida* subsp. *salmonicida* cultivated on blood agar and TYA medium. The bacteria lyse red blood cells and produce a water-soluble brown pigment. Photo: Anne Berit Olsen, Norwegian Veterinary Institute

7.3 Bacterial Kidney Disease (BKD)

By Duncan J. Colquhoun and Torfinn Moldal

The disease

Bacterial Kidney Disease (BKD) in salmonid fish is a serious, notifiable, and chronic disease caused by infection with the bacterium *Renibacterium salmoninarum*. Macroscopically, darkening of the skin, exophthalmia (protruding eyes), pale gills, distended abdomen, as well as ulers and wounds, are often observed. Internal organs may be swollen with few to many white to gray-white, small coalescing nodules (Figure 7.3.1a and b).

On microscopic examination, granulomas in the kidney and spleen can be seen, and the bacterium can be detected using special staining and immunohistochemical examination (Figure 7.3.1c). *R. salmoninarum* is a gram-positive, non-motile, slow-growing bacterium. It does not grow on standard agars and requires special media containing the amino acid cysteine, such as Kidney Disease Medium (KDM) (Figure 7.3.1d).

BKD is a worldwide disease in salmonid fish, both in wild and farmed populations. In Norway, BKD was first detected by the Norwegian Veterinary Institute in 1980 in offspring of wild salmon stocks. BKD outbreaks have most frequently occurred on the West Coast. The bacterium can be transmitted from one generation to the next through infected roe (vertical transmission). The disease can also spread from fish to fish, and infected wild salmon are believed to be the main source of the few BKD cases detected in Norway in recent years.

The disease affects only salmonid fish, and known susceptible species are salmon and brown trout/sea trout (*Salmo* spp.), Pacific salmon and rainbow trout (*Oncorhynchus* spp.), Arctic char (*Salvelinus* spp.), and grayling (*Thymallus thymallus*). BKD can cause acute mortality, especially in younger fish, but most commonly presents as a chronic disease. Lifelong carrier status occurs.

Disease control

The disease is notifiable and listed in category F (national fish diseases). There are no effective drugs or vaccines against this disease, and control relies on general biosecurity, screening of broodstock, and culling of infected stocks.

For more information about BKD, see fact sheet: https://www.vetinst.no/sykdom-og-agens/bakteriell-nyresjuke-bkd

The Health Situation in 2023

Official data

While bacterial kidney disease (BKD) has been detected only sporadically in Norway in recent years, the situation worsened significantly in 2023. BKD was confirmed in a total of 12 fish farming sites in 2023 (Figure 7.3.2). The disease was confirmed at six ongrowing salmon facilities and three broodstock facilities for salmon in production area 6 (PA6). Additionally, suspicion of BKD was raised in one ongrowing facility and one broodstock facility - both with salmon - in PA6 based on PCR detection of *R. salmoninarum*. In production area 4 (PA4), the disease was confirmed in two ongrowing salmon facilities and one sea site with rainbow trout. BKD was not detected in wild salmonid fish in Norway in 2023.

The Annual Survey

The increase in the number of facilities with BKD outbreaks in 2023 was reflected in the survey. For ongrowing salmon, three of 102 respondents rated BKD as a cause of mortality, six of 100 respondents considered BKD an increasing problem, while only one respondent experienced BKD as a cause of reduced welfare or growth (Appendix B1). However, none of the respondents considered BKD to be a problem in broodstock facilities, despite several detections in broodstock facilities in 2023 (Appendix C1 and C2). The disease was also not perceived as a problem in juvenile production facilities (Appendix A1 and A2).

Evaluation of the BKD situation

The current BKD situation in the Norwegian aquaculture industry is considered alarming. The source of infection is unknown, but it is suspected that the infection has spread partly with well-boats and partly with the movement of infected fish. There is no known link between the outbreaks in PA6 and PA4. BKD represents a serious threat to the industry since there is no effective vaccine or treatment. The current situation highlights the need for increased biosecurity measures in general and use of diagnostic investigations suitable for detecting BKD

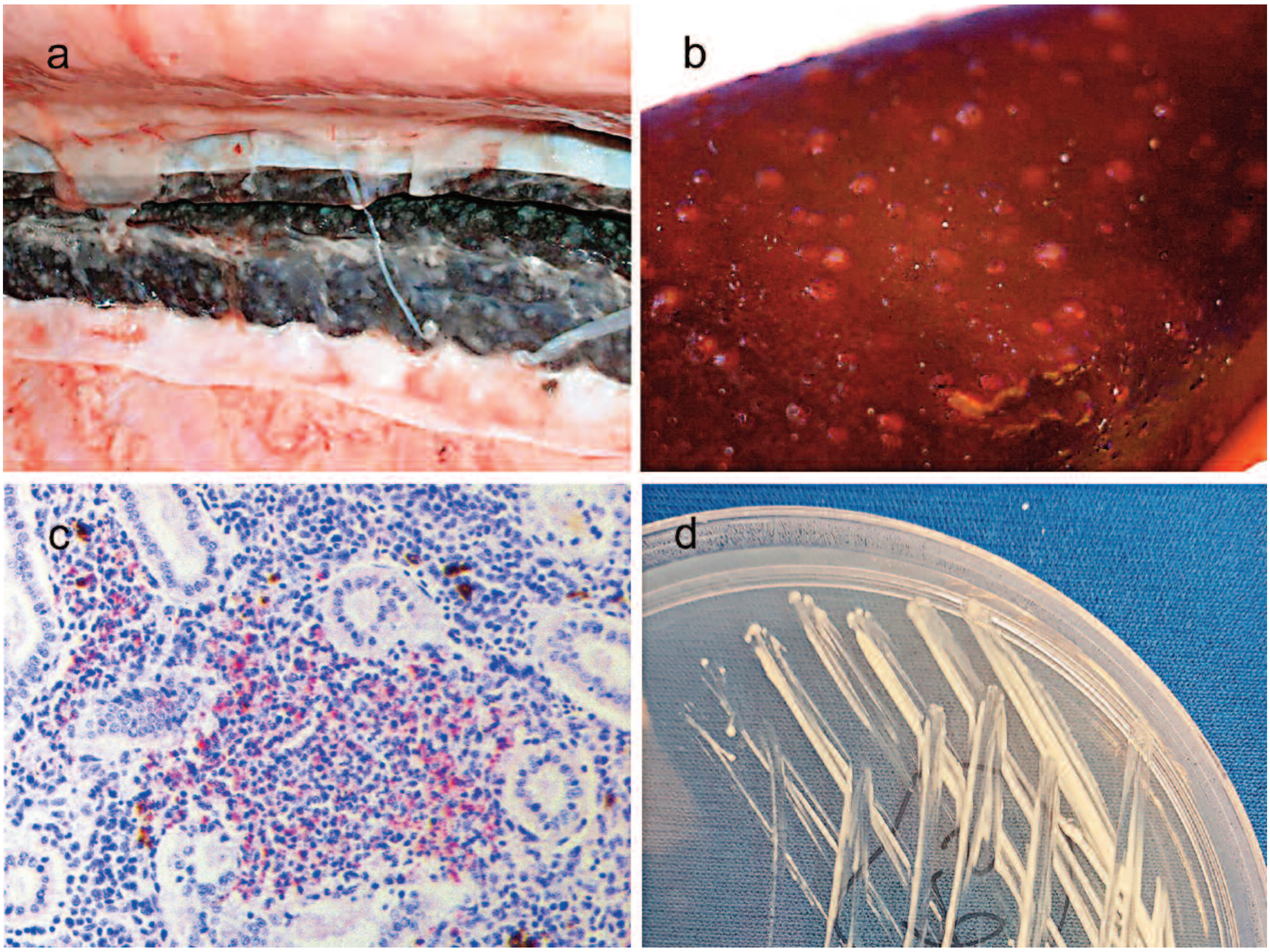


Figure 7.3.1 Bacterial Kidney Disease (BKD) in salmon. a) Pale nodules in the kidney. There may be few or many nodules, and the size varies. b) Signs of BKD may also be observed in organs other than the kidney; here, pale nodules in the spleen. c) Tissue section with *Renibacterium salmoninarum* in the kidney. The bacteria are stained red using an immunohistochemical technique. d) *R. salmoninarum* cultured on Kidney Disease Medium (KDM). Photo: Anne Berit Olsen and Hanne Nilsen, Norwegian Veterinary Institute

to be carried out on all fish showing macroscopic signs characteristic of the disease, mainly enlarged kidney and nodules in internal organs.

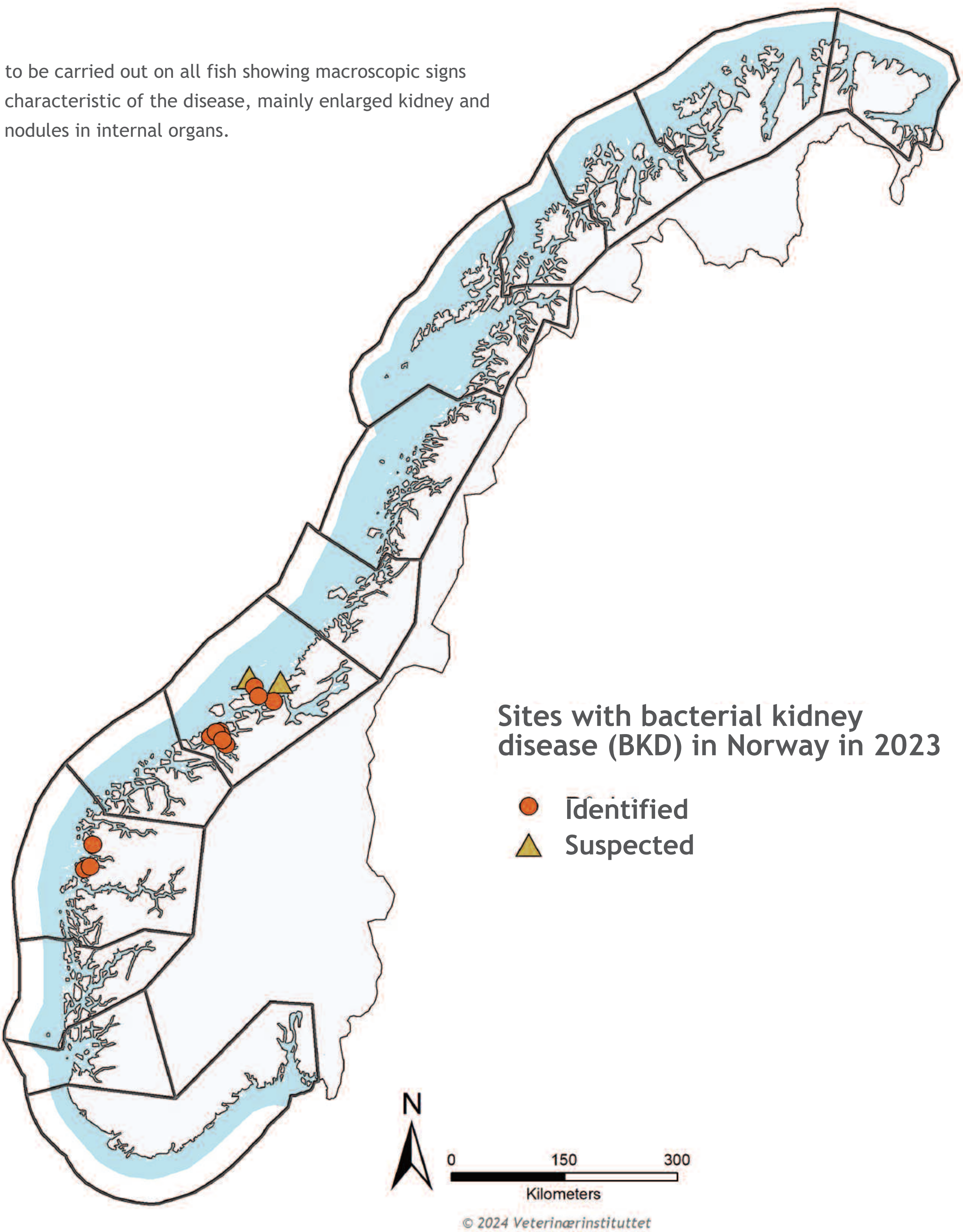


Figure 7.3.2 Sites with bacterial kidney disease (BKD) in 2023 distributed by production areas (PA), based on coordinated data from the Norwegian Veterinary Institute and private laboratories. Illustration: Attila Tarpai, Norwegian Veterinary Institute

7.4 Winter-ulcer

By Duncan J. Colquhoun and Anne Berit Olsen

The Disease

The development of skin lesions during the sea phase is a serious welfare issue for fish, resulting in increased mortality and reduced quality at slaughter. The development of lesions is a typical autumn and winter problem but can occur throughout the year.

The term "winter-ulcer" is primarily associated with infection by the bacterium *Moritella viscosa*, while "tenacibaculosis" is used when wound development is primarily associated with infection by *Tenacibaculum* spp. *M. viscosa* infections may be systemic, meaning that the bacterium infects the fish's internal organs (sometimes in the absence of skin lesions), while tenacibaculosis in Norwegian salmonids occurs almost exclusively as superficial infections.

Winter-ulcers develop mainly on the flanks of the fish (Figure 7.4.1), while tenacibaculosis typically manifests as deep wounds around the jaw (mouth rot) and head, as well as tail and fin erosions (fin rot) (Figure 7.4.2). Although both types of infections occur in fish throughout the sea phase, acute tenacibaculosis is most often associated with disease in relatively recently released smolts, at low sea temperatures. Tenacibaculosis is less common than winter-ulcer but can be more severe. Mixed infections with both *M. viscosa* and *Tenacibaculum* spp. are not uncommon (Figure 7.4.3).

Skin lesion development is often associated with previous handling such as delousing. Although *M. viscosa* and/or *Tenacibaculum* spp., alone or as mixed infections, can cause lesions, other bacteria such as *Aliivibrio (Vibrio) wodanis*, *Aliivibrio (Vibrio) logei*, and *Vibrio splendidus* are also often isolated. *A. wodanis* is often detected as a systemic infection and isolated in apparent pure culture from the kidneys of fish with skin lesions. The significance of such infections is not clear. Despite the condition not being reproduced in previous infection experiments, it cannot be ruled out that *A. wodanis* plays a role in the development of "winter-ulcer".

Disease control

Winter ulcer is non-notifiable and no official statistics relating to the prevalence of such infections are maintained. Nearly all Norwegian farmed salmon are vaccinated against *M. viscosa*. There are no commercial vaccines available against *tenacibaculosis*. In serious outbreaks, antibiotic treatments may on occasion be performed, but the effect is variable. *M. viscosa* genotypes different from the strain used in most vaccines are associated with many outbreaks of winter ulcer. The degree of evt. Cross protection is now being investigated by various vaccine manufacturers. New vaccines are being developed and field testing is underway.

Preventation should focus on production procedures and fish displaying visible wounds should be removed from the cages. Practical experience suggests that good smolt quality and optimal environmental conditions during sea transfer combined with minimal use of non-medicinal delousing during periods of cold water are extremely important.

For more information on winter-ulcer and atypical winter-ulcer, see fact sheets:

https://www.vetinst.no/sykdom-og-agens/klassiske-vintersar

https://www.vetinst.no/sykdom-og-agens/tenacibaculose

Figure 7.4.1 Winter ulcer, Atlantic salmon. Photo: Per Anton Sæther, Åkerblå

Figure 7.4.2 Skin lesions in the head/jaw region are commonly infected with *Tenacibaculum finnmarkense*.
Photo: Geir Bornø, Norwegian Veterinary Institute

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

Skin lesions were detected in farmed salmon along the entire coast in 2023. Due to the need for specific typing methods to differentiate between different subtypes of both *Moritella viscosa* and *Tenacibaculum*, subtyping is often not performed in connection with diagnostic work.

Combined data from the Norwegian Veterinary Institute and private diagnostic laboratories (Chapter 1 Data Basis) showed that winter-ulcer, regardless of the underlying cause, was detected in 339 fish farming sites with salmon during 2023. The underlying cause of wound development is not always known, and both *M. viscosa* and *Tenacibaculum* spp. can be detected together or alone. To the extent that the bacterial species was known, *M. viscosa* was recorded at 320 sites and *Tenacibaculum* spp. at 155 sites with salmon. Mixed infections with both Moritella and Tenacibaculum were detected in 136 of these sites. *Moritella viscosa* and *Tenacibaculum* spp. were also detected at eight (PO4 and PO5) and five (PO3-PO5) sites with rainbow trout, respectively, during the year. The geographical distribution indicates, as in 2022, that both *Tenacibaculum* and *Moritella* infections in salmon are fairly evenly distributed along the entire coastline.

The Annual Survey

In the survey, M. viscosa-associated winter-ulcer and tenacibaculosis ranked third and tenth, respectively, while "wounds" took fourth place as the most important health problem in farmed salmon during the sea phase (Appendix B1). Both infections stand out as causes of reduced welfare, ranked as number two and six, respectively. As a cause of mortality, *M. viscosa* associated winter-ulcer ranked second behind mechanical injuries associated with delousing, while tenacibaculosis was ranked ninth. Classical winter-ulcer also scored high as a cause of reduced growth (third place). For ongrowing rainbow trout, classical winter-ulcer was ranked relatively low as a cause of reduced growth and welfare and as a cause of mortality (Appendix B2). Tenacibaculosis was not considered a problem among the few respondents who scored challenges related to rainbow trout.

If all three categories related to external wounds in salmon during the sea phase; "wounds," winter-ulcer with *M. viscosa*, and tenacibaculosis are considered together, these are perceived by respondents as the greatest challenge in the sea phase for salmon in 2023, followed by mechanical injuries after delousing.

Evaluation of the winter ulcer situation

It is challenging to estimate the true prevalence of both *Moritella viscosa*-associated winter-ulcer and tenacibaculosis, since the diseases are not listed and are relatively easy to diagnose in the field. They are therefore likely underreported based on the number of samples sent to laboratories. Nevertheless, the detection of infection with *M. viscosa* at 320 sites indicates a serious situation. This is supported by fish health personnel ranking winter-ulcer, along with other types of wounds and delousing injuries, as the most important health problem in salmon during the market-size phase. The industry itself has communicated that the problems with winter-ulcer are partly due to the fact that the common basis-vaccines do not protect against the so-called "variant" or KK3 *Moritella viscosa*. In May 2023, a new vaccine against winter-ulcer was launched, and during 2023, a total of approximately 155 million doses of this vaccine were prescribed (Chapter 4 Biosafety, Figure 4.4.1). The new winter-ulcer vaccine is for active immunization of salmon and is reported to provide reduced clinical symptoms and reduced mortality caused by infections with variant *Moritella viscosa*. The duration of immunity is not specified. With the high number of smolts vaccinated in the second half of 2023, any positive effects can be expected during 2024.

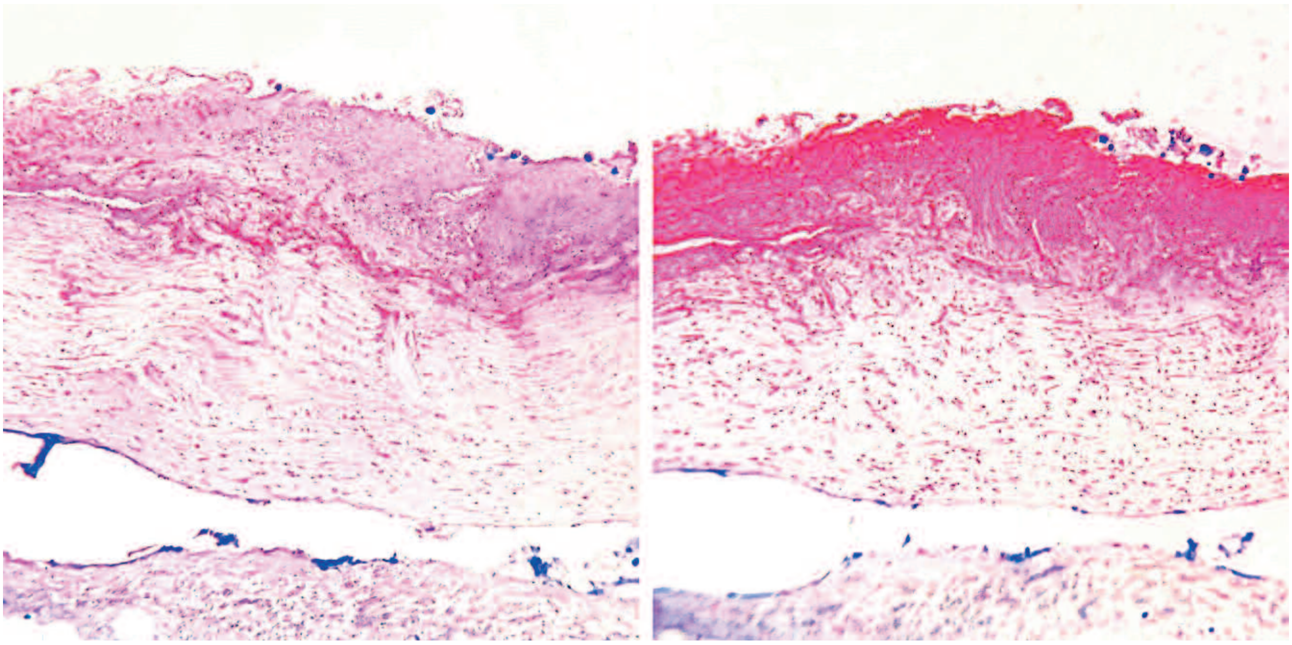


Figure 7.4.3: Tissue section of a salmon wound. Bacteria are stained red using immunohistochemical labeling. Winter ulcer in salmon are often infected with both *Moritella viscosa* (left) and *Tenacibaculum finnmarkense* (right). In this case, *T. finnmarkense* predominates, but typically, *M. viscosa* is the primary pathogen, and Tenacibaculum infects secondarily. Photo: Anne Berit Olsen, Norwegian Veterinary Institute

7.5 Pasteurellosis

By Hanne K. Nilsen, Snorre Gulla and Duncan Colquhoun

The disease

Infection with the bacterium currently known as Pasteurella "*atlantica* genomovar *salmonicida*" causes one of several diseases collectively referred to as pasteurellosis. Mortality and economic losses in salmon vary between outbreaks, and since 2018, the disease has been considered a serious bacterial disease with significant welfare consequences that typically affect large fish at the end of the production cycle. The ongoing epizootic appears to be limited to PO2-PO5. Typical clinical signs include inflammation of the pericardium, abdominal wall, and pseudobranch with pus formation. In addition, some fish may exhibit abscesses in the skeletal musculature and at the base of the pectoral fins. Bloody and inflamed eyes (Figure 7.5.1), which originally gave rise to the name "Varracalbmi" (Sami for blood eye), a characteristic feature of the first outbreak in Northern Norway in the early 1990s, is not present in all fish. Examination of tissue sections from diseased fish under a microscope may reveal changes characteristic of both acute and more chronic inflammation, such as abundant inflammatory cells and tissue fluid in addition to short rod-shaped bacteria in affected organs.

The term pasteurellosis is also used for infection with *Pasteurella skyensis*, which has caused recurring problems in salmon farming in Scotland. *P. skyensis* was first detected in Norway in 2020 but has not been detected since, as far as the Norwegian Veterinary Institute knows. Infection with this bacterial variant has been associated with signs of sepsis, including bleeding in the swim bladder and adipose tissue, as well as pericarditis and exophthalmia.

In lumpsucker fish used as cleaner fish in fish farming facilities, the disease is associated with *P. "atlantica* genomovar *cyclopteri*" (Chapter 12 The Health Situation of Cleaner Fish).

P. "atlantica genomovar *salmonicida*" has not proven to be very virulent in infection experiments. By PCR, the bacterium's genetic material (DNA) has been found on the surface of gills and skin of fish in fish farming facilities, in water when examining environmental DNA, and "traces" of the bacterium have also been found in mussels near ongoing outbreaks. The bacterium can be difficult to culture, and preliminary results from studies conducted at the Norwegian Veterinary Institute indicate that it likely has a poor ability to survive for long periods in seawater. Statistical analyses of production data have shown a correlation between outbreaks of pasteurellosis and thermal, brushing, and/or flushing-based delousing in the preceding month.

Disease control

The disease is not notifiable, and transmission routes are currently unclear. A high degree of genetic similarity between Norwegian salmon isolates of *P. "atlantica* genomovar *salmonicida*" from 2018 to 2022 may suggest that these have relatively recently spread from a common reservoir. Common biosecurity measures, such as frequent changing of delousing water during non-medicinal delousing (IMM) to prevent potential concentration of pathogens excreted from diseased fish, as well as disinfection of equipment and personnel, may be useful preventive measures against this disease. Autogenous vaccines against pasteurellosis have been developed, but the level of protection in the field is not documented. See also Chapter 4.4. Vaccines as biosecurity measures, for further discussion of vaccination against pasteurellosis.

For more information on *Pasteurella*, see fact sheet: https://www.vetinst.no/sykdom-og-agens/pasteurellose-hos-fisk.

The Health situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

In 2023, *P. "atlantica* genomovar *salmonicida*" and/or histopathological characteristics typical of pasteurellosis were detected in salmon at 27 sites. All detections were made in the sea off the west coast of Norway (PA1-PA5), and as before, most of the detections were in PA3 and PO4 (Figure 7.5.2). The detections were primarily associated with clinical disease. The disease causes characteristic changes in tissue sections that have not been observed in other bacterial diseases in salmon so far. Therefore, the data are based on findings of live bacteria from diseased fish and/or histopathological changes.

As before, the disease has been characterized by pericarditis and peritonitis, as well as abscesses in the skin (especially near the pectoral fins), musculature, and internal organs. Outbreaks have occurred over several months at some sites. The disease still occurs in large fish (2-5 kg), but detections have also been made in fish weighing as little as 1.5 kg. Increased mortality has been observed during outbreaks, and as before, there are reports of significant handling before outbreaks. The disease has been detected in populations simultaneously affected by viral diseases and/or other bacterial diseases, as before.

The Annual Survey

Pasteurellosis is considered one of the ten most significant health issues for salmon in both commercial farming facilities and broodstock facilities in 2023, according to Appendices B1 and C1. Similar to previous years, a relatively large proportion of respondents ranked pasteurellosis highly concerning both mortality and reduced welfare. Some believe that the disease's prevalence is increasing and is a contributing factor to reduced growth rates in salmon populations.

Figure 7.5.1 Eye damage in salmon with pasteurellosis. Photo: Hanne Nilsen, Norwegian Veterinary Institute

Evaluation of the pasteurellosis situation

Evaluation of the 2023 situation indicates that while the number of detections (27 sites) has decreased significantly compared to 2022 (52 sites), it remains at a high level. Some of the decline is likely due to increased focus on biosecurity, including awareness of the risks associated with reusing delousing water. Complex disease patterns with multiple infections involved in outbreaks and reports of significant handling suggest a general weakening of defense against disease. Pasteurellosis in salmon threatens fish welfare and sustainability in the industry. The disease has so far been prevalent along the coast of the western coast, but there is a risk of spreading to new areas.

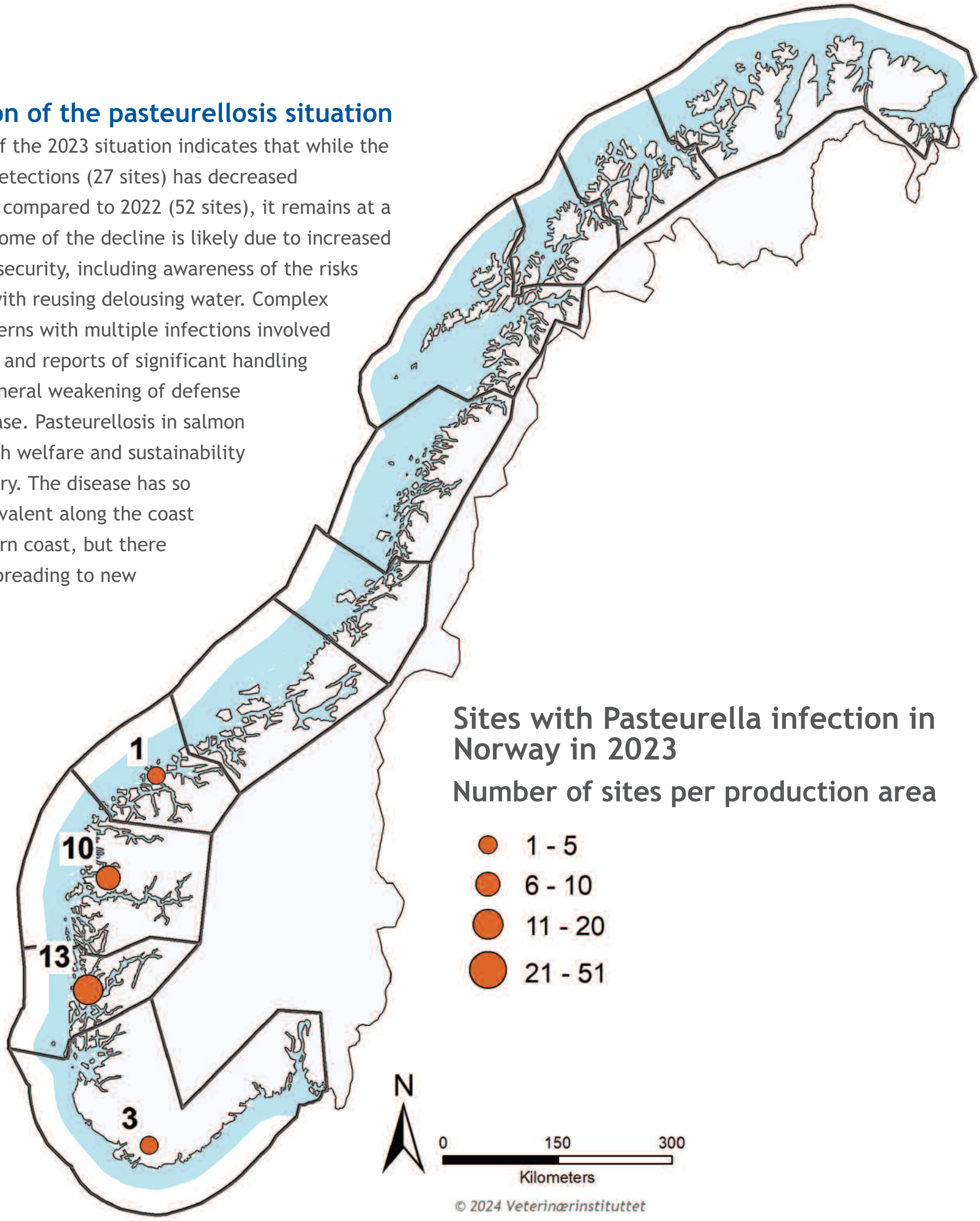


Figure 7.5.2 Number of pasteurellosis diagnoses in 2023 by production areas (PA) based on figures compiled from the Norwegian Veterinary Institute and private laboratories. PA1/PA2 and PA12/PA13 are merged due to few locations in these areas. Illustration: Attila Tarpai, Norwegian Veterinary institute

7.6 Yersiniosis

By Snorre Gulla and Anne Berit Olsen

The disease

Yersiniosis, caused by the bacterium *Yersinia ruckeri*, can affect several different fish species, but is primarily regarded as a problem in salmonids. In Norway, the disease is almost exclusively associated with farmed Atlantic salmon. While yersiniosis is often referred to as «enteric redmouth disease» internationally, common clinical manifestations in Norway include septicaemia with bleedings and circulatory failure (Figure 7.6.1), and to a lesser extent redness around the mouth.

Y. ruckeri infections may be carried both before and after sea transfer, but it is likely that transmission takes place mainly during the freshwater phase. While historically, yersiniosis at sea has primarily occurred shortly after sea transfer, outbreaks in large salmon at sea became more prevalent from ca. 2014, especially in Mid-Norway. Findings have indicated that most such outbreaks likely originate from persistent sub-clinical infections becoming activated due to handling and stress e.g. in association with delousing. From 2017, however, widespread use of injection vaccines against yersiniosis caused a decline in the number of outbreaks among large salmon at sea, although it appears now that this trend has yet again been reversed (see numbers below).

Recent research at the Norwegian Veterinary Institute has identified one specific genetic variant (clone) of *Y. ruckeri* exclusively found in Norway, where it has been responsible for nearly all major yersiniosis outbreaks since the mid-90s. Similar to numerous other geographically confined *Y. ruckeri* variants found across the world, the highly virulent Norwegian variant also groups within serotype O1. However, many other variants, of either serotype O1, O2, or others, are regularly detected in Norway as well, but these are seldom linked to severe clinical disease and are primarily isolated from other sources, such as clinically healthy fish and biofilm in hatcheries free of clinical yersiniosis. It should be noted that different *Y. ruckeri* variants sharing the same serotype are not necessarily closely related genetically.

Disease control

Likely due to significant problems in the sea phase of salmon farming, it seems that injection vaccines against yersiniosis before sea transfer are now in widespread use in Norway (Chapter 4.4 Vaccination as a biosafety measure). Some hatcheries also appear to have succeeded in eradicating virulent strains of *Y. ruckeri* from their facilities. However, one should be aware that the mere presence of *Y. ruckeri* in a facility is not equivalent to having a disease problem, as in addition to the one highly virulent variant mentioned, many other and seemingly low-virulent *Y. ruckeri* variants are also commonly found present in freshwater environments. Genotyping of cultured isolates can clarify which variant is being dealt with.

Y. ruckeri infections may be confirmed by cultivation of the bacterium e.g. from the kidney of affected fish. Cultivation is also necessary in order to enable monitoring of susceptibility to antimicrobials. Medicinal treatments are used only to a limited extent, and may cause development of resistant bacterial strains. Products based on bacteriophages, i.e. viruses specific to *Y. ruckeri*, are also available for environmental control of the bacterium.

For more information about yersiniosis, see fact sheet (in Norwegian):
https://www.vetinst.no/sykdom-og-agens/yersinia-ruckeri-yersiniose

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

Through 2023, *Yersinia ruckeri* was detected (by culture and/or PCR) from a total of 45 different sites. This includes 44 salmon farms (4 in freshwater, 33 in seawater and 7 unspecified), with 18 located in PA1-PA4, 11 in PA5-PA7, and 15 in PA8-PA10. The bacterium was also detected from wrasse on one site.

Overall, these numbers represent a significant increase from 2022 (36 sites), which itself constituted a near doubling from previous years (19 sites in 2021 and 16 sites in 2020). With 45 positive sites, 2023 thus becomes the year with the highest recorded distribution of *Y. ruckeri* in Norway, significantly surpassing 2015 and 2016 (34 sites both years), when yersiniosis problems at sea peaked prior to increased vaccination against the disease. It is worth mentioning, however, that the registrations for 2023 constitute a summary of findings from the Norwegian Veterinary Institute and private

Figure 7.6.1 Yersiniosis in adult salmon. Photo: Mattias B. Lind, HaVet

laboratories (Chapter 1 Statistical basis for the report), the latter of which have only been made available in recent years. Combined with the fact that routine PCR screening for *Y. ruckeri* appears to have become more widespread, this means that the annual number of sites with registered detection of the bacterium may not necessarily be directly comparable across years. Feedback from private laboratories nevertheless suggests that the majority of detections, also in 2023, were made in connection with clinical disease, although the clinical information pertaining to each individual case was often lacking.

Where in previous years, exact data on the extent of yersiniosis vaccination have been lacking, available figures from the Norwegian registry for veterinary medicinal products (VetReg) now reveal an extensive use (Chapter 4 Biosafety, Figure 4.4.1). According to VetReg, approximately 230 million salmon were i.p. vaccinated against yersiniosis in 2023, while about 450 million salmon were vaccinated with one of the three general vaccines with or without viral component(s) (general, general/IPN, or general/IPN/ISA). Over 50 percent of all vaccinated salmon thus also received yersiniosis vaccination, and these figures do not include any potential bath vaccination against the disease.

The Annual Survey

Overall, yersiniosis is ranked 15th as a problem in the hatchery phase and 12th as a problem in the ongrowing phase of salmon farming (Appendices A1 and B1). Yersiniosis is associated with mortality in both phases, and a significant proportion of the respondents report an increasing prevalence of the disease during the ongrowing phase. Among the 41 respondents who answered both that they had experience with vaccination against yersiniosis, and whether they had experienced clinical outbreaks of yersiniosis in vaccinated fish, 2 answered «yes», 3 answered «yes, but to a lesser extent than in unvaccinated fish», 32 answered «no», and 4 answered «don't know» (Chapter 4 Biosafety, Table 4.4.1). This tendency is also reflected in the survey's comments section, where several respondents emphasise a principally good effect of vaccination against yersiniosis, although limited and short-lived outbreaks in vaccinated juveniles are also mentioned to occur.

Evaluation of the yersiniosis situation

While some uncertainty exists as to whether recent years' steep increase in the number of sites with recorded detection of *Y. ruckeri* reflects a corresponding increase in clinical yersiniosis, it appears that evident problems with the disease in Norwegian salmon farming have once again increased. A sharp rise in the number of requisitioned vaccines against the bacterium may also indicate that the disease is perceived as a significant problem.

Through 2023, *Y. ruckeri* detections were recorded in all of Norway's aquaculture production areas except for the three northernmost ones, and a large majority of these detections were made in sea-farmed salmon. Recently published research has shown that stressful handling, such as during thermal delousing, stimulates increased shedding of *Y. ruckeri* from sub-clinically infected carriers. This may potentially constitute a biosecurity risk towards naïve fish treated simultaneously and/or subsequently in the same water.

While increased vaccine coverage from 2016 was followed by a significant decline in the number of yersiniosis cases at sea, this downward trend has now reversed, and the disease is clearly one that should be monitored in the time to come. However, the more recent increase (between 2020-2023) in the number of yersiniosis vaccines requisitioned, may provide grounds for hoping for a similar effect with fewer outbreaks in the years to come, as more vaccinated fish batches are transferred to sea.

7.7 Mycobacteriosis

By Julie Christine Svendsen and Toni Erkinharju, The Norwegian Veterinary Institute, and William Reed and Helene Wisløff, Pharmaq Analytiq AS

The disease

Mycobacteriosis in fish is an infectious disease caused by mycobacteria. The genus «Mycobacterium» encompasses a large number of species, of which only a small number has been associated with fish disease. In Norway, *Mycobacterium salmoniphilum* is the only species detected in fish.

Mycobacteriosis usually presents as a chronic disease, with a varying degree of mortality. Clinical signs are often non-specific, and include lethargy and reduced growth. Some individuals will develop skin lesions. Emaciation is typically observed in individuals with a prolonged course of disease. A more acute disease manifestation has been reported in the last few years. In these cases, histopathological investigation has revealed fibrinous peritonitis with bacteria along the peritoneum, necrosis in internal organs as well as large amounts of rod-shaped bacteria in blood vessels and the interstitium of the heart, gills, liver, kidney, skin and muscle tissue.

The source of infection is most likely direct contact with infected fish, either trough feed or water. A vertical transmission of the disease agent, from brood fish to offspring, has been described in some fish species. However, this is not considered a major problem. The incubation period is long, up to several weeks, and infected individuals may appear asymptomatic several years post infection. Some uncertainty remains as to whether mycobacteria in fish are primary or secondary pathogens. There are, however, several indications suggesting that an infection will weaken the immune defence of the fish and pave the way for secondary infections with other pathogens.

A revision of the nomenclature for the bacteria in this group has been suggested. However, there is some debate regarding the different proposals, and both 'Mycobacterium' as well as new genus names may be applied. *M. salmoniphilum* and *M. chelonae* have been proposed to be placed in the genus Mycobacteroides, *M. fortuitum* in the genus Mycolicibacterium, while *M. marinum* remains in genus Mycobacterium. Recently describes species are *M. shottsii*, *M. pseudoshottsii* and *M. salmoniphilum*.

Diagnostics

Typical autopsy findings include pale nodules (granulomas) in internal organs, as well as swollen spleen and kidney. Upon further histological examination granulomas may be observed in internal organs, occasionally with centrally located Splendore-Hoeppli bodies. Mycobacteria may be detected by the aid of special stains (Figure 7.7.1) or antibodies directed toward the bacteria (immunohistochemistry). M. salmoniphilum grows in the temperature range of 22-30°C. It will grow on regular blood agar, however it is best cultivated on selective culture media like Middlebrook 7H10-agar or CHAB agar. The bacteria can also be detected through molecular biology techniques.

Differential diagnoses depend on the fish species, and include infection with *Yersinia ruckeri, Francisella noatunensis, Piscirickettsia salmonis, Renibacterium salmoninarum, Nocardia* sp., *Rhodococcus* sp. and fungi.

Disease control

There is no effective treatment for mycobacteriosis. The cell wall of the bacteria, as well as granuloma formation, complicates treatment with antibiotics. As of today there are no approved vaccines against mycobacteriosis in fish.

For more information on mycobacteriosis, see fact sheet (in Norwegian): **https://www.vetinst.no/sykdom-og-agens/mykobakteriose-hos-fisk-mycobacterium-spp**

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

When compiling data from the Norwegian Veterinary Institute and private laboratories (Chapter 1 Data Foundation), in 2023, there were ten sites with confirmed mycobacteriosis or infection with *Mycobacterium* spp. These cases originated from several production areas, with PA3 being the southernmost registration and extending northward to include PA12-PA13. Most detections occurred in ongrowing facilities at sea, but hatcheries were also affected.

Data from Pharmaq Analytiq show an increasing number of cases of mycobacteriosis in salmon in recent years (Reed, W., Østevik, L., Lie, K.-I., & Wisløff, H., 2023). The laboratory had a higher number of confirmed cases in 2023 than the compiled figures mentioned above, which may be related to the fact that the Norwegian Veterinary Institute does not have data sharing agreements with all aquaculture companies (Chapter 1 Data Foundation).

The Annual Survey

The survey does not reveal mycobacteriosis as a problem concerning mortality and reduced welfare, and the disease is ranked low in terms of reduced growth. Three out of 100 respondents consider the disease to be an increasing problem. Similarly, in broodstock facilities, where respondents do not perceive mycobacteriosis as a problem regarding mortality, reduced welfare, or reduced growth, it is also ranked low in terms of increasing prevalence. In smolt farms, mycobacteriosis is ranked low in terms of mortality, reduced welfare, and increasing prevalence, and is not perceived as a problem regarding reduced growth.

Evaluation of the mycobacteriosis situation

Mycobacteriosis is not a notifiable disease in fish, and apart from data collection for the Norwegian Fish Health Report in 2023, there is no previous comprehensive overview of the number of disease outbreaks in salmonids in Norway.

The number of annual detections of mycobacteriosis at the Norwegian Veterinary Institute from 2018 to 2022 varied from three to eight cases. In cases where the bacterium was identified at the species level, only *M. salmoniphilum* was detected. A higher number of detections of mycobacteriosis at Pharmaq Analytiq in 2023 compared to the years 2018-2022 indicates an increasing occurrence.

Most fish-pathogenic mycobacteria, including *M. salmoniphilum*, do not grow at 37 °C, and there is currently no solid evidence to claim that human consumption of fish infected with mycobacteria represents a health risk. Several mycobacteria, including *M. marinum* and *M. chelonae*, which are closely related to *M. salmoniphilum*, can cause skin lesions in humans in the form of superficial granulomas and sores, and can spread to deeper tissues in immunocompromised individuals. General precautions to prevent bacterially infected material from coming into contact with damaged skin are recommended when handling infected fish.

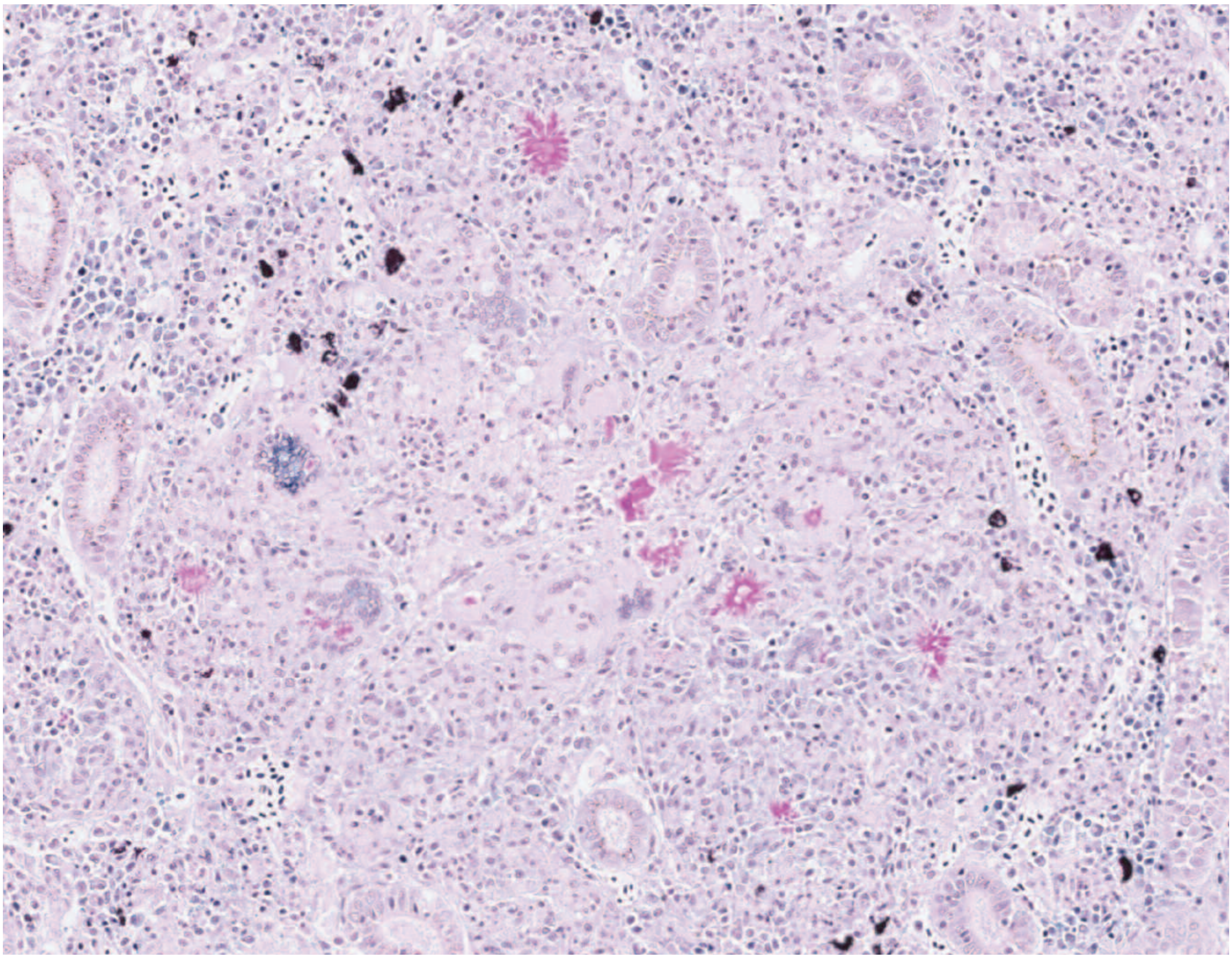


Figure 7.7.1 Kidney, Ziehl-Neelsen stain. Granulomatous inflammation with giant cells and Splendore-Hoeppli bodies. Immunohistochemical analysis for *Mycobacterium* sp. in the same individual showed postive staining of bacteria. Photo: Julie Christine Svendsen, Norwegian Veterinary Institute

7.8 Other Bacterial Infections in Salmonid Fish

By Duncan J. Colquhoun, Anne Berit Olsen, and Hanne Nilsen

Most bacterial infections result from an interaction between the bacterium, the fish, and the environment. A wide range of different bacteria are commonly identified from sick fish. These may include recognised disease-causing bacteria (pathogens) that are almost always associated with outbreaks, as well as more opportunistic bacteria that cause disease in stressed and weakened fish due to mechanical damage, handling, or environmental conditions, such as those related to water quality. Additionally, it is common for bacteria from the surrounding environment to quickly invade weak or dead fish.

During diagnostic work, it can be challenging to directly link cultured bacteria with disease. Findings are continuously evaluated so that new pathogenic variants and infections can be identified early. Culture based diagnostics from diseased fish are crucial in uncovering new ("emerging") pathogenic bacteria and ensures access to strains suitable for genetic typing and vaccine development.

Bacteria belonging to the genus *Serratia* have at times been associated with disease in salmonid fish worldwide. *Serratia* spp. and *Serratia proteomaculans* were isolated during diagnostic investigations performed by the Norwegian Veterinary Institute from several sites with salmonid fish during 2023. In some cases, this was the dominant type of bacterium, while in other cases it was detected as part of an abundant and likely opportunistic mixed flora.

Motile Aeromonas spp., including *A. hydrophila* and *A. sobria*, were again detected in farmed salmon during the fry and broodstock phases and in wild pink salmon. Such bacteria are commonly occurring, especially in freshwater sources. Although these bacteria are closely related to the serious fish pathogen (non-motile) *Aeromonas salmonicida* and are associated with disease in some species of warm-water fish, they are not considered 'primary' pathogens for fish in Norway. Such infections can often be linked to poor water quality or weakened fish.

Pseudomonas fluorescens and other *Pseudomonas* species can sometimes be detected in sick and dying fish. Like motile Aeromonads, *Pseudomonas* spp. are commonly occurring, especially in freshwater sources. Although most detections are perceived as opportunistic infections, in some cases, especially with *Ps. fluorescens*, they can be more directly linked to observed mortality. *Pseudomonas fluorescens* was identified in connection with bacteriological examinations performed by the Norwegian Veterinary Institute in some salmon facilities in 2023, both fry and ongrowing fish, as in 2022.

Carnobacterium maltoaromaticum can sometimes be associated with epicarditis and peritonitis in broodstock salmon and is occasionally isolated from fry and ongowing fish. The bacterium can be detected in rainbow trout and other salmonids and is also isolated from, for example, lumpfish. *C. maltaromaticum* was detected during diagnostic examinations performed by the Norwegian Veterinary Institute in several broodstock and salmon farming facilities in 2023. The bacterium was also detected in wild pink salmon from several rivers, as well as in trout and sea trout. *Carnobacterium* is a normal component of the gut flora in many fish species, and the bacterium is also detected in fish without disease.

Vagococcus salmoninarum was, for the first time since the 1990s, identified as the dominant bacterium in the heart and abdominal cavity of salmon from a broodstock site in Norway in 2021. The bacterium was detected in salmon at one broodstock and one market-size fish site in 2023. Vagococcus is not considered a 'primary' pathogen.

During 2023, infection with *Vibrio (Listonella) anguillarum* (serotype O1) was detected in salmon in one juvenile production facility and in both salmon and rainbow trout at another fry facility. A strain that could not be serotyped was isolated in connection with disease at a market-size salmon facility.

Pseudomonas anguilliseptica is a widespread disease-causing bacterium in lumpfish in Norway (Chapter 12 Health Situation of Cleaner Fish) and has been reported as pathogenic for salmonid fish in the Baltic Sea. In Norway, there was a single detection in rainbow trout in 2019, and in 2022, *Ps. anguilliseptica* was recorded for the first time by the Norwegian Veterinary Institute in a salmon. *Ps. anguilliseptica* was not detected in salmonids in 2023.

Tenacibaculum maritimum is known to cause disease in many fish species in relatively warm seawater, including salmon raised in the Pacific Ocean. The bacterium has sporadically been detected in the gills of Norwegian farmed salmon as one of several *Tenacibaculum* species that can be found in gill necrosis. *T. maritimum* was not detected in salmon by the Norwegian Veterinary Institute in 2023, but one detection in salmon in production area 4 was reported by an external laboratory.

Cold-water vibriosis, caused by *Aliivibrio (Vibrio) salmonicida*, was not detected in salmon or other fish species during 2023.

Atypical *Aeromonas salmonicida* was not detected in farmed salmon in 2023, but an isolate belonging to *A. salmonicida* A-layer type III was detected in a wild salmon from the Tana River in July. Atypical *A. salmonicida* infections have been uncommon in farmed salmon for many years since vaccination against *A. salmonicida* subsp. *salmonicida* (furunculosis bacterium) usually provides good protection against atypical variants.

Piscirickettsiosis, caused by *Piscirickettsia salmonis*, remains a serious problem in Chilean salmon farming and is sometimes the cause of losses in both Irish and Scottish aquaculture. The Norwegian/European variants of the bacterium are usually associated with lower mortality. *P. salmonis* was not detected in Norwegian salmon in 2023.

Several different bacteria are known to cause the phenomenon referred to collectively as 'epitheliocystis' in salmon, as well as other fish species. Most (if not all) of the bacterial types associated with epitheliocystis cannot be cultured, and precise diagnosis relies on molecular biological tools. Therefore, most underlying infections observed histopathologically are not determined to the species level. However, it seems that most cases of epitheliocysts examined more closely consist of the bacterium *Ca*. Branchiomonas cysticola and are primarily identified in the seawater phase of salmon farming. For more information on epitheliocystis and *Ca*. B. cysticola, see Chapter 10.1 Gill Health.

7.9 Sensitivity to antibacterial agents and antibiotic consumption

By Duncan J. Colquhoun, Hanne Nilsen, Kari Olli Helgesen, and Kari Grave

Sensitivity to antibacterial agents

The Norwegian Veterinary Institute monitors antibiotic resistance in bacterial isolates cultured from diseased farmed fish as part of diagnostic work every year. In addition, a smaller number of isolates found in wild fish, mainly wild salmonids, are also examined.

There is still very little use of antibiotics in Norwegian aquaculture, but antibiotic treatment may be necessary during outbreaks of bacterial disease in farmed fish to improve fish welfare or avoid significant losses in fish early in the production cycle. In Norway, antibiotic use is limited almost exclusively to oxolinic acid and florfenicol. Antibiotic use is known as one of the main causes of bacteria developing resistance to antibacterial agents, and it is therefore important that antibiotic consumption remains as low as possible. Some bacteria naturally have reduced sensitivity to certain types of antibiotics due to naturally occurring characteristics, such as cell wall permeability. One example is *Carnobacterium* spp., which is naturally resistant to quinolones. This bacterium is naturally present in the fish gut flora and is occasionally associated with disease.

In 2023, there is still little evidence of widespread or increasing resistance among bacteria found in diseased farmed fish in Norway. As in previous years, reduced sensitivity to oxolinic acid has been identified in certain strains of *Yersinia ruckeri* from a juvenile production facility in PA7. Reduced sensitivity to oxolinic acid was also detected in *Flavobacterium psychrophilum* typed as ST170, isolated from diseased juvenile salmon in PA5. There are no absolute limits for definition of so-called 'breakpoint' values for fish pathogenic bacteria, but values consistent with reduced sensitivity to oxolinic acid have been detected in several strains of *Vibrio anguillarum* isolated from diseased salmonids in PA3 and PA5.

There was no evidence of reduced sensitivity to antibacterial agents in fish-pathogenic bacteria isolated from marine fish species in 2023.

Antibiotic use

The use of antibiotics, in kg active substance, has historically been used as an indicator for the incidence of bacterial diseases. Vaccination against cold-water vibriosis and furunculosis in Atlantic salmon started up in the late 1980-ties and the early 1990-ties, respectively. Ever since then the use (in kg active substance) of antibiotic has been low (NORM NORM-VET reports), despite increasing production of farmed salmonids.

Table 7.9.1 shows the use of antibiotics for farmed fish, including cleaner fish, between 2015-2023 based on data from the Veterinary Prescription Register (VetReg) as of 15.03.2024. For these years, the data reported to VetReg have been validated against sales figures, from wholesalers, reported to the Institute of Public Health. The use in 2023 was 548 kg and therefore remains approximately at the same level as in 2021 and 2022.

VetReg contains, among others, information about fish species, production stage and diagnose. From 2015 to 2020 the number of antibiotic treatments of ongrowing fish (salmonids and marine fish) was relatively low (between 9 and 13), but for 2021, 2022 and 2023 the number of treatments of ongrowing fish has been increasing and were respectively 32, 49 and 84. Of the ongrower treatments in this three year period, 12, 24 and 46 concerned halibut, respectively. In 2023, atypical furunculosis was given as the diagnosis on 38 of 51 halibut prescriptions. As seen in figure 7.9.1, there is a trend of an increasing proportion of treatments in ongrowing fish in the period 2013 to 2023; from 15 percent in 2015 to 74 percent in 2023.

Table 7.9.1 Antibiotics, in kg active substance, prescribed for farmed fish, including cleaner fish, for the years 2015 to 2023, based on use data from the Veterinary Prescription Register (VetReg).[1,2]

	2015[1]	2016[1]	2017	2018[1]	2019	2020	2021	2022	2023
Florfenicol	183	134	264	857	152	113	531	397	516
Oxolinic acid	84	66	343	54	66	107	57	28	32
Oxytetracycline	0	0	0	19,875	0	0,16	0	0	0
Enrofloxacin	0,02	0,05	0,01	0,00	0,01	0,12	0,44	0,10	0,05
Amoxicillin	0	0	0	0	0	0,09	0	0	0
Total	267	199	607	930	218	220	588	425	548

[1]Minor deviations may be seen for the total amounts which is due to rounding of each single value [2]Differences in the figures compared to the 2022 Fish Health Report are due to updated calculation of the amounts prescribed for one florfenicol and one oxytetracycline product (Difference range from 1-8 kg lower for the years 2015-2022)

In some of the years from 2015 to 2023, the number of prescriptions of antibiotics for cleaner fish exceeded the number for food-producing fish. The number of antibiotic treatments of cleaner fish has however been greatly reduced. The highest number of prescriptions in the period 2015-2023 occurred in 2016 with 126 treatments, while in 2023 only three antibiotic prescriptions were dispensed for treatment of cleaner fish.

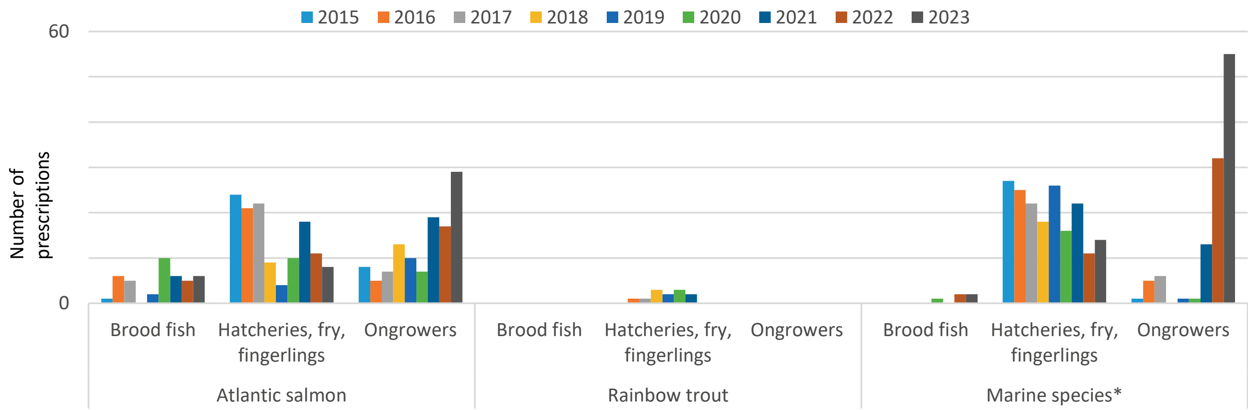


Figure 7.9.1 Number of treatments with antibiotics per fish species and production stages for the years 2015 to 2023 (cleaner fish and fish for trials were excluded). Number of treatments are defined as number of prescriptions reported to the Veterinary Prescription Register. *Cod, halibut, pollack, turbot and Arctic char. Two prescriptions for clams are not included in the figure.

8. Fungal diseases of salmonids

By Ida Skaar

The disease

Fungal diseases, or mycoses, can be differentiated into surface mycoses that are observed on the skin and gills, and systemic mycoses, which involve infection of one or more internal organs.

Most surface mycoses involve *Saprolegnia* spp. which may be observed as a light, cotton wool-like covering on the skin of the fish. *Saprolegnia* spp. is not a true fungus but belongs to the so-called oomycetes. *Saprolegnia* spp. occur in all freshwater bodies around the world and spread via motile spores (zoospores). In Norway, saprolegnia infections are most problematic in hatcheries (Figure 8.1.1)

Investigations have found that Saprolegnia spores are normally present in the water sources of Norwegian hatcheries. They colonise and multiply in biofilms in pipes and tanks, but may not be readily observed. The fish are therefore continually exposed to Saprolegnia spores, but infection occurs only if the fish is weakened or has damaged skin and mucus.

Systemic mycoses may be caused by a number of fungal species, but they are normally associated with the genera *Fusarium, Penicillium, Exophiala, Phialophora, Ochroconis, Paecilomyces, Ichthyophonus* and *Lecanicillium*. These are fungi that are present in the environment and we are not aware of any particular specific reservoir or mode of transmission. The most commonly diagnosed species is *Exophiala psycrophila*, which causes kidney granuloma. Mycoses are considered a minor problem in Norwegian aquaculture.

Disease control

Saprolegniosis was previously effectively controlled using the organic dye malachite green. Malachite green is, however, carcinogenic, and was banned for use in fish produced for food, first in the USA and soon after worldwide. This ban has led to saprolegniosis becoming a problem once again, as no effective alternative to malachite green has yet been identified.

Formalin is now the most cost-effective remedy against Saprolegnia, and in most cases it will be the first choice to treat in the event of an outbreak. Sales of formaldehyde in Norway are increasing, but the use of formalin in aquaculture is also controversial and is currently under consideration by EU. The use of formalin against parasites or oomycetes may thus become regulated or forbidden within the next few years. It is therefore important that focus is placed on the development of effective preventative measures.

Important prophylactic measures include avoidance of unnecessary stress and gentle handling under those situations in which handling is unavoidable e.g. grading, transport and vaccination. Good general hygiene is important, along with maintenance of good water quality to avoid build-up of spores in the farm. For eggs during incubation and during hatching, the main preventive measure is frequent removal of dead eggs and organic material.

For more information about saprolengiosis, see the fact sheet (in Norwegian):
https://www.vetinst.no/sykdom-og-agens/saprolegniose

The Health Situation in 2023

Data from the Norwegian Veterinary Institute.

The disease is normally diagnosed and treated in the field without further laboratory investigation. The Norwegian Veterinary Institute therefore only registers a limited number of saprolegniosis cases each year, which does not reflect the true impact of the disease. There were in the course of 2023, additional requests for advice outside the diagnostic service in which saprolegnia was related to high mortality in start-feeding fry and eggs. In 2023, Saprolegnia was identified in elleven diagnostic submissions involving ni salmon and one sea trout.

Saprolegnia infections in fish are mainly caused by *Saprolegnia parasitica*, but *Saprolegnia delica* was identified in one of the submissions. Gill mycosis was diagnosed in three salmon. Exophiala was identified as the tentative pathogen in the disease clarification from adult salmon.

Evaluation of the saprolegniosis situation

The Norwegian Veterinary Institute regularly receives inquiries about problems with Saprolegnia and fungal infections. However, based on the number of submissions and the responses from the participants in the survey, it may seem that fungi and oomycetes are effectively controlled by preventive measures and therefore are not perceived as a major problem in farmed fish. However, it may appear that *Saprolegnia parasitica*, in some cases, causes more severe disease in younger fish than is common in Norway. Whole-genome sequencing of isolates of

S. parasitica is underway to compare new isolates with well-characterized isolates to possibly explain this observation. The Norwegian Veterinary Institute also conducted a small project in 2023 to investigate the cause of fungal infections in lumpfish. It was concluded that *Exophiala psychrophila* was the dominant pathogen.

Figure 8.1 *Saprolegnia* spp. from salmon cultured on Sabouraud medium. Photo: Mari M. Press, Norwegian Veterinary Institute

9 Parasitic Diseases in Farmed Atlantic Salmon

By Geir Bornø and Haakon Hansen

Among the parasitic diseases and diseases in general, the salmon louse (*Lepeophtheirus salmonis*) remains one of the most significant challenges to salmonid farming. Infection levels in 2023 showed a slight decrease compared to 2022 and to the proceeding five-year period from 2017 to 2021, both in terms of adult female lice and preadult stages. While the production of salmon louse larvae during the wild salmon smolt migration period remained largely unchanged from 2022 in most production areas (PA), some regional variations were observed between different years. Salmon louse larval production during the spring smolt migration period increased from 2022 to 2023 in PA5, PA9, and PA13, while experiencing a decline in other areas.

In 2023, there was a 17 percent reduction in the number of medication-free treatments, although, as for 2022, they remained the predominant method for combating salmon lice infestations. The number of thermal treatments decreased by 24 percent from 2022, with mechanical delousing being the single most common delousing method in 2023. The number of weeks were medication-based lice treatment were carried out, remained relatively stable compared to 2022, with only a 6 percent reduction.

From the survey, it was apparent that increased mortality post-delousing is still considered to be very important, and delousing likely contributes indirectly to a large proportion of the overall mortality in the sea phase. Responses also highlights that injuries caused by delousing is considered a significant cause of reduced welfare.

Sea lice (*Caligus elongatus)* infestations do not appear to have posed major challenges in 2023, while there have been reports earlier years of cases where sea lice were such a significant problem that specific treatment were administered against it. Feedback from fish health personnel and inspectors from the Norwegian Food Safety Authority shows that sea lice infestations in 2023 are ranked low and pose few challenges.

Parvicapsulosis caused by the myxozoan parasite *Parvicapsula pseudobranchicola*, is a recurring disease problem in Atlantic salmon aquaculture in Troms and Finnmark. In 2023, like in previous years, this parasite posed significant challenges in terms of mortality, growth, and fish welfare. Based on the data and feedback received, it appears that disease associated with this parasite may exhibit a broader geographical distribution compared to previous years.

Paramoeba perurans, the causal agent of amoebic gill disease (AGD), was detected throughout the year from the county Vestland northward to the county Nordland. The parasite was detected at a significant number of sites in 2023, as was the disease. In cases of complex gill diseases of salmon in the ongrowing phase, *P. perurans* may be present alongside other parasites, such as the microsporidian *Desmozoon lepeophtherii*.

There are several other parasite species in farmed salmon that are commonly occurring and can become problematic. Most detections of these parasites are done by the fish health services. Since 2010, high prevalences of the tapeworm *Eubothrium crassum* have been reported from many farms, and problems with this parasite seem to be greatest in aquaculture facilities on the west coast and in central Norway. Additionally, single-celled parasites, such as *Ichthyobodo necator* (infecting salmon in freshwater), *I. salmonis* (infecting salmon in freshwater and in the sea), and *Trichodina* spp.

are commonly occurring in Norwegian fish farms. Based on the survey, problems with these parasites appears relatively low nationwide.

The x-cell parasite *Salmoxcellia vastator* (Figure 9.1), which was described from salmon and rainbow trout in 2021, was not detected in 2022 but was again detected in 2023 at two sites with rainbow trout. In one of these cases, the detection was considered clinically significant.

The parasite *Spironucleus salmonicida* also posed challenges in salmon farms Finnmark in 2023. Several facilities in the region experienced outbreaks of systemic spironucleosis. Since its first detection in 1989, there have been outbreaks in Troms and Finnmark with approximately 10 years intervals. However, the disease outbreaks in 2022 and 2023 were at a level not seen before. Systemic spironucleosis is a serious diagnosis with significant consequences for fish health, welfare, and economics.

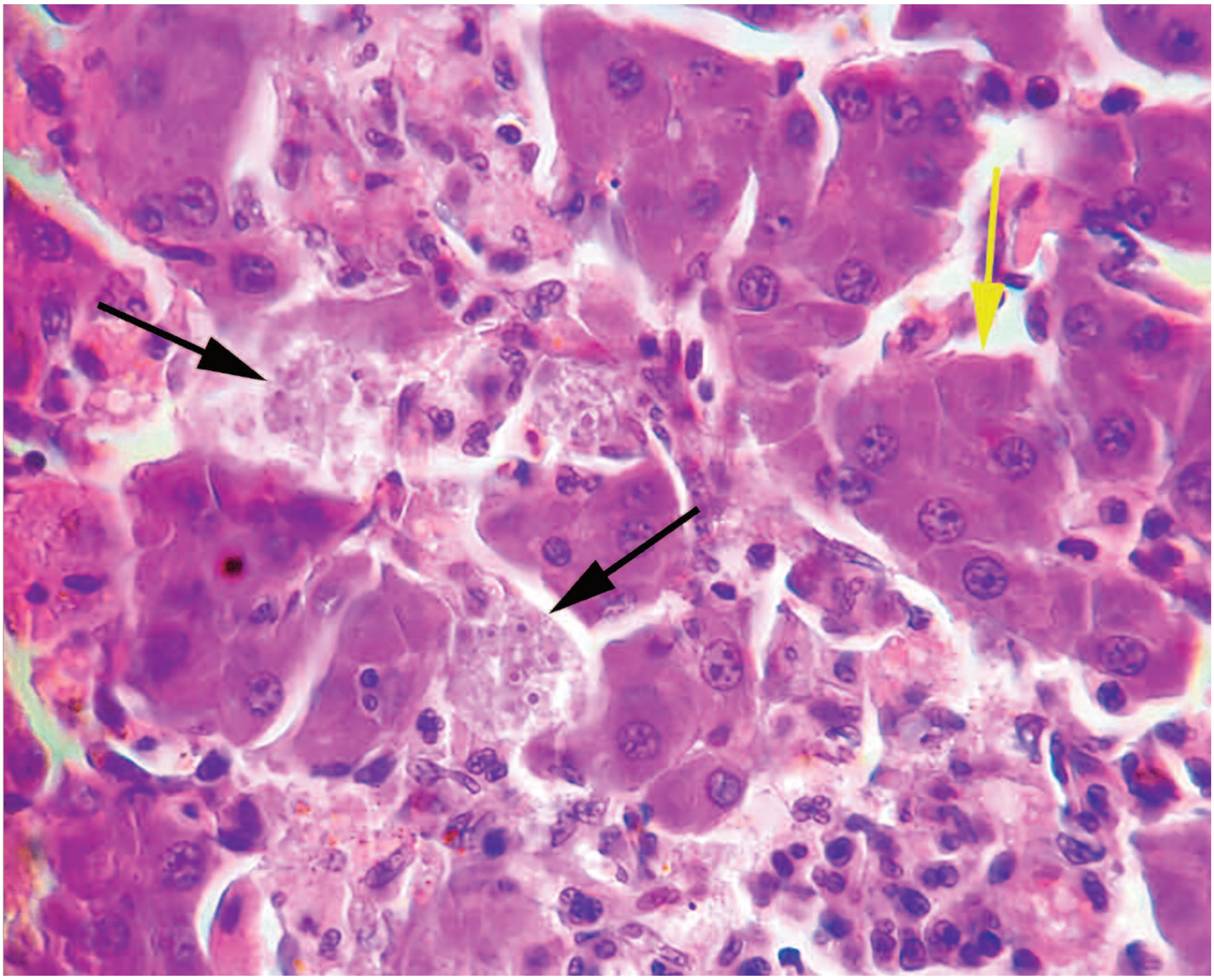


Figure 9.1 Tissue section of liver from salmon infected with the x-cell parasite *Salmoxcellia vastator* (black arrows). Each parasite contains several nucleus-like structures. Yellow arrow indicates normal liver cells (HE staining). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

9.1 Salmon lice (*Lepeophtheirus salmonis*)

By Lars Qviller, Leif Christian Stige and Kari Olli Helgesen

The disease

The salmon louse (*Lepeophtheirus salmonis*) is a naturally occurring crustacean parasite on salmonid fish in marine environments in the Northern Hemisphere (Figure 9.1.1). The life cycle consists of eight stages separated by exoskeleton moults. The parasite reproduces sexually. Adult females can produce up to 11 pairs of egg strings, each containing several hundred eggs. At high temperatures, each pair of egg strings hatches with a few days apart, while at low temperatures, it takes several weeks. The eggs hatch into larvae, which spread as plankton with ocean currents. In the first three planktonic stages, which can last for several weeks at low temperatures, the lice larvae can spread over many kilometers. The last five life stages are all parasitic on anadromous salmonids in their marine environment.

Salmon lice feed on the skin, mucus, and blood of their salmonid hosts. If the burden of lice in their latest life stages becomes too massive, this can result in wounds and anemia in the fish. Lesions may then be entry points for secondary infections, and result in osmoregulatory problems for the fish. High lice infestation may be fatal to the host.

Lice larvae can spread between farmed fish and wild fish. Due to the louse's potential for transmission and the number of available hosts, as well as the potentially serious effects on both wild and farmed fish, salmon lice are considered one of the most serious problems in fish farming in Norway today.

Disease control

The regulations set targets for the number of lice allowed per fish in aquaculture; one limit in spring and another for the rest of the year. The limit is set lower in spring due to the outmigration of the wild salmon smolts. Lice levels are monitored and reported weekly from all marine farms holding salmon or rainbow trout.

The main control measure against lice has traditionally been the use of antiparasitic drugs, but increasing levels of resistance to the available drugs has led to a situation in which alternative treatment methods now dominate. Often, farmers use a combination of preventive measures and continuous delousing using methods such as cleaner fish, as well as delousing with both non-medicinal and medicinal methods.

Increased treatment frequency and increased use of non-medicinal control methods have led to a significant increase in the cost of salmon farming in open cages. Increased treatment frequency also has a cost for the fish, as there is a risk of injury and death associated with any treatment. For more information on salmon lice, see the factsheet (In Norwegian): **https://www.vetinst.no/sykdom-og-agens/lakselus**

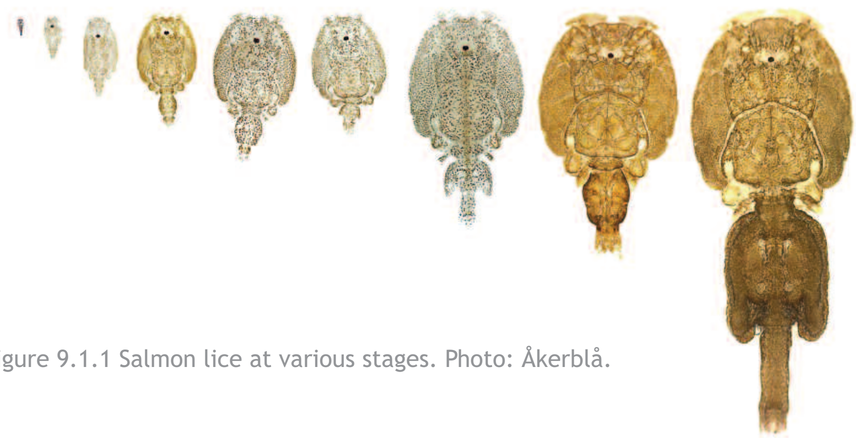


Figure 9.1.1 Salmon lice at various stages. Photo: Åkerblå.

The Health Situation in 2023

Official data

All marine farms producing salmonid fish are required to count and report the number of salmon lice weekly. The average of reported lice numbers per week for the entire country shows a cyclic variation, usually with the lowest lice count in spring and the highest in autumn (Figure 9.1.2). The highest number of adult female lice per fish was recorded in October (week 42) in 2023, while the highest number of other motile lice (preadults and adult males) per fish was recorded in January (week 1). The lowest number of adult female lice per fish was observed in May (week 21), while the lowest number of other motile lice per fish was observed in the transition between June and July (week 26). Overall, the lice level in 2023 was slightly better than in 2022 and in the five-year period from 2017 to 2021 (with an average of 0.14 adult female lice per fish in 2023 compared to 0.15 in both 2022 and the five-year period from 2017 to 2021,

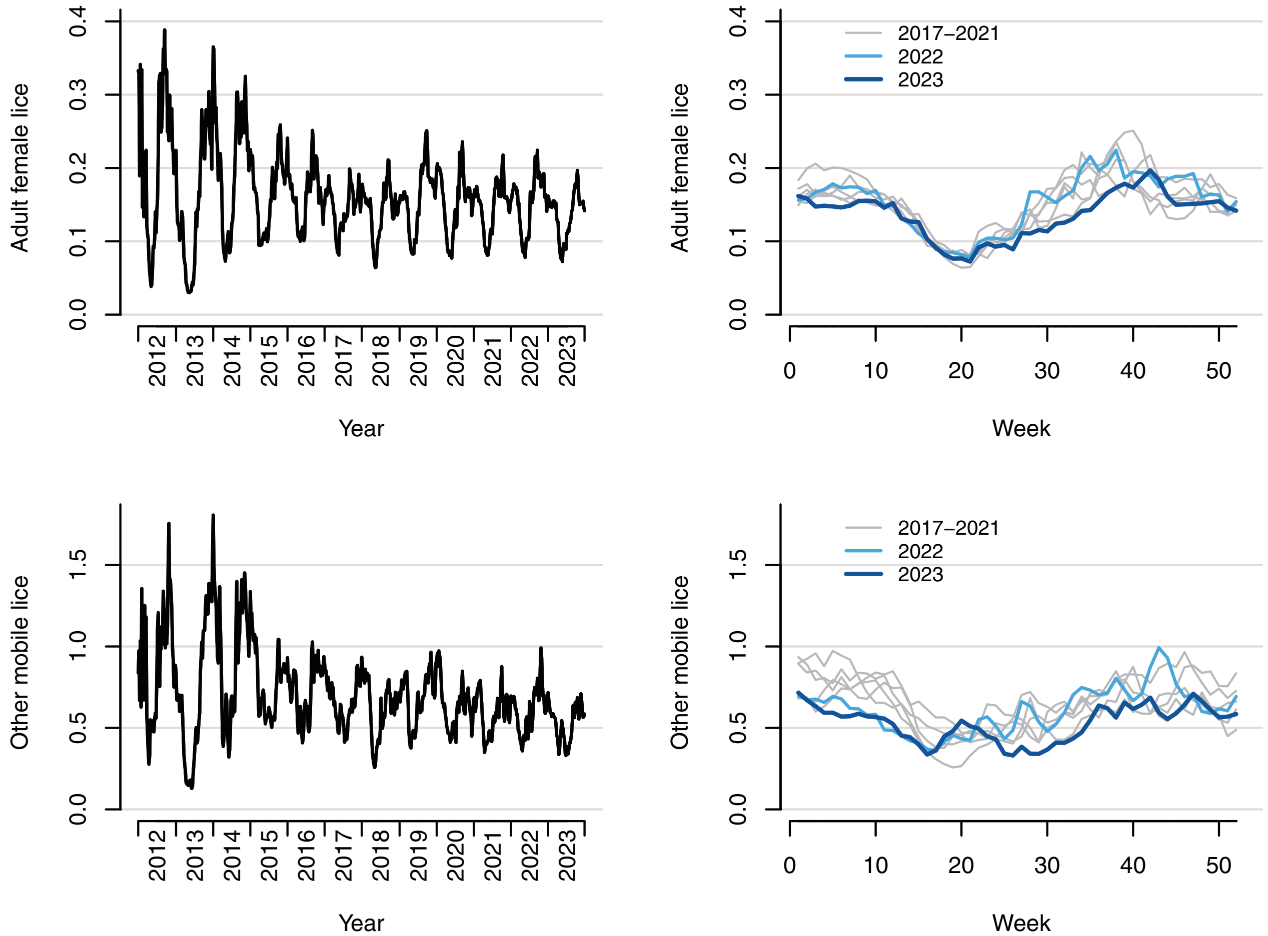


Figure 9.1.2 Average weekly reported salmon lice numbers from all marine aquaculture facilities, with salmon or rainbow trout, nationwide over the period January 2012 to December 2023 (downloaded from BarentsWatch 27.01.2024). The upper panels show adult female lice per fish, and the lower panels depict other motile stages of lice (preadult lice and adult male lice) per fish. The panels on the right show the seasonal trends for the past few years.

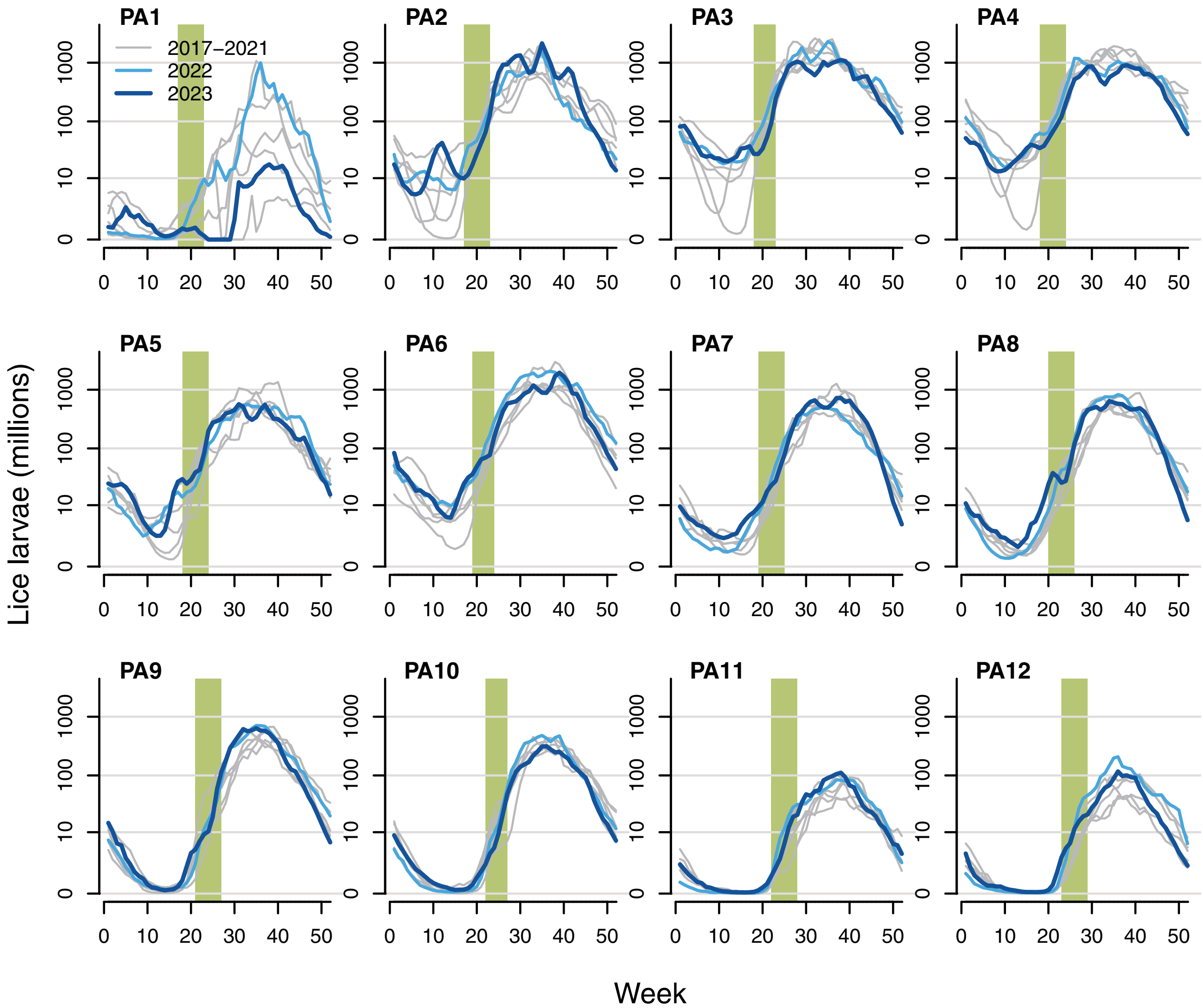


Figure 9.1.3 Estimated total production of salmon louse larvae (in millions) per week at all sites within each production area (PA). The lines depict the seasonal variation for each of the past years. Note that the y-axis is on a logarithmic scale. PA13 is excluded. This area had negligible larval production throughout the period (with the highest larval production estimated at 6.5 million larvae in week 41 of 2020). The green areas indicate the typical migration period of wild salmon smolts in each area.

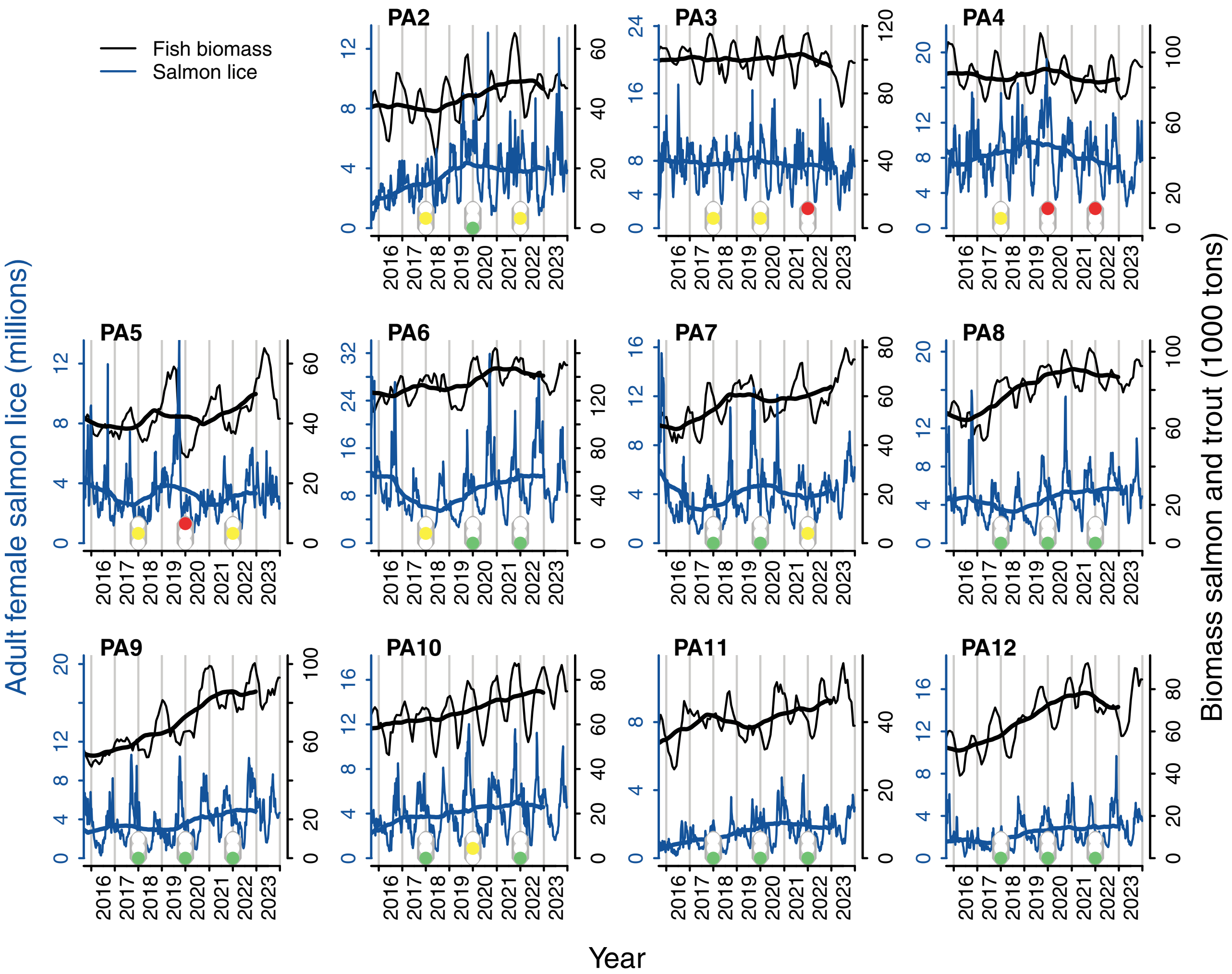


Figure 9.1.4 Temporal trends in salmon lice and farmed fish in each production area (PA) from 2016 to 2023. The blue lines represent the estimated total number of adult female lice on farmed fish, based on weekly reporting to the Norwegian Food Safety Authority. The black lines represent the biomass of salmon and rainbow trout in marine aquaculture facilities, based on monthly reporting to the Norwegian Directorate of Fisheries. The thick lines show moving two-year averages, so each point on the line represents the average for a period from one year before to one year after the time point, while the thin lines also show short-term variation. Note that the y-axis scale differs for different production areas. The traffic lights indicate which production areas received green, yellow, or red light decision in the Traffic Light System. Red lights for PA3 and PA4 in the first period are shown as yellow, as the red light did not result in a reduction in permitted production capacity. PA1 and PA13 are not shown because there were few operational aquaculture facilities in these areas.

while the average number of other motile lice per fish was 0.53 in 2023 compared to 0.61 in 2022 and 0.64 in the five-year period from 2017 to 2021).

To provide further insight into the situation regarding salmon lice beyond an assessment of average figures, we have calculated the production of salmon lice larvae. The calculation of lice larval production is based on reported lice numbers, sea temperatures, and fish numbers from all facilities, as well as knowledge of reproduction, development times, and survival rates of the various stages of salmon lice. The production of lice larvae is calculated for each of the 13 production areas (PAs) for the farming of salmonids along the coast (Chapter 1 Statistical basis for the report, Figure 1.1). Production growth in the aquaculture industry is to be assessed within each of these areas according to the so-called Traffic light system. For information on the Traffic light system and its status in 2023, see Chapter 11.4 Salmon lice and sustainability.

The highest larval production in 2023 occurred in PA2 to PA4 and PA6 (Figure 9.1.3). Larval production increased from 2022 to 2023 in PA2, PA7, PA11, and PA13, while it decreased in the other PAs. However, larval production in PA13 was still lower than in all other areas (90 percent lower than in the area with the second-lowest production, PA1). If one only looks at larval production during the out-migration period of wild salmon smolts, one sees that production in these weeks increased from 2022 to 2023 in PA5, PA9, and PA13, while it decreased in the other PAs. The larval production in PA2 and PA3 during the out-migration period in 2023, was also lower than in any year in the five-year period before 2022. The larval production was within the variation for this period in the other PAs.

The long-term trends in the total number of adult female lice in each production area are largely driven by trends in the amount of farmed fish (Figure 9.1.4). Changes in the number of female lice, in turn, affect the production of lice larvae, even though temperature and salinity also affect larval production. In PA2, however, there was an increasing trend in the biomass of farmed fish in the period 2019-2022, while the number of salmon lice remained fairly stable. Similarly, there has been a stronger decrease in the number of salmon lice in PA4 than expected based on the change in the biomass of farmed fish. This means that fewer salmon lice have been reported per kg of farmed fish in these areas. The permitted production capacity is regulated through the Traffic light system. As shown in the figure, the actual production does not always follow changes in the permitted production capacity. One reason for such differences is that the permitted production capacity is utilized to varying degrees at different times. Another reason is that facilities may be offered so-called exceptional growth if they document particularly low lice numbers and a maximum of one medicinal delousing treatment during the last production cycle, even if they are in red or yellow production areas (§12 of the Production area regulation). In broad terms, however, the pattern is that in green areas, the biomass of farmed fish and the number of salmon lice have increased, in yellow areas, the numbers have levelled off, and in red areas, the numbers have decreased.

When one distributes the produced lice larvae per week over the number of fish in the facilities, one sees significant differences in larval production per fish (Figure 9.1.5). The median value for the average production of lice larvae per fish per week was highest in PA3, and then decreased the further south or north the production area was located. This shows that the effect of any increased or decreased production of salmon and rainbow trout on the number of lice larvae produced will depend on where in the country the production change occurs.

The number of treatments against salmon lice in 2023 is summarized in Figure 9.1.6, Table 9.1.1, and Table 9.1.2. Medicinal treatments are the sum of the number of weeks the fish farms have reported treatments with the given active substance/substance class in their weekly reports to Norwegian Food Safety Authority (NFSA) (downloaded from Barentswatch.no). Treatments may have been carried out on individual cages or on entire facilities.

Figure 9.1.6 shows that the substantial reduction in the number of medicinal treatment-weeks, seen from 2015 to 2018, levelled off from 2019. On a substance/substance class-level Table 9.1.1 shows an increase in the number of weeks of azamethiphos-treatments in 2023 compared to 2022. This continues a trend of yearly increase, that started in 2019. The yearly decrease in hydrogen peroxide treatments that started in 2016, continued in 2023. The number of treatments using pyrethroids or emamectin benzoate were reduced compared to 2022, while the number of flubenzurone-treatments increased slightly. Emamectin benzoate was the most frequently used active substance in 2023 (55 percent of the treatments). Worth noticing is that medicated feed (emamectin benzoate and flubenzurones) are used over a period of days. These treatments are therefore more likely to be performed in consecutive weeks compared to bath treatments. The relatively frequent use of emamectin benzoate may be caused by the fact that the substance is said to prevent new infestation, in addition to being used to treat existing salmon lice infestations. Imidacloprid was marketed against salmon lice in Norway in 2021. This was the first time an active substances from a new class of antiparasitics were available for salmon lice treatments in Norway in two decades. Treatments with imidacloprid were registered first in 2023; with 11 treatment weeks. This is despite the fact that there were 24, 75 and 52 prescriptions issued for the new imidacloprid-medicine in 2021, 2022 and 2023 respectively (data from the Veterinary prescription registry (VetReg), downloaded 17.01.2024). What “other substance” in Table 9.1.1 means is not given. No use of medicines against salmon lice with other active substances/substance classes than the ones given in Table 9.1.1 is registered in VetReg in 2013-2023.

It is considered highly likely that the significant reduction in number of medicinal treatments and the increase in the use of non-medicinal treatment forms is related to development of resistance in the salmon lice. The resistance problem has been highlighted since 2014 in the annual reports of the surveillance program for salmon louse resistance. This year’s report will be published on https://www.vetinst.no/overvaking/lakselus-resistens.

Table 9.1.1 The number of weeks with reported medical treatments of a given category of active substance from 2013 to 2023. Pyrethroids are treatments containing the active substances deltamethrin and/or cypermethrin, while flubenzurons are treatments containing the active ingredients teflubenzuron and/or diflubenzuron. The numbers of treatment weeks were retrieved from Barentswatch on 06.02.24.

Active substance	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Azametiphos	375	560	485	208	57	33	76	122	151	239	273
Pyrethroids	840	779	526	230	72	51	67	48	34	31	14
Emamectin benzoate	171	438	601	637	521	454	581	605	607	586	540
Flubenzurones	196	208	242	279	142	77	104	90	57	35	58
Hydrogen peroxide	113	425	562	327	144	84	77	62	45	40	19
Imidacloprid	0	0	0	0	0	0	0	0	0	0	11
Other substance	148	185	338	824	197	40	24	13	74	100	59
Total	**1843**	**2595**	**2754**	**2505**	**1133**	**739**	**929**	**940**	**968**	**1031**	**974**

Table 9.1.2 Number of non-medicinal treatments reported [1]. The treatments are weeks in which sites have reported that they have carried out non-medicinal treatment against lice to the Norwegian Food Safety Authority (NFSA) as of 18.01.24. The treatment methods were divided into four categories: Thermal, mechanical, freshwater and other. Thermal treatment is defined as treatment with heated water and mechanical is defined as treatment using pressurised water and/or brushes. The combination categories indicate whether several delousing methods have been reported for the same farm in the same week.

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Thermal (TERM)	0	0	3	36	685	1245	1327	1447	1723	1456	1357	888
Mechanical (MECH)	4	2	37	34	311	236	423	674	823	862	1074	980
Freshwater (FW)	0	1	1	28	73	75	84	148	220	286	225	186
TERM + MECH	0	0	0	0	12	42	35	56	59	30	47	59
TERM + FW	0	0	0	0	16	21	17	27	20	63	141	227
MECH + FW	0	0	0	0	7	1	7	7	24	56	153	151
TERM + MECH + FW	0	0	0	0	0	0	1	0	1	5	9	12
Other	132	107	136	103	75	52	69	87	92	72	139	106
Total	**136**	**110**	**177**	**201**	**1179**	**1672**	**1963**	**2446**	**2962**	**2830**	**3145**	**2609**

[1] Until the autumn of 2023, categorized based on free text entries in lice reports to the NFSA. After the introduction of a new reporting form in the autumn of 2023, based on dropdown menus for treatment methods. Data reported to the NFSA as of January 18, 2024.

The number of reported non-medicinal delousing treatments decreased by 17 percent from 2022 to 2023 (Figure 9.1.6, Table 9.1.2). The non-medicinal delousing treatments sums up the number of weeks fish farms have registered the use of such methods in their weekly reports to NFSA. Since 2017 between 73 and 80 percent of the treatments were performed in some of the cages in the farm (and not all), but no figure for the proportion of the farm treated is provided. Therefore it is not possible to say if the reduction in treatment weeks also means a reduction in number of cages treated. However, the decrease in the number of treatment weeks is consistent with the salmon lice levels being lower in much of 2023, as compared to previous years, resulting in reduced need for treatments (Figure 9.1.2). With this, it appears that the increase in non-medicinal delousing, which has occurred most years since 2013, has now levelled off or reversed. Non-medicinal treatments are divided into categories: thermal (delousing with heated water), mechanical (delousing using water pressure and/or brushes), freshwater, and other. The number of thermal treatments decreased by 24 percent from 2022 to 2023 (including weeks when multiple non-medicinal methods were used). The number of mechanical delousings decreased by 6 percent, while the number of freshwater treatments, on the other hand, increased by 9 percent. Mechanical delousing was the most common non-medicinal delousing method in 2023 (46 percent of reported non-medicinal delousings, including weeks when multiple non-medicinal methods were used). Thermal delousing was nearly as common (45 percent), while freshwater was used in 22 percent of delousing events. In around 17 percent of weeks with non-medicinal delousing, multiple delousing types were reported to be used at the same facility (but not necessarily in the same cages). This is an increase from 11 percent in 2022 and 5 percent in 2021. The most frequently reported combinations were freshwater treatment together with either mechanical or thermal delousing. In addition to medicinal and non-medicinal treatments, various preventive methods against salmon lice and methods for continuous delousing were used, including lice skirts, cleaner fish, and the so-called lice laser.

The Annual Survey

In a survey targeting fish health personnel in fish health services, the NFSA, and aquaculture companies, respondents were asked about salmon lice in general and damages related to delousing in particular. Among 102 respondents who answered questions about causes of mortality in salmon at ongrowing facilities, only two chose grazing damage from salmon lice as one of the five most important causes, while 81 selected damages from delousing (Appendix B1). Overall, delousing-related damages were ranked as the most significant cause of mortality in ongrowing facilities for salmon in 2023. Regarding causes of reduced welfare in salmon during the ongrowing phase, ten out of 102 respondents selected salmon lice as one of the five most important causes, while 86 selected damages from delousing. This ranked salmon lice twelfth and delousing-related damages first on the list of causes of reduced welfare. In response to which problems were considered the five most important increasing issues for salmon in the ongrowing phase in 2023, four out of the 100 respondents chose grazing damage from salmon lice. Delousing-related damages were selected by 40 respondents, ranking as the third most important increasing problem in 2023. Additionally, 49 out of 99 respondents indicated that damages related to delousing were one of the five most important causes of reduced growth. Similar findings were observed for rainbow trout in ongrowing facilities, where mechanical damages from delousing were considered the most significant cause of both mortality and reduced welfare (Appendix B2).

The responses in the survey also indicate that treatments against salmon lice can be a problem in broodstock facilities (Appendices C1 and C2). Mechanical injuries resulting from delousing are ranked as the primary cause of both mortality and reduced welfare in broodstock facilities with salmon, and four out of fourteen respondents believe such injuries constitute an increasing problem. Grazing damage from salmon lice was not reported as an issue in broodstock facilities.

Free-text responses regarding the effectiveness and welfare implications of non-medicinal delousing methods vary. Several report good delousing efficacy and improved welfare when combining freshwater with other non-medicinal methods, especially in combination with thermal delousing. However, five respondents experience reduced delousing efficacy when using freshwater.

In total, 80 respondents had answered questions about injuries and mortality related to delousing. Of these, 81 percent reported experiencing increased acute mortality (over 0.2 percent mortality in the first three days after delousing) associated with delousing using heated water. Sixty-six percent of the respondents reported increased acute mortality when using mechanical methods, and 31 percent when using freshwater. Furthermore, 68 percent reported increased mortality in the first two weeks (delayed increased mortality) after delousing with tempered water, 60 percent with mechanical methods, and 26 percent with freshwater delousing. Increased acute mortality was thus most frequently reported with thermal delousing, followed by mechanical delousing, and least frequently with freshwater delousing among non-medicinal delousing methods. Similarly, increased delayed mortality was most frequently reported with thermal delousing, followed by mechanical delousing, and least frequently with freshwater delousing among non-medicinal delousing methods. The order is consistent with responses to similar questions in previous years. However, in previous years, these questions were answered with graded responses on a scale from 1 to 5. More details about welfare effects of non-medicinal delousing are discussed in Chapter 5 Fish Welfare.

Evaluation of the salmon lice situation

The average number of salmon lice per farmed fish nationwide was slightly lower in parts of 2023 than in previous years, while for the rest of the year, it remained within the variation seen in recent years. In PA2 and PA4, there are indications of a decreasing trend in the total number of salmon lice, which, in addition to the reported average lice count per fish, depends on the number of farmed fish. In most other areas, the trend is increasing, consistent with the increasing biomass of farmed fish.

The production of salmon lice larvae during the wild salmon smolt migration period, which, in addition to the total number of lice, depends on sea temperature, was lower than in previous years in PA2 and PA3. In the other production areas, larval production during the wild salmon smolt migration period did not deviate from recent years. The production of salmon lice was highest in PA2 to PA4 and PA6.

We observed a reduced use of non-medicinal lice treatments compared to 2022 (a total reduction of 17 percent), and simultaneously, a slight reduction in the use of medicinal treatments (a total reduction of 6 percent). The reduction in non-medicinal delousing occurred for both mechanical and thermal delousing, while the number of freshwater delousing treatments increased by 9 percent. Mechanical and thermal treatments were most common and used almost as often. In 2023, the increase in weeks where multiple non-medicinal methods were reported to be used at the same site continued; from 11 percent of the weeks in 2022 to 17 percent in 2023. We also note that the use of azamethiphos has increased for the fifth consecutive year, and in 2023, there was moderate use of the drug registered for lice treatment in 2021; containing the active ingredient imidacloprid (11 treatment weeks and 52 prescriptions).

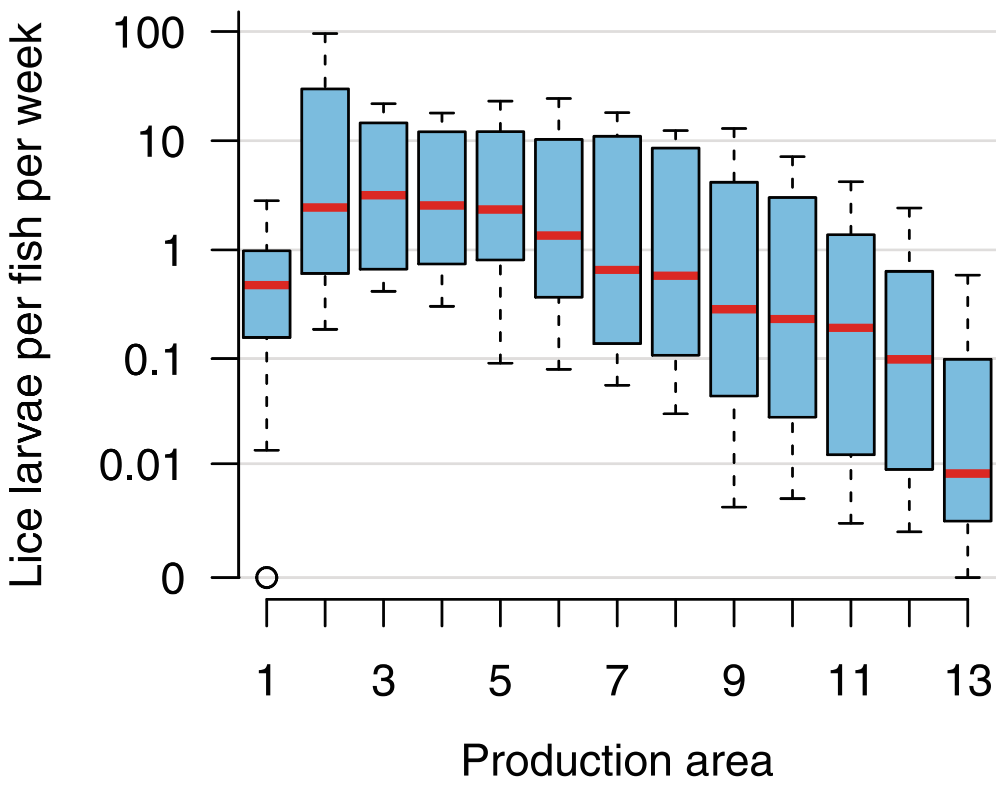


Figure 9.1.5 Estimated average production of lice larvae per fish per week within each production area (PA1- PA13) in 2023. The red lines represent median values, while 50% of the values are within the blue boxes.

Since 2017, measures against salmon lice have mainly been non-medicinal. In 2023, non-medicinal measures were reported to be used almost three times as often as medicinal measures. Fish health personnel reported through the survey that particularly thermal and mechanical treatments often resulted in increased mortality in the period after treatment. A total of 2609 non-medicinal treatments were reported in 2023, and it is therefore reasonable to assume that such treatments have a significant impact on the total mortality of salmon and rainbow trout at sea. In addition, delousing-related injuries were selected by fish health personnel as the most important causes of reduced welfare for both salmon and rainbow trout in this year's survey. This further emphasizes the connection between salmon lice treatments and fish welfare. The free-text responses indicate that many find effective combinations of non-medicinal methods where the mortality can be kept low, thus indicating a positive development. However, the use of various non-medicinal and medicinal methods, as well as combination treatments, presents a complex treatment landscape that can be challenging to understand the extent of. The welfare challenges associated with this increase are further discussed in Chapter 5. Five free-text responses report reduced treatment effectiveness when using freshwater, which may indicate some resistance development against freshwater. Reduced treatment effectiveness does not necessarily indicate resistance development, but such reports are cause for concern. If salmon lice were to develop resistance to freshwater, it could have serious consequences for wild salmonids.

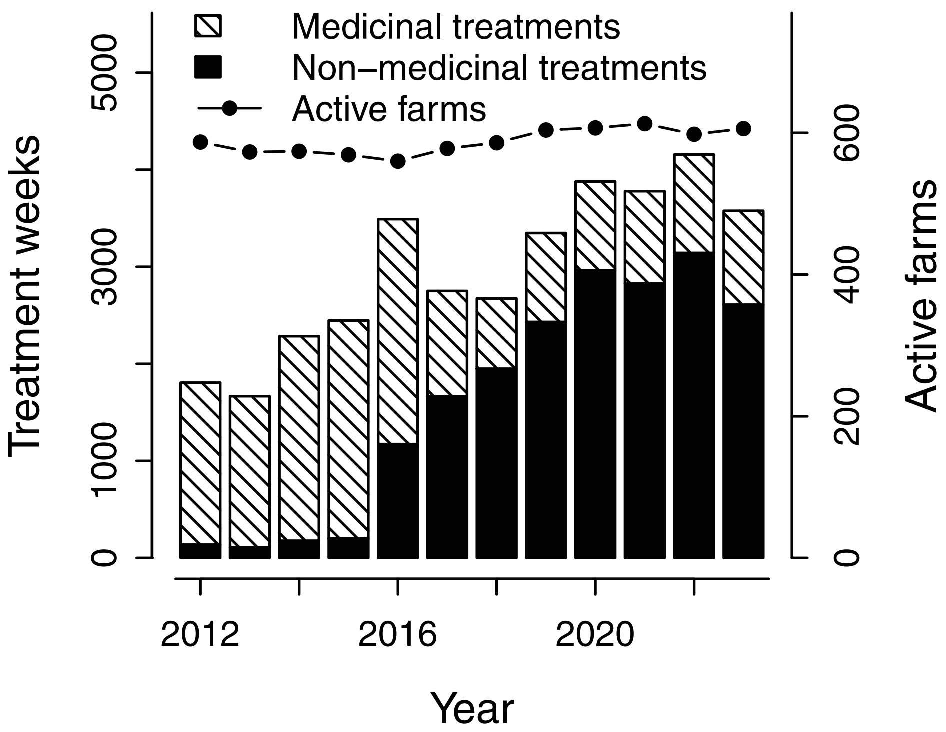


Figure 9.1.6 Number of reported medicinal and non-medicinal treatments against salmon lice and the number of active fish farms from 2012 to 2023. Treatments represent weeks where facilities have reported to the Norwegian Food Safety Authority that they have conducted lice treatments (downloaded from BarentsWatch on February 6, 2024). The number of active facilities is the average number of fish farms with salmon or trout in the sea in the respective year.

9.2 Sea louse - *Caligus elongatus*

By Geir Bornø, Øivind Øines, and Haakon Hansen

The disease

Caligus elongatus is a parasitic crustacean in the same family (Caligidae) as the salmon louse *Lepeophtheirus salmonis*. Like its relative, it primarily lives on the skin of fish in saltwater, although the very first nauplii stages after hatching do not require a fish host as the parasite swims freely in the water until it reaches the infective copepodid stage. The parasite has much lower host specificity than the salmon louse, which is only found on salmonid fish. *C. elongatus* has been found on about 80 species of fish, including salmonids, codfish, herring, flatfish, blennies, and lumpfish. Lumpfish is one of the main hosts of this parasite. Therefore, the crustacean is not only a parasite on salmon but also on the fish species used to reduce the number of salmon lice on farmed fish.

Like the salmon louse, *Caligus elongatus* has a direct life cycle without intermediate hosts, consisting of eight stages with molting between each stage. It is the copepodid stage and the adult stages that are capable of moving between host fish, as the other chalimus stages will be permanently attached to the fish, via a chitin thread that anchors it to the fish's surface. When the parasite reaches the adult stage, this anchoring will loosen, and the parasite can again move freely around on the host fish, or between hosts if it wishes. The speed at which it transitions between the various stages is mainly determined by temperature. The stages are somewhat different from the stages found in the salmon louse. The adult stages are more mobile than those of the salmon louse and highly capable swimmers. This means that they can undergo active host shifts, allowing lice from lumpfish to easily jump off the fish and infect salmon, and vice versa, under aquaculture conditions. Salmon, and any cleaner fish in the pens, can also become infected with *C. elongatus* from fish outside the pens. Not only can infective copepodids from these fish pose an infestation pressure on pen fish, but adults can also quickly establish themselves in pen fish. Rapid establishment of *C. elongatus* in a pen, without observed attached chalimus stages over time, is likely a consequence of adults coming from other fish outside the pen.

Calingus elongatus can cause damage to the skin of host fish, which can lead to secondary infections, but it generally inflicts less damage on the host than the salmon louse.

Caligus elongatus can be morphologically distinguished from the salmon louse by having so-called lunules on the underside right at the front of the cephalothorax (head part). During lice counts, the parasite can be distinguished from salmon lice, among other things, by being more translucent and less colorful, smaller, and often more mobile than salmon lice. However, it still requires good training to tell the difference. The mobility of *C. elongatus* can also lead to them jumping off before they are registered during counts. The parasite is sensitive to changes in salinity and is more likely to jump off fish that reside in less salty water.

Disease control

It has been reported, especially from the northern areas, that infestation with *Caligus elongatus* in some cases has been such a significant problem that treatment has been carried out against this parasite alone. However, treatment against *C. elongatus* is most often done simultaneously with treatment against salmon lice. It is reported that all medications have good efficacy against the parasite.

The Health Situation in 2023

The Annual Survey

In 2023, Caligus elongatus is ranked as a somewhat smaller problem than in previous years (Appendix B1). Seven out of 100 respondents believe that the parasite is an increasing problem for salmon in ongrowing facilities, which is halved from 2022. Three out of 99 respondents consider the parasite to be associated with reduced welfare, three out of 102 respondents believe it contributes to mortality, and six out of 102 respondents have indicated that the parasite contributes to reduced growth. Caligus elongatus was not registered as problematic in broodstock facilities with salmon. The same was the case for rainbow trout in either ongrowing or broodstock facilities (Appendices B1, C1, and C2).

Evaluation of the Caligus elongatus situation

Infestations with Caligus elongatus seem to have somewhat less extent in 2023 compared to previous years. Previously, challenges with skottelus have been greatest in northern Norway (PA10-PA13), but for 2023, there are no specific challenges reported by those who responded to the survey.

Figure 9.2.1 Salmon lice and *Caligus elongatus* (less) on sea trout. Photo: Rune Nilsen, Institute of Marine Research

9.3 Parvicapsulosis - *Parvicapsula pseudobranchicola*

By Haakon Hansen and Geir Bornø

The disease

Parvicapsulosis, caused by the parasite *Parvicapsula pseudobranchicola*, is a significant disease of Atlantic salmon in farms in Troms and Finnmark and the mortality rates during outbreaks are high in some instances.

Parvicapsula pseudobranchicola (Figure 9.3.1), is a parasite within the group Myxozoa and the class Myxosporea, myxosporidia. It has a complex life cycle, with a polychaete as the primary host and a salmonid fish as its intermediate hosts. While the parasite predominantly induces disease in farmed fish in northern regions, the parasite itself is commonly found in wild salmonid fish, including salmon, sea trout, and sea char, along the entire Norwegian coastline.

The primary target organ for *P. pseudobranchicola* in fish is the pseudobranchs, an organ responsible for supplying oxygen-rich blood to the eyes. The parasite's spores can infiltrate large portions of the tissue, causing extensive damage over time. Severe pseudobranch damage, including complete degeneration of the tissue, can result in reduced blood and oxygen supply to the eyes, potentially leading to impaired vision or blindness. Detection of the parasite is typically performed by histology and PCR.

For further information on parvicapsulosis, please refer to the fact sheet provided by the Norwegian Veterinary Institute:
https://www.vetinst.no/sykdom-og-agens/parvicapsulose

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private Laboratories

Data compiled from the Norwegian Veterinary Institute and private laboratories show that parvicapsulosis was detected in 25 salmon farms in 2023, which is similar to the levels observed in 2022. Of these farms, eleven were in PA12 and PA13. The remaining detections were distributed across PA6 (one location), PA8 (four locations), PA9 (four locations), PA10 (three locations), and PA11 (two locations). Additionally, the detection of the parasite
P. pseudobranchicola (PCR) were reported from 23 salmon locations, with twelve of these indicating the parasite to be of clinical significance, most of these in PA7.

The Annual Survey

While parvicapsulosis has been a recurring issue in salmon farming in the northernmost areas for many years, the 2023 survey did not report any noteworthy developments related to this disease. Although some problems regarding mortality and reduced welfare were noted, the primary feedback focused on issues with diminished growth (reported by 11 out of 99 respondents) (Appendix B1). The respondents did not perceive parvicapsulosis as an increasing problem (Chapter 5 Fish welfare, Figure 5.2.1C).

Evaluation of the Parvicapsulosis Situation

Parvicapsulosis remains a significant disease in salmon farming, especially in the northernmost regions. While outbreaks of the disease are mainly seen in the two northernmost counties, outbreaks also occurred in PA6, PA8, and PA9 in 2023, and this is a more geographically widespread occurrence of disease outbreaks compared to previous years. Given the known distribution of the parasite in wild salmonids along the entire coast, its detection also in farmed fish beyond the northernmost regions is plausible. However, it is premature to speculate whether outbreaks will become more prevalent further south in the future.

In 2023, an Icelandic research group claimed to have identified the final host for the parasite. This new knowledge will provide the basis for new studies of the parasite's biology and life cycle, which again can result in mitigating measures for the disease. Parvicapsulosis continues to present challenges in terms of increased mortality, diminished fish welfare, and stunted growth and no treatment exists for this disease.

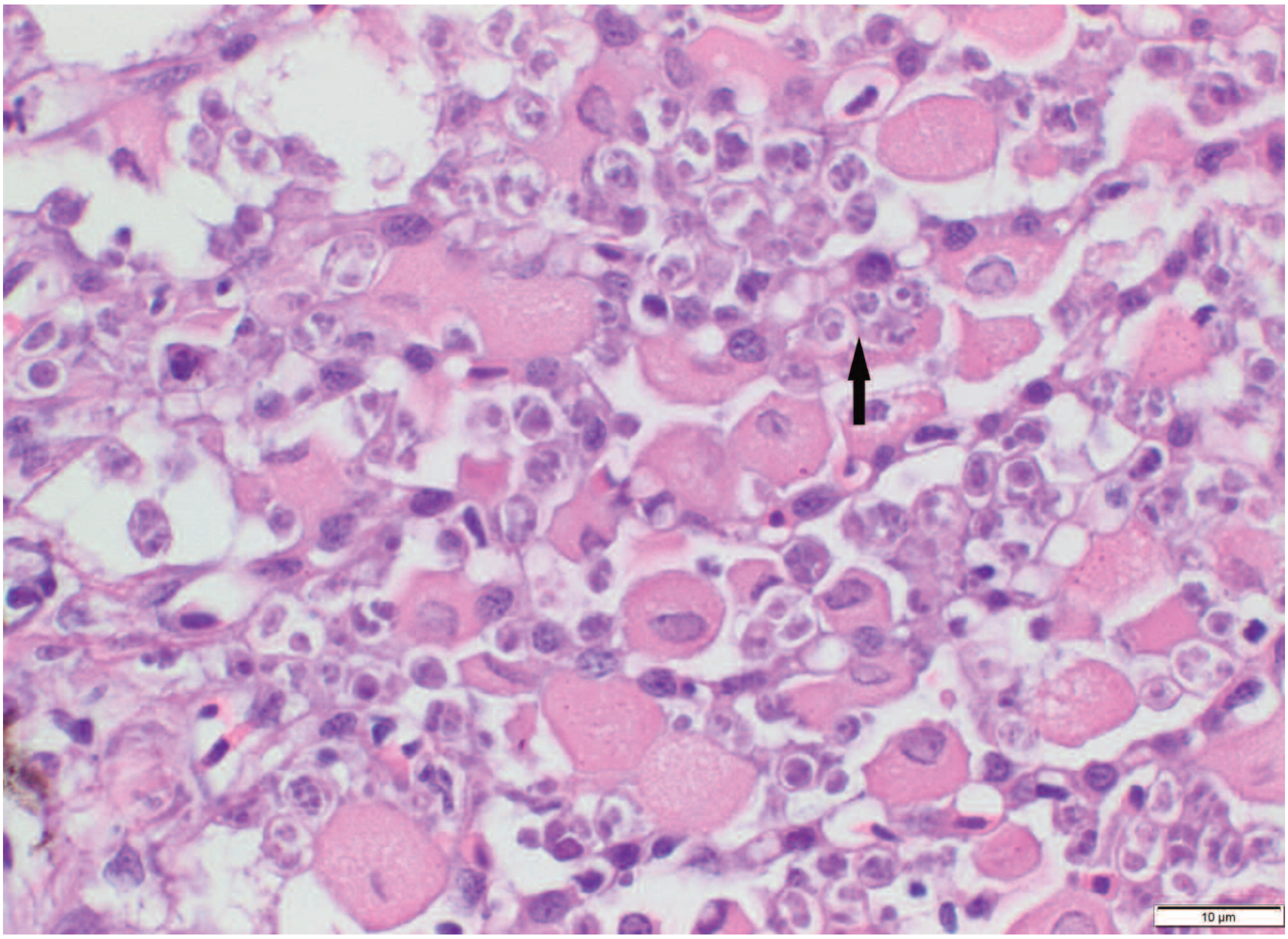


Figure 9.3.1: Pseudobranchia in salmon affected by the multicellular parasite *Parvicapsula pseudobranchicola* (indicated by the arrow). Photo: Toni Erkinharju, Norwegian Veterinary Institute.

9.4 Amoebic gill disease (AGD) - *Paramoeba perurans*

By Geir Bornø and Haakon Hansen

The disease

Amoebic Gill Disease (AGD) is caused by the amoeba *Paramoeba perurans* (synonym *Neoparamoeba perurans*). AGD is not a notifiable disease.

Since the mid-1980s, the disease has annually caused significant losses in the production of farmed salmon in Australia (Tasmania). In the mid-1990s, *P. perurans* was discovered in the Atlantic Ocean, and the amoeba has since been detected increasingly further north. *P.perurans* and AGD was first detected in Norwegian farmed salmon in 2006, but several years passed without subsequent detection of the amoeba. However, since 2012, the amoeba has caused significant losses in the Norwegian aquaculture industry. AGD occurs in farmed fish in saltwater, primarily in Atlantic salmon, but the disease has also been detected in other farmed species such as rainbow trout, turbot, lumpfish, and various wrasse species.

The two main risk factors for AGD outbreaks are stated to be high salinity and relatively high seawater temperature. Pathological findings are limited to the gills, where white, slimy patches can be seen with the naked eye (Figure 9.4.1). Amoebas from the gills can be detected in fresh smears examined under a microscope or by PCR. A definitive AGD diagnosis is made through microscopic examination of the tissue (histology).

Disease control

AGD is treated with hydrogen peroxide (H_2O_2) or freshwater. Neither treatment appears to be 100 percent effective, and treatment may sometimes need to be repeated within the same production cycle. Treatment with freshwater is gentler for salmonids and seems to be more effective against the amoeba than treatment with H_2O_2.

Treatment for AGD is most effective when administered early in the disease development. This

Figure 9.4.1 Amoebic Gill Disease (AGD) in salmon. The white spots on the gills caused by the amoeba *Paramoeba perurans*. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

reduces the likelihood of relapse and the time it takes for AGD to redevelop. Therefore, it is important to monitor the presence of amoebas on farmed fish to detect the disease at an early stage. This is usually done through PCR screening and visual examination of the gills.

A specific scoring system has been developed for classifying macroscopic gill changes caused by AGD. This scoring system is an important tool for fish health services. After repeated treatments, evaluating gill scores can be difficult, and the method requires a lot of experience. There are several factors/agents that can induce AGD-like gill changes, so it is important to confirm an AGD diagnosis with histological examinations and PCR analyses.

For more information about AGD, see the Norwegian Veterinary Institute's fact sheet: **https://www.vetinst.no/sykdom-og-agens/amobegjellesykdom**

The Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

AGD was identified at 73 salmon sites and four rainbow trout sites in 2023. This is at the same level as in 2022. Most findings are reported from PA6, with 28 sites, but the disease has been detected from PA1 to PA8 (Figure 9.4.2). Only the agent (*P. perurans)* was detected at 175 salmon sites and three rainbow trout sites. Of these, approximately one-third were reported to have clinical significance (associated with disease) while the rest were either not answered regarding field clinical significance or were reported to be without clinical significance. *P. perurans* with unknown clinical significance was detected as far north as PA9.

The Annual Survey

Feedback from the survey shows that about a tenth of the respondents believe that AGD is increasing in occurrence in salmon during the grow-out phase (Appendix B1). AGD is considered a relatively important contributor to reduced growth in salmon farming in the sea and to some extent also as a cause of mortality and poor welfare. Some respondents believe that AGD is increasing in occurrence and importance for reduced growth and poor welfare in broodstock facilities with salmon (Appendix C1). None of the respondents believed that AGD is a problem for rainbow trout, neither in ongrowing or broodstock facilities (Appendices B2 and C2).

Evaluation of the AGD Situation

AGD continues to be a serious disease in Norway but seems to have stabilized at the level of 2022. There is a high number of sites reporting problems with AGD. The disease has been detected in PA8, which is further north than previous detections, and southward. The number of outbreaks and severity of individual outbreaks vary from year to year, which may be related to climatic conditions.

Farmed and fish health services have gained good experience in managing AGD, both in determining if treatment is necessary and when treatment should be carried out during disease development. This, along with frequent screening, contributes to better disease control.

In some areas, increased experience and knowledge has led to fewer treatments because the stakeholders have found that the disease can naturally phase out, especially with changes in environmental conditions in late autumn.

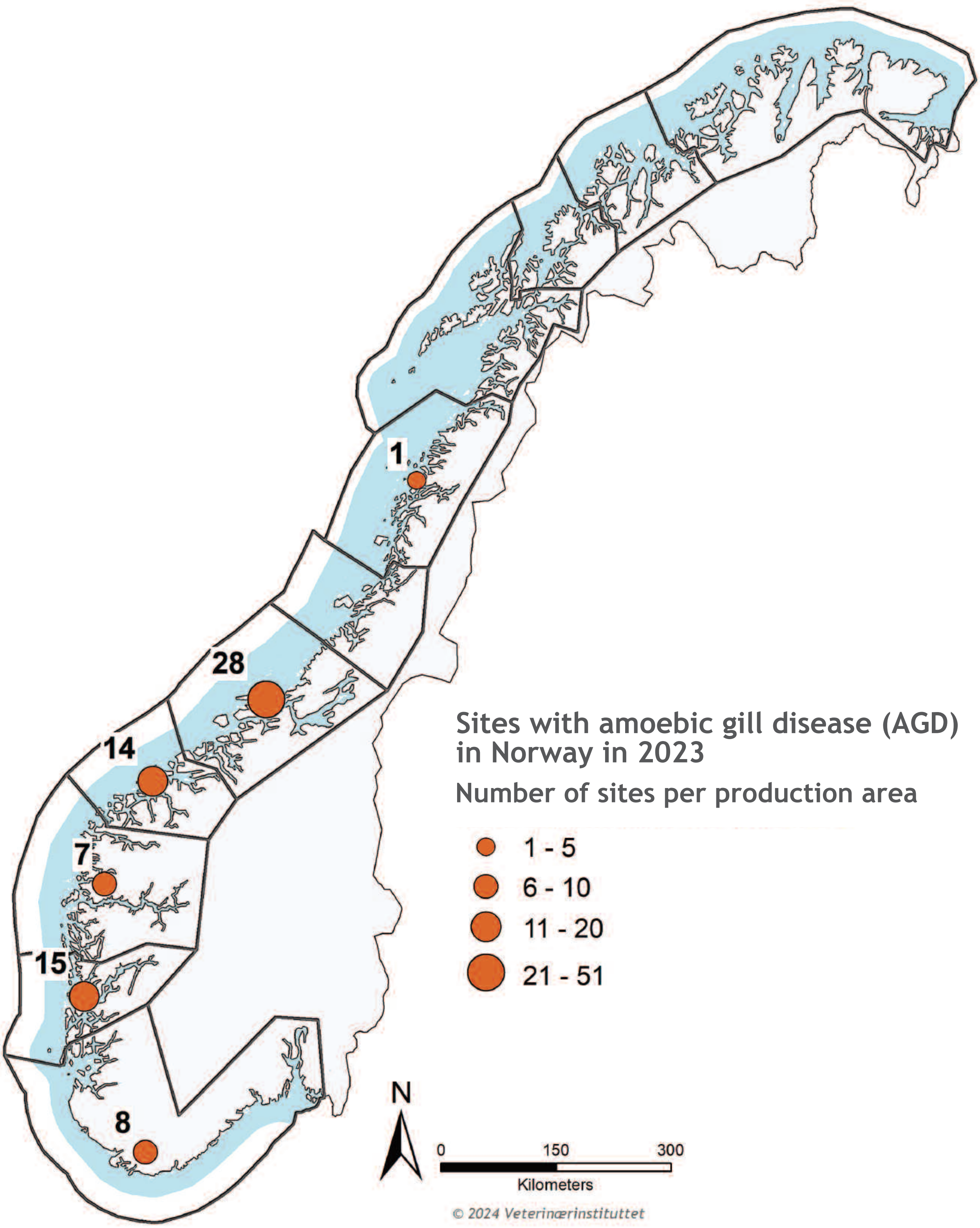


Figure 9.4.2 Number of AGD diagnoses in 2023 distributed across production areas (PA), based on compiled data from the Norwegian Veterinary Institute and private laboratories. Few sites in PA1 and PA2 have resulted in the merging of these production areas. The same applies to PA12 and PA13. Illustration: Attila Tarpai.

9.5 Tapeworms – *Eubothrium crassum*

By Haakon Hansen and Geir Bornø

The disease

Tapeworms (Cestoda) belong to flatworms (Platyhelminthes), and are parasites that reach sexual maturity in the intestines of their hosts. Their life cycles are complex, involving multiple hosts, with fish serving as both intermediate and final hosts for various tapeworm species. Among the tapeworm infestations detected in farmed Atlantic salmon during the marine phase, *Eubothrium crassum* (Figure 9.5.1) is the most prevalent. Copepods serves as the first intermediate hosts, and the fish become infected by ingesting copepods containing infective stages.

Inside the fish, adult *E. crassum* attaches itself with its scolex (head) in the pyloric caeca. These sexually mature parasite produces a high number of eggs, which are released into the water through the fish faeces, where they can be ingested by the copepod intermediate hosts. Left untreated, *E. crassum* can grow to a length exceeding one meter.

Infestation with tapeworms can lead to increased feed consumption and reduced growth in the fish. While *E. crassum* is commonly found in wild salmon throughout the country, both in fresh and salt water, the occurrence in farmed fish in the sea phase it is not common north of Trøndelag.

Disease control

Infestations with *Eubothrium* sp. are treated with praziquantel (PZQ). However, there have been concerning reports indicating either limited effectiveness or reduced efficacy of these treatments, possibly due to development of resistance to PZQ in *E. crassum*. A reduction in the number of reported treatments and a decline in the sale of PZQ was seen from 2015 to 2022. However, the sale of PZQ doubled from 2022 to 2023.

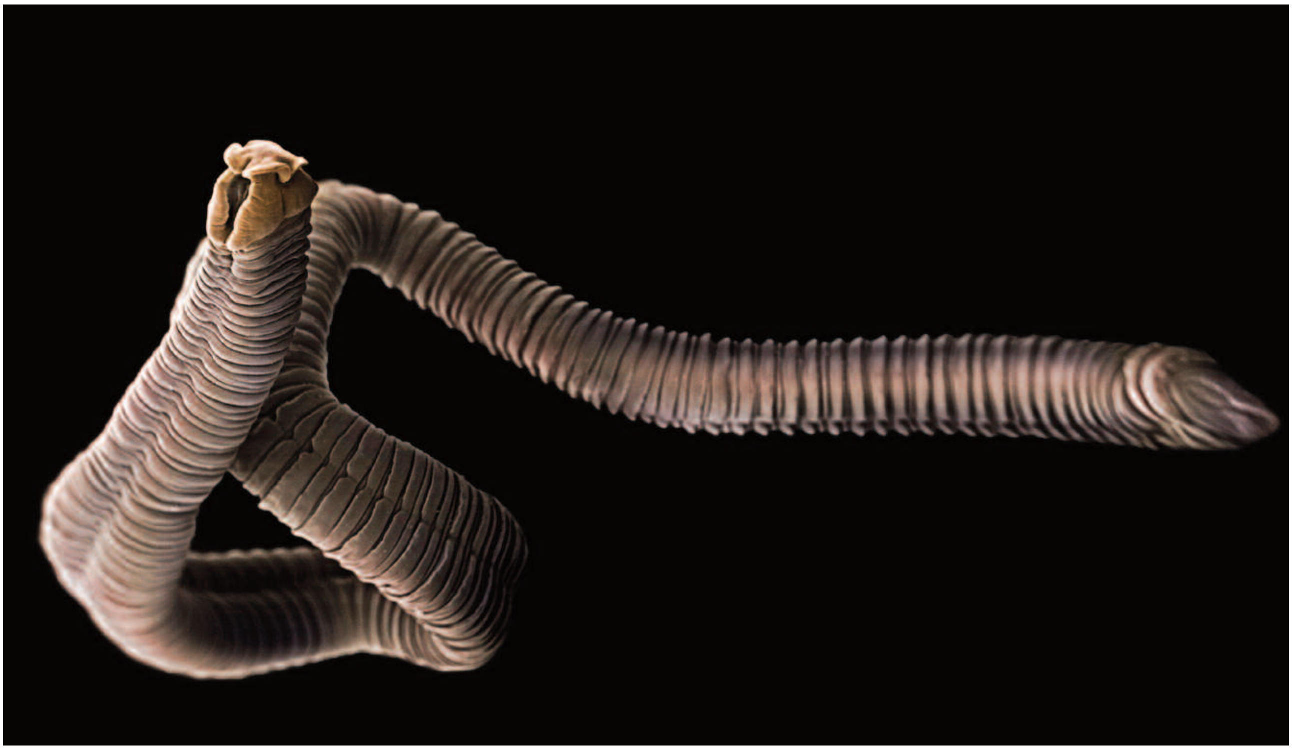


Figure 9.5.1 Tapeworm (*Eubothrium crassum*), magnified 50 times. Image taken with scanning electron microscope and colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

The health situation in 2023

Data from the Norwegian Veterinary Institute

In 2023, the Norwegian Veterinary Institute detected tapeworms in four ongrowing farms with Atlantic salmon, a slight decrease compared to previous years.

The Annual Survey

Two out of 99 respondents answered that tapeworm infestations leads to reduced growth in ongrowing farms with salmon (Appendix B1). Earlier reported concerns of compromised welfare associated with *E. crassum* infestations were not seen among this year's respondents, and tapeworms are not considered important for mortality. For salmon broodstock facilities, no respondents considered tapeworms an important cause of either mortality, growth or welfare (Appendix C1), and the same result was seen for ongrowing farms and broodstock facilities of rainbow trout. None of the respondents report tapeworms as an increasing problem (Appendix B2 and C2).

Evaluation of the tapeworm situation

Tapeworm infestations are commonly reported from salmon in the sea phase, especially in Western Norway and in central Norway and most detections are done by the fish health services. While tapeworms are generally not determined to species level, it is assumed that *E. crassum* constitutes the majority of cases. The feedback from the fish farming industry indicates a relatively stable situation regarding tapeworm prevalence.

Fish-eating birds can transport parasites over large areas via excrement. Photo: Eivind Senneset

9.6. Systemic spironucleosis - *Spironucleus salmonicidar*

By Haakon Hansen, Erik Sterud (Pure Salmon Technology), Toni Erkinharju and Geir Bornø

The disease

Systemic spironucleosis is caused by the parasite *Spironucleus salmonicida* and is a rare disease in farmed fish. *S. salmonicida* is a parasite of salmonids in freshwater, generally causing not harm to the fish, but when infecting salmon in the sea the infection can become systemic and result in severe disease. Also other species of *Spironucleus* have been detected in fish in Norway, both in salmon and other fish hosts, where they are typically inhabit the gall bladder and intestine, normally causing no harm.

Systemic, spironucleosis was first seen in Atlantic salmon in Finnmark in 1989-1991 in four ongrowing facilities that had all received smolt from the same hatchery. It is likely that this hatchery is the source of all cases of systemic spironucleosis in Finnmark to date. Following this first outbreak, it took about ten years before a new outbreak was seen in farmed salmon in 2001, also this time in Finnmark. In 2022, the disease was detected in farmed salmon in the sea, with subsequent mortality, at several farming facilities in Finnmark, and the challenges with the disease was ongoing throughout 2023. Following the outbreak in Finnmark in 2022, the parasite was also detected in lumpfish. This is surprising and demonstrates that the parasite can be transmitted from salmon to lumpfish in the marine phase (see also below and the Fish Health Report for 2022 for more details about the parasite and the disease).

In systemic spironucleosis, the parasite migrates from the intestine to all organs, including skin, internal organs and muscles, where it forms abscesses and other characteristic lesions (Figure 9.6.1 and 9.6.2). The factors triggering *S. salmonicida* to spread from the intestine to other tissues are unknown. Upon microscopic examination of the contents of the abscesses, there will typically be a multitude of highly mobile flagellates of approximately 10 µm. Mortality in farmed salmon can be high, but even in apparently healthy fish, muscle abscesses can be found at autopsy or slaughter, rendering the fish unsuitable for food. In the single outbreak seen on char so far, the char appeared less affected than the salmon. It was therefore speculated whether char is more resistant to the parasite than salmon.

The transmission mechanisms for *S. salmonicida* is unknown, and the actual infective stage is not identified. Most likely, the parasite spread as cysts (encapsulated individuals) freely in water, as transmission via a cyst stage is known from other species in the genera *Giardia* and *Spironucleus*. However, cysts have so far not been detected, although the parasite genome contains genes that code for proteins that are important for the formation of cyst walls. An alternative to spreading

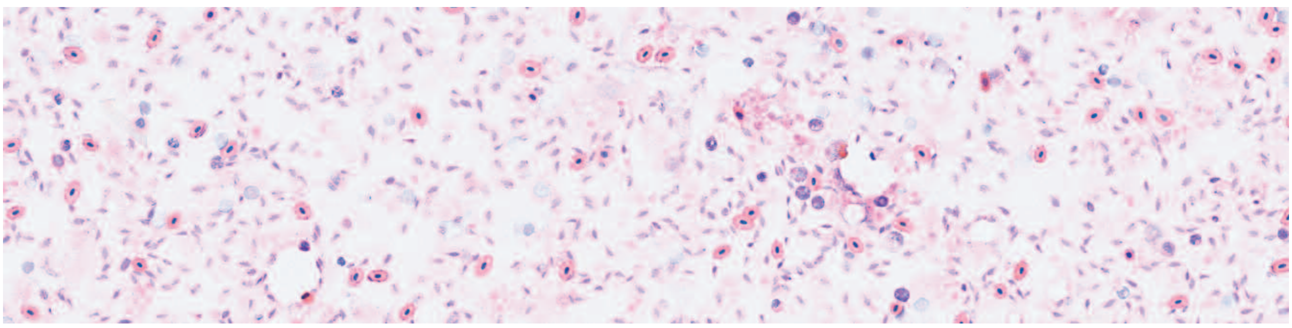


Figure 9.6.1. Smears from abscesses in salmon with abundant amounts of *Spironucleus salmonicida* flagellates. May-Grünwald-Giemsa stain. Photo: Toni Erkinharju, Veterinary Institute

via cysts is for the parasite to spread as free-swimming stages (called trophozoites), or via fish faeces containing trophozoites. In a recent study, it was demonstrated that trophozoites can be transmitted from fish to fish by oral ingestion, and this later lead to systemic disease. Due their solid walls, cysts are likely to be resistant to survival in the environment and will therefore have a much longer infectious period than trophozoites.

Spironucleus parasites are quite easy to recognize by light microscopy (Figure 9.6.1), but DNA analyzes are required to identify the species. Both conventional PCR and qPCR methodology are available for identification of the species and it is recommended to examine several tissues, including the intestine, to increase the probability of detecting the parasite.

The health situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

Compiled data from the Norwegian Veterinary Institute and the private laboratories show that spironucleosis was present in salmon at three locations in PA12 and PA13 in 2023. PCR analyses alone detected *S. salmonicida* in ten ongrowing facilities for salmon in the same area. One of the detections was stated to be of clinical significance, while clinical significance is unknown for the others.

The Annual Survey

In 2022, Spironucleosis was added to the list of current diseases and conditions included in the survey for the first time. For 2023, few respondents perceived spironucleosis as an important cause of mortality (4 out of 102), reduced growth (3 out of 99), reduced welfare (4 out of 102) or as a growing problem (2 out of 100) in farmed salmon in ongrowing facilities (Appendix B1). In salmon in broodstock facilities, no one experienced the disease as a problem (Appendix C1).

Evaluation of the systemic spironucleosis situation

Systemic spironucleosis is a diagnosis with severe implications for fish health and fish welfare. The disease has been rare thus far, but it can be assumed that *S. salmonicida* has a wider distribution than that indicated solely by microscopic examinations and DNA analyses. While disease has primarily been observed in fish in the sea, there is a possibility that it may also occur in hatcheries in the future, especially considering the current practice of prolonged holding time on land before the fish are released into the sea. The process of smoltification and transition to marine conditions can impose significant physiological stress on fish, which is critical to consider given the limited understanding of the underlying causes of infection and disease development.

Modern hatchery production, with seasonally independent smoltification and release into the sea, involves intensification of production. This can make the fish more vulnerable to infection with Spironucleus. There is limited knowledge about the eventual survival and establishment of infectious organisms in the RAS plants' biofilters and bioreactors. In addition, there is a lack of knowledge about possible cyst formation in *Spironucleus*, and about the flagellate's ability to survive in the environment.

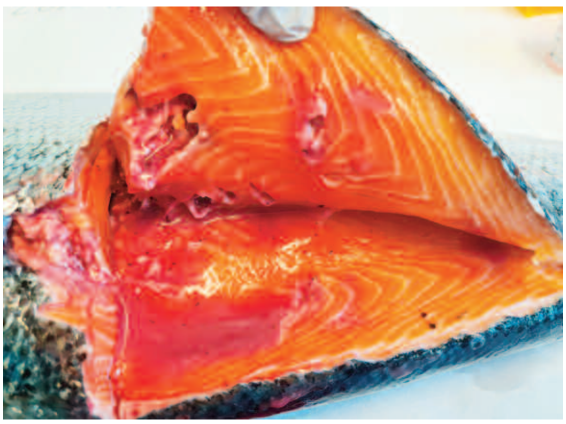


Figure 9.6.2 Abscess in the muscle of salmon, caused by *Spironucleus salmonicida*. Photo: Geir Bornø Veterinary Institute.

10 Other Health Problems in Farmed Salmon

By Julie Christine Svendsen

This chapter discusses health issues in farmed salmon that are not caused by pathogens. They are sometimes referred to as non-infectious diseases or production disorders, and can be effects of the external environment. Here, gill disease, poor smolt quality and runt syndrome, nephrocalcinosis, hemorrhagic smolt syndrome (HSS), water quality, vaccine side effects, as well as problems with algae and jellyfish are discussed.

Registered cases of gill disease, in conjunction with this year's survey, show that this remains a significant and growing issue for salmon in the ongrowing phase, with considerable implications for both fish growth, welfare, and as a cause of loss. Nationally, gill disease is considered the second most important health challenge for salmon in ongrowing facilities, and it scores highest as a cause of reduced growth. Gill problems at sea have previously been registered particularly in late summer and autumn, but it seems that salmon in ongrowing facilities are increasingly affected throughout the year. Substantial efforts, particularly open information exchange from all stakeholders, are still required to gain better control over gill problems. There is already extensive screening and registration, providing significant opportunities to identify risk factors and establish targeted interventions.

Issues with smoltification and development of runt syndrome also continue to pose challenges along the Norwegian coast. The causes are often complex and difficult to define. This applies both in the ongrowing phase as well as in the hatcheries. Especially in the hatcheries, both of these issues are considered important reasons for reduced growth, mortality, reduced welfare, and to be increasing problems. Survey responses show a near doubling in the proportion of respondents who consider smoltification problems to be increasing, compared to the previous year. There are also certain key points reiterated in respondents' concluding, general comments regarding production in the hatcheries. These include the need to lower intensity and to focus more on fish welfare, survival, and robustness. The Norwegian Veterinary Institute's data show a slight increase in the number of sample submissions reporting increased mortality of salmon smolts at sea.

Nephrocalcinosis and HSS are still cited among the biggest health challenges for salmon in hatcheries. Nephrocalcinosis (also known as kidney calcification and kidney stones) is well known in farmed fish and is cited as one of the main causes of reduced welfare and growth in both salmon and rainbow trout in hatcheries. It is believed that HSS is a contributing factor to mortality associated with smoltification problems in some hatcheries and that the condition may be caused by osmoregulatory issues, but there is little literature on the subject. Overall, nephrocalcinosis is ranked as the second most important health challenge for salmon in hatcheries in 2023, after poor water quality, while HSS ranks third. Nephrocalcinosis in salmon smolts is still scored as the most increasing problem, in line with last year's assessments. HSS is considered, also like last year, the main cause of mortality in hatcheries for salmon. The persistence of severity for both these health problems indicates that current preventive measures are not sufficient.

Good water quality is crucial for good fish health. This is highlighted in this year's survey, where poor water quality is considered the most significant challenge for salmon in hatcheries. Almost half of the respondents answered yes to H_2S being a factor that negatively affected welfare in RAS facilities in the past year, a significant increase from previous years. Reviewing events handled by the Norwegian

Institute for Water Research (NIVA) related to poor welfare or increased mortality in land-based facilities shows that abnormal behavior, reduced fish health, and increased mortality in RAS facilities are often due to a combination of several adverse conditions including H2S, particle loading, high CO2, and total ammonium-nitrogen. Mortality associated with toxic levels of metals such as aluminum, iron, and copper was also observed in 2023. Based on inquiries to NIVA regarding total gas pressure (TGP) and conducted measurements, it appears that weak gas oversaturation in land-based facilities is relatively common. Furthermore, NIVA's follow-up of events for various aquaculture - and wellboat companies related to poor water quality in wellboats shows that the number of events is a serious fish welfare problem and can result in significant economic losses.

Results from this year's survey show that it is relatively common among respondents to experience increased mortality and/or reduced appetite after vaccination. In diagnostics, tissue damage which is likely attributable to vaccine reactions is regularly registered (mainly in the form of granulomatous peritonitis), in fish from both hatcheries and ongrowing facilities. Compared to last year's responses, there is a tendency for an increase in both mortality, reduced appetite, and vaccine administration errors. Whether this represents a real deterioration of vaccine side effects is unclear, but it indicates a need for extra attention to these issues in the future.

Algal blooms and jellyfish attacks can result in greatly increased mortality, as well as reduced fish health and welfare. Both algae and jellyfish have caused periodic problems that tend to become extensive when they occur. Many farmers experienced this last autumn when string jellyfish attacks were registered along large parts of the coast. Both the extent of the damage as well as the losses were considerable, and jellyfish attacks were rated nationwide as the overall fifth-largest problem for salmon in ongrowing facilities. It was considered the most important increasing problem.

Good water quality is essential for good fish health. Photo: Rudolf Svensen

10.1 Gill health in farmed salmonids

By Brit Tørud, Mona Gjessing and Anne Berit Olsen

Gill anatomy and function

The surface of the gills is almost as large as the surface area of the skin and is a crucial barrier to the environment, just like the skin and intestinal mucosa. Pathogens spread more easily in water than in air and the gills are more exposed to potential pathogens compared to animals that breathe with lungs. To ensure easy gas exchange, the distance between the outside and the inside of the body must be short. In addition to gas exchange, excretion of nitrogenous waste products, acid-base regulation, and hormone metabolism, the gills function as a barrier. The gills have a large reserve capacity and a certain ability to regenerate. However, healthy gills are essential for good health. The thin layer of mucus that covers the surface of a healthy gill contains immune components that contribute to the barrier function of the gills. The interbranchial lymphoid tissue (ILT) is located in the base of the filament and extends along its trailing edge. The function of ILT has not yet been fully elucidated.

Gill diseases

Salmonids in aquaculture are prone to gill injuries and gill diseases (Figure 10.1.1) throughout their life cycle. These conditions compromise fish welfare and can also lead to increased mortality. The substantial reserve capacity of the gills allows for significant changes to take place before the fish displays clinical signs of disease. Both operational procedures, unfavorable water environments, infectious agents, algae, and jellyfish, either one of them or in combination, can harm the gills. In many cases, it is difficult to define the predisposing factors. There are several known agents that can cause problems in the gills. The best characterised include the amoeba *Paramoeba perurans*, the causative agent of amoebic gill disease (AGD) in salmon in seawater, the fungus-like organism (microsporidian) *Desmozoon lepeoptherii*, salmon gill poxvirus, which can cause severe acute disease (Chapter 6.8 Salmon Pox), and infection with *Ca.* Branchiomonas cysticola. Infection with *Ca.* Branchiomonas cysticola can manifest in various ways but severe gill disease with inflammation and necrosis especially in the seawater phase is not uncommon. In addition, the bacterium *Tenacibaculum* spp. can cause necrotizing gill inflammation. With the exception of *P. perurans* and *Tenacibaculum* spp., it has not yet been possible to cultivate any of these pathogens, therefore controlled experiments are difficult to conduct. Effort should be made to successfully culture these pathogens in order to gain more insight into their biology and find ways to combat the diseases they may cause.

Systemic bacterial infections, such as pasteurellosis, furunculosis, bacterial kidney disease (BKD), and mycobacteriosis, can cause pathological changes in the gills and issues related to these microorganisms are described in other chapters of this report.

AGD has been progressively spreading north. Key risk factors associated with AGD include elevated seawater temperature and salinity, as discussed elswhere in this report (Chapter 8.4 on Amoebic Gill Disease (AGD)). Climate change is anticipated to lead to increased seawater temperatures, potentially exacerbating the situation. Furthermore, elevated water temperatures can impact other gill pathogens, combined with decreased oxygen solubility at higher temperatures.

In recent years, several large hatchery and post-smolt facilities have come into operation. Among these, recirculation technology (RAS) dominates. Unfavourable water chemistry (Chapter 10.5 Water Quality) and an imbalanced microbial environment with the growth of potentially pathogenic organisms can compromise the gills. In the freshwater phase, infection with the oomycete *Saprolegnia* spp. is not uncommon and can be a sign of poor water quality. Smolt may carry infections from the hatchery, which can further worsen gill health after transfer to seawater.

An increased prevalence of *Ca*. Branchiomonas cysticola (recognized as the primary bacterium forming epitheliocysts) has been noted during thermal delousing procedures. Although the precise role of *Ca*. Branchiomonas cysticola in each case remains uncertain, research indicates that this bacterium is of great significance and is underdiagnosed. Additionally, when employing freshwater treatment, where water is recycled for delousing, alterations in water chemistry can increase the risk of metal deposition on the gills, as illustrated in Figure 10.1.2.

Gill disease has been a significant problem for many years, not only in Norwegian salmon farming, but also in other salmon-producing countries worldwide. In 2013, a global collaboration platform, the Gill Health Initiative, was established and in 2023 the Norwegian Veterinary Institute organized the “Gill Health Initiative Conference” in Oslo. The aim is to establish a platform where researchers, industry professionals, and other stakeholders can interact and address these often complex challenges.

Several tools

Standardization of scoring protocols is needed to achieve even better knowledge-sharing in Norway, globally, and as tools for gill health monitoring within each company. This applies to both macroscopic and histopathological assessment. Automated *in situ* hybridization for the detection of Salmon Gill Pox-Virus in tissue samples has now been established. *In situ* hybridization is a method allowing visualisation of an agent or other targets in the tissue. As histopathological examinations are time-consuming, significant resources are put into the development of artificial intelligence that eventually will contribute to streamline routine gill diagnostics. Regular sampling of gills for histopathological and PCR examination is important to monitor gill health. Continued routine gill sampling of facilities is essential, particularly preceding risk periods, to uncover crucial factors contributing to compromised gill health. This proactive approach enables the early identification of potential issues, facilitating the timely implementation of targeted interventions.

Prevention and treatment

Ensuring optimal water quality is paramount in hatcheries to maintain good gill health. Stringent biosecurity protocols must be enforced to prevent the introduction of infectious agents into the facility via biological materials or inlet water. Recirculating systems, often harboring more particles compared to flow-through systems, present unique challenges. However, there's currently limited documentation on the potential impact of these particles on gill health.

In cases of recurring gill disease within recirculating aquaculture systems (RAS), sanitizing the biofilter to mitigate potential risks is recommended. Among gill diseases in marine environments, only amoebic gill disease (AGD) is treatable. Some employ lice skirts at varying depths to shield fish from algae and jellyfish, although the indiscriminate nature of these organisms poses a challenge.

Smolt that is put in the sea should not be carriers of gill agents. In sea water it is important to keep the nets clean and have flushing routines that do not burden the gills with loose bifouling. As previously mentioned, regular examination of gill samples throughout the production cycle is recommended as an integral part of risk assessment before fish handling.

The Health Situation in 2023

Gill diseases are non-notifiable and therefore not reported to the Norwegian Food Safety Authority (Mattilsynet). The occurrence of gill diseases is therefore not determined with certainty.

Throughout the past year, the Norwegian Veterinary Institute has received diagnostic cases of salmon in hatcheries with gill damage, either as the primary diagnosis or as an additional concern, consistently across all months through the year. Certain facilities experienced gill disease as a recurrent issue. The prevalent observation, consistent with previous years, was the presence of thickened and fused gill filaments, often without a specific identifiable cause. It is suspected that water quality may have played a significant role in some of these cases. Only a minority of cases were diagnosed with bacterial, parasitic, or fungal involvement. Notably, there were very few cases of gill problems reported in rainbow trout within hatchery settings.

In 2023, the NVI's data revealed that samples from sea-farmed salmon with gill-related diagnoses were distributed consistently across the year, with a slight uptick noted in January and during the period spanning September to December. Interestingly, there were notably fewer submissions in June. Persistent gill issues were observed in certain locations, suggesting multifactorial causes in many cases.

Regarding gill disease in sea-farmed salmon involving epiteliocysts identified via histopathology, comprehensive data from both the Norwegian Veterinary Institute and private laboratories are available for 2023. Such findings were documented at 83 locations, spanning all production areas, with PA10 (18) and PA6 (15) recording the highest occurrences. The bacterium *Ca.* Branchiomonas cysticola, associated with gill disease even in the absence of epitheliocysts, was detected by PCR in 189 locations along the entire coast, with PA3 (40) and PA6 (34) registering the highest number of detections.

Submissions to the Norwegian Veterinary Institute suggest that gill disease featuring epitheliocysts was detected consistently throughout the year although with the prevalence reported in May and June, peaking notably from July to November.

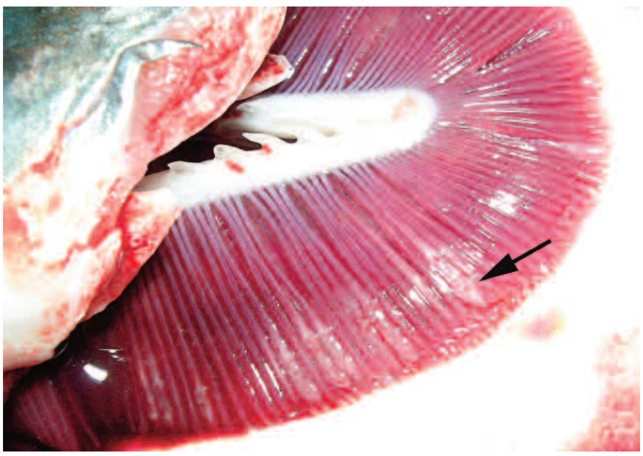


Figure 10.1.1: White, thickened and firm areas on the gill filaments of salmon indicating a significant proliferation of surface cells, which is a chronic reaction that does not heal. Photo: Brit Tørud, Norwegian Veterinary Institute

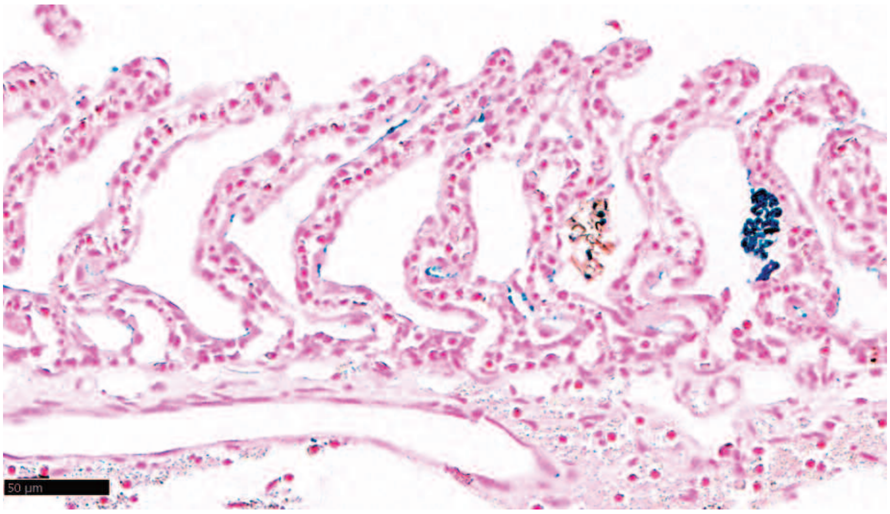


Figure 10.1.2: Tissue sections of gills stained with Prussian blue (potassium ferrocyanide in acidic solution for detection of trivalent iron). Iron is labeled blue. The lamellae are covered with a thin layer of iron in several areas. Some lamellae are stuck together, probably due to altered surface tension as a result of iron deposition. Photo: Mona Gjessing, Norwegian Veterinary Institute

Costia (*Ichthyobodo* sp.) was mostly reported as part of complex gill disorders. Submissions of cases involving gill bleeding were received throughout the year, but in the Norwegian Veterinary Institute's material, there was a peak in November. Gill bleeding is still poorly understood and historically most prevalent in the autumn. There were few submissions to the Norwegian Veterinary Institute from rainbow trout in sea-farmed facilities with gill diagnoses.

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Gill diseases or injuries do not stand out as major problems in either salmon or rainbow trout in the hatchery phase, but some respondents attribute gill diseases as the cause of mortality (Appendix A1 and A2).

For salmon in grow-out facilities, gill disease is considered the second most important health challenge and ranks highest as the cause of reduced growth. Respondents rank complex gill disease as the third most common cause of mortality and reduced welfare, following delousing and winter ulcer. Gill disease ranks second highest as an emerging problem after jellyfish injuries in 2023. The breakdown of results by production areas PA1-PA5, PA6-PA9, and PA10-PA13 suggests that the greatest gill problems are on the West Coast and in Central Norway, while gill diseases rank lower on the list in the north. In rainbow trout, gill disease shares second place together with three or four other health problems in the sea phase after mechanical damage during de-lousing. Almost half (6 out of 14) of the respondents experience gill disease as an increasing problem (Appendix B1 and B2).

Non-specific gill disease occurs in both flow-through and RAS. In the free text responses, some noted that increased turbidity and particles in the water in the hatchery phase lead to increasing gill problems. Some commented that feed that was not adapted to RAS, could have a negative effect on the gills, and poor water-treatment was observed due to equipment failure. In the marine phase, amoeba, jellyfish and algae were seen in connection with gill damage. Gill bleeding was observed in association with delousing. Multifactorial gill disease was seen together with HSMB, CMS and PD, and it was noted that adverse conditions with overloading a locality's tolerance appeared to increase the risk of gill problems.

Evaluation of the gill health situation in salmon farming

The annual survey shows that gill disease is a significant and still growing problem for salmon in the marine phase and of great importance both for growth, welfare and as a cause of loss.

In previous years, problems with gills at sea-locations have particularly been recorded in late summer and autumn, but now that salmon apparently are gradually affected throughout the year. In recent years, there has been a surge in new knowledge, the development of additional tools, and improvements in monitoring techniques. Substantial effort is still required, and exchange of knowledge to gain better control of the gill problems is still missing. Extensive screening and registration already exist and make a great potential for defining risk factors and establishing targeted measures.

10.2 Poor smolt quality and runt syndrome

By Synne Grønbech and Benedikte Hansen Bendiktsen

About poor smolt quality

Poor smolt quality can increase the risk of unsatisfactory development, growth, and health after sea transfer. Osmoregulatory problems associated with poor smoltification lead to increased stress and a higher risk of health problems and mortality in the early period after sea transfer.

Challenges with smoltification in hatcheries can include several factors: poor water quality and tank environment, inadequate tank capacity, uneven light stimulation, early sexual maturation, development of "pseudosmolt," uneven smoltification, desmoltification, and more. Diseases, both infectious and environmentally induced, will disrupt the smoltification process. For example, hemorrhagic smolt syndrome (HSS), wound development, salmon pox, and nephrocalcinosis will negatively affect smolt quality. Efforts to control smoltification control of smoltification, with representative sampling of the fish group and accurate assessment of smolt status, are important measures that can ensure good smolt quality.

Runt syndrome

Runt syndrome is a condition where fish become emaciated or do not grow normally, developing into thin "losers" or "sticks." The term is mainly used for fish in ongrowing facilities, but losers are also seen in hatcheries. Typical findings in histological examination of losers include little or no fat tissue around internal organs (perivisceral adipose tissue) and increased amount of melanin-containing pigment/melanization in the kidney. It is believed that loser fish are more likely to acquire parasites and diseases than fish of normal weight . As an example, tapeworm infection in losers is a common finding. Thus, loser fish can increase the risk of pathogen transmission and disease outbreaks.

The cause of runt syndrome is unclear, and several factors may be involved. Stress and stress-related situations likely contribute to the development of the syndrome. Problems related to smoltification and poor smolt quality may also increase the risk. In the sea phase, it has been observed that fish that have survived IPN, PD, and parvicapsulosis can become emaciated. Optimal smoltification, sea transfer at the right time, follow-up in the early sea phase, and optimization of feeding strategy are important for normal development, growth, and health of salmonids.

Fish that develop runt syndrome can live for a long time and represent a significant animal welfare problem. In many cases, it can be challenging to remove such fish from the cages, however removing them is an important measure for the welfare of the affected fish and for reducing the risk of infection by other fish.

The Health Situation in 2023

Data from the Norwegian Veterinary Institute

Incomplete systematic registration of problems with smoltification, smolt quality, and runt syndrome makes it difficult to provide good statistics of occurrence in Norwegian aquaculture. Nevertheless, we have tried to provide an overview from the past year, based on information received by the Norwegian Veterinary Institute from fish health personnel.

In 2023, the Norwegian Veterinary Institute diagnosed "emaciation" at eight ongrowing sites with salmon, which is approximately on par with 2022 and 2021. This diagnosis was also made at one hatchery site with rainbow trout.

During the year, there were 41 sample submissions reporting increased mortality of salmon smolts in the sea phase. This is higher than in 2021 and 2022, where the number was 35. One submitter reported increased mortality of smolts at an ongrowing facility with rainbow trout. The number of cases reporting increased mortality in smolts in the hatchery phase was one for rainbow trout and nine for salmon. Of the latter, six cases were from RAS facilities.

In the majority of cases with reported increased mortality or with "emaciation" as a diagnosis, submitters describe wound problems, possibly also with signs indicating sepsis. Several describe findings associated with heart disease. Some have a history of or suspect HSMI prior to sea transfer. A few describe suspicion of HSS and kidney calcifications.

In the above cases (from both ongrowing and hatchery sites), the following diagnoses were most often made after histological and/or bacteriological examination, here listed in descending frequency: bacterial wound infection (possibly with sepsis), calcifications in kidney or pseudobranch, HSMI, gill pathology, and HSS.

Yersiniosis was detected in three cases of salmon smolts in the sea phase, where the disease had been detected at the hatchery in one of the cases. IPN was detected in two cases of salmon smolts in the sea phase.

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For salmon in the ongrowing phase, runt development unsurprisingly ranks high on the list (fourth place) as an important cause of reduced growth, and relatively lower on the list for the other categories (important cause of mortality, reduced welfare, increasing problem) (Appendix B1). Inadequate smoltification is attributed slightly more significance for mortality and reduced welfare, and is indicated as an important cause in 8 percent and 10 percent of the responses, respectively.

In the hatchery phase for salmon, problems with smoltification and emaciation/runt development have greater significance, and both enter the top ten list for all categories (Appendix A1). Smoltification problems and their significance for mortality have the same ranking as in 2022 (Table 10.2.1).

Significantly fewer respondents have answered equivalent questions for rainbow trout, both for freshwater and ongrowing phases, resulting in greater uncertainty in weighting problems (Appendices A2 and B2). The responses indicate that problems with emaciation/runt development in the hatchery phase are significant, while smoltification problems receive fewer ticks.

The background for smoltification problems and also the development of runt fish is often complex, and it may be

Table 10.2.1: Respondents' assessment of the five most significant issues with salmon smolt (including post-smolt on land), based on whether they result in mortality, reduced growth, reduced welfare, or are perceived as an increasing problem.

Ranging	Mortality	Reduced growth	Reduced welfare	Increasing problem
1	Hemorrhagic smolt syndrome (HSS)	Emaciation/losers	Fin erosion, Poor water quality	Nephrocalcinosis
2	Poor water quality	Poor water quality	Nephrocalcinosis	IPN
3	Nephrocalcinosis, wounds	Nephrocalcinosis	Wounds	Unresolved disease conditions, Poor water quality
4	Fin erosion	Shortened operculum	HSS	Wounds
5	Wounds	Wounds, HSS, Deformities	Wounds, Shortened operculum	Sores

difficult to provide concrete, unambiguous answers for each facility. In general, the fish's health status and water quality in the facility are likely to be significant.

For more details regarding the ranking of problems in salmonids in the hatchery phase, see Table 10.2.1 and 10.2.2 and Appendices A1 and A2.

As in previous years, the survey allows for free text entry. The following are highlighted in connection with the hatchery phase and smolt quality in this year's responses:

Some believe that health monitoring can be improved at certain facilities, with regards to sufficient sampling and examination for relevant diseases. It has been observed that the status of fish groups before sea transfer has been assessed to be, while in subsequent health visits after sea transfer, observations of many fish with parr-markings and "dry" fish have been made. There are also cases where the underperformance of recently sea transferred fish is attributed to smoltification, without further explanation, where the respondent suspects a more complex background.

An increasing trend of challenges related to operational conditions in the hatchery phase is commented on. Infectious causes of disease and welfare problems are not highlighted in the same way. However, some respondents have observed increasing incidence of mortality and poor growth associated with IPN, as well as increasing incidence of yersiniosis and mycobacteriosis. High prevalence of PRV in the smolt phase in some facilities is also mentioned, with sporadic outbreaks of HSMI, with unknown consequences for the first time in the sea phase.

High density and intensive production are highlighted as important factors for following problems. There are described cases in RAS facilities where high temperatures and intensive operation, combined with low salinity and high water hardness, lead to fish becoming prematurely blank and eventually developing osmoregulatory disturbances (nephrocalcinosis, HSS), and where the group also becomes unsynchronized in smolt status. A respondent comments that there is a lot of pseudosmoltification in all facilities, and thus subsequent challenges with further production and the time until actual smolt phase and sea transfer.

Table 10.2.2: Respondents' assessment of the five most significant issues with rainbow trout smolt, based on whether they result in mortality, reduced growth, reduced welfare, or are perceived as an increasing problem.

Ranging	Mortality	Reduced growth	Reduced welfare	Increasing problem
1	Nephrocalcinosis	Nephrocalcinosis	Nephrocalcinosis	Nephrocalcinosis
2	IPN	Deformities, HSMI-like disease (infection with PRV-3)	Deformities	IPN
3	Deformities	HSMI-like disease (infection with PRV-3)	Shortened operculum, IPN	Deformities, HSMI-like disease (infection with PRV-3)
4	Emaciation/losers	Emaciation/losers, Fin erotion	Emaciation/losers, Fin erotion	Emaciation/losers Fin erotion, Unresolved disease conditions, Wounds, Moving fish between production units with different water quality
5	Shortened operculum, HSMI-like disease (infection with PRV-3)	Shortened operculum, IPN, Unresolved disease conditions	Poor water quality, wounds, Moving fish between production units with different water quality	(0)

(0) no checkboxes on other issues

Regarding water quality, challenges with gas supersaturation and gas bubble disease are described. Lack of control of H_2S is also mentioned, both in low-grade form and due to routine failure, which can lead to acute events. The latter is particularly relevant in RAS using brackish water. High turbidity and high CO_2 levels are also reported. For flow-through systems, it has sometimes been suspected that metals have had a negative effect on smoltification during flood periods. One respondent has the opinion that equipment failure is still a major problem, especially in the newest facilities where the delivered equipment does not function as expected. This poses welfare challenges both in terms of poor water quality and through suboptimal fish handling. It is also problematic that feed not adapted to RAS can result in poor water quality and potentially affect light control negatively.

In some fish groups in RAS departments, an increase in tail fin rot and wounds after smoltification is observed when the fish density approaches 57-60 kg/m3. Some experience challenges with vaccine access and delayed vaccination, resulting in increased density in tanks and fin erosion. Unspecified gill irritation very often detected, both in RAS and flow-through facilities. High turbidity has been a suspected contributing factor in RAS facilities. Nephrocalcinosis is still considered a welfare challenge, but with a reduction in the number of the most severe cases. The condition rarely causes mortality in the hatchery phase, but in more severe cases, there is sometimes high mortality after sea transfer.

One respondent mentions a high proportion of prematurely sexually mature male parr, which has caused challenges after smolt release. It is described that it has been several years since this has been observed to the same extent.

There are some main points that are repeated in respondents' concluding, general comments regarding production in the hatchery phase. These include that intensity should be reduced, and that there should be more focus on fish welfare, survival, and robust fish. It is criticized that regulations are violated for economic purposes, for example, by releasing sick and/or inadequately smoltified fish.

Regarding comments about runt development in the sea phase, some respondents report that this is associated with an increasing frequency of eye injuries.

Evaluation of the situation for smolt quality and runt syndrome

Operational conditions, facility design, and good routines to ensure fish welfare are all factors of great importance for optimizing smolt production. The use of low salinity throughout hatchery production and desmoltification is mentioned to be problematic elements. Fluctuations in water temperature in flow-through systems are still challenging for smoltification, especially in the production of spring smolts. The use of so-called large smolts and post-smolts is part of the strategy to reduce exposure time in the sea to both sea lice and infections with viruses and bacteria. Several RAS facilities are built to produce hatchery fish up to 1 kg. High biomass can pose challenges with water quality and synchronization of fish groups during smoltification. The performance of large smolts and post-smolts after sea phase in the sea varies, highlighting a need for more knowledge about this production method.

Based on the results from the survey, inadequate smoltification and the development of runt syndrome are still problems along the Norwegian coast. The reasons for suboptimal smoltification and runt development are often complex, and with increasingly diverse ways of producing hatchery fish, both in terms of new production technology and smoltification protocols, the field is relatively complex today. Production planning, with a focus on fish health and welfare at both the individual and group level, is particularly important for smolt to have the best possible starting point for life in the sea.

10.3 Nephrocalcinosis

By Arve Nilsen and Anne Berit Olsen

The disease

Historically, nephrocalcinosis (NC) has been a problem in breeding of rainbow trout in water with high levels of CO_2. The disease is reported to be common in Norwegian hatcheries for both salmon and rainbow trout and is also known from intensive farming of other fish species. NC may be a sign of poor water quality or suboptimal farming methods and is thus an important welfare indicator in farmed salmonids. When NC is observed, several other negative effects on fish welfare may be expected in the facility.

Nephrocalcinosis (kidney calcification, kidney stones) is typically visible as white longitudinal stripes in the kidney (Figure 10.3.1). In severe cases, especially the posterior half of the kidney becomes swollen, nodular, and grayish. Histopathological examination shows deposits of mineral-rich material in the kidney's excretory system, where urine is formed (Figure 10.3.2). Even with mild deposits, the epithelium in the tubules is damaged. Over time, the tubules become dilated and blocked, which in turn affects and damages the surrounding hematopoietic tissue. Deposition of calcareous material can also be seen in other organs, as the pseudobranch (the fish's reduced first gill arch) and the stomach wall.

Since urine formation is essential for the fish to rid itself of waste products, damage to the excretory system will disrupt the physiological homeostasis. Additionally, severe NC with extensive destruction of the hematopoietic tissue may lead to reduced immune competence and decreased production of red blood cells.

In histology, tissue samples can be stained using a special method that gives calcium salts a strong brown colour. This diagnostic test is used to distinguish calcareous concretions in NC from other material that may occur in the kidney tubules. Chemical analyses of kidney deposits from various projects have shown that they mainly consist of phosphate stones, which also contain the minerals calcium, magnesium, carbon, and nitrogen. Urine must be alkaline for such phosphate stones to form. The normal pH in salmon is estimated to be 7.5, and therefore the conditions may be particularly favourable for such deposits in salmon.

Nephrocalcinosis is often an additional finding in the disease haemorrhagic smolt syndrome (HSS) (Chapter 10.4 HSS). Typical findings in HSS are bleeding into the kidney tubules and eventually more extensive bleeding in muscles and internal organs. Recent studies indicate that HSS does not predispose to kidney calcification, although these conditions can occur under the same farming conditions.

Kidney damage in NC can in some cases resemble visible findings in the listed disease bacterial kidney disease (BKD) and must therefore be examined in the laboratory.

Aetiology

Several environmental and operational factors are likely to be associated with the development of NC. The environmental cues given to synchronize the parr-smolt transformation (smoltification) may be an important factor, but other management factors such as temperature, water chemistry, and potential early use of seawater are also considered to be significant. It has been speculated that intensive production systems with high temperature and rapid growth rates combined with environmental signals that do not provide the fish with a natural physiological transition from living in freshwater to becoming a marine fish may have a negative effect on kidney function, acid-base balance, and mineral metabolism. This can in turn predispose to changes in the kidneys' ability to filter blood, and to regulate the mineral content and pH in urine and thus increase the risk of kidney stones. In addition to problems that can arise when water quality is critically poor over time, large variations in water quality may also likely be detrimental to the fish.

The Norwegian Food Safety Authority has recommended an upper limit of 15 mg/L for CO_2 in fish farms. A common consequence of increased levels of CO_2 in water is an increased level of CO_2 in the blood, which the fish regulates by taking up the buffer bicarbonate (HCO^{3}-) from the water. This occurs through a pumping mechanism in the gills where bicarbonate is extracted from seawater in exchange with negatively charged chloride ions (Cl^-) in the fish's blood. With this process, blood pH will increase, and plasma chloride decrease. It has also been shown that high levels of CO_2 can lead to increased levels of stress hormones, altered pH in the blood, changes in the fish's mineral metabolism, changes in the content of free amino acids in the muscles, or changes in the blood's composition of nutrients and minerals.

Several experiments have shown that high levels of CO_2 increase the risk of developing NC, both in freshwater, brackish water, and seawater. At the same time, other experiments have shown an increasing degree of physiological stress and reduced growth at CO_2 levels from 5 to 40 mg/L, but without the development of NC being detected. That high levels of CO_2 can cause NC is also shown in studies where mild and moderate kidney injuries occurring in groups exposed to high CO_2 are rapidly restored after the fish has been transferred to water with low CO_2 levels. However, pronounced kidney injuries might not heal and instead be the cause of increased mortality. Most cases of NC are reported from groups of pre-smolt, smolt, or post-smolt. In hatcheries, the peak incidence will often occur immediately prior to sea transfer. Increased incidence has also been reported to be associated with increased salinity in the post-smolt phase, while laboratory experiments have shown that high CO_2-related NC in salmon smolt disappears after transition to full seawater. In rainbow trout, NC can be detected throughout much of the sea phase.

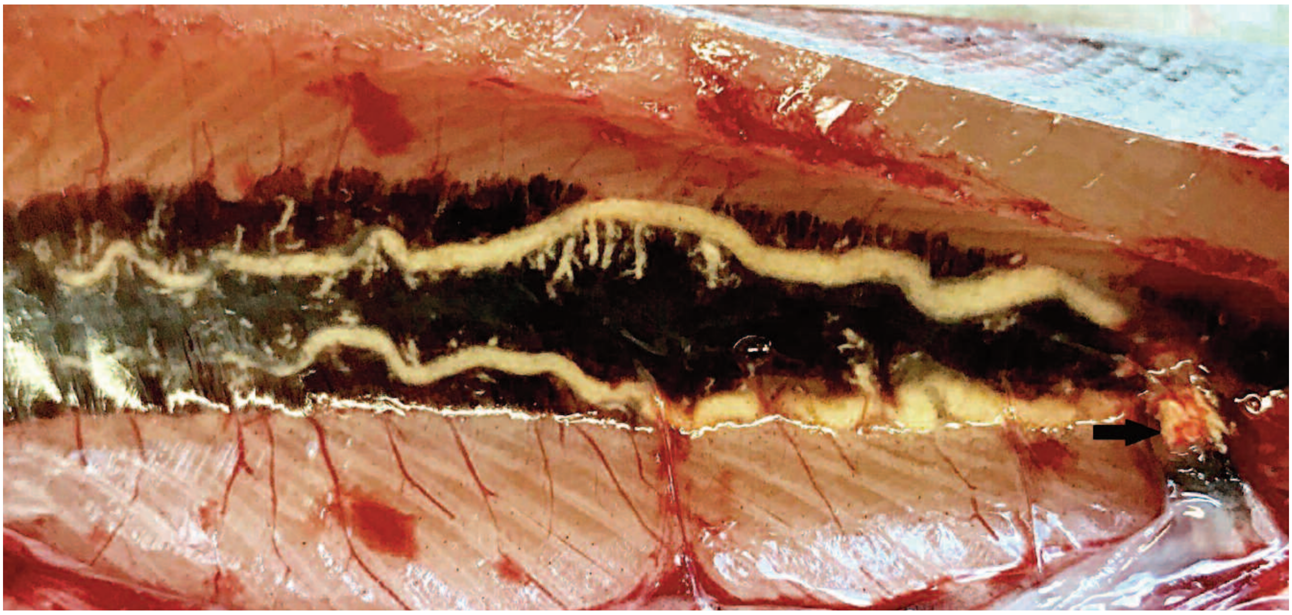

Figure 10.3.1 Severe nephrocalcinosis. Collecting ducts and urinary bladder (arrow) are distended with yellowish-white calcareous material. Photo: Stim

Disease control

Nephrocalcinosis is considered an environmentally related disease. Ensuring good quality of intake water, stable water quality in tanks, including CO_2 and pH, and satisfactory water flow (specific water consumption) can reduce the risk of developing NC. Monitoring of water parameters and metabolic waste products such as CO_2 should be carried out systematically and with relevant equipment and methods. Important prophylactic measures will be to maintain a stable and good water quality, and to implement well-established and documented protocols for parr-smolt transformation. There may also be reason to be cautious about how seawater is used in production, both early in the hatchery phase and in connection with smoltification and transition to the post-smolt phase.

Regular sampling of kidneys for histopathological examination is recommended to identify early signs of NC development, as an indicator of a suboptimal rearing environment. Frequent necropsy and screening of dead or moribund fish for visible signs of NC is also important.

The Health Situation in 2023

In a survey of parr and smolt in six hatcheries along the coastline in the period 2019 to 2021, an average prevalence of NC of 35.8 percent and a prevalence of HSS of 10.7 percent were found, but with large differences between the facilities. It was a consistent observation that the incidence increased through the winter until the time of sea transfer. Similar results for NC were also found in another recent study of 11 hatcheries in Mid-Norway. Thus, routine diagnostic data for this condition are probably underestimated. Diagnoses are often established on field investigations based on typical kidney changes, and some cases go undetected because the deposits are not necessarily visible. Nephrocalcinosis diagnosed by histopathology in the laboratory is in many cases reported as an additional diagnosis in cases with other causes of investigation.

In the Norwegian Veterinary Institute's sample journal, NC was detected in approximately 60 commercial facilities with salmonid fish, mostly with salmon and some with rainbow trout. NC was also found in submissions from aquaculture facilities, wild salmon, lumpfish, and halibut. In the NVI's material, kidney stones in salmon were detected in all age groups, including fry, parr, smolts before and after seawater transfer, adult fish, and broodstock. In hatcheries, most cases of NC were diagnosed in fish with weight between 30 and 200 grams, but there were isolated cases of calcareous precipitations even down to 2-3 grams. In the seawater phase, approximately half of the reported cases were from fish smaller than 1 kg. For rainbow trout, most of the cases in the NVI's material were from larger fish around 2.5 kilograms.

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For salmon in hatcheries, nephrocalcinosis was rated by respondents as the most rapidly increasing health problem, out of all the 26 conditions assessed in the survey. Respondents experienced nephrocalcinosis as one of the three main reasons for reduced welfare, decreased growth, and increased mortality. Overall, nephrocalcinosis was ranked as the second most important health challenge for salmon in the hatchery phase in 2023, only surpassed by poor water quality. For hatcheries with rainbow trout, we have fewer responses to the survey, but here nephrocalcinosis was ranked as the clearly most significant health challenge in 2023.

Nephrocalcinosis is still considered to have limited significance for mortality, reduced growth, and reduced welfare for salmon in the seawater phase. Regarding rainbow trout in seawater (few respondents), NC achieves the second-highest score for reduced welfare and growth, and lower scores on the other questions.

Evaluation of the nephrocalcinosis situation

The results of the survey clearly show that nephrocalcinosis remains a common diagnosis of great importance for the health and welfare of both salmon and rainbow trout in hatcheries, and thus also for the survival and health of the fish in the seawater phase. The rapid increase of NC as a health issue in salmon hatcheries in 2023 is alarming.

In grow-out facilities, nephrocalcinosis is often detected in the first few months after seawater transfer and is likely a damage the fish has carried from the hatchery. Moderate tissue damage will often disappear shortly after sea transfer, while it may take longer to heal larger kidney injuries. Also in 2023, nephrocalcinosis was detected in some cases in adult salmon. It is uncertain whether this is related to conditions the fish has been exposed to in earlier phases, or if it has other causes. This should be further investigated.

The disease is closely related to operational conditions such as water quality and likely also smoltification protocols. Poor water quality was overall assessed as the biggest problem in hatcheries for salmon in 2023. By improving water quality and other operational conditions, it should also be possible to prevent the development of nephrocalcinosis.

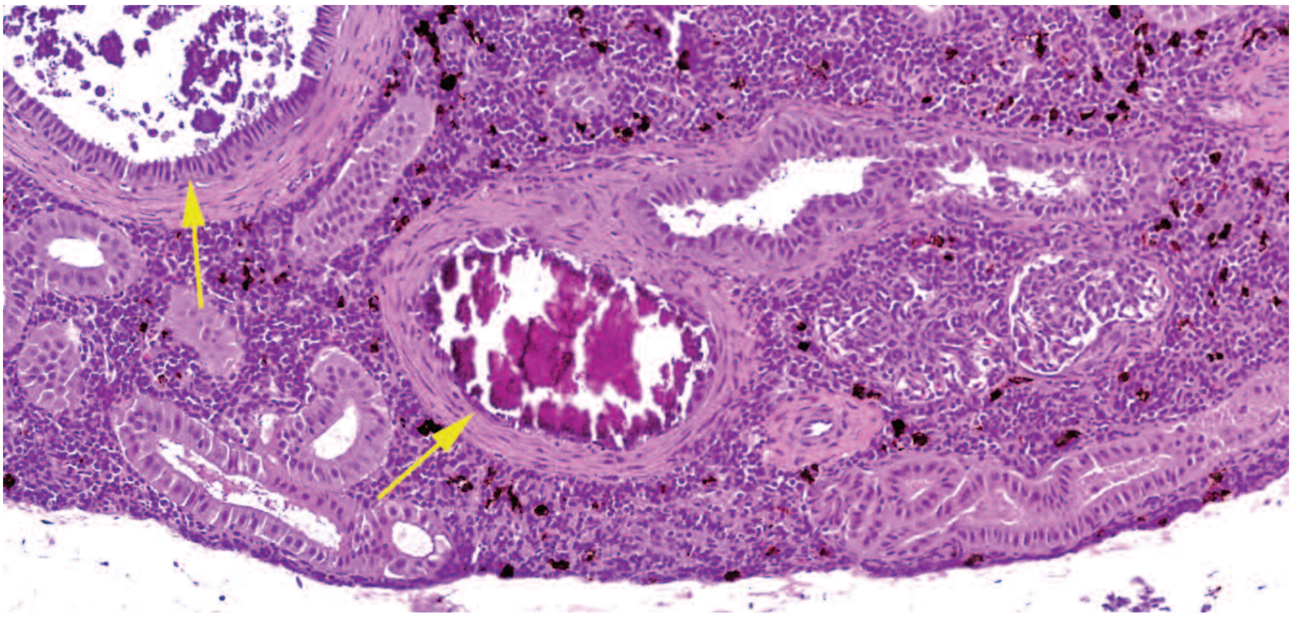

Figure 10.3.2 Renal calcification in salmon. Histopathological examination shows calcareous material in the collecting ducts for urine (arrow). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

10.4 Hemorrhagic smolt syndrome (HSS) / Hemorrhagic diathesis (HD)

By Geir Bornø, Anne Berit Olsen, and Toni Erkinharju

The disease

Hemorrhagic smolt syndrome (HSS), also known as hemorrhagic diathesis (HD), is a bleeding disorder in salmon that typically occurs in the late smolt phase and early after the release of salmon smolts into the sea. The fish often develop a bleeding pattern in the muscles, peritoneum, and internal organs and exhibit pale gills as a sign of anemia. Typically, in the early phase, bleeding occurs into the kidney's excretory system (tubules), where urine is formed (Figure 10.4.1). This condition often affects large, fine fish. The disease has also been described in salmon in Scotland.

The cause of this condition is not known, and so far, it has not been documented that the disease is caused by infectious agents. It is believed that the condition is related to osmoregulatory problems associated with the smoltification process, but this requires further research. HSS usually does not result in particularly high mortality, but in some cases, several thousand individuals with this condition and relatively high acute mortality have been reported. Normally, the condition improves in affected fish groups a few weeks after transfer to seawater.

Disease control

There is no control of this condition, but the development of the disease can be slowed/stopped by transferring affected fish groups to the sea. It is very important to consider more serious, infectious diseases such as viral hemorrhagic septicemia (VHS) as a possible differential diagnosis, as this condition also presents a bleeding pattern similar to what is seen in HSS/HD. When suspecting HSS, it is therefore necessary to secure samples for histopathological examination and PCR detection of the VHS virus.

Figure 10.4.1: Hemorrhagic smolt syndrome (HSS) in salmon smolts. Photo: Anne Berit Olsen, Norwegian Veterinary Institute.

The Health situation in 2023

Data from the Norwegian Veterinary Institute

As in 2022, the diagnosis of HSS in the Norwegian Veterinary Institute's material from 2023 was made on salmon from few hatcheries. In one case, HSS-like changes was observed in small fish (parr of 10-20 grams), something which has been sporadically observed earlier. The occurrence of HSS is uncertain. The disease is not notifiable, some samples are analyzed by private actors, and in some cases, samples are not sent for laboratory examination.

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Respondents also in 2023 list HSS as the most important problem related to mortality in salmon in the smolt phase (33 out of 59) (Appendix A1). Furthermore, HSS is assessed as the fifth most important cause of reduced welfare (21 out of 59) and reduced growth (13 out of 54). Some of the respondents (5 out of 47) consider the condition to be an increasing problem.

Evaluation of the HSS situation

In both 2021, 2022, and 2023, HSS was ranked in the survey as the most important cause of mortality in salmon smolt. The total occurrence of the disease is uncertain but may seem to have been relatively stable, although some respondents in both of the past two years have considered HSS to be an increasing problem in their areas. HSS is a disease that has been registered over many years, but where to date, there is still very limited knowledge about causal relationships.

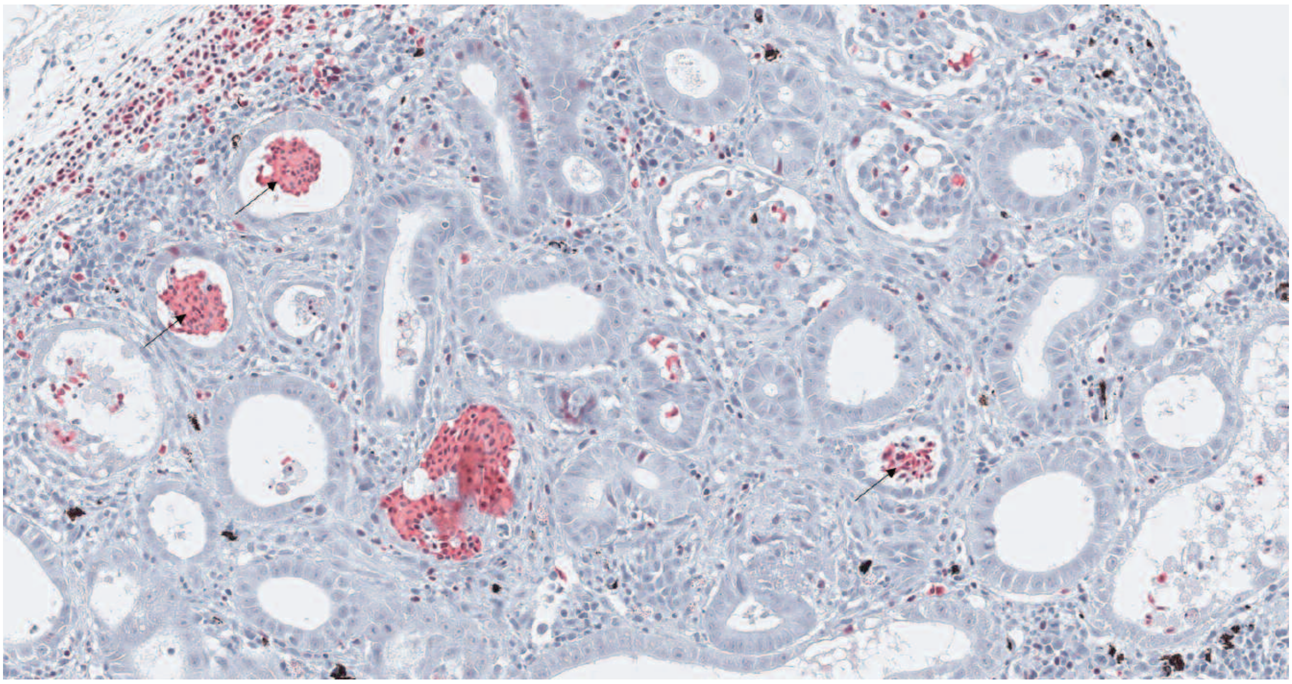


Figure 10.4.2: Tissue section of hemorrhagic smolt syndrome (HSS) in salmon smolts. Arrows indicate bleeding in the kidney's excretory system (tubules). Luna stain. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

10.5 Water Quality

By Åse Åtland, Endre Steigum og Ole-Kristian Hess-Erga
Norwegian Institute for Water Research (NIVA), Aquaculture Section

For many fish farmers, water quality is considered to be complex. Many physio-chemical parameters work together, and a certain understanding of these interactions is necessary to be able to assess whether a water quality is harmful to the fish or not. Whether the fish's welfare is negatively affected by the water quality also depends on the fish species, life stage and the total load the fish is exposed to in the form of other stressors such as handling, density, disease and other factors. NIVA's role is to assist with research and advice in this field, to both facilitate the understanding of water chemistry issues in fish farming and not at least to contribute to good, preventive measures and practical water treatment solutions. This is the sixth year with water quality as a separate theme in the Fish Health Report, and many of the various challenges NIVA has presented before are still relevant. During 2023, NIVA has worked on just over 40 mortality incidents. This amounted to approx. 20 percent of all the water chemistry-related cases we assessed for the aquaculture industry in Norway during 2023. Of these, we will characterize 24 as acute mortality events, and the largest proportion of these (58 percent) were linked to freshwater treatment in wellboats (14 cases). The review below is based on NIVA's own registrations and compared with the results of the survey.

Landbased facilities

With respect to water quality, a distinction was made in the survey between flow-through facilities and recirculating aquaculture systems (RAS). For each of these, we have looked at which main types of water chemistry challenges the respondents have listed as reasons for reduced fish welfare. The various water quality parameters (e.g. CO_2, O_2, temperature) were assessed separately, i.e. they were not weighted against each other.

In flow-through systems, as much as 53 percent of the respondents answered that they had experienced temperature-related challenges that caused reduced welfare (Figure 10.5.1). Furthermore, 38 percent answered that CO_2 had a negative effect and 26 percent that oxygen-related problems and turbidity affected welfare negatively. The other categories (metal toxicity, hydrogen sulphide (H_2S), pH and ammonia/nitrite) had a lower proportion of respondents who answered yes to a negative effect on fish welfare. This picture is also reflected in the comments of the respondents, where it is pointed out that low temperatures in winter and high temperatures in summer have caused problems in flow-through facilities. Low temperatures are linked to wound problems and lack of wound healing, whereas high temperatures are, among other things, linked to reduced growth and particle problems due to the increased need for feeding which leads to more feed spill and feces in the water.

Corresponding results from the survey relating to RAS showed that 46 percent of respondents answered yes to H_2S being a factor that had negatively affected welfare in 2023 (Figure 10.5.2). This is a clear increase from previous years (Figure 10.5.3). Furthermore, 41 percent answered that gas supersaturation had caused poor welfare and 33 percent that elevated levels of CO_2 affected welfare negatively. This is reflected in the comments given by the respondents. The H_2S events described do not appear to be of the massive, acute mortality type, with a few exceptions. Problems related to high particle content with subsequent gill irritation have been commented on by several respondents.

A review of the incidents NIVA has dealt with related to poor welfare or increased mortality in land-based facilities can provide a clear causal link, where, for example, quantitative measurements of gill metal give a clear indication. In other cases, the causal relationships are more unclear. As with the survey, NIVA's material also shows that mortality events related to elevated levels of H_2S do occur, and that this most often occurs in RAS systems with addition of seawater. The main reason for the formation of H_2S in brackish water RAS is that the added seawater contains over 1000 times more sulphate (SO_4^{2-}) than fresh water, which sulphate-reducing bacteria can under certain conditions convert into toxic H_2S. Such conditions can occur in sediments of organic material in pipes and/or in the biofilter with little oxygen present and under given conditions (thick biofilm, accumulation of dead fish, limited aeration, high organic load and low pH). Sensors have been developed that can measure H_2S in very low concentrations. This development has been important to learn more about which levels of H_2S the fish experience and where in an RAS systems there is the greatest risk of H_2S formation.

NIVA has registered a number of cases where water samples have shown elevated levels of H_2S in RAS, around 4-9 µg/l. This is considered to be well above the background levels of H_2S in the RAS, but lower than what we have previously experienced can lead to acute mortality in salmonids (35 µg/l H_2S). In principle, it is recommended not to exceed 2 µg/l for long-term exposure. In cases where changes in fish behavior, reduced fish health and increased mortality were observed, there was often a combination of several unfavorable conditions, including H_2S, particle load, high CO_2 and high total ammonium-nitrogen (TAN).

Mortality linked to toxic levels of the metals aluminum, iron and copper has also been observed in 2023. There are good water treatment solutions for such problems. Dosing of liquid sodium silicate in the intake water to complex the mentioned metals into non-toxic forms is a well-documented method. When this nevertheless causes problems, it is either because the fish farmer has not had good enough water chemistry monitoring of metals or because the silicate dosage has not been optimized.

NIVA also received several inquiries about total gas pressure (TGP) in water and the effect on fish, and this is in accordance with what the survey indicated for RAS facilities. 100 percent TGP means that the total gas pressure in the water is equal to the total gas pressure just above the water surface. Under such conditions, gas bubbles will not form in the water. It is only when the total gas saturation becomes higher than 100 percent

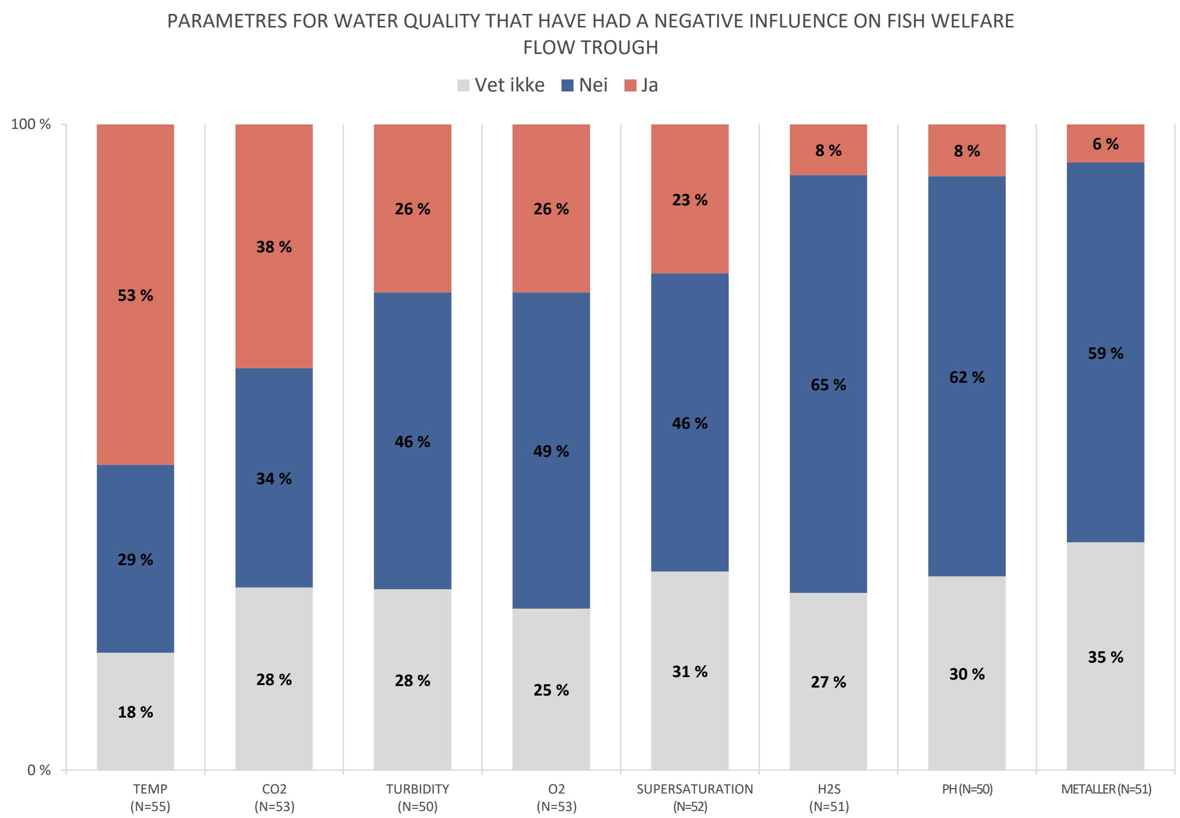


Figure 10.5.1 Proportion of respondents who stated that they had experienced that various water quality parameters had influenced fish welfare negatively in flow through farms in 2023. The number of respondents are given following each water quality parameter (N). N-compounds = Nitrogen compounds

that you must be cautious. In such cases, more gases are dissolved in the water than the water can hold. Based on these inquiries and measurements carried out, it may appear that slight gas supersaturation in facilities on land is relatively common. Whether weak and chronically gas-saturated water is problematic for the fish is not known with certainty, but there are many indications that the fish avoid this by mostly staying a few meters below the surface. During well boat operations, however, this can be a bigger problem (discussed in the next section).

Water quality related incidents in well boat operations

The survey does not include a breakdown of specific chemical causative factors in wellboat operations. Of the respondents who answered questions about reduced fish welfare linked to poor water quality in wellboats during smolt transport and/or wellboats with freshwater treatment (lice/AGD), 19 percent and 21 percent respectively, answered that they experienced this "occasionally". The majority answered "never", "rarely" or "don't know". The review below is therefore based on NIVA's follow-up of incidents for various fish farmers and well boat companies. As mentioned in the introduction, incidents in wellboats make up the majority of the total number of acute mortality incidents assessed by NIVA. During 2023, a total of 16 such incidents were recorded, of which 14 can be characterized as acute with high mortality and all but one related to freshwater treatment in a well boat. The number of incidents is a serious fish welfare problem and can result in large financial losses. The review of such incidents shows that several water-chemical factors have contributed. Among other things, elevated metal concentrations (aluminum and zinc) and H_2S in the water, as well as problems that can be caused by gas supersaturation. Furthermore, the incidents often appear to be multifactorial and connected to several of these problems at the same time. Problems related to aluminum toxicity are most

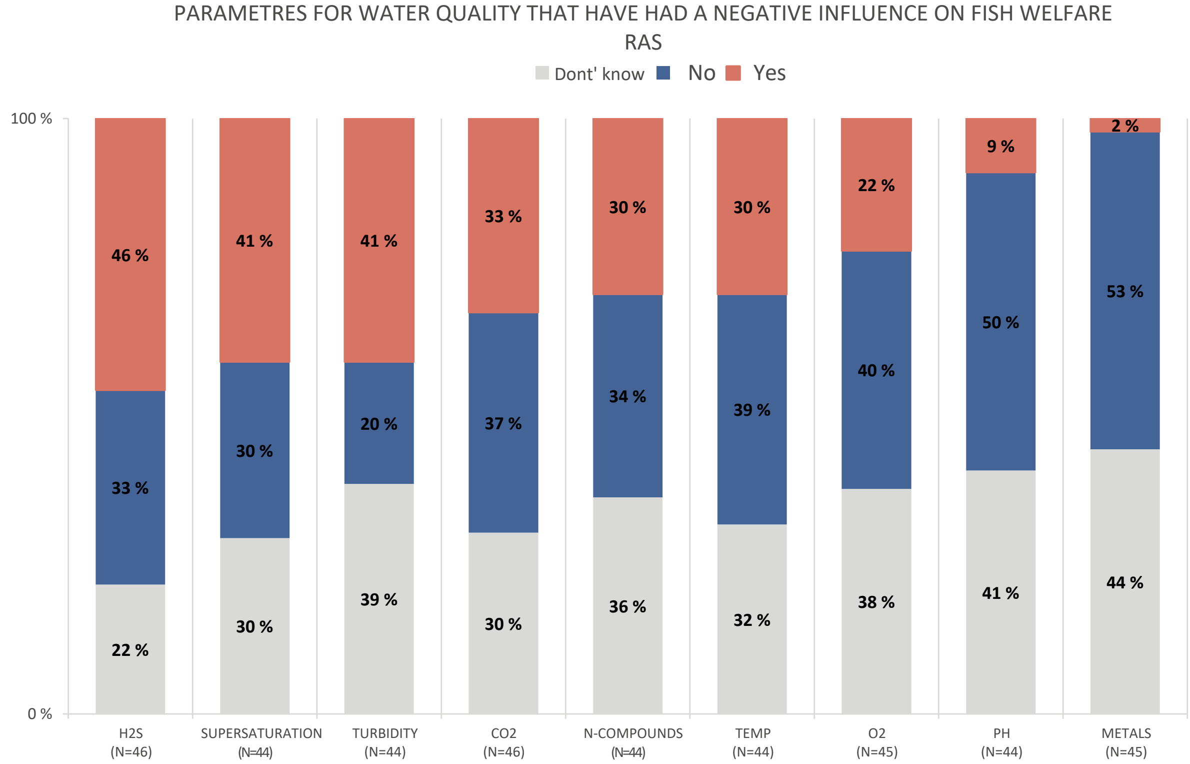


Figure 10.5.2 Proportion of respondents who stated that they had experienced that various water quality parameters had influenced fish welfare negatively in recirculate farms in 2023. The number of respondents are given following each water quality parameter (N). N-compounds = Nitrogen compounds

often linked to the quality of the fresh water used in the treatment, while zinc appears to be concentrated during the treatment, probably released from zinc-anodes in contact with the treatment water. In an earlier report from the Norwegian Food Safety Authority, it was recommended that the critical limits for zinc in soft water types should probably be set to 30 µg/l, and for hardness of >50 mg CaCO3/l, a limit value of approx. 200 µg Zn/l for salmon fish. Updated knowledge in this area is expected through the ongoing FHF project NYBRØK.

High gas supersaturation with a certain duration, on the other hand, has been shown to have a serious effect on fish through controlled experiments in the NYBRØK project (see Norwegian Fish Farming magazine no. 10/23). If the total gas pressure in the water is above 100 % TGP, bubbles can form in the water. However, it is important to specify that bubbles will not be able to form in the water when the TGP is less than 100%, even if a single gas is supersaturated (for example N_2 gas). TGP (%) must therefore always be used and not residual gas or N_2 (%) when the effect on fish is to be assessed.

How to reduce water quality induced incidents?

Thorough documentation and review of mortality episodes, as well as good water chemistry monitoring, is essential to reduce this type of mortality in the Norwegian aquaculture industry.

Furthermore, it is important to ensure the best possible level of documentation is ensured - this applies to both incidents in land- and sea-based facilities. The mortality events should be evaluated in collaboration with fish farmers, well boat companies, fish health services, veterinarians, and experts in water quality. In this way, learning and knowledge can be ensured.

New generations of fish farmers are coming up, and the educational institutions play an increasingly important role from upper secondary schools, vocational schools to university-level educations. It is essential to ensure both good basic knowledge in water chemistry as well as industry-relevant experience-based knowledge.

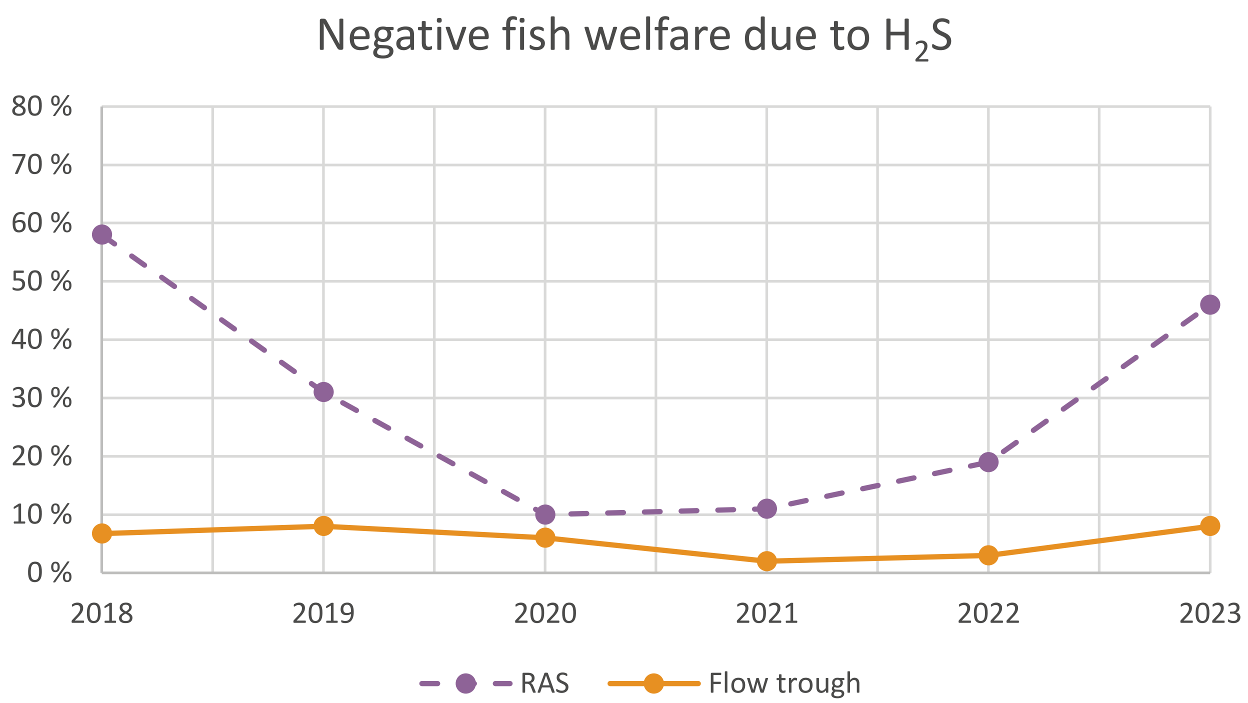


Figure 10.5.3 Results from the annual survey (%) related to H2S having negatively affected fish welfare in recirculation (RAS) and flow through farms in 2018 to 2023

10.6 Vaccine side-effects

By Kristoffer Vale Nielsen and Sonal Jayesh Patel

This chapter focuses on vaccine side effects and welfare challenges in the vaccination process. Vaccination as a biosecurity measure and to reduce the severity of disease (vaccine efficacy) is discussed in Chapter 4 Biosecurity.

Fish can be vaccinated by immersion, bath, orally through feed, and by injection. In Norway, intraperitoneal (i.p.) injection with multivalent oil-based vaccines is the most common basic vaccination method for salmonid fish. Several suppliers of vaccination machines offer multi-channel solutions, where simultaneous vaccination with up to three vaccines in the abdominal cavity and one intramuscularly is possible. It is common to vaccinate salmonid fish at the pre-smolt stage so that they are protected against various infectious diseases that may occur in the sea phase. Bath or immersion vaccines are used when there is a need for immunization of small fish (typically less than 20 grams) or when injection vaccination is not optimal for other reasons.

Injection vaccination at the pre-smolt stage may cause various acute side effects in the vaccinated population or among a certain percentage of the fish group. These side effects may result from the vaccination process and/or due to the vaccine itself. Acute side effects of vaccination may often appear as reduced appetite or increased mortality for a shorter period. Adverse events if any during vaccination process may affect the side effects or the efficacy of the vaccines. For example, vaccine leakage through the injection site will result in fish being exposed to a lower dose than needed. Incorrect injection or deposition of the vaccine may result in stronger side effects or reduced efficacy, and contamination of vaccination equipment may result in infection and mortality in fish shortly after vaccination.

Long-term side effects commonly observed in salmon post i.p. vaccination with oil-adjuvanted vaccines include various degrees of adhesions between organs in the abdominal cavity, between internal organs and the abdominal wall, melanin deposition, and reduced appetite and growth for a period after vaccination (Figure 10.6.1). There have also been reports of spinal deformities, where a specific type called "cross-stitch

Figure. 10.6.1 Minor adhesions and melanin depositions in the area around the injection site.
Photo: Kristoffer Vale Nielsen, Norwegian Veterinary Institute

vertebrae" has been associated with some of the oil-adjuvanted PD vaccines. These side effects can be assumed to be painful for the fish. The degree of side effects will vary with vaccine type and conditions surrounding vaccination such as fish size, degree of misplaced vaccination, injection pressure, water temperature, hygiene, etc.

In 2023, 17 reports of welfare events related to vaccination were received by the Norwegian Food Safety Authority (Chapter 5 Fish Welfare). This is approximately at the same level as in years 2021 and 2022.

The Annual Survey

59 out of 112 respondents (53 percent) reported having experience with vaccination of salmonids, vaccine side effects, and/or the degree of protection post vaccination.

The results show that it is relatively common among respondents to register increased mortality and/or reduced appetite post vaccination (Figure 10.6.2). Degree of mistargeted deposition of vaccine in more than 5 percent of the fish occurs relatively rarely, suggesting that the level of precision is satisfactory in most cases. Compared to last year's reports, there is a tendency for an increase in both increased mortality, reduced appetite, and mistargeting. Whether this represents a real worsening in vaccine side effects is unclear, but it indicates a need for extra attention to this issues in the future.

Twelve respondents used the free-text field to provide additional information regarding acute vaccine side effects and the vaccination process. Several of these, claim that episodes of mortality following vaccination can often be related to technical issues or handling. Others mention challenges related to low water temperature during and post vaccination. These challenges include wound development and transfer to sea before the recommended number of degree-days to achieve immunity.

The survey shows that most respondents believe that long-term vaccine side effects, to a certain extent, occur relatively rarely (Figure 10.6.3). Among several side

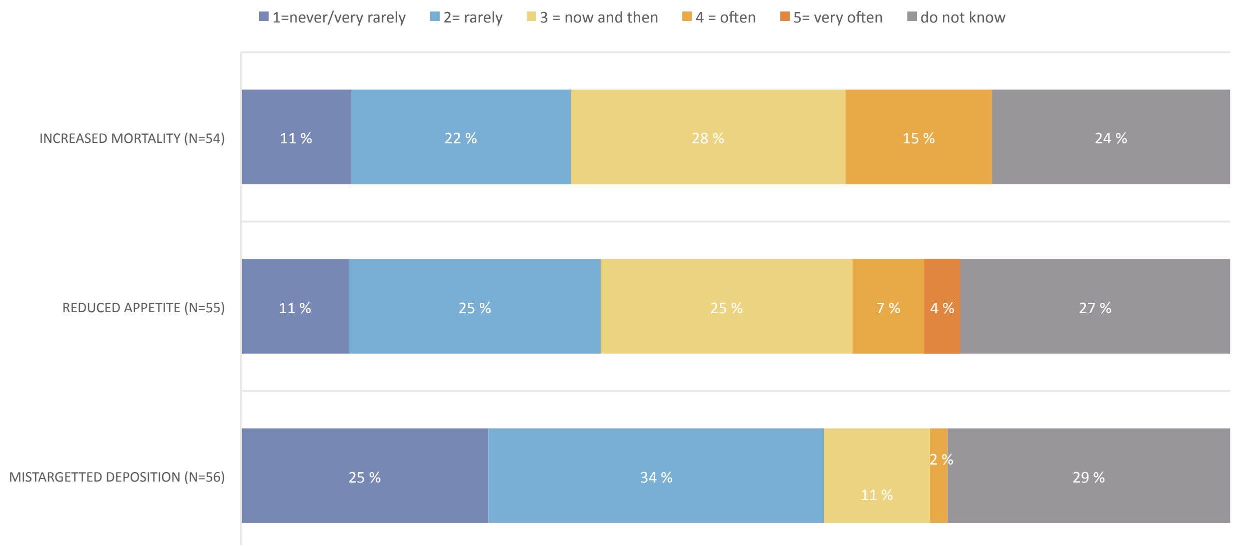


Figure 10.6.2 Summarized responses to the question: "How often do you experience the following acute vaccine side effects and vaccination process in hatcheries ?", with the side effects "Increased mortality after vaccination", "Reduced appetite lasting more than 7 days", and "Mistargeting in more than 5 percent of the vaccinated fish". The scale for each category was from 1 = never/very rarely to 5 = very often, as well as an option of "do not know". The columns for each acute side effect indicate the percentage of the responses within each category.

effects such as spinal deformities, reduced growth, melanin in fillets, and the degree of adhesions, melanin is perceived as the most common. The long-term side effects in year 2023 are at approximately at the same level as in 2022.

Regarding long-term vaccine side effects, nine respondents had provided other or elaborating comments. These respondents were concerned about spinal deformities and increased degree of adhesions around the buccal cavity/pharyngeal region, and that this can, among other things, cause problems for gonad development in broodstock. The cause of the increased adhesions is stated to be related to the viscosity of the vaccine.

In the overarching welfare questions in the survey, where a wide range of disease and welfare issues are compared, vaccine injuries do not rank high on the list of the welfare problems in salmon and rainbow trout farming. Taking into account the extent of vaccination, and thus the possible extent of reduced welfare due to vaccine side effects, it is crucial to continually focus on reducing the side effects.

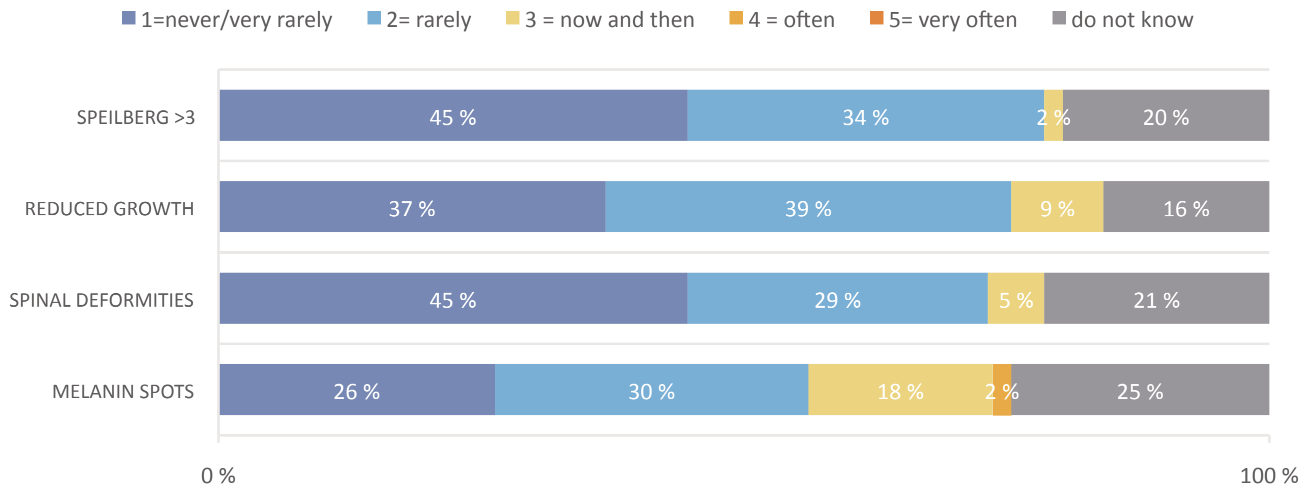
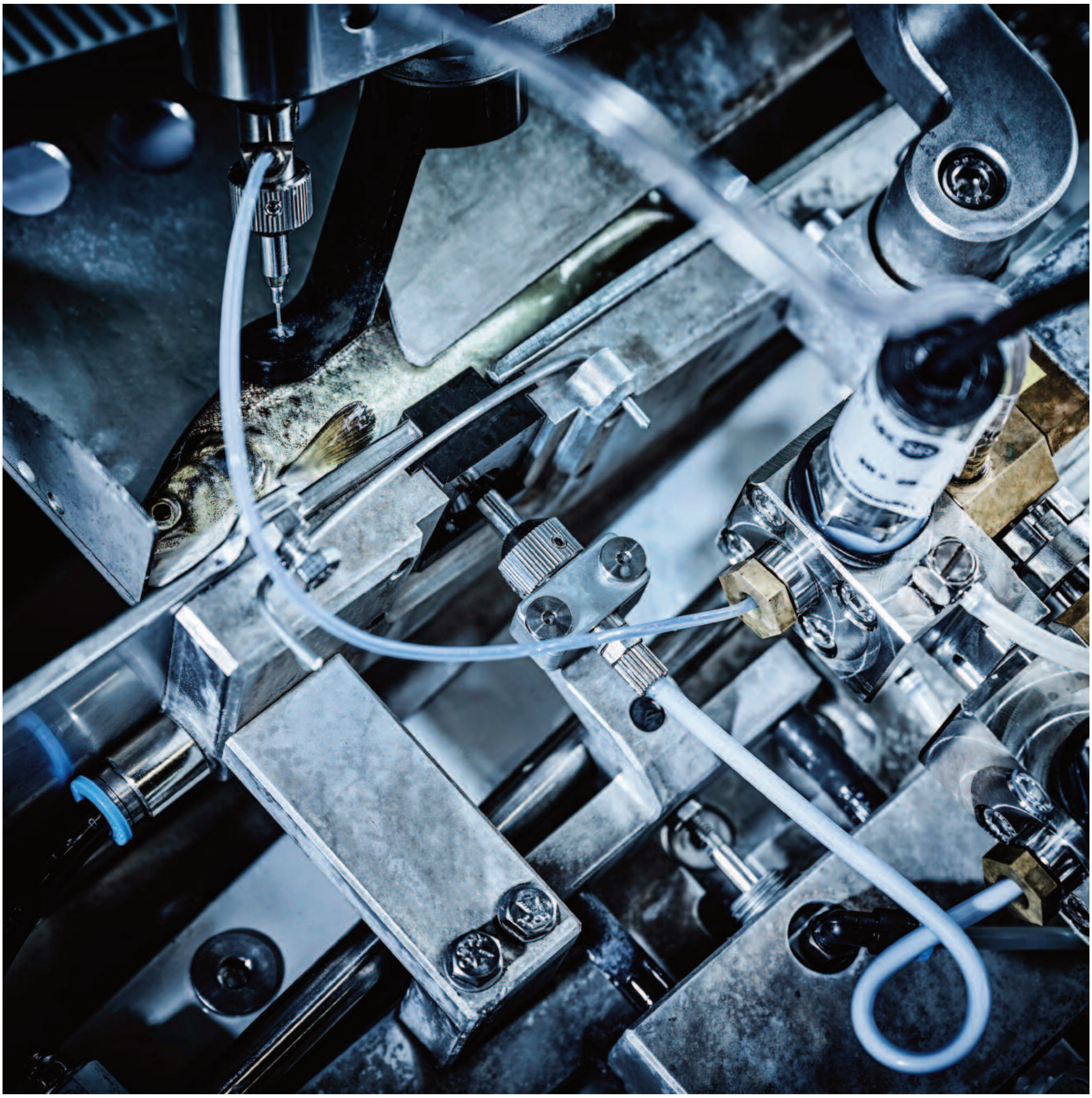


Figure 10.6.3 Summarized responses to the question: "How often do you experience the following long-term vaccine side effects in grow-out facilities/slaughter lines?": "Speilberg score grade 3 or above in more than 10 % of examined fish" (Speilberg > 3, N = 56), "Suspicion of reduced growth in the fish group due to vaccine side effects" (Reduced growth, N = 57), "Suspicion of vaccine-induced spinal deformities in more than 5% of the fish" (Spinal deformities, N = 56), and "Suspicion of vaccine-induced melanin spots in muscle tissue" (Melanin, N = 57). The scale for each category was from 1 = very rarely/never to 5 = very often, as well as an option of "do not know". The columns for each long-term side effect indicate the percentage of the responses within each category.



Vaccination is an important biosecurity measure in Norwegian aquaculture. The image shows vaccination of salmon using atomatic machines, where one vaccine is given in the dorsal muscle and another in the abdomen simultaneously. The fish are pre-anesthetized, and the correct needle placement is calculated by the software for each individual. Photo: MSD Animal Health.

10.7 Algae, Jellyfish and Fish Health

By Geir Bornø, Julie Christine Svendsen, and Even Thoen (PatoGen)

Algae and Jellyfish

Both algae and jellyfish can cause various types of harm to fish, often affecting individual facilities, but occasionally leading to larger outbreaks both in Norway and abroad. Harmful effects that jellyfish can inflict on fish can be indirect, such as clogging of water flow into the pens resulting in subsequent oxygen depletion, or direct. The direct effects include mechanical blockage of the mouth and gill cavity and toxic effects from the jellyfish's stinging cells. The latter can cause damage particularly to exposed surfaces such as skin, eyes, and gills. Lesions caused by jellyfish stinging cells can pave the way for secondary infections, and eye injuries can lead to weakened or lost sight. Acute mortality has been particularly linked to gill damage. It has also been described that affected and stressed fish may panic and swim into the net wall, which in turn can worsen the injuries.

In 2023, the string jellyfish Apolemia uvaria (Figure 10.7.1) caused high mortality in farmed fish, and the damage inflicted by the jellyfish on gills and skin had serious consequences for the fish's health and welfare (Figure 10.7.2).

Algae have not been a serious problem since 2019 when the northern part of Nordland and southern Troms were severely affected by the toxic algae *Chrysochromulina leadbeaterii*, leading to very high acute mortality.

The Health Situation in 2023

The Annula Survey

Based on responses from fish health personnel and inspectors in the Norwegian Food Safety Authority in this year's survey, jellyfish are considered a major challenge for both salmon and rainbow trout in 2023. Overall, jellyfish are rated as the fifth-largest health problem for salmon in ongrowing facilities nationwide (Appendix B1), somewhat more severe in PA10-PA13 where jellyfish problems rank fourth (Chapter 5 Fish Welfare, Figure 5.1.1c).

More than half of the respondents (57 out of 100) have indicated jellyfish as one of the most increasing problems for salmon in ongrowing facilities in 2023, placing jellyfish at the top of the list of increasing occurrences. Jellyfish are further reported to pose welfare challenges (25 out of 102) and reduced growth (8 out of 99 respondents).

Jellyfish are also ranked relatively high as a problem for rainbow trout in terms of mortality, reduced welfare, and as an increasing problem in ongrowing facilities (Appendix B2). Algae are not perceived by the respondents as a significant health problem for salmon and rainbow trout in ongrowing facilities in 2023, ranking relatively low on the list of health problems.

Evaluation of the Jellyfish Situation

Throughout the autumn of 2023, fish personnel reported significant quantities of jellyfish during site visits, especially the colony-forming string jellyfish Apolemia uvaria. The string jellyfish was first registered in Norway in 1997 and has since sporadically caused significant mortality in farmed fish. The Institute of Marine Research writes in this year's risk report for Norwegian fish farming about cases of string jellyfish attacks reported to the Norwegian Food Safety Authority last autumn. Their summary shows that a total of 51 sites reported attacks by string jellyfish. Geographically, there were most affected sites in PA3, with 20 reported cases. PA10 was also heavily affected with eight cases, followed by PA2, PA11 and PA12 being more affected than the remaining production areas (Table 10.7.1). The reports came in from October to December.

Figure 10.7.1 String jellyfish (*Apolemia uvaria*). Photo: Erling Svensen

String jellyfish have accounted for a significant portion of mortality in the aquaculture industry in 2023, especially late autumn and up to the turn of the year. It has been necessary to destroy or slaughter relatively small fish for welfare reasons and poor prognosis.

Jellyfish pose a continuous threat to fish in aquaculture environments. Climate change with increasing sea temperatures may change the dynamics of most types of jellyfish. Furthermore, overfishing of wild fish will reduce natural jellyfish predation, thereby increasing the risk of exposure to aquaculture facilities. For open pens, fish may quickly be exposed to jellyfish flakes without prior warnings. The situation may worsen as jellyfish are crushed against the net wall before entering the pen and coming into contact with the fish. Furthermore, exposure to jellyfish in many cases may be short-lived, and it is suspected that most cases remain undetected. There is also significant concern that jellyfish may enter treatment water in various non-medicinal methods. To date, there is no control of intake water, and in several cases, there is suspicion that jellyfish may be the cause of rapidly occurring gill disease after such treatments. Careful monitoring of gill health (both macroscopic and

Table 10.7.1: Number of reported cases of string jellyfish attacks to the Norwegian Food Safety Authority per production area (PA) during the autumn of 2024. Source: Risk report Norwegian fish farming 2024, Institute of Marine Research.

	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12
Number of jellyfish attacks	0	5	20	2	1	0	3	0	3	8	4	5

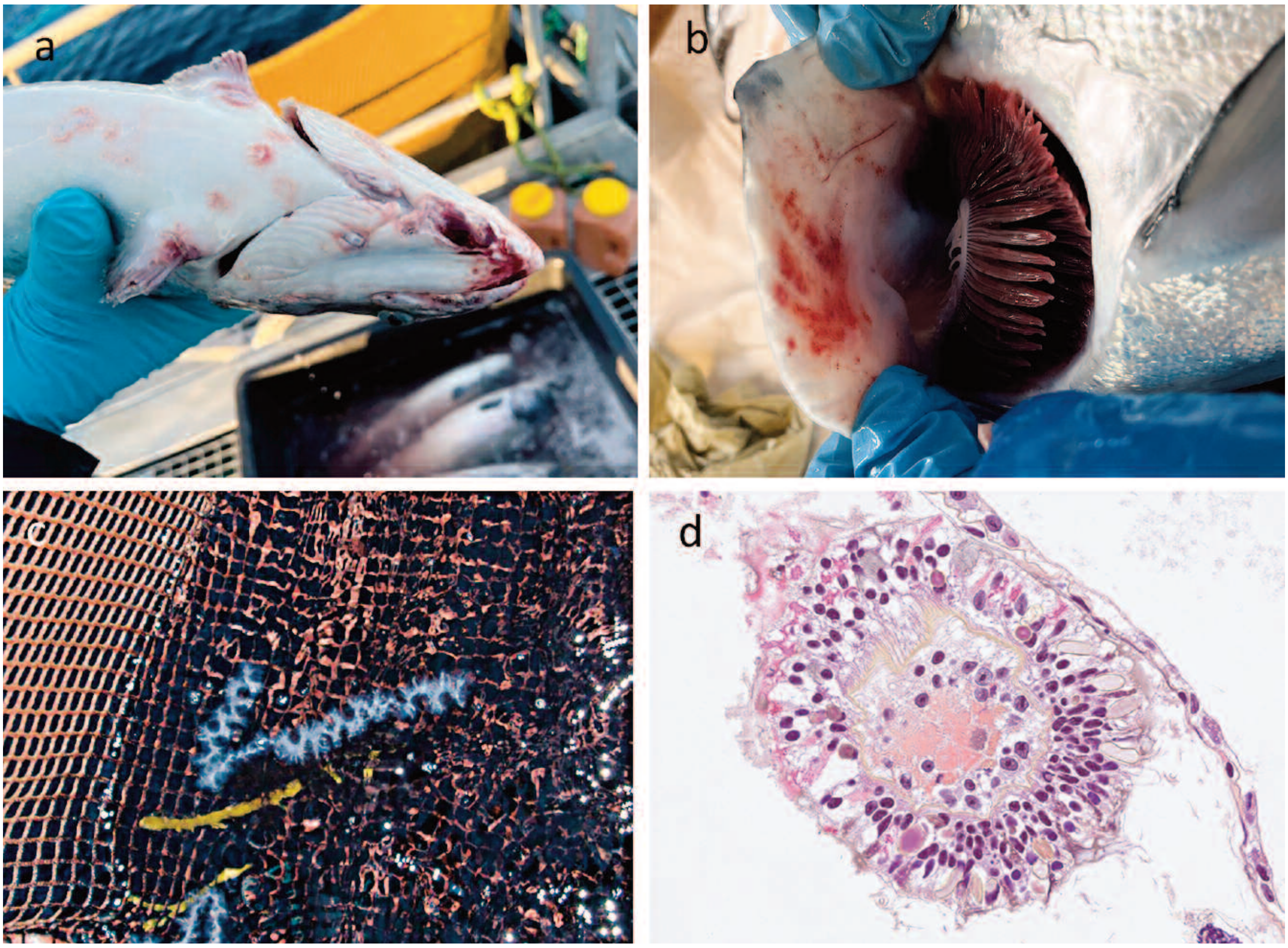


Figure 10.7.2 Damage to salmon caused by string jellyfish. a) Salmon with bleeding, wounds, and eroded fins. b) Gill damage. c) String jellyfish in the net. d) Tissue section of string jellyfish (HE staining). Photo: a) Margareth Møgster, Institute of Marine Research, b) Monica Nordberg, Aqua Kompetanse c) Åkerblå d) Geir Bornø, Norwegian Veterinary Institute.

histological) and a vigilant eye on the water environment will be crucial to uncover the correlation.

Much work remains in mapping the tissue damage caused by the various types of jellyfish. This knowledge must be in place before the extent of jellyfish-induced gill damage can be fully understood. For example, systematic monitoring programs and preparedness measures at each site could alleviate the situation.

See the Norwegian Fish Health Report 2022, Chapter 9.7 Algae, Jellyfish and Fish Health, for more background on algae, as well as a description of gill tissue changes associated with string jellyfish impact.

11. Health situation in wild fish

By Åse Helen Garseth

Wild fish under pressure

The nature crisis is considered one of the greatest challenges facing humanity. The term refers to the dramatic loss of species and biodiversity resulting from human activities. Habitat alteration is the greatest threat for wild species both in Norway and internationally. Additionally, climate change, introduction of alien species, and overexploitation of resources pose significant threats.

When the international Red List for species was updated in 2023, 25 percent of the assessed freshwater fish species were assessed to be at risk of extinction. At least 17 percent of the threatened freshwater species were affected by climate change, and 33 percent by alien species and diseases (International Union for Conservation of Nature). Atlantic salmon was assessed to be in the near-threatened category due to a global population decline of 23 percent from 2006 to 2020. Wild Atlantic salmon now occur in a small portion of the rivers in Northern Europe and North America where they originally inhabited. Atlantic salmon are affected by several different threats, some of which directly or indirectly impact the health.

To make their assessments, researchers rely on access to information about the factors affecting the species. Knowledge of health status can also contribute to better management of wild populations. The history of *Gyrodactylus salaris* in Norway, from introduction and spread to control, is a good example of this. Other pathogens also have the potential to reduce populations, including the parasite *Tetracapsuloides bryosalmonae*, which is discussed in the next chapter. Knowledge of wild fish as reservoirs of infection is important for managing disease in the aquaculture industry. On the other hand, there is also a need for knowledge on how disease transmission from aquaculture affects wild populations. Within the Norwegian Veterinary Institute's societal mission lies the responsibility to monitor and investigate infectious diseases in animals. This responsibility also includes wild fish in freshwater and marine environments.

Sources of knowledge about wild fish health

Knowledge about the health of wild fish can be generated through monitoring, disease investigation, and research. In this fish health report, data are primarily based on the work of the Norwegian Veterinary Institute. This includes the Wild fish health portal, which relies on vigilance and reporting from fishermen, researchers, managers, and the general public who frequent natural areas.

In 2023, a large number of stock enhancement hatcheries contributed their health data from wild-caught anadromous broodfish.

Organized health monitoring programs

On behalf of the Norwegian Food Safety Authority, the Norwegian Veterinary Institute annually conducts monitoring for Gyrodactylus salaris in salmon rivers, as well as monitoring for crayfish plague (Aphanomyces astaci) in noble crayfish. The Institute of Marine Research conducts health monitoring for salmon lice and various fish-pathogenic viruses in wild salmonids on behalf of the Norwegian Food Safety Authority.

In 2023, as in 2019 and 2021, the Norwegian Veterinary Institute included samples from pink salmon in health monitoring of wild fish and the monitoring and control program for VHS and IHN. The Norwegian Veterinary Institute considers it important to map the infection status of selected listed pathogens in addition to investigating reported diseases in pink salmon. Due to the general interest in pink salmon, there are several institutions mapping health aspects of pink salmon. This has been done through various student projects. Collectively, these contributions will eventually provide valuable knowledge about this species.

Health control of wild broodstock for stock enhancement and gene bank for wild salmon

Stock enhancement facilities and gene banks for wild salmon are required to conduct health checks on wild-caught anadromous salmonid fish used as broodstock (Aquaculture Operations Regulations). Unlike commercial broodstock farming, there is a specific requirement for wild anadromous broodstock to be tested for bacterial kidney disease (in practice, testing for *Renibacterium salmoninarum*). In this context, several facilities also choose to examine other pathogens relevant to the area where the broodstock is caught. Over time, these investigations generate a time series of studies in multiple watercourses. Chapter 11.2 and 11.3 presents results from testing of wild-caught broodstock in the gene bank for wild salmon and stock enhancement hatcheries in 2023.

Wild Fish Health Portal

According to the animal health regulations, everyone is obliged to notify the Norwegian Food Safety Authority of abnormal mortality and other signs of serious illness in wild aquatic animals. According to the regulations, the notification shall be given in the manner prescribed by the Norwegian Food Safety Authority, which is via the Norwegian Veterinary Institute's Wild Fish Health Portal.

The Wild Fish Health Portal is thus part of the national preparedness, and its main purpose is to facilitate effective notification when serious events affecting fish health in Norway are discovered. In addition to providing valuable insight into the health of wild fish in general, it identifies health challenges that should be actively followed up with further investigation and monitoring. The reporting system applies to all species of fish in freshwater and marine environments. Reported cases are continuously evaluated by experts in fish health, and all those reporting a case should receive a response from the Norwegian Veterinary Institute.

It is not only in connection with serious infectious diseases that the reporting system can be used. The more the system is used, the more knowledge is generated about the health of wild fish, and the better the Norwegian Veterinary Institute becomes as a professional community on this topic.

More than 60 different cases of disease and mortality in wild fish were reported to the Norwegian Veterinary Institute in 2023. Several of the cases were reported outside of the portal itself. The reports covered diseases in both salmonids, freshwater fish, and marine fish and came from all over the country (Figure 11.1).

Other relevant reporting systems

Some of the inquiries to the Wild Fish Health Portal concern species identification, often in combination with diseases. Discoveries of alien species should be reported to the Norwegian Biodiversity Information Centre, via the database "Species Observations." At the Norwegian Institute of Marine Research's "Volunteer for the Sea" platform, you can also register observations and contribute to mapping the occurrence of various species in the sea. This has been particularly important in 2023 when the string jellyfish *Apolemia uvaria* spread along the coast and caused damage to farmed fish. Acute pollution should be reported to the fire department at 110. Stranding of shrimp and krill are reported to the Institute of Marine Research.

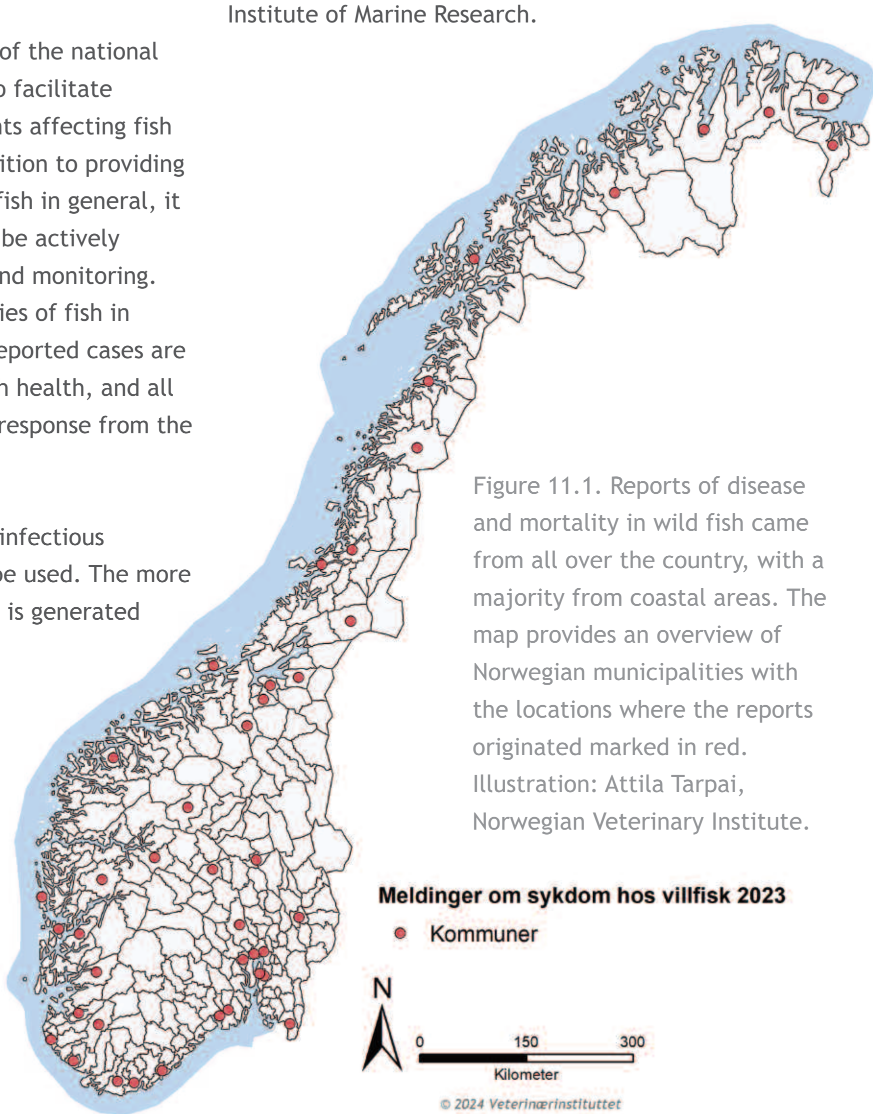


Figure 11.1. Reports of disease and mortality in wild fish came from all over the country, with a majority from coastal areas. The map provides an overview of Norwegian municipalities with the locations where the reports originated marked in red. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

11.1 Health status of wild fish

By Åse Helen Garseth, Lisa Furnesvik and Haakon Hansen

Notifiable bacterial diseases

Bacterial Kidney Disease (BKD)

Bacterial Kidney Disease (BKD) is caused by the bacterium Renibacterium salmoninarum and is a serious notifiable disease (category F). This means that suspicion of BKD in wild fish, such as through positive PCR analyses from wild-caught broodstock, should be immediately reported to the Norwegian Food Safety Authority or the Norwegian Veterinary Institute. Diagnosis should be verified by the Norwegian Veterinary Institute, which serves as the national reference laboratory. BKD is also discussed in Chapter 7.3 and in fact sheets provided by the Norwegian Veterinary Institute: **https://www.vetinst.no/sykdom-og-agens/bakteriell-nyresjuke-bkd.**

There is no vaccine or relevant medication for BKD. Accordingly, prevention of transmission and disease must rely on measures to reduce infection in aquaculture and stock enhancement activities.

Health control of wild broodfish: The most important individual measure against BKD in stocking programs is health examination of broodfish aimed at eliminating carriers of the bacterium. This measure is based on the fact that *R. salmoninarum* is transmitted from parents to offspring through fertilized eggs, known as vertical transmission. Testing of individual broodfish, followed by disposal of infected egg batches from carrier parent fish, or the entire brood stock is a measure that interrupts this route of transmission. The most common testing method

Table 11.1.1 Overview of reported qPCR results from testing of wild anadromous broodfish examined by stock enhancement hatcheries in 2023. The table shows the number of fish tested for *R. salmoninarum* (*R.salm.*), *Aeromonas salmonicida (A. salm.)* and other pathogens in each river. R. salmoninarum was not detected in 2023. (Notes: [1]: Based on the capture of wild fingerlings that are reared to become brood fish. [2]: Based on precocious males. *One PRV-1 positive. ** Three PRV-3 positive.)

County	River	Species	R. salm.	IPNV	ISAV	PMCV	PRV-1 /PRV-3	A. salm.	Analyse-lab.
Telemark	Skienselva	Salmon	40	0	0	0	0	0	PatoGen
Rogaland	Imsa	Salmon	42	0	0	0	0	0	Pharmaq
	Suldalslågen	Salmon	41	0	0	0	0	0	PatoGen
Vestland	Aurlandselva [1]	Salmon	143	0	0	0	0	0	Pharmaq
	Dale-elva (Hordaland)	Salmon	39	0	0	0	0	0	Pharmaq
	Fortunselva[2]	Salmon	9	0	0	0	0	0	PatoGen
	Fortunselva	Salmon	12	0	0	0	0	12	PatoGen
	Lærdalselva	Salmon	22	23	0	0	0	0	PatoGen
	Vikja	Salmon	12	12	12	0	12	0	Pharmaq
	Årøy	Salmon	20	0	0	0	0	0	PatoGen
Møre og	Eresfjord	Salmon	14	14	14	0	14*	14	PatoGen
Romsdal	Eresfjord	Sea trout	8	8	8	0	8**	8	PatoGen
	Surna	Salmon	14	14	14	0	0	14	PatoGen
	Bævra	Salmon	12	12	12	0	0	12	PatoGen
	Toåa	Salmon	10	10	10	0	0	10	PatoGen
Trøndelag	Gaula	Salmon	13	13	0	0	0	13	Pharmaq
	Mossa	Salmon	13	13	13	0	0	0	PatoGen
	Stjørdalselva	Salmon	10	10	10	0	0	0	PatoGen
Total	**17 elver**		**474**	**129**	**93**	**0**	**12**	**83**	

today is qPCR. Table 11.1.1 shows reported results from qPCR-based testing conducted for stock enhancement hatcheries in 2023.

Testing for *R. salmoninarum* can also be based on culturing for the bacterium. However, this method is more time-consuming because *R. salmoninarum* grows slowly and requires special growth media supplemented with the amino acid cysteine to grow (such as Kidney Disease Medium (KDM) or selective KDM-medium (SKDM). The use of standard blood agar is therefore not suitable. At the Norwegian Veterinary Institute, KDM plates are incubated up to 12 weeks.

The health control of wild broodfish conducted by stock enhancement hatcheries is the most important source of knowledge about the occurrence of *R. salmoninarum* in wild salmonids. In addition, routine autopsies, histopathological examinations, and culturing for the bacterium on suitable media in connection with disease clarification in wild fish are important contributions to surveillance. With the resurgence of BKD in commercial aquaculture, vigilance within the wild fish segment is also increasing.

Occurrence in wild fish: In Norway, BKD was first detected in offspring from wild Atlantic salmon in 1980. According to the Aquaculture Operation Regulation, all wild anadromous salmonids used as broodfish in stocking programs must go through a post mortem examination and at least be tested for bacterial kidney disease. Approximately 500-1000 wild-caught salmonids are thus examined every year. Over the 20-year period from 2004 to 2023, *R. salmoninarum has been detected in* four watercourses in connection with health control of wild broodfish, rivers Ekso in 2005, Vosso in 2012, Lærdal in 2014 and Dale in Hordaland in 2019. Detection in Ekso was based on ELISA conducted by the Faroe Islands Food and Veterinary Authority, detection in Vosso was based on PCR, histology, and immunohistochemistry, while detection in Lærdal and Dale were based on qPCR (see figure 11.1.1). *R. salmoninarum* was not detected in wild salmonids in 2023.

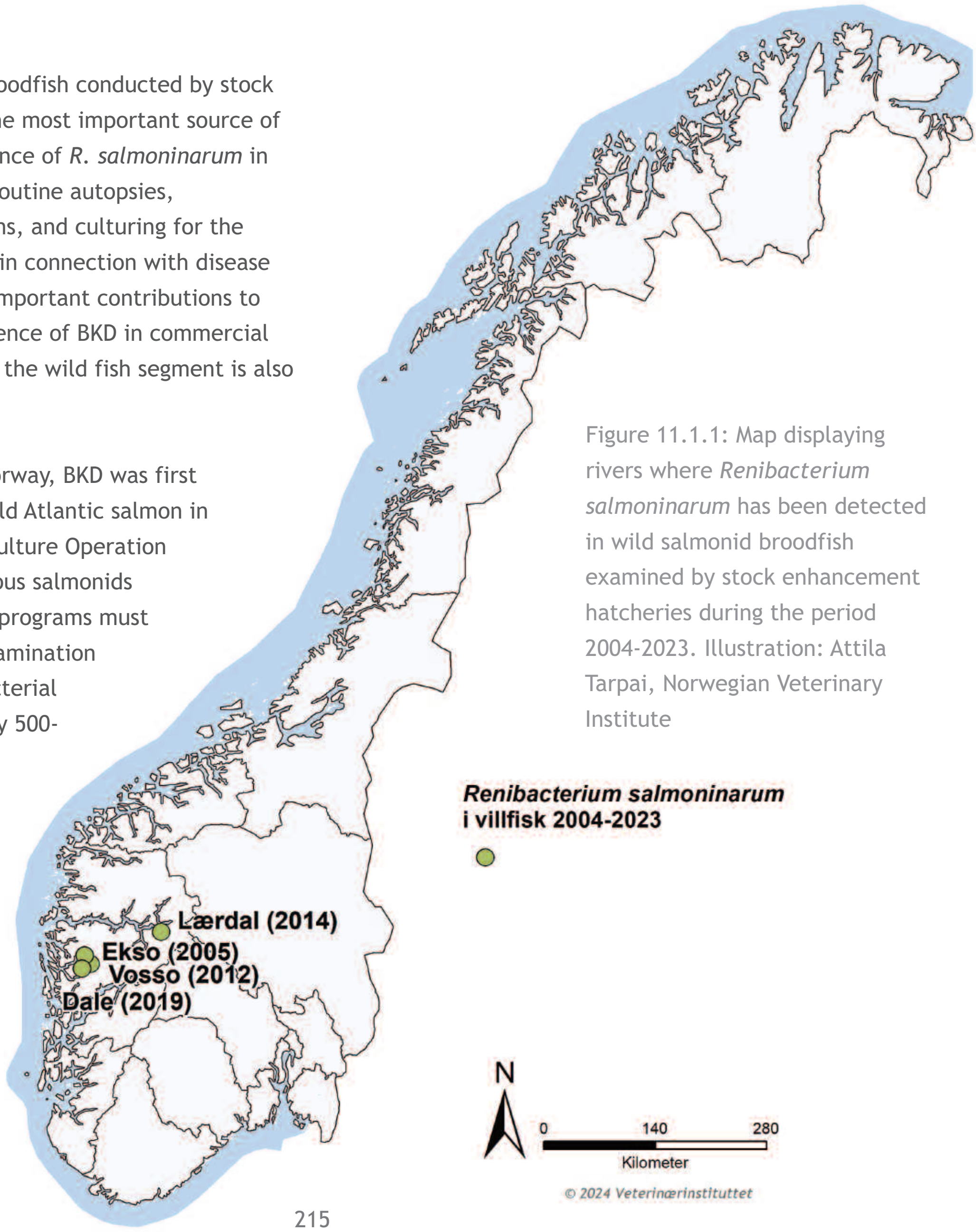


Figure 11.1.1: Map displaying rivers where *Renibacterium salmoninarum* has been detected in wild salmonid broodfish examined by stock enhancement hatcheries during the period 2004-2023. Illustration: Attila Tarpai, Norwegian Veterinary Institute

Figure 11.1.2 Classic furunculosis in a wild Atlantic salmon (top). Furuncle in a wild Atlantic salmon with classic furunculosis (bottom). Photo: Anton Rikstad (top) and Geir Bornø, Norwegian Veterinary Institute (bottom)

Classic furunculosis

Classical furunculosis is caused by the bacterium *Aeromonas salmonicida* subsp. *salmonicida* and is a notifiable disease (category F). All suspicions of the disease or detections of the bacterium in wild fish must be immediately reported to the Norwegian Food Safety Authority or the Norwegian Veterinary Institute. The diagnosis must be verified by the Norwegian Veterinary Institute, which serves as the National reference laboratory.

The bacterium causing classical furunculosis was introduced to Norway on two known occasions. The first instance occurred with infected farmed rainbow trout from Denmark in 1964, and the second occurred with infected farmed salmon smolt from Scotland to aquaculture facilities in northern Trøndelag in 1985. The introduction in 1964 led to the spread to wild salmon in the River Numedalslågen, resulting in near yearly outbreaks among wild salmon during the period from 1966 to 1979. The last detection in Numedalslågen was in 1990. Following the introduction to northern Trøndelag in 1985, the infection spread among aquaculture sites and further to wild salmonids in watercourses. Nearly 40 years after the introduction, the reservoir of infection established in watercourses around the Namsen fjord persists. Another long-term consequence of the introduction is that the aquaculture industry, four decades later, still vaccinates over 400 million farmed fish annually to protect against this infection. In addition to salmonids, lumpfish are also susceptible to *Aeromonas salmonicida* subsp. *Salmonicida*. Classical furunculosis is also discussed in Chapter 7.2 and in fact sheets provided by the Norwegian Veterinary Institute.
https://www.vetinst.no/sykdom-og-agens/furunkulose.

Common findings in adult fish with furunculosis are bloody boils, known as furuncles, in the musculature and sores in the skin (Figure 11.1.2). Monitoring in wild populations is based on vigilance among those in the field and reporting to the Norwegian Food Safety Authority or to the Norwegian Veterinary Institute via the Wild Fish Health Portal. Post-mortem examinations, culturing on standard growth media, and histopathological examinations are important for uncovering the disease. Due to a resurgence of classical furunculosis in commercial aquaculture during the period 2020-2022, stock enhancement hatcheries were encouraged to test wild-caught broodfish for the bacterium (Table 11.1.1 and 11.2.1). Over the past two decades, the disease has been detected in wild salmon in some of the rivers draining to the Namsen fjord and in River Spildervassdraget in the County of Nordland (Figure 11.1.3).

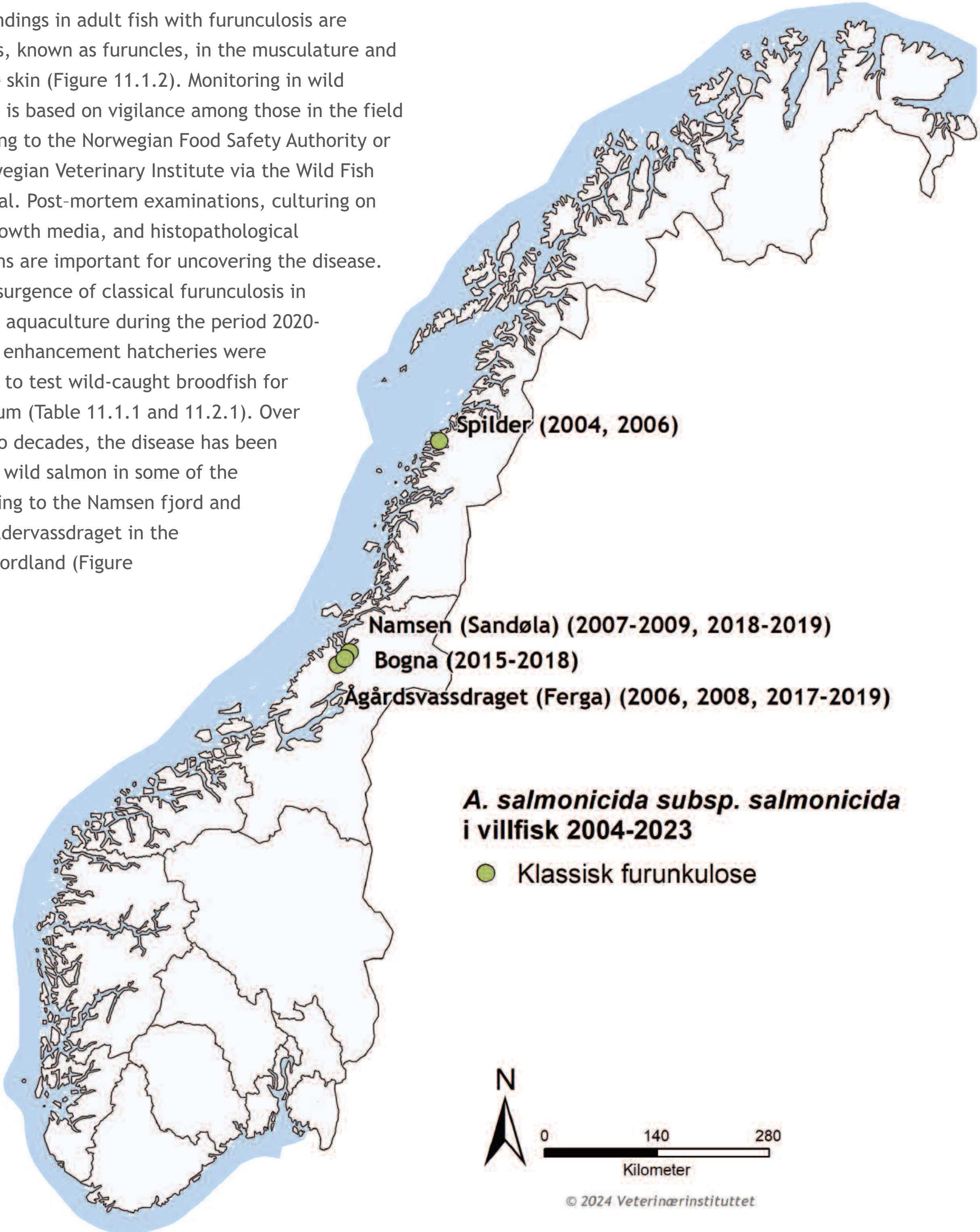


Figure 11.1.3 Map displaying where classic furunculosis (*A. salmonicida* subsp. *salmonicida*) has been detected in wild salmonids during the period 2004-2023. Classic furunculosis was last detected in 2019. Illustration: Attila Tarpai, Norwegian Veterinary Institute

Non-notifiable bacterial diseases

Atypic furunculosis

Atypical furunculosis is caused by infection with so-called atypical subspecies of the bacterium *Aeromonas salmonicida*. So far, four atypical subspecies have been described: *A. salmonicida* subsp. *acromogenes, masoucida, pectinolytica* and *smithia*.

In 2023, infection with atypical *Aeromonas salmonicida* was detected in a wild Atlantic salmon found in the River Tana (Figure 11.1.4). The salmon had pale gills and organs, and pinpoint bleeding was observed on an otherwise yellowish discolored liver.

Motile Aeromonas

Unlike *Aeromonas salmonicida, Aeromonas hydrophila, A. cavia, A. veronii,* and *A. sobria* are motile. These bacteria are considered opportunistic, meaning that they can cause disease in the host if the opportunity arises, which is usually the case when the host is weakened by other factors. The bacteria are described as ubiquitous in freshwater.This is also in contrast to *A. salmonicida* subsp. *salmonicida*, which has limited distribution in Norway. Disease caused by motile Aeromonas has been described in many species, including wild fish and fish in aquaculture and aquariums. Motile Aeromonas are also associated with the development of wound infections and gastroenteritis in humans. Therefore, it is recommended to use waterproof gloves when handling sick and dead fish. In rare cases, these bacteria have also caused severe necrotizing infections in humans with severely compromised immune systems.

In Norway, we have so far had few cases in wild fish where motile Aeromonas plays a primary role. However, detections of *A. hydrophila* have been made in aquaculture facilities and aquariums in this country as well. In 2021, pure cultures of *A. hydrophila* were found in samples from a pink salmon in River Gjersjøelva (Figure 11.1.5 and 11.1.6). Motile Aeromonas as part of a mixed flora are a common finding in moribund and dead wild fish. Climate change makes it relevant to monitor the occurrence of infections with bacteria in this group.

Figure 11.1.4 Atlantic salmon from River Tana infected with atypical *Aeromonas salmonicida*. It is uncertain whether the symptoms shown in the picture are caused by this infection. Photo: Kristoffer Vale Nielsen, Norwegian Veterinary Institute

Figure 11.1.5 *Aeromonas hydrophila* infection in female pink salmon before spawning. Photo Sander England (top). Section through musculature of the same pink salmon. Photo: Brit Tørud, Norwegian Veterinary Institute

Figure 11.1.6 Growth of *Aeromonas hydrophila* in pure culture on blood agar after inoculation from kidney and muscle of pink salmon in Figure 11.1.5. Photo: Duncan Colquhoun, Norwegian Veterinary Institute

Figure 11.1.7 Saith (*Pollachius virens*) with symptoms consistent with classic vibriosis. Photo: Ole-Håkon Heier

Classic vibriosis

Classical vibriosis is a systemic infection caused by the bacterium V*ibrio anguillarum* (V. anguillarum) or its close relative *V. ordalii*. *Vibrio anguillarum* is commonly found in seawater and brackish water and causes disease in several species of wild and farmed fish worldwide. In Norway, the disease caused significant mortality in salmon farming in the 1980s and 1990s before effective vaccines were introduced.

Signs of classical vibriosis include general symptoms such as apathy and mortality in individuals with ulcerations or bleeding in the skin and bloody boils in the musculature. Infected fish may also have protruding eyes (exophthalmos). Upon autopsy, fluid in the abdominal cavity (ascites) and small hemorrhages on organs and in adipose tissue (petechiae), or an enlarged spleen, may be observed.

High water temperatures often contribute to the development of classic vibriosis. The disease is observed in marine fish, particularly at high water temperatures. Since *V. anguillarum* is a common bacterium in seawater and brackish water, salmon can also become infected there. Low water levels in rivers can delay the salmon run and increase fish density in the estuaries, thereby increasing the likelihood of transmission. Damage to the skin barrier, caused by, for instance, sea lice and predators, can also contribute to susceptibility to infection. Once the infection is established in a fish population, the bacterium proliferates in the fish, leading to increasing infectious pressure and disease development.

With climate change, increasing water temperatures are expected both in seawater and freshwater, as well as lower water levels in rivers. Classic vibriosis may

Figure 11.1.8 Atlantic salmon with classic vibriosis. Photo: Frode Dalen

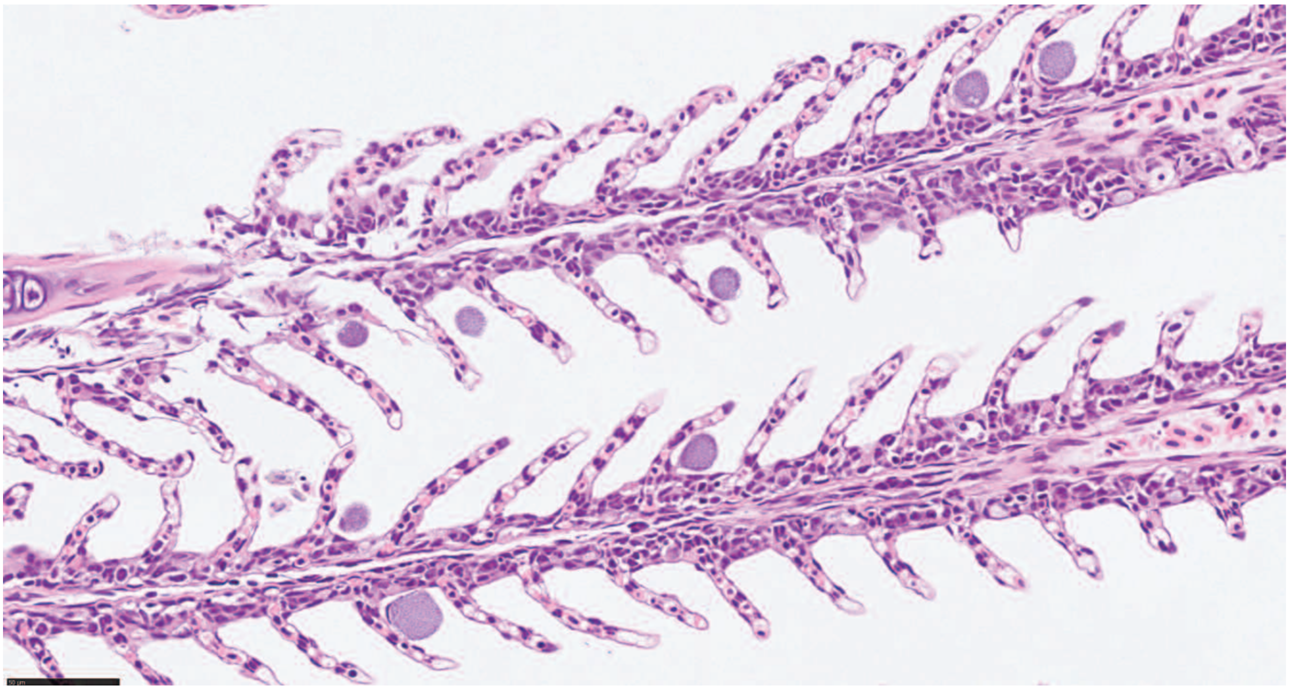


Figure 11.1.9 Histological image of gills of Atlantic salmon with multiple epithelial cysts. The gill tissue around the epithelial cysts appears unaffected. Photo: Lisa Furnesvik, Norwegian Veterinary Institute

therefore become a more common diagnosis in the years to come. *V. anguillarum* primarily infects fish, crustaceans, and shellfish. There are still sporadic cases of classic vibriosis within aquaculture, especially at high water temperatures in late summer. Outbreak of classic vibriosis in wild marine fish was most recently reported to the Norwegian Veterinary Institute from Molde municipality in 2020. Classic vibriosis caused mortality in wild Atlantic salmon in River Lysakerelva and River Akerselva in the inner Oslo Fjord in 2022. Mortality in Lysakerelva was estimated at 60 salmon. Classic vibriosis was not detected in 2023.

Epitheliocystis

Epitheliocystis is a bacterial infection affecting epithelial cells of the gills and skin. The disease has been found in Atlantic salmon and in over 90 different species in freshwater and marine environments in several countries. While the condition is often documented in farmed species, there is less documentation of epitheliocystis among wild fish. Therefore, there is also less knowledge about how this condition impact wild fish on the individual and population level.

Affected fish often develop cysts in the gill epithelium. Histology findings are irritated and thickened epithelium, tissue necrosis and adhesions of gill lamellae. In severe cases adhesions of gill lamellae reduce the respiratory surface resulting in respiratory failure, reduced ability to handle stressful situations with increased demand for oxygen or even death.

Previously, bacteria from the genus *Chlamydiae* were considered to be the cause of epitheliocystis. Novel research has shown that there is a complex composition of different bacterial species causing epitheliocystis. Epitheliocystis is also often occurring concurrently with other infectious agents. The Norwegian Veterinary Institute investigated 65 cases of epitheliocystis in farmed Norwegian Atlantic salmon, and in 83 percent of the cases, the bacterium *Candidatus Branchiomonas* cysticola was detected. Other bacterial species detected in epitheliocystis include *Candidatus Piscichlamydia* salmonis and *Ca.* Clavochlamydia salmonicola. *Ca.* P. salmonis is found both in wild- and farmed fish in both freshwater and seawater. Ca. C. salmonicola also infect wild- and farmed fish, but only in fresh water. It has been suggested that the bacteria causing disease are unique to individual fish species.

In 2023, the Norwegian Veterinary Institute has detected epitheliocystis in wild trout and salmon from rivers in the Western cost of Norway and in wild salmon from the North-western cost of Norway. In these cases, there was little tissue reaction associated with the epitheliocysts (figure 11.1.9).

Disease caused by fungi and oomycetes (water molds)

Disease caused by fungi and oomycoses manifests as superficial fungal infections on the skin and gills, as well as systemic infections in internal organs (Chapter 8 Fungal Diseases). In this chapter, three variants of diseases in wild and cultured fish are discussed. Superficial mycoses in wild fish in Norway are most commonly caused by species within the genus *Saprolegnia*. Systemic mycoses can be caused by several different fungal species, and here we discuss infection with *Exophiala* and *Phoma herbarum*.

Saprolegniosis

Saprolegniosis caused by oomycetes in the genus *Saprolegnia* is the most commonly observed disease in this group. Oomycetes share similarities with fungi but are more closely related to brown algae (kelp) than true fungi.

Saprolegnia spp. occur in freshwater, and disease primarily occurs in fish with damage to their skin or those subjected to various forms of stress. Saprolegniosis can be caused by several different Saprolegnia species, with varying abilities to cause disease. The severe cases observed in several rivers during the period 2021-2023 are all associated with the species *Saprolegnia parasitica (S. parasitica)*, considered the most pathogenic species. In infection trials at the Norwegian Veterinary Institute, different isolates of *S. parasitica* have resulted in mortality rates ranging from zero to 89 percent in salmon.

Changes in the pathogenic ability of the fungus have been discussed in connection with the outbreaks in Norway in 2022. This is due to both the high mortality observed in affected populations and the pathological changes observed during autopsies and histopathological examinations. Autopsies reveal bleeding under the fungal lesions, and histopathological examinations show infiltration of *Saprolegnia* in the subcutaneous tissue, musculature, and blood vessels, along with secondary bacterial infections.

When the oomycet infects the skin, changes typically begin on the head, back, and fins. If the affected areas become too large, the fish may die due to failure in salt and water balance (osmoregulation). The oomycet can also cause infection in the gills, leading to suffocation of the fish. Secondary infections may play a role in the course of the disease. In most rivers, various forms of environmental impact are reported to have played a contributory role. However, there is insufficient information about such risk factors, such as habitat disturbance, discharge, agricultural influences, and other adverse environmental conditions.

The disease is easily diagnosed in the field as the infection appears as a white or cotton-like coating. Since

Figure 11.1.10 Saprolegniosis in a trout (*Salmo trutta*)
Photo: Submitted to the Norwegian Veterinary Institute

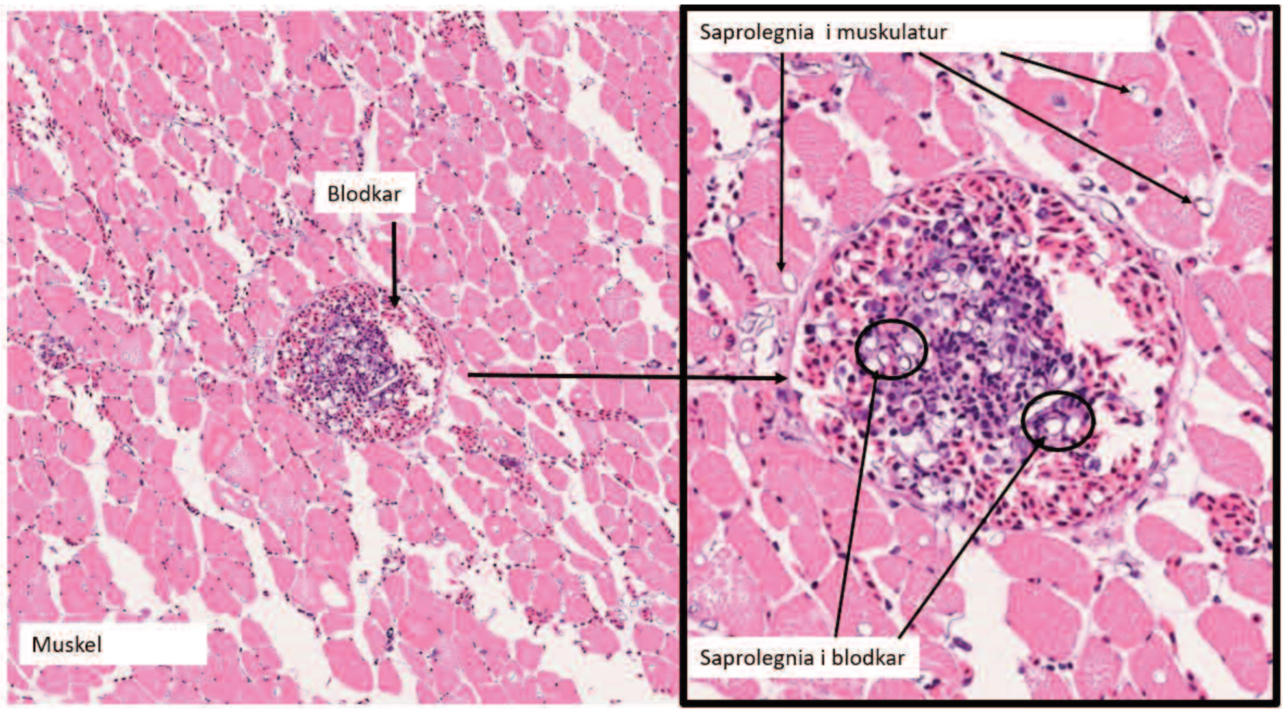


Figure 11.1.11 The image shows *Saprolegnia parasitica* in muscle tissue and blood vessels in a wild Atlantic salmon diagnosed with saprolegniosis. Photo: Mona Gjessing, Norwegian Veterinary Institute

there are different species within the *Saprolegnia* family, and these have varying abilities to cause disease, the diagnosis should be confirmed by identification at species level during outbreaks with high mortality. If mortality occurs before spawning, achievement of the spawning stock goal may be affected.

The Norwegian Veterinary Institute did not receive reports of severe mass mortality due to saprolegniosis in 2023, but the condition is likely underreported as it is considered a normal finding in some watercourses. Reports of saprolegniosis primarily come from rivers flowing into the area from the Swedish border (Enningdalselva) and along the coast up to Trøndelag. In addition to native salmonid fish, saprolegnia-like infections are also observed in pink salmon, especially after spawning. However, the Norwegian Veterinary Institute has not received saprolegnia isolates for species identification from pink salmon.

Exophiala sp.

Exophiala sp. can causes a systemic fungal infection in fish, animals and humans. Disease symptoms in fish include abnormal swimming behaviour, including spiral swimming, protruding eyes, ulcers in the head region and swollen abdomen. Upon post mortem examination, swollen kidneys with large white to grey nodules (granulomas) consisting of fungal hyphae are observed (Figure 11.1.12). Similar nodules can also be observed in the liver and spleen, and infection has also been detected in the brain.

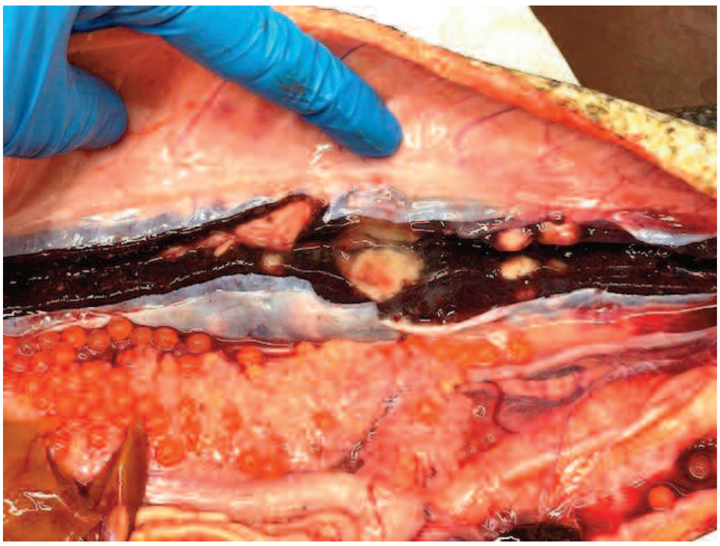


Figure 11.1.12 Atlantic salmon with *Exophiala* sp. in the kidney. Photo: Siri Giskegjerde, Åkerblå

E. salmonis infection can cause a systemic chronic granulomatous inflammatory response, often with the presence of giant cells. The kidney is a particularly susceptible organ, but infections of brain tissue and other internal organs can also occur. Histopathology is a common method to detect *Exophiala*. The fungus grows in the infected tissue with brown septate hyphae. Special stains can be used to facilitate the detection of fungal hyphae in the tissue. Molecular biological methods or culture on special media can also be used.

Exophiala sp. is a polymorphic, black yeast-like fungi belonging to a genus in the family *Herpotrichiellaceae* (Figure 11.1.13). The genus includes over 60 known species. *Exophiala* sp. lives in various habitats throughout the world. Several different species cause infection in fish, including *E. aquamarina, E. pisciphila, E. psycrophila* and *E. salmonis*. *E. salmonis* was the first species described to infect fish.

Occurrence and significance in wild fish: Fungal infection in the kidneys (mycotic nephritis) with the species *Exophiala salmonis* and *Phialophora intermedia* were detected in three Atlantic salmon from a river in Rogaland in 2022 and five Atlantic salmon from the same river in 2023. The infections were discovered by the fish health service during examination of broodfish used in the stocking program. Infected fish were also of stocked origin, meaning that they were previously released from the stock enhancement hatchery. Infections with Exophiala among wild fish likely occur more frequently than documented. Infections with *E. salmonis* occur sporadically in aquaculture, and mortality is usually low. However, cases with up to 40 percent mortality in farmed Atlantic salmon have been described from Canada.

Figure 11.1.13 *Exophiala* sp. on growth medium. Photo: Ellen Christensen, Norwegian Veterinary Institute.

Phoma herbarum

The fungus *Phoma herbarum* is most commonly known as the cause of infections in plants. However, this species can also cause fungal infections in fry and fingerlings, primarily affecting the swim bladder, digestive system, and peritoneum. The term "swim bladder fungus" is often used to describe this condition. The fungus can also invade other organs. *Phoma herbarum* has also been found in salmon during the sea phase. The signs of disease in infected fish will vary depending on which organs are affected. Infected fish may exhibit abnormal swimming behaviour and lie on their sides. They often have protruding, swollen, and bloody vents. It is likely that fish become infected through the intake of feed or by ingesting air to regulate swim bladder volume.

Occurrence and significance in wild fish and aquaculture: Swim bladder fungus is sporadically observed in aquaculture facilities as an issue affecting individual fish, but it has also been observed as a herd problem on a larger scale. Infected individuals will die. It is unknown whether this infection also has significance for wild juvenile fish.

Disease caused by parasites

Proliferative kidney disease (PKD)

Proliferative kidney disease (PKD) is a serious condition in several salmonid fish species such as Atlantic salmon (*Salmo salar*), trout (*Salmo trutta*), Arctic char (*Salvelinus alpinus*), pink salmon (*Oncorhynchus gorbuscha*), rainbow trout (Onchorhynchus mykiss), European whitefish (*Coregonus lavaretus*) and grayling (*Thymallus thymallus*) in freshwater. The disease should not be confused with bacterial kidney disease (BKD).

PKD is caused by the multicellular parasite *Tetracapsuloides bryosalmonae*, which belongs to the group of myxozoan parasites. The parasite primarily infects freshwater bryozoans, where sexual reproduction occurs. Here the parasite produces spores that are released into the water and that can infect salmonids. In fish, the parasite spreads with the bloodstream and it reproduces in most of the inner organs of the fish. It is the kidney that is the main target organ of the parasite, hence the name of the disease. In the kidney, an asexual reproduction of the parasite occurs with production of spores that are shed and spread through the fish's urine. These spores are different from those formed in the bryozoans. Although *T. bryosalmonae* can infect salmonids, fish are not required for the parasite to complete its life cycle. The parasite can spread from bryozoans to bryozoans and thus complete its life cycle without a fish host. The parasite also have a resting/spreading stage (statoblasts) in bryozoans.

It is important to distinguish between the presence of the parasite *T. bryosalmonae* and development of the disease PKD as salmonids can be infected without developing disease. As a rule of thumb, disease develop when the water temperatures exceeds 15 °C for more than 14 days. At lower temperatures, development takes longer time. Consequently, disease outbreaks often occurs in late summer. The problem can be exacerbated in regulated rivers with low flow rates, where temperatures can become high.

External signs of the disease are pale gills and swollen kidney. The fish's immune system can cause major tissue changes in the kidney and spleen, which can cause the abdomen to look swollen. In addition, the fish may have protruding eyes and darkened skin. The kidneys may have a more greyish colour than the normal dark, reddish colour. The parasite can be diagnosed in tissue sections, especially in the kidney and spleen, or it can be detected by PCR.

In Switzerland and Austria, PKD has led to a significant reduction of wild salmonids. In Norway, PKD was detected in rivers in Åbjøra and Jølstra in 2006. Likely, the disease have caused a reduction in smolt production by between 50 and 75 percent in these rivers. In the years following these outbreaks, several watercourses and lake were screened for the parasite, showing that the parasite has a widespread occurrence in Norway.

In 2023, the Norwegian Veterinary Institute in collaboration with the Norwegian Institute for Nature Research (NINA) detected PKD in salmon fry from River Mandalselva. A total of 100 fingerlings of Atlantic salmon were examined, of whom 50 were screened by PCR and 50 were examined histologically. The parasite *T. bryosalmonae* was present in 21 individuals investigated by PCR, and PKD was present in four individuals examined by histopathology. In PKD, the parasite cause major tissue changes in the kidney (Figure 11.1.4). Common findings is fibrinous nephritis, multifocal giant cells, degenerations, and necrosis of the renal interstitium. It is expected that the number of PKD outbreaks will increase in line with climate change.

Red vent syndrome (Anisakis) in Atlantic salmon (Salmo salar)

Red vent syndrome affects salmon in seawater, or salmon returning from seawater. The name is descriptive of the condition in which infected fish get an inflamed, swollen and bloody vent. The condition is now known to be caused by a local inflammatory reaction triggered by the presence of roundworm (nematode) *Anisakis simplex* that are infecting the vent area. Accordingly, the disease is no longer a syndrome. In histological sections, inflamed subcutaneous tissue, ulcerations of the epidermis and

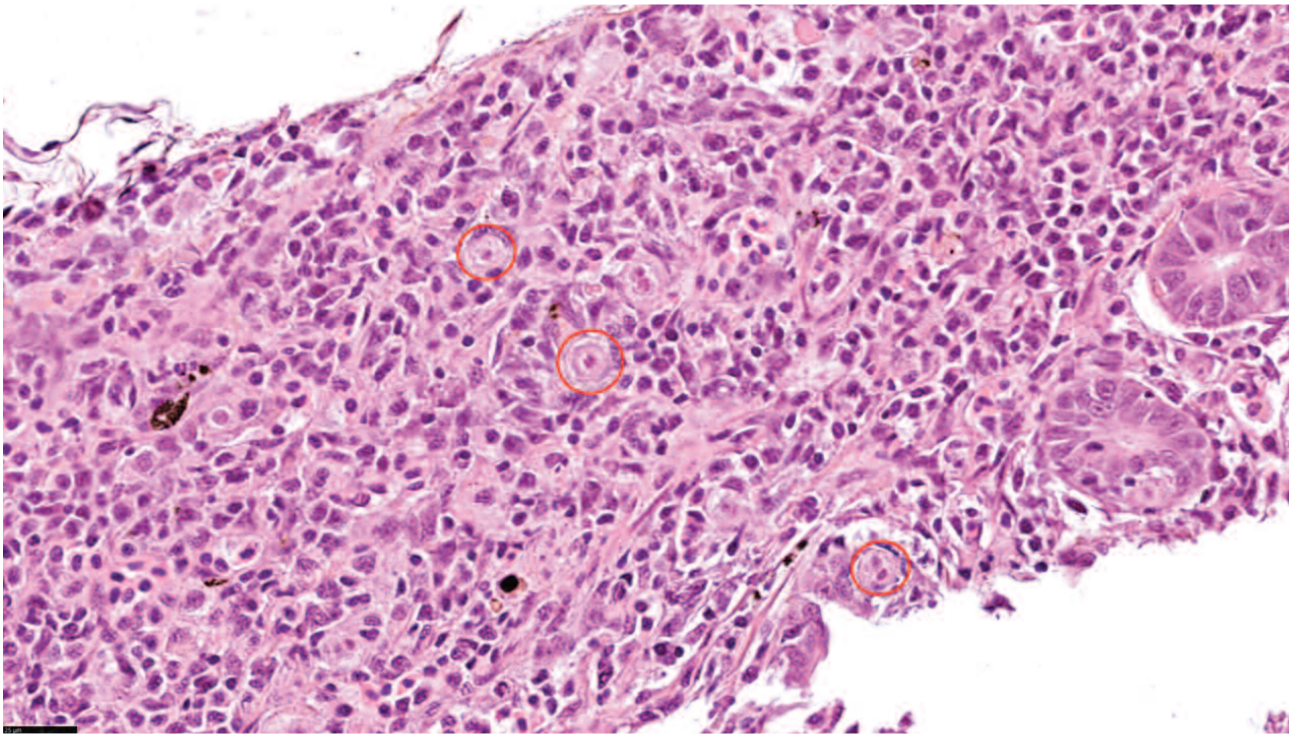


Figure 11.1.14 Histological image of affected kidney tissue from Atlantic salmon infected with *Tetracapsuloides bryosalmonae* (PKX cells) (red circle). Photo: Lisa Furnesvik, Norwegian Veterinary Institute

Figure 11.1.15 Image of an Atlantic salmon with red vent syndrome caused by *Anisakis* sp. Photo: Submitted to the Norwegian Veterinary Institute

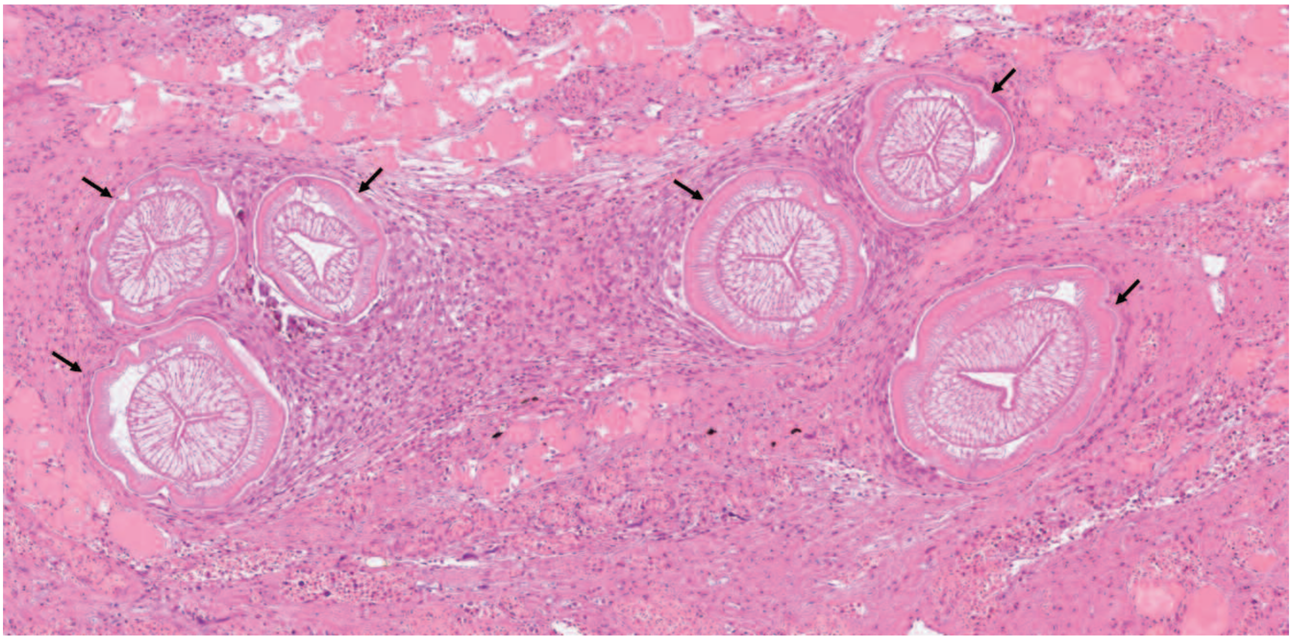


Figure 11.1.16 Histological image of an Atlantic salmon infected with nematodes (black arrows) around the vent (red vent syndrome). Photo: Toni Erkinharju, Norwegian Veterinary Institute

encapsulated parasites are observed (Figure 11.1.15 and 11.1.16).

Even with a high number of roundworms within a limited area around the vent, affected fish apparently have a good health status. Nevertheless, the impact of the parasite on the fish is not fully understood.

A. simplex has a complex life cycle with sexual reproduction in marine mammals (definite host) and three developmental stages (larval stages) in marine crustaceans and fish species (intermediate hosts). *A. simplex* can infect a number of different marine species including pelagic, benthic and anadromous species (e.g. herring (*Clupea harengus*), saithe (*Pollachius virens*), Atlantic salmon (*Salmo salar*), cod (*Gadus morhua*) and mackerel (*Scomber scombrus*)). Probably all marine fish are susceptible to this parasite, yet red vent syndrom is a disease course that has mainly been described in Atlantic salmon in Norway, Scotland, Ireland and Iceland. In Scotland, the condition has also been described in sea trout (*Salmo trutta*).

Humans can be infected with Anisakis larvae and develop a disease called anisakiasis which can cause abdominal pain, nausea, abdominal cramps and diarrhea. The symptoms can resample peptic ulcer or food poisoning. Anasakiasis is associated with consumption of raw or insufficiently heat-treated seafood (for example, smoked salmon). Anisakis larvae are only sporadically detected in farmed salmon, and there is generally little risk of infection with the parasite from consuming farmed salmon fed with pellets. However, the parasite is considered a normal finding in wild salmon. Therefore, wild fish should be frozen or adequately cooked before consumption. In addition to anisakiasis, some people are allergic to Anisakis. Allergic reactions can occur despite freezing before consumption.

A. simplex is common in cool marine waters such as the Atlantic, Pacific, and Arctic oceans. The parasite also appears in freshwater as encapsulated larvae in salmonids after marine migration.

A. simplex is a very common finding in wild salmon. For example, *A. simplex* is detected during post mortem examination in nearly 100 percent of wild broodfish captured by stock enhancement hatcheries. The parasite is easily observed on the surface of the liver and on other internal organs. In a study from Namsenfjorden (2021), 90 Atlantic salmon were examined for *A. simplex* and all fish were found to be infected by the parasite. Nearly 30 percent of the parasites were found in the musculature, and furthermore, 93 percent of the parasites in musculature were found near the vent. Another study documented the occurrence of Red vent syndrome in eight of eleven surveyed Norwegian rivers.

In 2023, the Norwegian Veterinary Institute was contacted by river owner associations concerned about an increase and change in the occurrence of Red Vent syndrome.

Argulus

Fish lice in the genus *Argulus* are parasitic crustaceans that have been known as pests in aquaculture since the 1700s. They can cause mortality both in farmed and wild fish. There are many species in the genus, most of which are parasites of freshwater fish. In Norway, we are familiar with the large fish louse (*Argulus coregoni*), which is a common parasite on salmonid fish such as trout (*Salmo trutta*) and European whitefish (*Coregonus lavaretus*), and the small fish louse (*A. foliaceus*), which infects a wide range of fish species including perch (*Perca fluviatilis*), trout, pike (*Esox lucius*), and three-spined stickleback (*Gasterosteus aculeatus*). Figure 11.1.17 shows *Argulus* on the abdomen of a trout. Fish lice can cause severe damage to fish through grazing on the skin.

Argulus are mobile on the fish; they jump on and off, and between hosts to feed and lay eggs. They can also survive for several days outside the host. Fish lice are round and flat in shape and are characterized, among other things, by the first pair of maxillae (mouthparts), which are modified and function as suckers. *Argulus* does not have egg strings like those seen in the salmon louse (*Lepeophtheirus salmonis*) but rather have eggs in the ovaries and lay them in rows on a suitable substrate. Eggs laid in late summer hatch in the fall (September), while eggs laid later in the autumn can overwinter and hatch in the spring. This allows for two generations per year, but the population density of fish lice is often highest in the fall. Fish can be infested with *Argulus* without apparent problems, and there must be many of them to cause mortality in the fish. Often only a few lice are observed on the fish because, as described, the parasites jump off the host when it is caught. The Norwegian Veterinary Institute has also been notified of the presence of *Argulus* in water bodies associated with Snåsavatnet in 2023.

Figure 11.1.17 *Argulus* on the abdomen of a brown trout. Photo: Submitted to the Norwegian Veterinary Institute

Figure 11.1.18 Image of an Atlantic salmon from Enningdalselva, with skin lesions (circular bleeding in the skin) consistent with red skin disease. Photo: Brit Tørud, Norwegian Veterinary Institute

Diseases with non-infectious or unknown aetiology

Red skin disease in River Enningdalselva

Skin disorders are among the most common reasons for inquiries to NVI pertaining to disease in wild salmon. Disease symptoms and disease affecting the skin comprise a large and complex group of conditions, with a significant amount of uncertainty regarding causative factors. For the condition known as red skin disease, no established diagnostic criteria exist, meaning there is no agreed-upon description of pathological changes and test results that must be present for an individual to be diagnosed with red skin disease.

At the Norwegian Veterinary Institute, the diagnosis is based on the presence of red, often ring-shaped skin lesions primarily, but not exclusively, located on the abdomen of fresh run salmon (Figure 11.1.18). Additionally, it is considered characteristic that salmon with red skin disease often exhibit reduced consciousness, are more sluggish, weaker, or easier to catch than expected. Histopathological examination reveals haemorrhages beneath the epidermis and microvesicles (small blisters) in the epidermis. Furthermore, signs of thrombosis in the subcutaneous tissue have been observed in cases from 2023 (Figure 11.1.19).

Geographical distribution: Since consensus diagnostic criteria have not been established, different criteria may be applied both within and between countries when using the term red skin disease. The condition will also change as secondary infections, such as those caused by motile *Aeromonas* sp. and *Saprolegnia* sp., establish and develop. Therefore, it must be noted that there may be

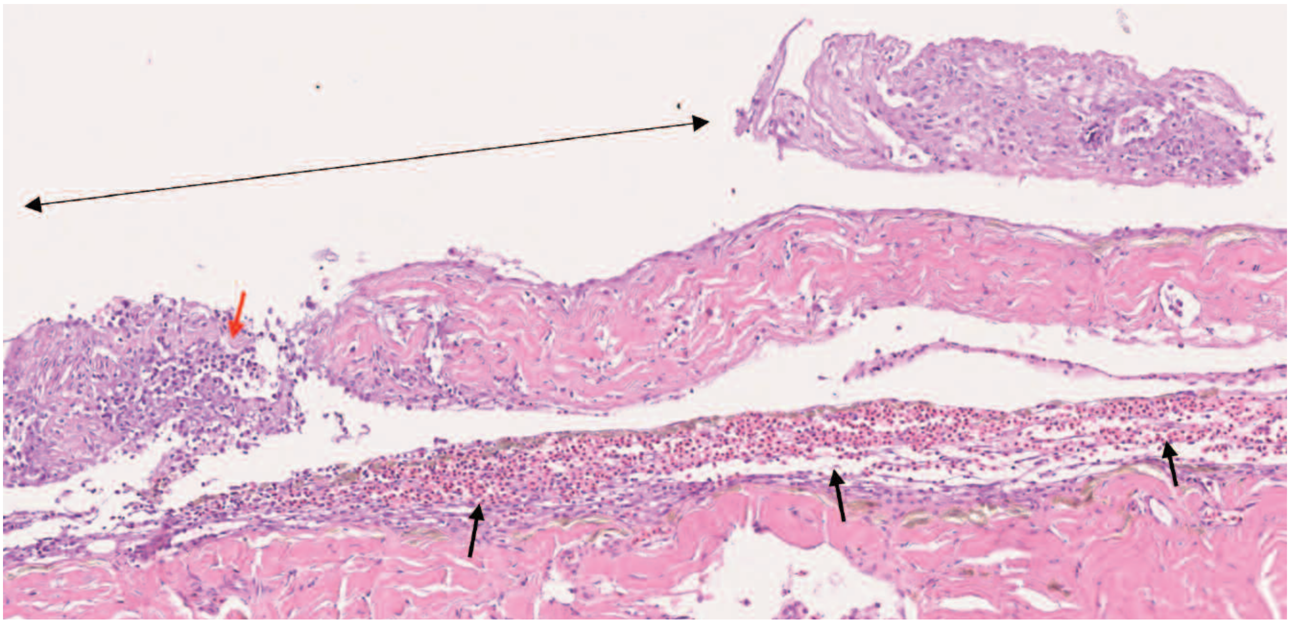


Figure 11.1.19 Histological image of skin lesion from an Atlantic salmon with red skin disease. Hemorrhages (black arrows) and inflammation (red arrow) can be seen in the subcutaneous area around the scale pocket. The long black arrow shows an area where the epidermis is absent. Some degeneration/necrosis of the epidermis and dermis is also observed. Photo: Lisa Furnesvik, Norwegian Veterinary Institute

various underlying causes and conditions being reported. Nonetheless, the Norwegian Veterinary Institute assessment is that there is good reason to believe that the same disease condition has been or is registered in wild salmon in other European countries, including Denmark, Sweden, Ireland, and Scotland. In the Norwegian context, the Veterinary Institute has so far only detected red skin disease in salmon in Enningdalselva. However, the Norwegian Norwegian Veterinary Institute receives inquiries, image material, and diagnostic material of fish from other watercourses where the condition of the salmon resembles red skin disease.

The cause of red skin disease is currently unknown. The NVI conducted extensive investigations in the period 2019-2020 and has conducted new sampling and examinations in 2023.
The main focus of the investigations has been to use both general and specific methods to determine whether the condition is caused by known or hitherto unknown pathogens. The NVI investigations and results has thus far not supported the hypothesis that the disease is primarily caused by an infectious agent. This means, among other things, that important diseases known from Norwegian fish farming do not seem to be involved in the disease development. However, the Norwegian Veterinary Institute cannot rule out infection as the primary cause.

The way the disease presents itself suggests that salmon are affected by one or more factors in the environment they inhabit. Defining where the salmon are affected and what distinguishes affected salmon from healthy ones during a disease outbreak will be important for understanding the disease. Scale analyses and genetic analyses (the latter conducted by the Norwegian Institute for Nature Research) have shown that the affected salmon examined by NVI were of wild origin (i.e., the salmon are neither escaped farmed salmon nor offspring of escaped farmed salmon). To uncover the cause of red skin disease, there is a need for dedicated interdisciplinary research collaboration.

Red skin disease has been previously mentioned in the Fish Health Report for 2019, 2020, and in a separate fact sheet.
https://www.vetinst.no/sykdom-og-agens/red-skin-disease-hos-vill-laks-en-ny-tilstand.

Fatty liver in wild haddock and whiting in aquaculture pens

In July 2023, several dead haddock (*Melanogrammus aeglefinus*) and a whiting (*Merlangius merlangus*) were found in a fish farm in Northern Norway. During the relevant time period, no abnormal mortality was observed among Atlantic salmon in the fish farm, nor among wild fish outside the facility. The wild haddock and whiting likely got caught in the fish pens during net changes. Both haddock and whiting had distended abdomen due to enlarged “fatty” livers.
Histopathological examinations confirmed pronounced accumulation of fat in the liver cells in four out of five individuals, as well as congestion of blood vessels in the liver and in adipose tissue surrounding the pancreatic glands (Figure 11.1.21). Parasites (multiple metazoa and possible tapeworms) were also observed in the intestine, including inside the intestinal wall. Bacteriological examinations were performed without finding any bacteria, and as a precaution, specific qPCR analyses for nodavirus were performed without detection of the virus.

Figure 11.1.20 The image to the left shows of whiting (*Merlangius merlangus*) with a distended belly. The image on the right shows a haddock (*Melanogrammus aeglefinus*) with enlarged and fatty liver in the abdominal cavity. Photo: Geir Bornø, Norwegian Veterinary Institute.

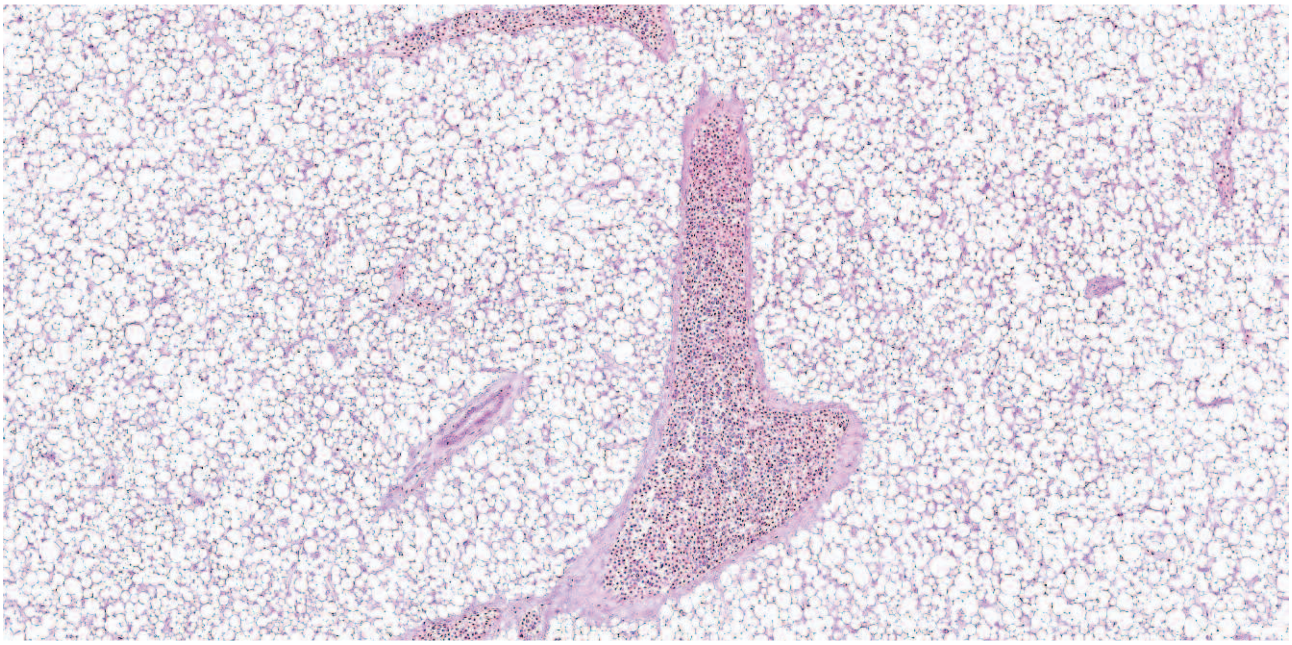


Figure 11.1.21 Histological image of a liver with pronounced presence of fat vacuoles. Photo: Toni Erkinharju and Benedikte Hansen Bendiktsen, Norwegian Veterinary Institute

Accordingly, the main finding in these fish was elevated fat accumulation in the liver, and it was concluded that this was likely to have led to the mortality.

When wild fish are confined in fish pens, they have access to salmon feed and, to a lesser extent, their natural prey. Several Canadian studies show that the most optimal nutrient composition in feed for haddock is a high proportion of protein (50-55 percent), low proportion of carbohydrates (<14 percent), and low proportion of fat (<14 percent). Compared to cod, haddock have a lower ability to mobilize stored fat from the liver and is particularly susceptible to developing fatty liver if the feed has (excessively) high fat content. Salmon feed has a high fat content (around 30 percent fat, 13 percent carbohydrates, and 53 percent protein), and it is likely a high intake of fatty salmon feed that has caused the significantly enlarged liver. Efforts should be made to prevent wild fish to enter fish pens both in terms of welfare for the trapped fish and in terms of biosecurity. In addition, farmed fish should not be overfed, as the wild fish surrounding the farms will be attracted to the pens and feed there. Reports show reduced harvest quality in wild fish that have eaten large quantities of salmon feed.

Pollack (Pollachius pollachius) with fin rot in the Husnesfjord

In March, NVI received reports from a fisherman that had fished pollack (*Pollachius pollachius*) with severe fin rot

Figure 11.1.22 Image of severe fin rot in pollack (*Pollachius pollachius*). Photo: Submitted to the Norwegian Veterinary Institute

Figure 11.1.23 Photomontage of common bream (*Abramis brama*) with spawning spots (white arrow) and larger areas of thickened grayish skin. Photo: Gabriel Mattingsdal Eggebø, NMBU

in Husnesfjorden in Tysnes municipality. The fin rays (bones) were exposed and protruded far out of the skin. The fisherman reported that similar changes had been observed earlier in both saithe (*Pollachius virens*) and Pollack. In addition, cod (*Gadus morhua*) had also been observed with disease changes around the eyes. Fin rot is often associated with the bacterium *Tenacibaculum* sp., which thrives in cold sea temperatures. The bacterium “consumes" the fish's skin, causing ulcers (especially in the head region and eyes) and fin rot. No samples were submitted from this particular fish, and the cause of the severe fin rot was not determined.

The fin rays (bones) was exposed and sticking far out of the skin (Figure 11.1.22). Similar changes was observed earlier in both and pollack. I. The bacteria *Tenacibaculum* sp. can cause changes like fin rot and ulcers in the head region. The bacteria thrives in cold temperatures in the sea and feeds on the skin of fish. Samples from this particular fish were not submitted to NVI, and the cause of this serious fin rot was thus not determined.

A breach in the skin barrier serves as an entry point for pathogens such as bacteria and viruses in addition to being painful. It is valuable for the Norwegian Veterinary Institute to have such cases registered in the Wild fish health portal. In addition it would be useful to examine the relevant fish.

*Skin disorder in common bream (*Abramis brama*)*

Common bream (*Abramis brama*) is a species within the carp family that can grow to a weight of 8-9 kg and the length of 75 cm. In Norway, the species usually do not exceeding 1.5 kg. The common bream lives in fresh water and spawns in May-June at temperatures around 14 °C. Common bream is widespread in Central Europe, Asia and in larger parts of Sweden. In Norway, the species lives in watercourses in the areas: Telemark, Buskerud, Vestfold, Østfold, Akershus and Innlandet.

In early summer 2023, two students at Norway University of Life Sciences (NMBU) discovered skin disorders in common bream during fieldwork in Lågendeltaet nature reserve in Lillehammer.

The Norwegian Veterinary Institute received four fresh common bream stored on ice. In addition, tissue samples on formaldehyde and other fixatives were taken from two more individuals in the field. Two of the fresh individuals were marked "early phase", and the other two were marked "medium phase". External findings in the male fish were white spots of around 1 mm in diameter of the head, scales and fin rays. This is findings are consistent with so-called "spawning spots". Similarly, the female fish had a reddish (hyperaemic) skin surface with scratches across the sides, which is also a normal finding during spawning season. These “spawning spots” were also present in fish denoted as "medium phase" together with larger areas (2-3 cm) of thickened, hard, greyish skin (figure 11.1.23). Histological analyses shows inflammatory changes, dead tissue and thickening of the epidermis in these areas (Figure 11.1.24).

Specific qPCR analyses for Cyprinid herpesvirus were negative. Microbiological findings were *Saprolegnia* sp. and mould from one individual, and a mix of the bacteria *Lactococcus* sp. and *Aeromonas sobria*. This is probably not the prime cause of the observed skin condition.

Further investigations are needed to find the reason for these abnormal skin changes.

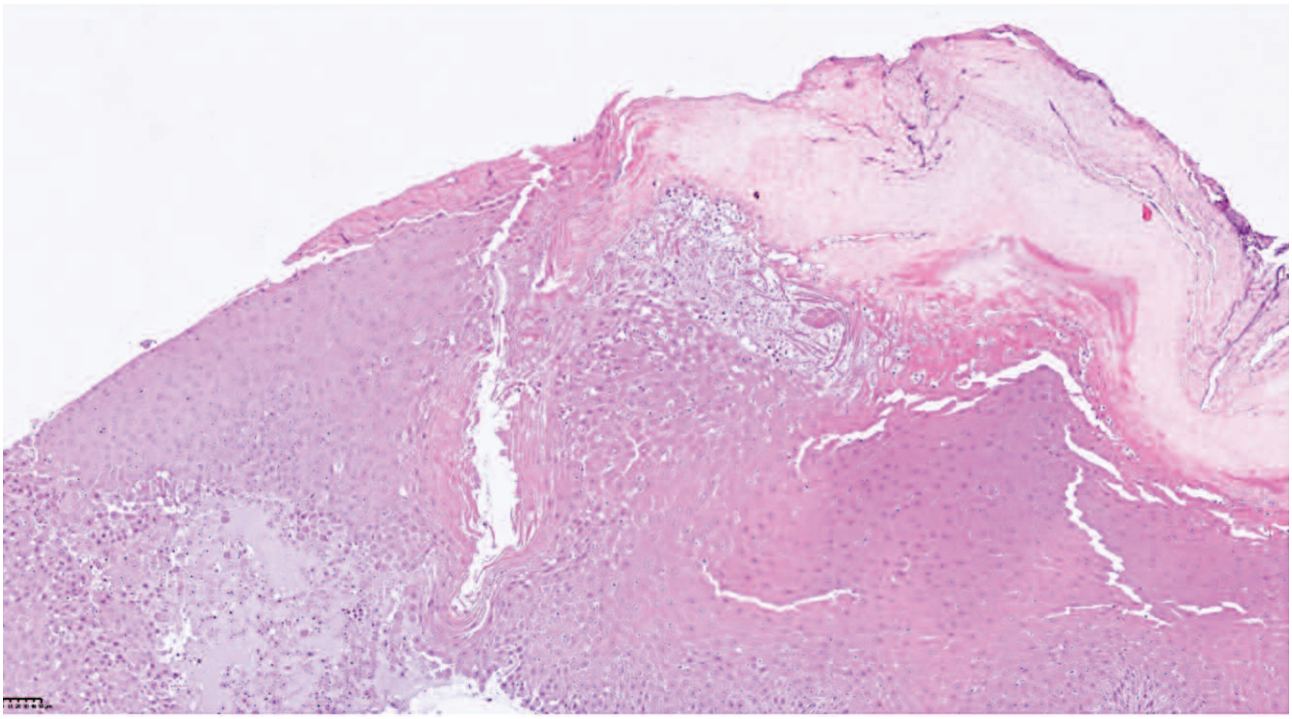


Figure 11.1.24 Histological image showing inflammatory changes, dead tissue, and thickened epidermis in common bream with skin lesions. Photo: Raoul Valentin Kuiper, Norwegian Veterinary Institute

11.2 Health situation in wild salmonid broodstock for the Gene bank for wild salmon

By Siri Kristine Sollien Gåsnes, Åse Helen Garseth and Lisa Furnesvik

The national gene bank program for wild Atlantic salmon was established in 1986 by the Directorate for Nature Management (now the Norwegian Environment Agency) to safeguard threatened salmon populations. Today, the program also includes anadromous trout (sea trout) and anadromous Arctic char. The gene bank program consists of a biobank with cryopreserved milt and five gene bank facilities where salmon populations are maintained through live offspring from wild-caught salmon, known as a living gene banks. The five facilities are located in Bjerka in Nordland, Haukvik in Trøndelag, Hamre and Herje in Møre og Romsdal, and Ims in Rogaland.

The Norwegian Veterinary Institute is the national centre of expertise for the Norwegian gene bank program and coordinates the activities on behalf of the Norwegian Environment Agency. This includes responsibilities for fish health and biosecurity. The aim of the gene bank's biosecurity strategy is twofold: 1) to prevent propagation and spread of infectious disease during reestablishment and restocking projects, 2) secure good fish health within the live gene banks and thereby avoid disease outbreaks that could cause genetic selection and/or loss of genetically unique and important populations.

Conservation efforts are carried out in five regions with different backgrounds. In the Nordland/Vefsn region, the Driva region, and the Drammen region, the background is the parasite *Gyrodactylus salaris* and the associated control strategy. In Sunnmøre, conservation in gene banks has become necessary due to weak stocks with a complex background. In the Hardanger region, the genetic integrity of salmon is threatened by the escape of farmed salmon, and both salmon and sea trout are also threatened by sea lice from the aquaculture industry.

Health examination

The establishment of populations in gene banks is based on wild broodfish captured in the respective rivers. The introduction of offspring from these parents to the gene bank facilities entails a risk of introducing pathogens along with the fish material. To reduce the likelihood of introducing infection, only disinfected roe from approved broodfish is introduced to the facilities.

To be approved, the broodfish must undergo a control of the genetic integrity, meaning they must be approved as wild salmon based on scale analysis at the Norwegian Veterinary Institute and genetic analysis at the Norwegian Institute for Nature Research (NINA). In addition, the broodfish must pass a health examination based on autopsy findings, bacterial cultivation, and PCR analysis for specific pathogens. Fertilized roe from wild broodfish is quarantined until test results and conclusions from the health examination are available. Tissue samples placed on RNAlater are taken from all wild-caught broodfish for storage in the biobank, among other things, to enable retrospective investigations and research.

The aim of health examination is to reduce the likelihood of introducing pathogens with disinfected roe. Therefore, particular emphasis is placed on known vertically transmitted pathogens. Additionally, the gene bank has a responsibility to reduce the likelihood of introducing pathogens with unknown transmission routes into the gene bank facilities. Various measures are employed:

1. Research on vertical transmission of pathogens: The gene bank conducts its own research and development activity where vertical transmission, from parents to offspring, is examined through testing offspring from pathogen-carrying broodfish.
2. Risk-benefit assessment: Additionally, a risk-benefit assessment is conducted in each individual case. This assessment considers both the characteristics of the specific pathogen, its presence in the environment, the quantity of pathogens in the tested material, and the importance of each fish to the conservation efforts.

The health examination in the gene bank program follows trends in health situations of farmed fish generally in Norway. The status of fish diseases caused by bacteria has been changing in recent years in the aquaculture industry, including the status of bacterial kidney disease, furunculosis, pasteurellosis, and yersiniosis. With ongoing climate change, it is also expected that diseases from bacteria thriving in higher temperatures, will increase in occurrence and significance. There is a need to monitor this development. Bacterial cultivation from wild-caught broodfish was therefore reintroduced in 2021.

In a limited number of rivers, the populations are so weakened that a sufficient number of adult broodfish is not available. In these cases, salmon parr are captured and genetically tested (wild/farmed) and then reared to become broodfish, known as a parr-based gene bank. The method is also used for sea trout. When such broodfish is used, they undergo the same health examinations as wild-caught broodfish.

Results of broodstock health examination 2023

In 2023, 234 salmon (of which 48 were captured as parr) and 203 sea trout (of which 26 were captured as parr) were examined in the broodstock health examination of the national gene bank program.

Bacterial cultivation

Renibacterium salmoninarum or *Aeromonas salmonicida* subsp. *salmonicida* were not detected by cultivation from kidney on blood agar and kidney disease medium (KDM). Otherwise, sporadic detections of bacteria commonly found in the fish's environment and capable of causing infections in weakened fish were observed. *Flavobacterium psychrophilum, Carnobacterium divergens*, likely *Pseudomonas fluorescens, Aeromonas* sp., and *Pseudomonas* sp. were individually detected in one individual each. One individual was found to have both *Pseudomonas* sp. and *Flavobacterium* sp.

PCR analysis

PCR analysis of kidney tissue was conducted for *R. salmoniarium*, infectious pancreatic necrosis virus (IPNV), infectious salmon anemia virus (ISAV), and piscine orthoreovirus (PRV-1 in salmon and PRV-3 in sea trout).

IPNV, R. salmoninarum, and ISAV were not detected. PRV-1 was found in 5 out of 234 examined adult wild-caught salmon, distributed across 4 out of 19 examined rivers. The numbers are too low for further analysis. PRV-3 was detected in 33 out of 177 (18.6 percent) of wild-caught adult sea trout, distributed across 10 out of 13 examined

Table 11.2.1: Overview of salmon examined in the broodfish health examination of the national gene bank program in 2023, along with results from PCR analyses. PCR analyses of kidney tissue were conducted for infectious salmon anemia virus (ISAV), infectious pancreatic necrosis virus (IPNV), piscine orthoreovirus-1 (PRV-1), and *Renibacterium salmoninarum* (BKD). Only results for PRV-1 are presented in the table since *R. salmoninarum*, IPNV, and ISAV were not detected.

Region: Production area (PA)	Rivers	Number of salmon examined	Number of salmon positive for PRV-1
Drammen (PA1)	Drammen, Lier	39	1
Hardanger with Vosso (PA3)	Granvin, Jondal, Kinso, Rosendal, Steinsdal, Vosso	34	2
Hardanger (PA3), parr-based	Austrepoll, Bondhus, Rosendal, Ænes, Øyreselva	48	0
Sogn og Sunnfjord (PA4)	Aurland, Jølstra	51	2
Sunnmøre (PA5)	Eidsdal, Norddal	53	0
Driva (PA6)	Batnfjord, Usma	9	0
Helgeland (PA8)	Rossåa	7	0
Total	**19 rivers**	**241**	**5**

rivers. There are geographical differences in the occurrence of PRV-3 in the examined material. In Hardanger, 38.2 percent of sea trout were carriers of the virus, while 4.9 percent of sea trout in the Drammen region and 10.7 percent in the Driva region were carriers of PRV-3 (Table 11.2.1 and 11.2.2).

Broodfish are kept together in tanks for a period before stripping and health examination. This allows for internal transmission of pathogens within the tanks, resulting in higher prevalence than in wild fish in rivers. However, fish from different rivers are not kept together. These two factors must be considered when interpreting the results. For both PRV-3 and PRV-1, the result for a river may be influenced by operational factors such as the duration of tank holding time. Neither PRV-3 (sea trout) nor PRV-1 (salmon) was detected in parr-based gene banks in 2023.

Table 11.2.2: Overview of sea trout examined in the broodfish health examination of the national gene bank program in 2023, along with results from PCR analyses. PCR analyses of kidney tissue were conducted for infectious salmon anemia virus (ISAV), infectious pancreatic necrosis virus (IPNV), piscine orthoreovirus-3 (PRV-3), and *Renibacterium salmoninarum*. Only results for PRV-3 are presented in the table since *R. salmoninarum*, IPNV, and ISAV were not detected.

Region: Production area (PA)	Rivers	Number of sea trout examined	Number of sea trout positive for PRV-3
Drammen (PA1)	Selvik, Sande, Lier	81	4
Hardanger (PA3)	Granvin, Jondal, Mundheim, Omvikedal, Strandadal, Steinsdalselva, Uskedal, Ådland	68	26
Hardanger (PA3), parr based	Austrepoll, Bondhus, Rosendal, Ænes, Øyreselva	26	0
Driva (PA6)	Batnfjordselva, Litjdalselva	28	3
Total	**18 rivers**	**203**	**33**

11.3 *Gyrodactylus salaris*

By Haakon Hansen, Øystein Nordeide Kielland, Vegard Gåsnes Sollien, Kristin Bøe and Åse Helen Garseth.

The parasite and the disease

Gyrodactylus salaris has been introduced to Norway on several occasions since the 1970s, and has so far been detected in 53 Norwegian watercourses. More information on *G. salaris* and gyrodactylosis can be found in the Norwegian Veterinary Institute's fact sheet: **https://www.vetinst.no/sykdom-og-agens/gyrodactylus-salaris**

Surveillance for *Gyrodactylus salaris* in Norway 2023

The Norwegian Veterinary Institute coordinated three surveillance programmes for *G. salaris* in 2023, under contract from the Norwegian Food Safety Authority. These programmes are, a) the surveillance programme for *Gyrodactylus salaris* in Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) in Norway (OK-programme), b) the post-treatment surveillance programme for *Gyrodactylus salaris* (FM-programme) and, c) the surveillance programme to document absence of Atlantic salmon and *G. salaris* in River Drammenselva, upstream of Hellefossen following closure of the salmon ladder in 2019. See the reports from the various programmes published here:
https://www.vetinst.no/overvaking

A total of 3006 salmon and rainbow trout from 86 hatcheries and 2273 salmon from 69 rivers were examined in the OK-programme in 2023. In the FM-programme, 153 salmon from River Fusta, Nordland County, and fins from 519 Arctic char from three lakes in the Fusta catchment, Nordland County, were examined. Gyrodactylus salaris was not found in any of the samples.

In connection with an investigation of the infection status in smaller watercourses in regions with known infection, *G. salaris* was detected in two new watercourses in 2023; Gylelva (watercourse number 109.7Z) and Ebbestadelva (watercourse number 012.2Z). The investigation was commissioned by the Norwegian Environment Agency as part of the ongoing treatment efforts in the Driva region and the preparatory measures for treatment in the Drammen region. It is worth noting that both Gylelva and Ebbestadelva are small water courses and do not host self-sustaining populations of salmon.

Infection status and the current threat situation

Following the declaration of freedom from *G. salaris* infection in the Skibotn region in 2022, only Fustavassdraget in Nordland, within the Vefsna region, remained included in the declaration of freedom program. The program for the other rivers included in the Vefsna region concluded in 2017. Within the Fusta watershed, both salmon parr from the river itself and a substantial number of Arctic char from the lakes above the salmon-bearing stretch underwent examination (see above). The program for Fustavassdraget was finalized in 2023 and *G. salaris* was not detected. As a result, the final watercourse in the Vefsna region, and consequently the entire region, could be declared free from *G. salaris* infection as of January 2024. This milestone also means that all previously infected regions north of the Driva region are now declared free, leading to a significant reduction in the number of infected salmon stocks.

Rivers subjected to treatment remain classified as infected until officially declared free from infection. Following the declaration of freedom for Fustvassdraget, only ten out of the original 53 watercourses are categorized as infected. These are Driva, Litjdalselva, Usma, Batnfjordselva, and Gylelva in Møre and Romsdal, Drammenselva, Ebbestadelva, and Lierelva in Buskerud, as well as Sandeelva (Vesleelva) and Selvikvassdraget in Vestfold (Figure 11.3.1).

Gyrodactylus salaris is present in both Russia, Sweden, and Finland, posing a potential threat to Norway through new introductions. However, as of 2023, there have been no reports of detection of the parasite in areas bordering Norway.

Eradication measures in 2023

Historically, *G. salaris* has caused great damage to infected salmon populations, and the authorities' ambition is to eradicate the parasite from all infected watercourses. the Norwegian Norwegian Environment Agency has designated the Veterinary Institute as the National Competence Centre for combatting *G. salaris*, and the institute is responsibility for executing all measures aimed at eradicating the parasite from Norwegian rivers.

In 2023, the second round of treatment against *G. salaris* was carried out in the Driva region. This time, chlorine was used in combination with rotenone in River Driva and Litjdalselva, while only rotenone was used in the rivers Usma and Batnfjordselva. After the detection of the parasite in Gylelva, this river was treated twice with rotenone. Conservation work, studies and mapping have also been carried out in the Drammen region.

Skibotn infection region

In the Skibotn region in Troms and Finnmark, rebuilding of the sea trout and Arctic char populations is ongoing after the treatments carried out in 2015 and 2016. These measures are planned to be completed in 2024. Restocking of salmon by release of roe from live gene bank has been completed.

Driva infection region

Gyrodactylus salaris was first detected in River Driva in Møre and Romsdal in 1980. This infection region consists of the rivers Driva, Litjdalselva, Usma, Batnfjordelva and Gylelva (new in 2023).

River Driva is long, with many inaccessible places along the anadromous stretch. To limit the extent of the treatment area and thereby increase the likelihood for success, a migration barrier (preventing upwards migration alone) was built in 2017 at Snøvasmelan, approximately 25 km from the river mouth. In 2020 and 2021, method testing was conducted for the use of alternative main chemical (monochloramine) to combat *G. salaris* in the Driva river. This resulted in an expectation of increased survival of juvenile salmon and increased emigration of smolt from the watercourse in the coming years, with a reduction in the number of *G. salaris* in the watercourse. However, it was clear that the parasite was still present in the watercourse, and with an expected increase in smolt emigration, the risk of infection further in the region would also increase. The uncertainty about

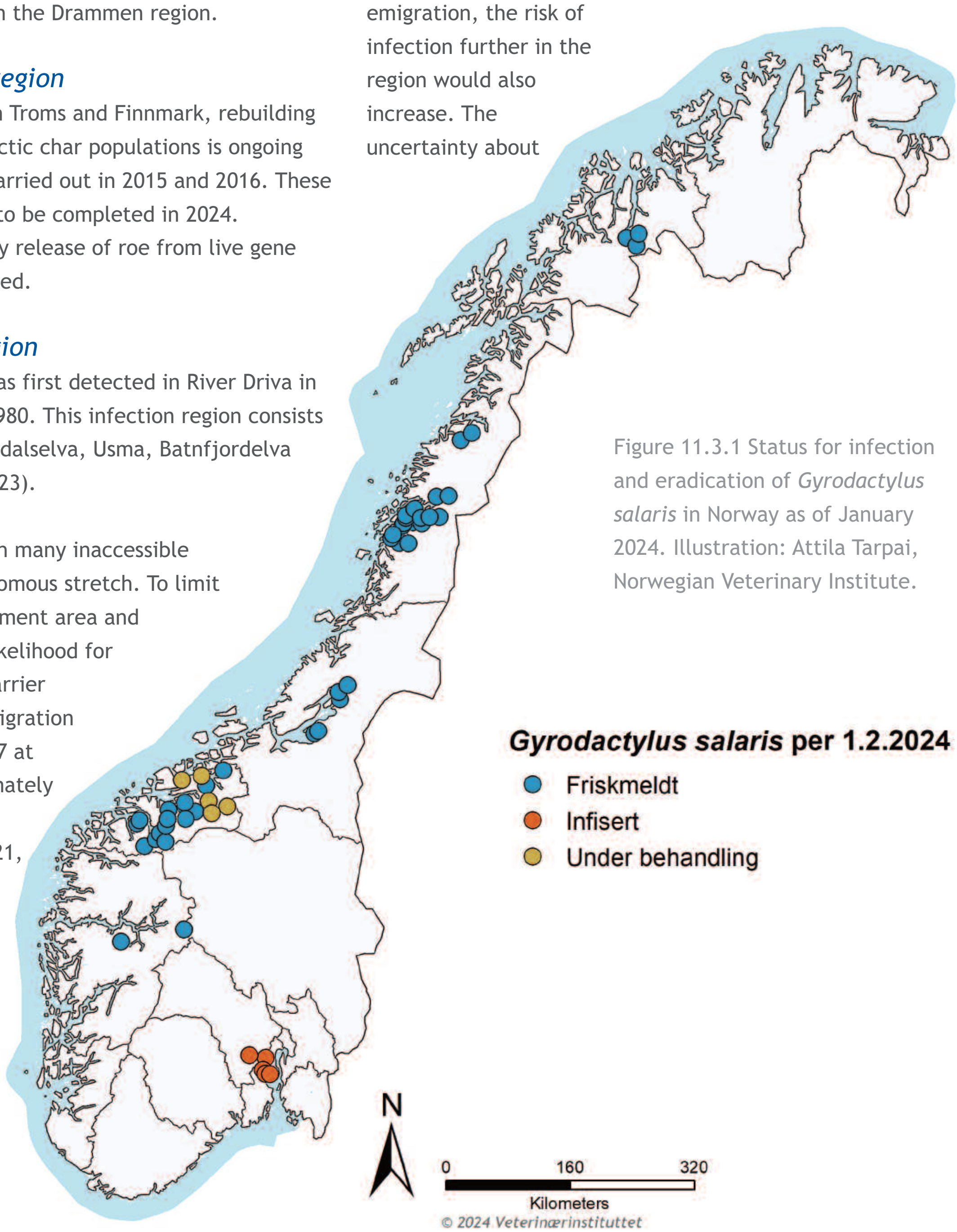


Figure 11.3.1 Status for infection and eradication of *Gyrodactylus salaris* in Norway as of January 2024. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

possible hosts for *G. salaris* still being present upstream of the barrier was acknowledged. A comprehensive assessment concluded to commence full-scale eradication of *G. salaris* in the Driva region in 2022. The entire watercourse with side streams from the salmon barrier at Snøvasmælan down to the fjord was treated in August 2022 and August 2023. In 2022, the Norwegian Institute for Natural Research detected DNA from *G. salaris* in environmental DNA surveys upstream of the barrier. In addition, one six-year-old salmon and two hybrids of salmon/trout were caught far upstream of the barrier using an electrofishing boat. The salmon parr was moderately infected with *G. salaris*, while the two hybrids were uninfected. These findings confirmed the need to carry out the already planned supplementary chlorine treatment of this section of the river. Following this treatment, DNA from *G. salaris* was not detected in eDNA samples. However, as such monitoring cannot be used to confirm that *G. salaris* is not present, plans are still being made for extended monitoring and a supplementary treatment with chlorine and rotenone in Driva in 2024.

To conserve the sea trout population in River Driva, all sea trout that are intercepted by the barrier are moved above the barrier after genetic species confirmation and salt treatment. These procedures are carried out to prevent the migration of hybrids and to remove potential parasites, respectively. From 2020 and onwards, sea trout have also been collected downstream of the barrier and moved upstream of the barrier. A representative sample of the salmon population in River Driva is kept in the live gene bank for wild salmon. The conservation work for salmon in Batnfjordselva has followed the same course as

Figure 11.3.2 Mapping of a water source in a tributary to the Lierelva. The mapping must ensure that all water bodies that may have permanent or temporary residence of salmon fry are included in the control area. Photo: Helge Bardal, Norwegian Veterinary Institute.

in River Driva. In 2020, the collection for the gene bank was expanded to include sea trout from Batnfjordselva and Litjdalselva and salmon and sea trout from Usma. Collection of material for the gene bank from the various rivers in the region has been completed as of January 2024. The coordination group for the control and conservation work in the region is led by the County Governor in Møre and Romsdal, and otherwise consists of representatives from the Norwegian Food Safety Authority, the Norwegian Environment Agency and the Norwegian Veterinary Institute, as well as a local coordinator employed by Sunndal municipality.

Drammen infection region

This region comprises the five rivers Drammenselva, Lierelva, Sandeelva, Ebbestadelva and Selviksvassdraget. In 2018, an expert group established by the Norwegian Environment Agency concluded that successful treatment of the Drammen region is possible and that both the rotenone and aluminium methods could be used. It was concluded that the rotenone method is likely to provide the best chance of success. At the same time, the rotenone method has significant disadvantages for fish populations. For the chlorine method, there is not sufficient empirical basis regarding the hydrochemical criteria necessary for a successful treatment. However, the method seems to have had the desired effect in Driva and Litjedalselva with the hydrochemical conditions present there. Further evaluation in the next years will give more background knowledge and experience, which will be invaluable in determining whether chlorine treatment should be the primary method used in the Drammen region.

In preparation for future treatments, a comprehensive mapping of topography, has been undertaken in and around Sandeelva, Selvikvassdraget, and Lierelva, to identify all areas that can hold infected salmon. Similarly, extensive mapping of Drammenselva has been conducted up to Hellefoss, with the exception of Vestfosselva (Figure 11.3.2). Since 2019, the fish ladder at Hellefossen has remained closed to prevent the upstream migration of salmon, and the salmon and *G. salaris* population above Hellefossen are monitored in a separate monitoring program under the auspices of the Norwegian Food Safety Authority. The results from this OK program are not yet ready for 2023. However, results from the monitoring program from 2020 to 2022 indicated that the closure of the fish ladder at Hellefossen had yielded the intended effect thus far. Atlantic salmon were not captured by electrofishing above Hellefossen in 2021 and 2022. However, environmental DNA monitoring suggested the potential presence of salmon in 2022, though no traces of *G. salaris* were detected in the same samples from either 2021 or 2022. An expert panel on fish barriers has concluded that salmon are most likely able to pass Hellefoss and Døvikfoss during elevated water levels. During the centenary flood "Hans" in 2023, the fish ladder at Hellefoss was flooded and potentially facilitating upstream migration of salmon during this event. Consequently, it is probable that the stretch up to Embretsfoss will also be included in future treatment plans, without significantly complicating the process beyond an anticipated increase in workload.

Since 2016, the Norwegian Veterinary Institute has been collecting salmon from Lierelva and Drammenselva for inclusion in the live gene bank, with the goal of safeguarding salmon stocks in the Drammen region. This conservation initiative was further expanded in 2020 to encompass salmon and sea trout from Sandeelva and Selvikvassdraget, followed by the inclusion of sea trout from Lierelva in 2021. To preserve the sea trout population in Drammenselva, all sea trout intercepted in the fish ladder at Hellefossen between 2020 and 2022 underwent genetic testing and salt treatment before being relocated upstream of the dam. However, in 2023, this measure was discontinued due to a low number of sea trout intercepted by the ladder. The coordination group for the control and conservation work in the region is led by the County Governor in Oslo and Viken and otherwise consists of representatives from the County Governor in Vestfold and Telemark, the Norwegian Food Safety Authority, the Norwegian Environment Agency and the Norwegian Veterinary Institute, as well as a local coordinator employed by Øvre Eiker municipality.

11.4 Salmon lice and sustainability

By Lisa Furnesvik, Julie Christine Svendsen and Åse Helen Garseth

About salmon lice

Salmon lice (*Lepeophtheirus salmonis*) are parasitic crustaceans found on wild and farmed salmonids in the marine environments. Salmon lice feed on the fish's skin, mucus, and blood causing significant damages to wild Atlantic salmon smolta, sea trout and Arctic char. Grazing damage from lice reduces the skin's function as a protective barrier against infection and can also impair the fish's ability of fish to regulate salt and water balance. Heavy infestations of lice can lead to lethal outcomes.

The life cycle of salmon lice consists of eight stages separated by molts. The parasite reproduces sexually, and each of the two egg strings of an adult female lice contains several hundred eggs. The spread of salmon lice occurs during the three initial free-living stages. The duration of the infectious period depends on water temperature. In the final five stages of the life cycle, salmon lice live as a parasite on the host. Salmon lice are considered one of the most serious problems in Norwegian aquaculture today. This is because salmon lice spread to wild fish and causes harm to them, but also because farmed fish have to undergo frequent and often harsh treatments to keep the number of lice low.

For more information about salmon lice, see Chapter 9.1 in this report and NVI fact sheet: https://www.vetinst.no/sykdom-og-agens/lakselus

The Traffic Light System

Growth in the aquaculture industry should be sustainable and is therefore regulated through the so-called "Traffic Light System." Currently, mortality of migrating wild salmon smolts due to salmon lice infestation is the only sustainability indicator in the Traffic Light System. https://trafikklyssystemet.no/

A steering committee consisting of representatives from the Norwegian Institute for Nature Research (NINA), The Institute of Marine Research and the Norwegian Veterinary Institute has appointed an expert group that annually reviews scientific documentationand assessment the risk of mortality in wild salmon smolts. Low risk corresponds below 10 percent mortality, moderate risk corresponds 10-30 percent mortality, and high risk corresponds over 30 percent salmon lice-induced mortality in wild salmon smolt.

Based on the expert group's assessments, the steering committee's gives scientific advice to the Ministry of Trade, Industry, and Fisheries (NFD). The NDF makes the final decision on the matter of the colour of a production area in the Traffic light system. They emphasis both the scientific advice from the steering committee and The Ministry's assessment of socioeconomic consequences. Consequently, results may differ from the steering committee's and expert group's advice. The main rule in the Traffic Light System is that in production areas assigned a red traffic light, aquaculture operators are required to reduce production by up to six percent; in yellow areas, neither growth nor reduction is allowed, while aquaculture operators in green areas can increase production by up to six percent.

In the expert group's report from 2023, production area (PA) 3 is classified as high risk (red), PA2 and PA4-PA7 are categorized as moderate risk (yellow), while PA1 and the six northernmost areas are assessed to have low risk of mortality (green) (Figure 11.4.1). Changes include PA4, which was assessed as high risk in 2022, being classified as moderate risk in 2023, while PA8, previously considered moderate risk, was assessed to have low risk in 2023. Table 11.4.1 shows the expert group's conclusions for the 13 production areas from 2016 to 2023.

Drug resistance and freshwater tolerance

Freshwater treatments against salmon lice and amoebic gill disease (AGD) have become increasingly popular in recent years. The method is considered relatively gentle for farmed salmon compared to several mechanical methods against salmon lice. Freshwater is not considered a drug, and there is no regulation of its use as a delousing method. Salmon lice have developed resistance to several of the medicinal treatments after repeated exposure. Extensive use of freshwater has raised concerns that lice may also develop resistance to freshwater. If lice are selected for increased freshwater tolerance, the consequences will be significant for wild salmonids. In the Norwegian Veterinary Institute's survey, several respondents (six) commented in the free-text field that they observe reduced effectiveness of freshwater treatment against salmon lice. The Norwegian Food Safety Authority has issued recommendations for cautious use of the method because risk assessments indicate that repeated use may increase lice tolerance to freshwater. It is recommended not to use the method more than twice a year, in addition to only using the method early in the course of infection. All treatment must be stopped if the salmon lice show signs of increased tolerance to freshwater, and it is important to actively use sensitivity tests.

Sea trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*)

The Norwegian Scientific Advisory Committee for Atlantic Salmon (VRL) has assessed the human-induced threats to sea trout based on their impact on populations and the likelihood of further damage in the future. In the assessment that was published in 2023, salmon lice are considered the greatest threat to sea trout. The salmon lice can alone drive the sea trout stocks into a crisis. It will be necessary for new measures to be implemented to reduce the infection pressure from fish farms, otherwise salmon lice will be decisive for the development of the sea trout population in the future.

In the parliamentary document 16 (2014-2015) “Predictable and Environmentally Sustainable Growth in Norwegian Salmon and Trout Farming” the Ministry state that the Traffic Light System should also include effects of salmon lice on sea trout and Arctic char. According to the expert group, the infection pressure of salmon lice increase in PA1-PA10 after the period defined as critical for migrating salmon smolt. This is a period where sea trout and Arctic char migrate in the fjords. The life history and behaviour of sea trout differ from those of Atlantic salmon, but there has been no reassessment of lice-induced mortality for either species. The steering committee has recommended that new criteria should be made to include sea trout and Arctic char in the Traffic

Table 11.4.1 The expert group's assessment in the period 2016-2023. Low corresponds to less than 10 percent salmon lice-induced mortality in wild salmon smolts, moderate (mod) corresponds to 10-30 percent mortality, and high corresponds to more than 30 percent salmon lice-induced mortality in wild salmon smolts.

Production area (PA)	2016	2017	2018	2019	2020	2021	2022	2023
PA1. Swedish boarder - Jæren	Low	Low	Low	Low	Low	Low	Low	Low
PA2. Ryfylke	Mod	Low	Mod	Low	High	Low	Mod	Mod
PA3. Aera Karmøy to Sotra	High	High	High	Mod	High	High	High	High
PA4. Nord-Hordaland to Stad	Mod	High	Mod	High	Mod	High	High	Mod
PA5. Stad - Hustadvika	Mod	Mod	Mod	High	Low	Mod	Mod	Mod
PA6. Nordmøre - South of Trøndelag	Mod	Low	Low	Low	Low	Low	Mod	Mod
PA7. North of Trøndelag with Bindal	Mod	Low	Mod	Low	Mod	Mod	Mod	Mod
PA8. Helgeland - Bodø	Low	Low	Low	Low	Low	Low	Mod	Low
PA9. Vestfjorden and Vesterålen	Low	Low	Low	Low	Low	Low	Low	Low
PA10. Andøya - Senja	Low	Low	Low	Mod	Low	Low	Low	Low
PA11. Kvaløya - Loppa	Low	Low	Low	Low	Low	Low	Low	Low
PA12. West of Finnmark	Low	Low	Low	Low	Low	Low	Low	Low
PA13. East of Finnmark	Low	Low	Low	Low	Low	Low	Low	Low

Light System. When the parliament introduced resource rent tax there is a requirement that indicators should include, impact on sea trout, emissions, and mortality.

Pink salmon (*Oncorhynchus gorbuscha*) and salmon lice

The Institute of Marine Research (IMR) leads the Norwegian salmon lice monitoring program (NALO). Salmon lice are monitored in Atlantic salmon by trawling in fjords, and in sea trout and Arctic char by use of traps and nets. In 2023, pink salmon were included in the monitoring program for salmon lice and the first official registrations were made in Oksfjord, Bugøynes and Jarfjord in the Counties of Troms and Finnmark.

A total 216 pink salmon were caught with traps in the sea. Altogether 444 lice were registered on 95 of the pink salmon. The findings consists of both salmon lice (*Lepeophtheirus salmonis*) and *Caligus elongatus*. Of the registered lice, 74 percent were *C. elongatus*, 20 percent adult salmon lice and 6 percent salmon lice in the attached stages. These results support the hypothesis that pink salmon can serve as a source of infection for wild salmonids in Norway and emphasizes the need for further monitoring.

The Norwegian Institute of Marine Research's findings indicate that pink salmon may contribute to the spread of salmon lice and *Caligus elongatus* to local salmonids. The pink salmon is mostly a problem for local salmonids in the northern parts of Norway, where they invade in great numbers. In PA13 (Eastern Finnmark) there were more pink salmon registered than local salmon in 2023.

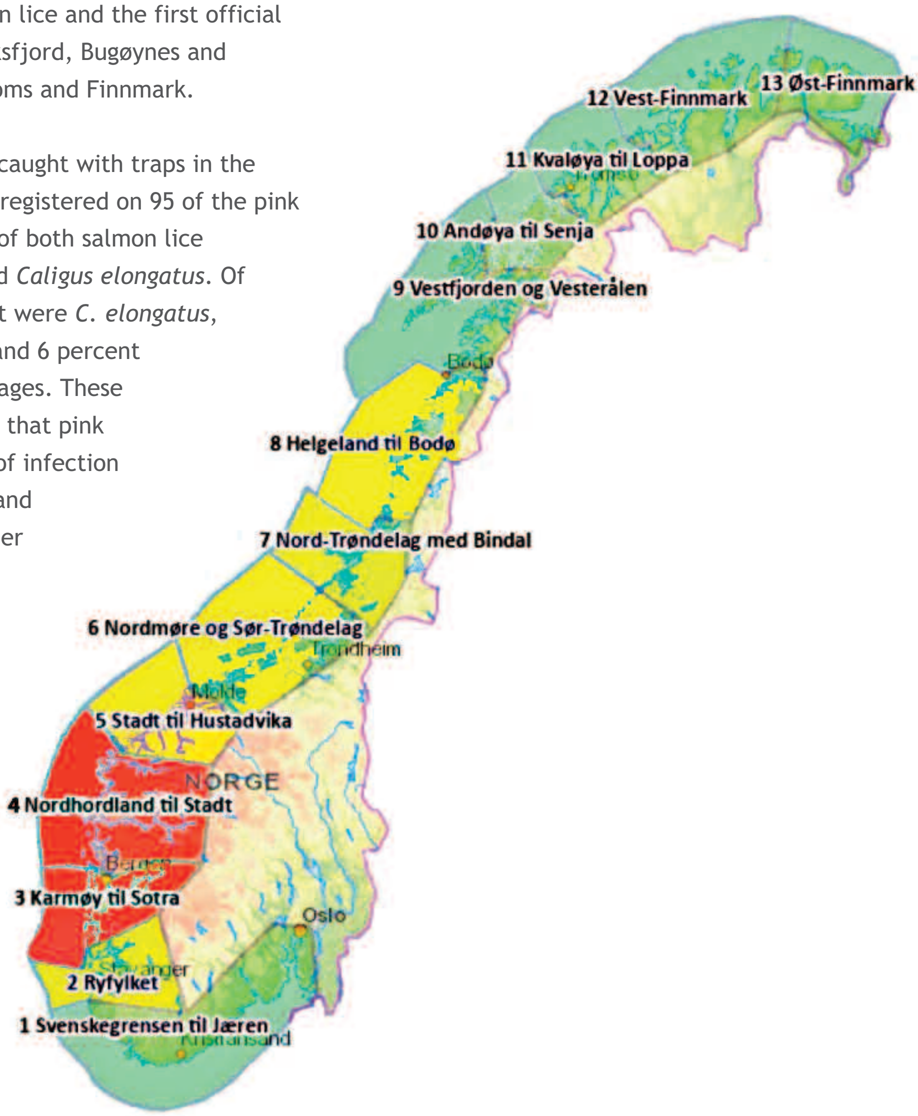


Figure 11.4.1 The Traffic Light System. The Ministry of Trade, Industry and Fisheries' (NFD's) colouring of production areas in 2024. Green; production capacity can be increased, yellow; production can continue at current capacity, red; production capacity must be reduced. Illustration: NFD

11.5 Pink salmon

By Åse Helen Garseth, Lisa Furnesvik, Torfinn Moldal, Julie Christine Svendsen, Kristoffer Vale Nielsen, Hanne Nilsen og Anne Berit Olsen

Pink Salmon (*Oncorhynchus gorbuscha*)

This alien invasive Pacific salmon has established self-sustaining populations in Norwegian and Russian rivers after extensive releases in Russia until 1999. The species has spread to both sides of the northern Atlantic Ocean and appears to be highly adaptable. Pink salmon were observed in Norwegian rivers as early as the 1960s, but it was not until 2017 that the species caught the general public's attention due to a significant increase in both number and geographical distribution. From 2019, it became mandatory to report pink salmon catches in Norway, and the records show that the occurrence has continued to increase from 2017 to 2023. Pink salmon have a strict two-year life cycle, and it is the odd-year spawners that are most numerous in Norway.

In 2023, a total of 364,000 pink salmon were caught in Norway. Of these, 16,100 were caught during angling in rivers and 98,770 (183 tons) were caught during salmon fishing in the sea (SSB). In addition, nearly 250,000 individuals were removed from the rivers through organized control measures against pink salmon – the vast majority from rivers in Troms and Finnmark. (https://www.miljodirektoratet.no/aktuelt/datavisualisering/pukkellaks-uttak/).

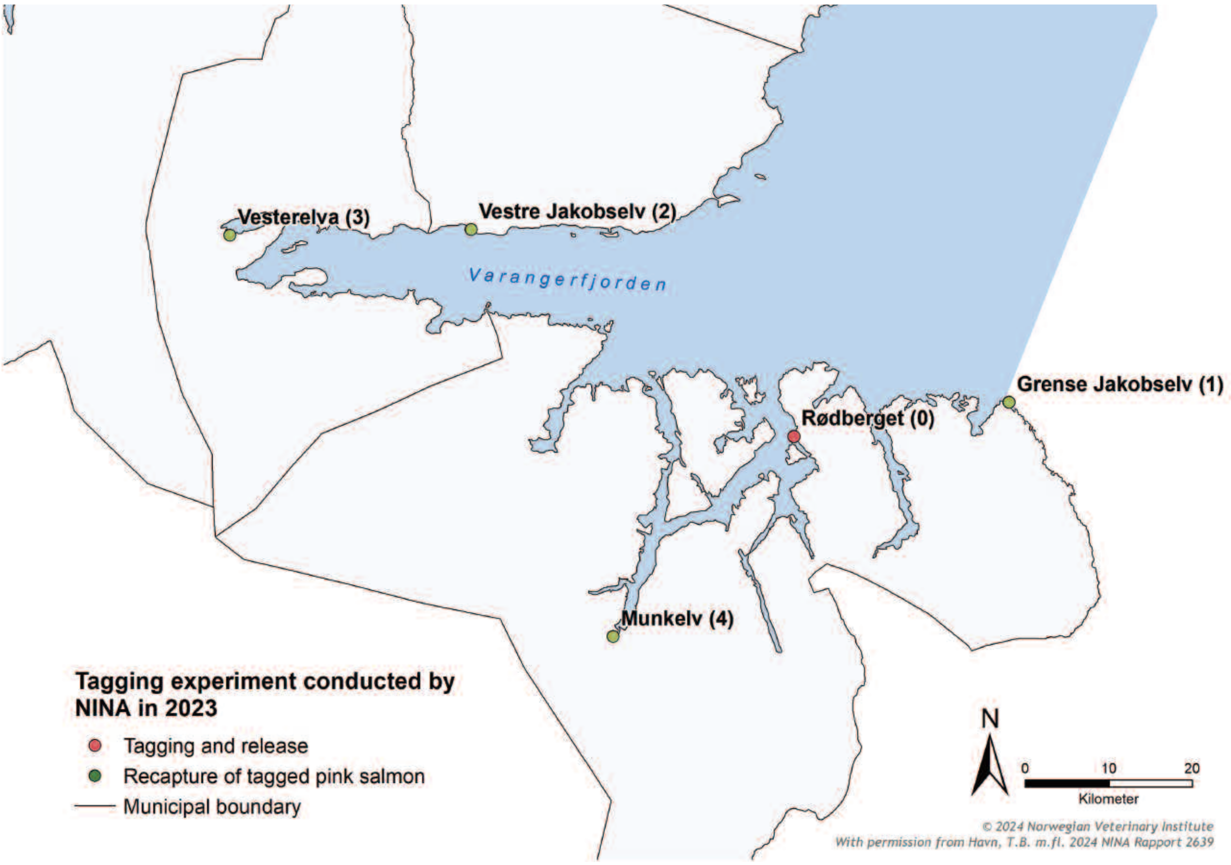


Figure 11.5.1 In 2023, researchers at NINA conducted an experiment in which 35 pink salmon caught in wedge nets at Rødberget, were marked and released again. Of these, six pink salmon were reported recaptured in four different locations. In River Grense Jakobselv, 37 km from Rødberget, a tagged pink salmon was caught after 17 days. In River Vestre Jakobselv, 47 km from Rødberget, a pink salmon was caught after 16 days. In River Vesterelva 76 km from Rødberget, one pink salmon was recaptured after 18 days, and in River Munkelv, 33 km from Rødberget, three pink salmon were caught on days 9, 15 and 25 after tagging and release on Rødberget. (Reproduced with permission from Havn et al. 2024, Norwegian Institute for Natural Research Report 2639). Illustration: Attila Tarpai, Norwegian Veterinary Institute.

For comparison, a total of 111,800 pink salmon (191 tons) were caught and removed in the rivers and 38,930 pink salmon (72 tons) in sea salmon fishing in 2021.

There is a need for more knowledge about the ecological and economic effects of pink salmon, including whether they can contribute to introduction or local spread of pathogens. An important reason for the extensive secondary spread of pink salmon is that the homing behaviour of this species is weaker than for instance in our native Atlantic salmon, meaning that pink salmon to a lesser degree return to the river in which they were hatched. Further research on the homing behaviour of pink salmon is of interest because it may provide an indication of the local effects of control measures.

The local behaviour of pink salmon returning from marine migration is also of particular interest. Local ecological knowledge is that pink salmon occur in schools that move in the fjord system before entering the rivers. A tagging experiment conducted by the Norwegian Institute for Nature Research (NINA) showed that pink salmon caught, tagged, and released from a sea fishing location spread in multiple directions and were recaptured in various rivers within a radius of nearly 80 km (Figure 11.5.1). The behaviour is thus unpredictability in a disease situation.

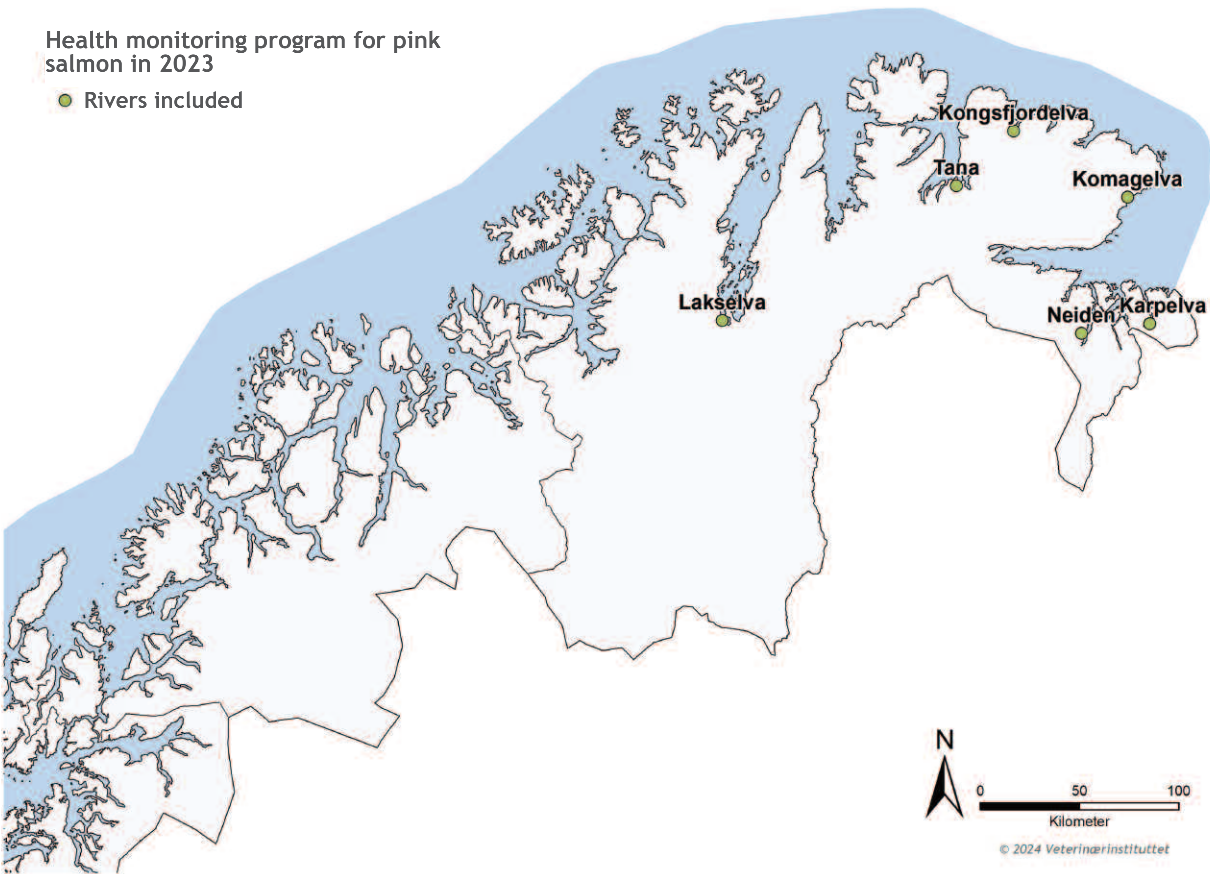


Figure 11.5.2 Map of Northern Norway displaying the location of six rivers in the County of Finnmark that were included in the health monitoring program for pink salmon in 2023. Illustration: Attila Tarpai, Norwegian Veterinary Institute.

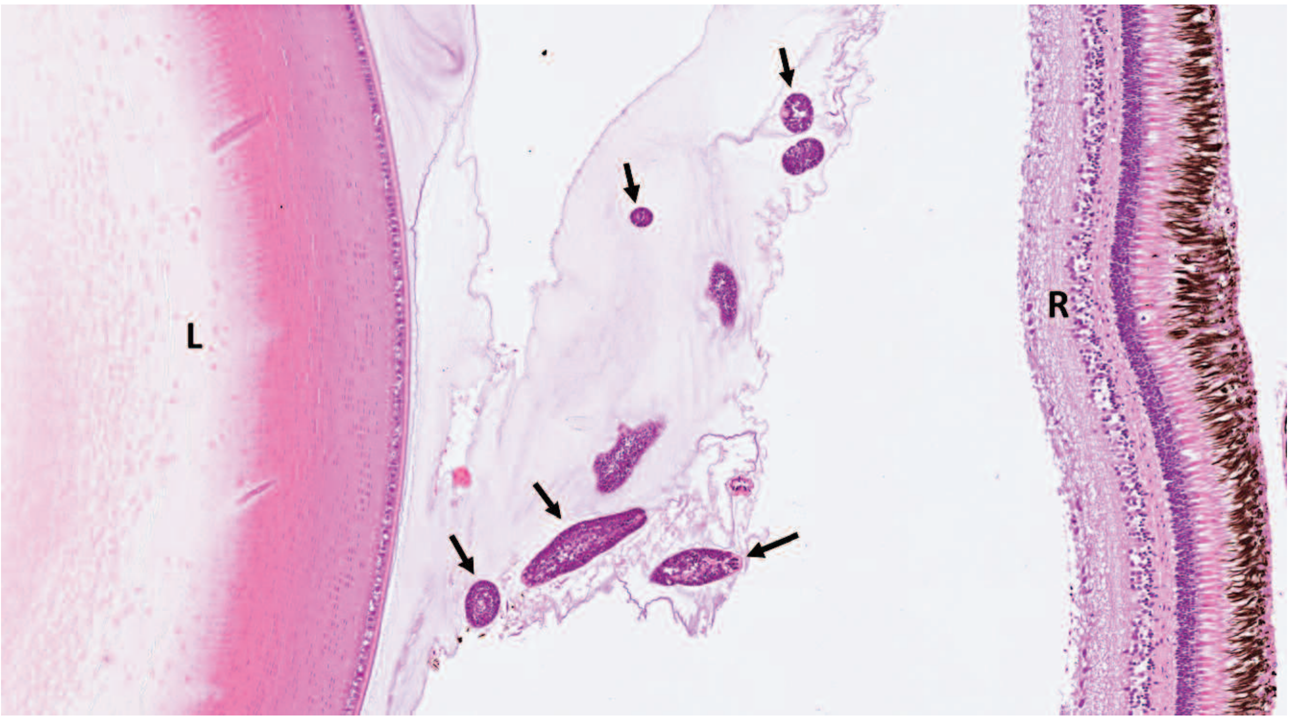


Figure 11.5.3 Histological image showing multiple parasites (morphology compatible with eye fluke) shown with black arrows in the eye of pink salmon. The lens in the eye is marked with (L) and the retina is marked with (R). Photo: Lisa Furnesvik, Norwegian Veterinary Institute.

Organized Health Monitoring in 2023

The Norwegian Veterinary Institute has conducted health monitoring of pink salmon since 2019. In 2023 health monitoring was organized through the project "Ocean Health". Altogether 184 randomly selected “healthy” pink salmon were sampled from rivers Lakselv, Tana, Neiden, Karpelv, Kongsfjordelva, and Komagelva from July 2nd to August 9th (Figure 11.5.2). Samples for histological, bacteriological and/or qPCR analyses were collected. The Norwegian Veterinary Institute's health monitoring of pink salmon did not reveal any serious notifiable fish diseases, nor did it detect the PRV-1 virus, which causes heart and skeletal muscle inflammation in Atlantic salmon.

PCR Investigations

The NVI conducted PCR analyses on samples from 161 pink salmon. The analyses were partly carried out in connection with the Norwegian Food Safety Authority's monitoring program for the two viral diseases, viral hemorrhagic septicemia (VHS) and infectious

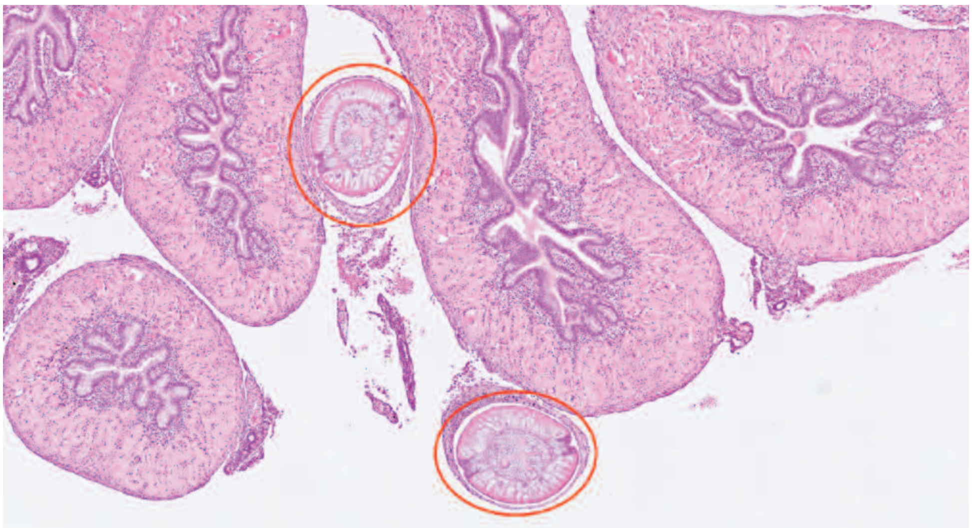


Figure 11.5.4 Histological image showing two encapsulated nematodes (red circle) in the abdominal cavity between the pyloric blind sacs. Photo: Lisa Furnesvik, Norwegian Veterinary Institute.

Figure 11.5.5 Yellow-pigmented skin changes in pink salmon are observed sporadically.
Photo: Håvard Vistnes

hematopoietic necrosis (IHN). In addition, tests were conducted for infectious salmon anemia virus (ISAV), *Renibacterium salmoninarum*, which causes bacterial kidney disease (BKD), and piscine orthoreovirus-1 (PRV-1). None of these pathogens were detected.

Bacterial Culturing

Tissue samples from the kidneys of the majority of examined pink salmon were cultured for bacteria. Kidney samples were sent chilled to the laboratory for further culturing on blood agar, kidney disease medium (KDM), and selective kidney disease medium (SKDM). The primary purpose of the culturing was monitoring for *R. salmoninarum* (BKD) and Aeromonas salmonicida subsp. Salmonicida (classical furunculosis). It was also of interest to assess the presence of other bacteria. *R. salmoninarum* and *A. salmonicida* subsp. *salmonicida* were not detected in the examined pink salmon.

Histological Examinations

To enable histological examinations of pink salmon with findings during microbiological investigation, organ

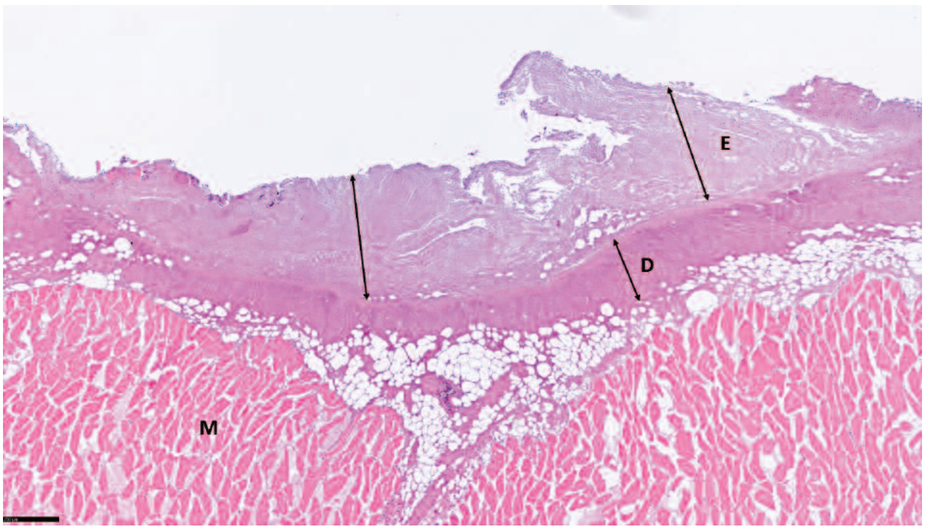


Figure 11.5.6 Histological image showing the area of skin with yellow pigmented skin changes. Histologically, a thickening of the epidermis (E) is seen, marked with arrows. Beneath the epidermis is the dermis (D) and below that again is skeletal muscle (M). Photo: Lisa Furnesvik, Norwegian Veterinary Institute

Figure 11.5.7 Seemingly identical jaw deformities were observed in three pink salmon in River Tana. Two of these were captured on the same day. Photo: Roar Sandodden, Norwegian Veterinary Institute.

samples were collected for histopathology from all pink salmon included in the health monitoring.

Although bacteriological and PCR examinations did not warrant further investigations, a selection of pink salmon were examined by histology. Histological examinations revealed several parasites, including eye flukes (Figure 11.5.3) and a variety of nematodes encapsulated in the body cavity and around or inside internal organs (Figure 11.5.4). The presence of nematodes in wild fish is considered a normal finding.

Reports from the Public

In addition to the described targeted surveillance, NVI encouraged the general public to report observations of pink salmon showing signs of illness prior to spawning via the "Wild Fish Health Portal". Sampling kits with instructions were distributed to some river owner associations and to the association for salmon fisheries in the sea. In 2023, there were no reports indicating suspicion of infectious diseases in pink salmon.

Yellow pigment aberrations

Pink salmon with a specific yellow pigmentation in the skin are observed sporadically and have caught attention by the public. Yellow-green marbled epidermis of pink salmon has also been described from the Pacific Ocean and it is suggested that the condition is caused by partial albinism. A pink salmon with yellow pigmentation of the skin was included in the health monitoring program. Viral or bacterial infection was not detected, but histological examination of the affected skin areas revealed some tissue changes (Figure 11.5.5 and 11.5.6).

Jaw Deformities

In the pink salmon trap in River Tana, three pink salmon with apparently identical jaw deformities were recorded (Figure 11.5.7). In addition, to jaw deformities, spinal deformities were observed in pink salmon.

12. The Health Situation of Cleaner Fish

By Toni Erkinharju, Snorre Gulla, Julie Christine Svendsen, and Synne Grønbech

Use of Cleaner Fish in Aquaculture

In recent years, significant amounts of both wild-caught and farmed cleaner fish have been used in the fight against salmon lice. Cleaner fish is a collective term for lumpfish (Figure 12.1) and various species of wrasse. The most commonly used wrasse species are goldsinny wrasse, corkwing wrasse, and ballan wrasse, while rock cook is used to a lesser extent.

According to data reported to the Norwegian Directorate of Fisheries as of 20.02.2024, a total of 33.9 million cleaner fish were released in Norway in 2023. This is lower than the adjusted figures for 2022 and 2021, with releases of 36.3 and 48.3 million cleaner fish, respectively. Although this immediately seems to indicate a decrease in the use of cleaner fish from 2022 to 2023, it should be noted that the figures for 2023 could increase considerably as the registers are updated and corrected. In 2023, 17.5 million lumpfish were released, compared to 19.5 million in 2022 and 28.2 million in 2021, but the final figures for 2023 could increase. For release and sales figures for wrasse species, refer to the Directorate of Fisheries' Biomass Statistics and Aquaculture Statistics (https://www.fiskeridir.no/Akvakultur/Tall-og-analyse).

Compared to wrasse, lumpfish are considered easier to farm, in addition to having a shorter production cycle. Lumpfish are also more active and thrive better than wrasse at lower water temperatures, making them more commonly used in the northernmost parts of the country. For previous years, it has been noted that producers' releases of lumpfish, especially in Southern Norway, were lower in the summer and autumn, probably as a measure to reduce mortality rates after release. Based on reported data distributed by month and production area (Biomass Statistics), a similar trend can be seen for 2023, especially in PA2-PA6.

Lumpfish used as cleaner fish are farmed, while a large proportion of wrasse are wild-caught. Wrasse fishing is regulated and takes place in traps or pots during the summer. After capture, the fish are transported to salmon farms in wellboats, smaller boats, or tank trucks.

In addition to fishing along the Norwegian coast, wild-caught wrasse has also been imported from Sweden, since demand exceeds the supply from fishing and farming in Norway. From a biosecurity perspective, such transport is undesirable due to the potential for spreading disease-causing agents that the cleaner fish may carry.

Several studies, such as the Norwegian Food Safety Authority's cleaner fish campaign conducted in 2018/2019 and the Auditor General's report from 2023 on the authorities' work on fish health and welfare in the aquaculture industry, have pointed out significant welfare challenges and high mortality rates among cleaner fish in sea cages. The main challenges for health and welfare associated with the use of cleaner fish in Norway are mortality and problems that are directly or indirectly related to various forms of handling, such as during delousing, wound development, and several bacterial diseases. In particular, lumpfish have shown susceptibility to several different disease-causing agents. Several of these can occur simultaneously, making it difficult to determine the primary cause of disease and mortality.

Diseases and Agents in Cleaner Fish

Bacteria

Atypical *Aeromonas salmonicida, Vibrio anguillarum, Vibrio ordalii*-like bacteria, *Pasteurella* sp. ('*P. atlantica* genomovar *cyclopteri*'), *Pseudomonas anguilliseptica, Moritella viscosa*, and *Tenacibaculum* spp. are among the most common bacterial species identified in connection with disease outbreaks in wrasse and/or lumpfish in Norway. Other bacteria are also isolated from sick and dying fish, but the significance of these as disease-causing agents in cleaner fish is uncertain.

So-called atypical *Aeromonas salmonicida* causes the disease atypical furunculosis, and there are two genetic variants of the bacterium that dominate in Norway (A-layer types 5 and 6). The typical disease picture is chronic infection with the formation of boils, sores, and inflammatory nodules (granulomas) in internal organs with microcolonies of bacteria (Figure 12.2). A. salmonicida subsp. salmonicida, which causes the disease classic furunculosis in salmonid fish, is notifiable (category F). In recent years, this bacterium has been sporadically detected in lumpfish in an area in Trøndelag with known endemic infection in wild salmonid fish (Chapter 7.2 Furunculosis).

Classic vibriosis, caused by *Vibrio anguillarum*, is an important disease in marine fish and also occurs sporadically in cleaner fish. Clinical signs include sores, fin rot, external skin hemorrhages, and internal organ bleeding. High water temperatures are often associated with the development of the disease, but outbreaks of vibriosis have also been described in lumpfish at temperatures as low as 6°C. Serotype O1 and several subtypes of O2 are most common in cleaner fish.

Infection with Vibrio ordalii-like bacteria has occurred sporadically in farmed lumpfish in Norway. These infections can lead to severe hemorrhagic septicemia and are associated with high mortality rates. Recurring outbreaks have also been observed.

Other Vibrio and *Aliivibrio* species, such as *V. splendidus, A. logei, A. wodanis*, and *V. tapetis*, are often isolated from cleaner fish. However, the significance of these bacteria for disease in cleaner fish is uncertain, as several of them are common environmental bacteria in seawater. It is likely that stressful conditions and external influences can make cleaner fish susceptible to infection and disease with bacteria that would not normally cause this in healthy individuals.

Fig. 12.1: Lumpfish (*Cyclopterus lumpus*). Picture taken at the Lofoten Aquarium. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

Pasteurella sp. causes the disease pasteurellosis in farmed lumpfish in Norway and Scotland. A closely related variant of the bacterium also causes disease in salmon in Norway (Chapter 7.5 Pasteurellosis). In 2020, *Pasteurella atlantica* genomovar *cyclopteri* was proposed by the Norwegian Veterinary Institute as a working name for the group of Pasteurella bacteria that cause disease in lumpfish. Clinically, the disease manifests as bacterial sepsis, with skin lesions in the form of white spots, fin rot, ascites, and bleeding in the gills and at the base of the fins. Disease outbreaks can occur both in the hatchery phase and at sea. The mortality associated with outbreaks can be very high, sometimes up to 100 percent.

Pseudomonas anguilliseptica was first detected in lumpfish in Norway in 2011. The disease usually manifests as hemorrhagic septicemia and has been detected at several sites in recent years.

Moritella viscosa occurs regularly in cleaner fish, often in connection with wound conditions, and preferably at lower seawater temperatures. In addition, *Tenacibaculum* spp. is often isolated from wound fish and from fish with fin rot, both in pure culture and in mixed flora with other bacteria. *Tenacibaculum* spp. has also been isolated from lumpfish with so-called "crater disease". They are naturally distributed in the marine environment, and several species, such as *T. maritimum, T. finnmarkense, T. dicentrarchi*, and *T. soleae*, have been described from cleaner fish. Several of these species are also isolated from salmonid fish with sores (Chapter 7.4 Winter ulcer).

Among bacterial infections reported in cleaner fish in countries other than Norway are *Piscirickettsia salmonis*, which causes piscirickettsiosis in salmonid fish, in lumpfish in Ireland in 2017, and *Photobacterium damselae* subsp. *damselae* in wild-caught ballan wrasse in England in 2019.

It was recently shown in an experimental study from Canada that lumpfish can be susceptible to infection with *Renibacterium salmoninarum*, which causes the listed disease bacterial kidney disease (BKD) in salmon. In the study, lumpfish were infected by injection and developed a chronic infection where the bacterium could be re-isolated from organ samples for almost a hundred days. So far, natural outbreaks of *R. salmoninarum* have not been detected in any cleaner fish species, and the bacterium is only described in the literature as a serious pathogen for various species of salmonid fish.

In 2021, one case of mycobacterial infection (formerly called fish tuberculosis) was reported at a site with wrasse in Norway. Such bacterial infection can lead to the development of chronic disease with the formation of granulomas (inflammatory nodules) in several organs. The disease also occurs in many other fish species, including salmon (Chapter 7.7 Mycobacteriosis). Mycobacteriosis has not been described in lumpfish.

Fungi

Fungal diseases occur sporadically in cleaner fish. In lumpfish, episodes of increased mortality and systemic infection caused by yeast fungi (Exophiala) have been described, with three species, *E. angulospora, E. psychrophila*, and *E. salmonis*, identified. Infections with *E. psychrophila* have previously been reported in lumpfish in Norway and were detected at one site in 2022.

Parasites

Several single-celled and multicellular parasites have been described in both wild and farmed cleaner fish. Especially the species *Paramoeba perurans, Nucleospora cyclopteri, Trichodina* sp., *Ichthyobodo* sp., *Kudoa islandica, Gyrodactylus* sp., *Caligus elongatus, Eimeria* sp., and *Ichthyophonus* sp. are considered potentially serious for cleaner fish in Norwegian aquaculture and can cause mortality. For the species *P. perurans, C. elongatus*, and *Ichthyophonus* sp., as well as Anisakis simplex (herring worm), it is also important that they can transmit between cleaner fish and salmon.

The amoeba *Paramoeba perurans*, which causes amoebic gill disease (AGD), was first detected in Norwegian farmed salmon in 2006 and has since been found in both lumpfish and wrasse. Like in salmon and other fish species, the parasite causes pathological changes in the gills and can become a problem with severe infections. The amoeba has been found both in cleaner fish at sea with salmon and in lumpfish in land-based tanks.

Microsporidia are single-celled intracellular parasites. In Norway, *Nucleospora cyclopteri* has been found in lumpfish. This parasite infects the nucleus of white blood cells, thus destroying the leukocytes in infected lumpfish. Infected fish often develop pale and enlarged kidneys, with or without white nodules. The parasite is difficult to detect in routine histological examinations and is therefore most likely underdiagnosed in samples examined solely by histology.

Infestation with the ectoparasite *Caligus elongatus* (sea louse) has been reported as a problem in lumpfish in several areas in Troms and Finnmark. In some cases, several hundred individuals have been observed on one fish. The parasite causes sores on the fish that can also make it susceptible to secondary infections with other agents. Lumpfish have previously been shown to be the main host for one genotype of sea lice. Due to low host specificity, the parasite can potentially spread to salmon.

In 2022, systemic spironucleosis was reported in salmon

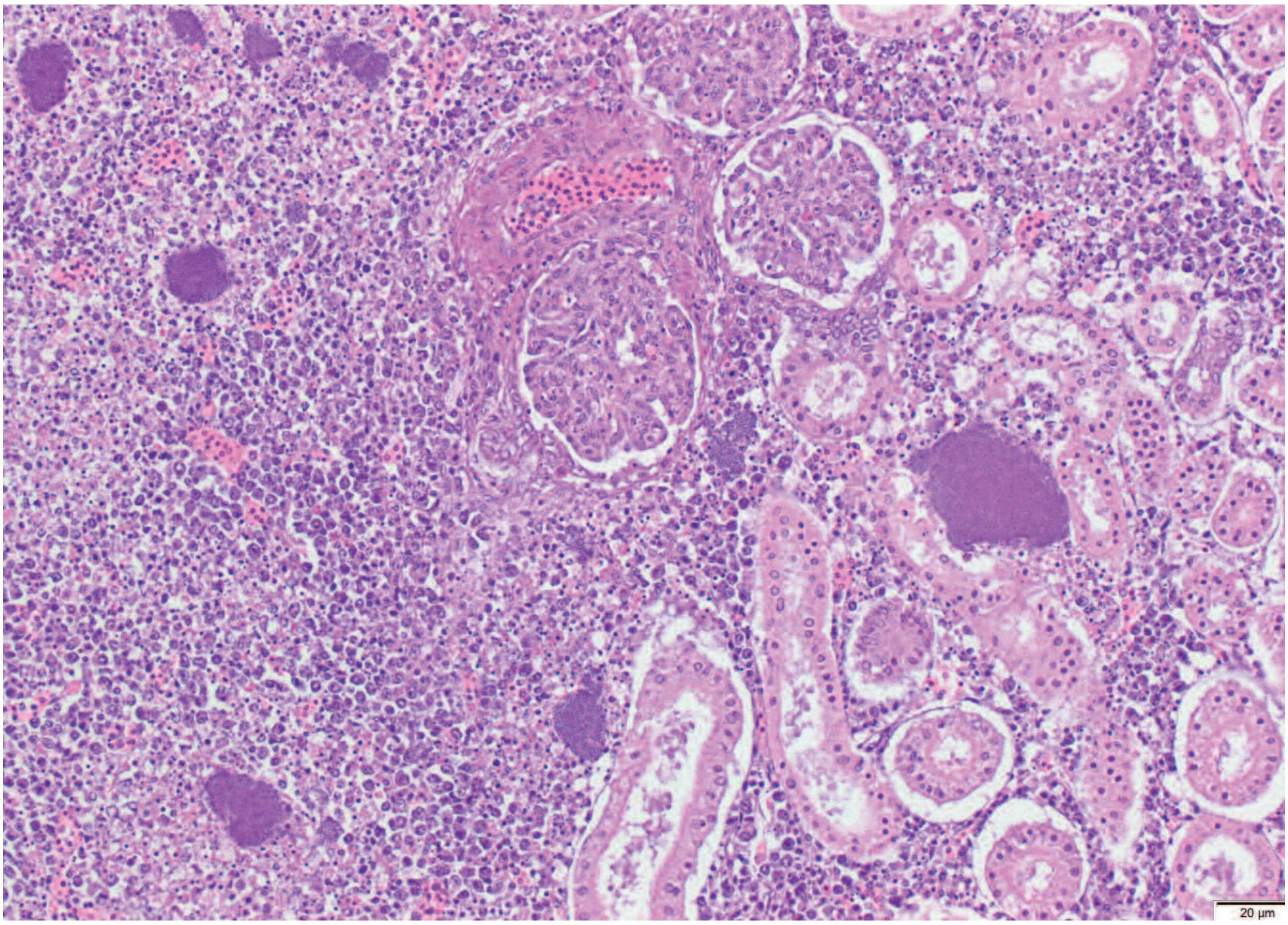


Fig. 12.2: Microcolonies of rod-shaped bacteria in the kidney of lumpfish with atypical furunculosis. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

at several commercial fish farm sites in Northern Norway (Chapter 9.7 Systemic Spironucleosis - *Spironucleus salmonicida*). At one of these sites, infection with *Spironucleus salmonicida* was also detected in lumpfish through histopathological examination combined with PCR and sequencing.

Viruses

The Cyclopterus lumpus virus (CLuV), or lumpfish flavivirus, has been frequently reported in farmed lumpfish since 2016, with a gradual decrease in detections in recent years. Nationwide, the virus has been among the major challenges for lumpfish, especially in the fry stage. During disease outbreaks, high mortality has been reported in facilities where the virus is detected. Massive necrosis of liver cells can occur at high virus levels. Chronic courses exhibit changes resembling cirrhosis. The virus is believed to occur along the entire Norwegian coast and was recently reported in connection with a mortality episode at an aquaculture producer in England. Imported lumpfish from Norway were used, and the case likely represents the first known outbreak in the country.

Other types of viruses have also been reported from cleaner fish, including a new ranavirus, from lumpfish in Ireland, Scotland, the Faroe Islands, and Iceland, tentatively named European North Atlantic Ranavirus. The virus is reported to be closely related to epizootic hematopoietic necrosis virus (EHNV), which is notifiable. The virus has not yet been detected in cleaner fish in Norway.

In 2018, two new viruses were described from diseased lumpfish fry with fluid-filled intestines (diarrheal condition), tentatively named Cyclopterus lumpus Totivirus (CLuTV) and Cyclopterus lumpus Coronavirus (CLuCV). It is not known what significance these viruses have for lumpfish in aquaculture. At the end of 2020, a new virus associated with high fry mortality in ballan wrasse was found, tentatively named Ballan wrasse birnavirus (BWBV).

Experiments have shown that lumpfish can be infected with nodavirus and that wrasse and lumpfish can be infected with infectious pancreatic necrosis virus (IPNV). None of these viruses have been reported in cleaner fish in Norwegian aquaculture. Findings of nodavirus have previously been reported from wild-caught wrasse along the Norwegian and Swedish coasts. Viral hemorrhagic septicemia virus (VHSV) has been detected in wild-caught wrasse and lumpfish in Scotland and Iceland, respectively, but has not been reported from cleaner fish in Norway.

The salmonid pathogenic viruses salmonid alphavirus (SAV), infectious salmon anemia virus (ISAV), piscine myocarditis virus (PMCV), and piscine orthoreovirus (PRV) have been detected in isolated cases in cleaner fish that have been kept with sick salmon in sea cages in or outside Norway. The detections had little or unknown clinical significance for the cleaner fish, and in several cases, sample contamination could not be ruled out. In 2020, a unique variant of the SAV virus was described from ballan wrasse in Ireland, proposed as SAV genotype 7 (SAV7). None of these viruses have been detected in lumpfish.

Other Diseases and Health Issues

Cataracts (clouding of the lens in the eye) have previously been common findings in lumpfish in hatchery and broodstock facilities. Calcifications in the kidney (nephrocalcinosis) are sporadically detected to varying extents in cleaner fish.

Health Situation in 2023

Data from the Norwegian Veterinary Institute and private laboratories

Bacteria

In 2023, the Norwegian Veterinary Institute and other laboratories detected infection with atypical A. salmonicida based on cultivation and/or molecular methods in lumpfish and wrasse at 14 and 30 locations, respectively. Information on clinical significance was lacking, but to the extent available, findings consistent with atypical furunculosis were reported in all cases. In comparison, in 2022, atypical *Aeromonas salmonicida* was detected in lumpfish at 12 locations and in wrasse at 25 locations.

Infection with *A. salmonicida* subsp. *salmonicida* (furunculosis) was not detected in cleaner fish in 2023.

The disease pasteurellosis (infection with *Pasteurella atlantica* genomovar *cyclopteri*) was detected by the Norwegian Veterinary Institute and private laboratories in lumpfish at three locations in 2023.

In 2023, *Pseudomonas anguilliseptica* was detected by the Norwegian Veterinary Institute in lumpfish at three locations. Comparable figures for 2022, 2021, and 2020, with 11, 15, and 18 affected locations, respectively, show a decrease in the number of detections in recent years. *P. anguilliseptica* was not detected in wrasse in 2023.

The Norwegian Veterinary Institute detected *Vibrio anguillarum* in ballan wrasse at one location in 2023. In lumpfish, *V. anguillarum* serotype O2b was detected at one location. *Vibrio ordalii*-like bacteria were not detected in lumpfish in 2023.

A wide range of Vibrio and Aliivibrio species (*V. splendidus, A. logei, V. tapetis, A. wodanis*, and unspecified *Vibrio* spp.) were also isolated from cleaner fish in 2023, often in mixed flora.

In 2023, the Norwegian Veterinary Institute and other laboratories detected infections with *M. viscosa* in lumpfish at elleven locations and in wrasse at five locations, while *Tenacibaculum* spp. were detected in lumpfish at four locations and in wrasse at eight locations. In cases where species identity was determined, *T. dicentrarchi* and *T. maritimum* were detected in wrasse at two and three locations, respectively.

Among other bacteria, *Yersinia ruckeri* was detected in wrasse at one location in 2023.

Fungi

There were no registered cases of fungal disease or infection with specific fungal types in cleaner fish in 2023.

Virus

No viruses were detected in diagnostic material from cleaner fish submitted to the Norwegian Veterinary Institute in 2023. Data from private laboratories show one location with detection of cyclopterus lumpus virus (CLuV) or lumpfish flavivirus virus in 2023, while 12 locations had detections of the virus in 2022.

Parasites

In 2023, the Norwegian Veterinary Institute and other laboratories detected Amoebic Gill Disease (AGD) in lumpfish at four sites and in wrasse at one site. Additionally, the parasite *Paramoeba perurans* was found in wrasse at three other sites where clinical signs associated with disease outbreaks were observed.

Among other parasites, the flagellate *Spironucleus salmonicida* was detected by private laboratories in lumpfish at one site in Northern Norway in 2023. In wrasse, the Norwegian Veterinary Institute detected *Ichthyobodo* sp. (Costia) flagellates at one site in 2023. Nematodes were detected by the Norwegian Veterinary Institute at one site in lumpfish in 2023.

Nucleospora cyclopteri was not detected in lumpfish by the Norwegian Veterinary Institute in 2023. The parasite has also not been detected in recent years. As previously mentioned, it is likely that *N. cyclopteri* may be underdiagnosed, as the parasite is often difficult to detect in routine histological examination.

Other Diseases and Health Issues

Data from the Norwegian Veterinary Institute show a total of two sites for lumpfish with detection of nephrocalcinosis in 2023. In addition, calcareous material has been detected in other organs (such as gills and intestines) in lumpfish at one site. Variable degrees of emaciation have also been recorded in lumpfish at a couple of sites. Rectal prolapse was detected in a few corkwing wrasse from one site. The condition is sometimes observed in cleaner fish and likely has several causes.

The Annual Survey

For cleaner fish after being introduced into grow-out facilities, 34 percent of respondents estimate that mortality among lumpfish is at approximately the same level as in previous years, while 14 percent believe it has increased, 4 percent think it has decreased, and 48 percent answer that they do not know. The corresponding figures for wrasse are 26 percent (unchanged), 8 percent (increase), 11 percent (decrease), and 55 percent (do not know).

For cleaner fish in the hatchery phase (both lumpfish and wrasse), production-related conditions such as wear and tear and suboptimal care are ranked highest among respondents, with undetermined disease ranked third. Among specific infectious diseases, AGD, atypical *A. salmonicida*, and Vibrio are ranked highest. The most notable difference between the two cleaner fish groups in the hatchery phase is that wounds are ranked higher for lumpfish, while AGD ranks higher for wrasse.

After being released into salmon pens, handling is ranked as the most significant health problem for both lumpfish and wrasse (Appendix D2 and E2). For lumpfish, this is closely followed by non-medicated delousing, which is also ranked quite high for wrasse. Although the order varies somewhat between the two cleaner fish groups, several other potential production-related disorders are also ranked relatively high for both, including fin erosion, emaciation, wounds, medicated delousing, suboptimal husbandry, and undetermined illnesses. Among specific infectious diseases, atypical *A. salmonicida* is clearly ranked highest for both groups.

For further assessments of cleaner fish in the survey, refer to Chapter 5 Fish Welfare.

Evaluation of the Cleaner Fish Situation

As in previous years, fish health personnel report high mortality among cleaner fish used as lice eaters in salmon farming facilities. Alongside infectious, especially bacterial, diseases, production-related issues such as mortality and reduced welfare during non-medicated delousing of salmon continue to pose problems. Although precise mortality data are not currently available, previous reports have indicated near-total losses of cleaner fish throughout the production cycle. Feedback from the survey suggests no significant change in this regard. There are reports indicating a downward trend, and in some cases, complete cessation of the use of cleaner fish. Both animal welfare and practical considerations are cited as reasons for this.

Keeping multiple fish species in the same pen can also pose challenges regarding biosecurity. This will be particularly relevant when using wild-caught cleaner fish, as well as when transporting cleaner fish from other geographical regions. Previous studies have shown transmission of *Paramoeba perurans (*AGD) between cleaner fish and farmed fish in experiments, and it cannot be ruled out that cleaner fish may act as vectors for other pathogens. The finding of *Spironucleus salmonicida* in both salmon and lumpfish at one site in 2022 indicates possible transmission of the parasite between these two species. It is important to monitor the dynamics of infection in the holding of multiple fish species at the same site. This is especially true for pathogens with a marine reservoir that can cause disease in salmonids.

13. The health situation of cod and other marine species in aquaculture

By Mona Gjessing, Toni Erkinharju and Hanne Nilsen

The farming of Atlantic cod (*Gadus morhua* L, hereafter referred to as cod) can be traced back to the 1880s when cod larvae were hatched at the Flødevigen Biological Station and released into the sea to enhance local populations. Commercial cod farming around the turn of the millennium were partially successful, but production collapsed around 2012. Key factors contributing to the collaps included the availability of other whitefish species, early sexual maturation of farmed cod, and various infectious diseases. During this period, significant research and development efforts were undertaken, which the industry continues to benefit from today. There has been considerable genetic progress in growth, and it is claimed that todays farmed cod exhibit better traits regarding escapement and sexual maturation. The industry aims to delay sexual maturation as much as possible to prevent cod from spawning in pens, as gonad development and spawning are energy-intensive processes. Light management is utilized to delay sexual maturation, although it appears to be more complex in cod than in salmon. Data from the Norwegian Directorate of Fisheries indicate that seven companies farm cod across 16 sea locations.

Flatfish and wolfish are bottom-dwelling species, and the design of the substrate is crucial for their well-being. Although the development of halibut farming has been ongoing since the 1980s, today it remains limited in production with few active farms. Issues such as eye migration during metamorphosis and incorrect pigmentation pose fewer challenges today due to changes in feeding and environmental conditions.

Farming of spotted wolfish began experimentally in the 1990s and there are a few farms today. Larval production appears to be somewhat simpler than for halibut; for instance, spotted wolfish larvae can be fed dry feed immediately after hatching. Turbot thrives best in warmer water and is produced in land-based facilities where temperature can be regulated.

Diseases in cod and other marine species in aquaculture

Viral nervous necrosis (VNN)/viral encephalo- and retinopathy (VER) is a serious viral disease affecting the central nervous system and can lead to losses in cultured marine species. In halibut, infection with Atlantic halibut reovirus (AHRV) can cause necrosis in the liver and pancreas and increased mortality. Infection with infectious pancreatic necrosis virus (IPNV) can result in changes in multiple organs, particularly necrosis in the part of the pancreas that produces digestive enzymes. Among bacterial diseases, francisellosis, caused by infection with *Francisella noatunensis* subsp. *noatunensis*, is a severe disease that causes granuloma formation in multiple organs. This disease was one of the reasons why cod farming was previously unsuccessful. *Atypical furunculosis* (caused by infection with "atypical Aeromonas salmonicida") is another important bacterial disease that causes granulomas in internal organs, particularly the kidneys and spleen. The bacterium is common and can cause mortality in most cultured marine species. *Vibrio anguillarum* can also lead to severe septicemia and mortality in cod. Bacterial skin infections with *Moritella viscosa* and *Tenacibaculum* spp. are not uncommon, and gill disease with epitheliocysts is also described in cultured cod. Infestation with the parasites Ichthyobodo spp. and Trichodina spp. on the skin and gills can cause problems in both halibut and cod. Cod can also be infested with lice, including sea lice (*Caligus elongatus*) and cod lice (*Caligus curtus*).

Egg retention, where eggs are released into the abdominal cavity, and intestinal volvulus (Figure 13.2) are particularly serious welfare problems for cod. An overview and understanding of the causes of intestinal problems are lacking, but it is speculated that the type of feed given to farmed cod may be part of the problem. Furthermore, several cases of extensive circulatory disturbances with notable changes, especially in the heart, have been described. The causes of these conditions are unclear.

Disease control

Viral nervous necrosis (VNN)/viral encephalo- and retinopathy (VER) and francisellosis are notifiable diseases in cod in Norway (category F).

For more information, see the fact sheet (in Norwegian): https://www.vetinst.no/sykdom-og-agens/francisellose

https://www.vetinst.no/sykdom-og-agens/nodavirus-hos-marin-fisk-vnn-ver

The Health Situation in 2023

Official data

Francisellosis and VNN/VER were not reported in marine species in 2023.

Data from the Norwegian Veterinary Institute

Cod

In 2023, ten diagnostic cases were received from five food fish sites and two fry sites. Most of the cases were submitted due to changes in the heart and/or intestinal disorders. Gill problems and wounds were also reported. In summary, histopathological examinations revealed circulatory disturbances in the stomach/intestines , in addition to a few cases of bacterial gastroentertitis, where cardiac changes such as congestion and thrombi were noted in some fish.

Other marine farmed fish

In 2023, nine diagnostic cases were received from four locations with turbot, halibut, or lumpfish. Among compiled data from the Norwegian Veterinary Institute and other laboratories, various findings were noted, including the detection of atypical furunculosis in halibut and turbot.

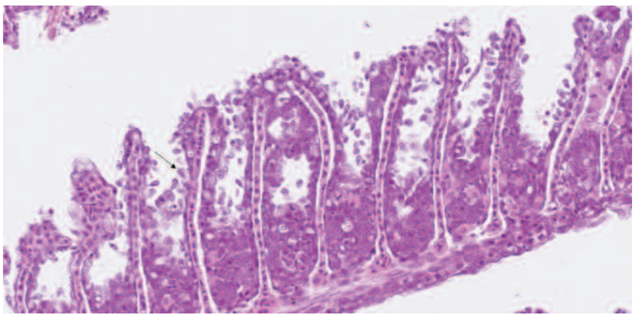


Figure 13.1 Gill from halibut showing abundant amounts of "Costia" or *Ichthyobodo* sp. (likely I. hippoglossi) parasites on the surface of the lamellae (arrow). Photo: Toni Erkinharju, Norwegian Veterinary Institute.

The Annual Survey

Well over half of the respondents in the survey mention poor intestinal health as an issue. This is estimated to lead to high mortality, and it is reported that the problem persists throughout the production cycle and increases with the fish's size. Some report this in combination with heart problems. For halibut, some respondents report issues with parasitic gill inflammation (Ichthyobodo hippoglossi and Trichodina spp.), sunburn, reovirus, and deformities.

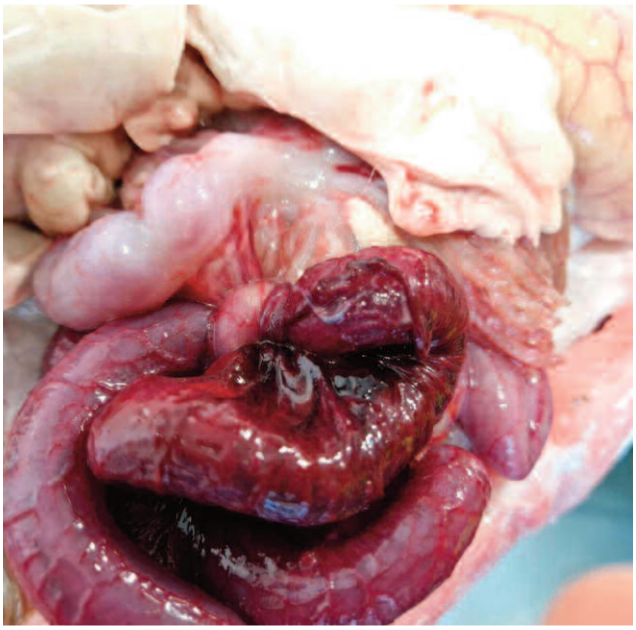


Figure 13.2 Market-ready cod with intestinal volvulus and extensive circulatory disturbances. Photo: Mona Gjessing, Norwegian Veterinary Institute.

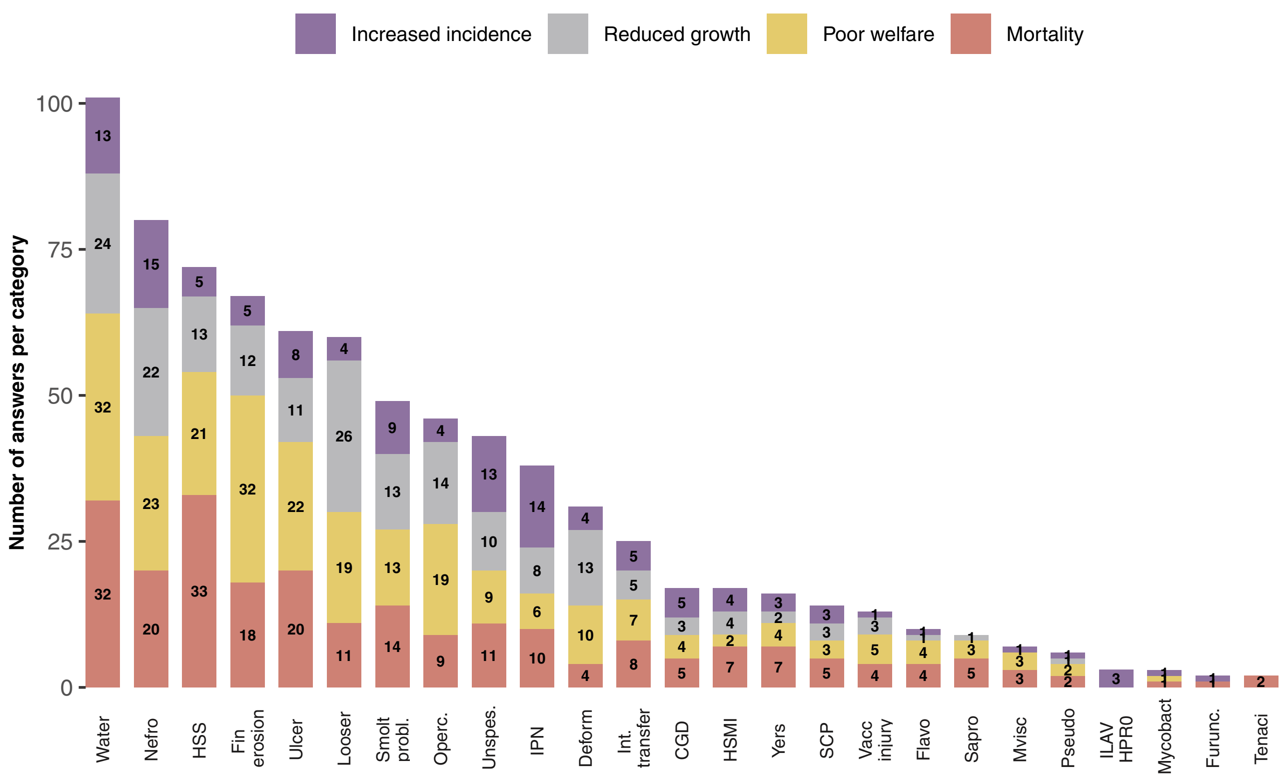
Appendix A1:

Health problems in juvenile salmon production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in salmon hatcheries were asked to cross off the five most important of 26 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=47 respondents who responded on increasing prevalence, N=54 on reduced growth, N=59 on reduced welfare and N=59 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were:

CGP	=	gill disease complex/multifactoral
Deform	=	deformities
Fin eros	=	fin erosion
Flavo	=	*Flavobacterium psychrophilum* infections
Furunc	=	Furunculosis
HSMI	=	heart and skeletal muscle inflammation
HSS	=	haemorrhagic smolt syndrome
Int transfer	=	moving fish between operational
IPN	=	infectious pancreas necrosis
ISAV HPR0	=	infection with non-virulent ISAV (ISAV HPR0)
Looser	=	runted fish, runt syndrome, emaciation
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Mycobact	=	infection with Mycobacteria
Nefro	=	nephrocalcinosis
Operc.	=	shortened gill covers
Pseudo	=	infection with *Pseudomonas* spp.
Sapro	=	infection with *Saprolegnia* spp.
Smoltprob	=	smoltification problems
SPC	=	single-celled parasites on gills/skin (e.g *Ichthyobodo* spp., *Trichodina* spp.)
Tenaci	=	infection with *Tenacibaculum* spp. (non-classic winter ulcer)
Ulcer	=	skin ulcers and underlying tissues, unspecified cause
Unspes	=	unspecified diseases
Vacc	=	vaccine side effects
Water	=	poor water quality departments with different water qualities (e.g. RAS to flow-through)
Yers	=	infection with *Yersinia ruckeri* (yersinosis)



Appendix A2:

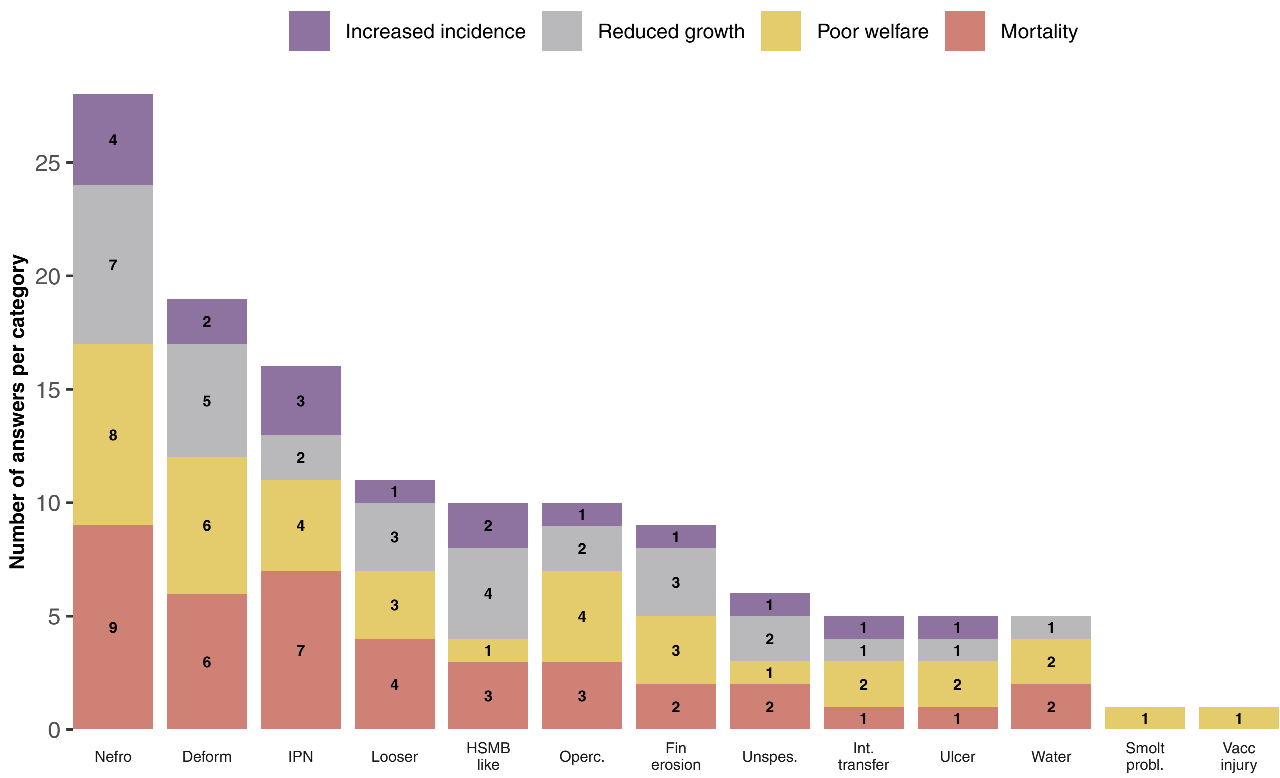
Health problems in juvenile rainbow trout production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in salmon hatcheries were asked to cross off the five most important of 22 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence).

There were N=7 respondents who responded on increasing prevalence, N=11 on reduced growth, N=11 on reduced welfare and N=12 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Deform	=	deformities
Fin eros	=	fin erosion
HSMI like	=	heart and skeletal like muscle inflammation
Int transfer	=	moving fish between operational
IPN	=	infectious pancreas necrosis
Looser	=	runted fish, runt syndrome, emaciation
Nefro	=	nephrocalcinosis
Operc	=	shortened gill covers
Smoltprob	=	smoltification problems
Unspes	=	Unspecified disease
Ulcer	=	skin ulcers and underlying tissues, unspecified cause
Vacc	=	vaccine side effects
Water	=	poor water quality departments with different water qualities (e.g. RAS to flow-through)



Appendix B1:

Health problems during ongrowing salmon

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in salmon ongrowing facilities were asked to cross off the five most important of 35 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=100 respondents who responded on increasing prevalence, N=99 on reduced growth, N=102 on reduced welfare and N=102 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were:

AGD	= amoebic gill disease
Algae	= algae
Caligus	= *Caligus elongatus* (grazing injuries following infestation with *C. elongatus*)
CGP	= gill disease complex/multifactoral
CMS	= cardiomyopathy syndrome
Collision	= jumping injuries, collision with equipment in cage
Deform	= deformities
Fin eros	= fin erosion
Furunc	= furunculosis (infection with *Aeromonas salmonicida* subsp *salmonicida*)
HSMI	= heart and skeletal muscle inflammation
IPN	= infectious pancreas necrosis
ISA	= Infectious salmon anaemia (infection with ISAV HPR-deleted)
Jellyfish	= jellyfish
Looser	= runted fish, runt syndrome, emaciation
Mech injury delouse	= mechanical harm related to delousing
Mech injury	= mechanical harm not related to delousing, e.g. after manual handling, transport
Mvisc	= infection with *Moritella viscosa* (classic winter ulcer)
Mycobact	= infection with Mycobacteria
Nefro	= nephrocalcinosis
Parvi	= infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Pasteu	= infection with *Pasteurella* sp. (pasteurellosis)
PD	= Pancreas disease
Salmon louse	= salmon lice (grazing injuries following infection with *Lepeoptheirus salmonis*)
Sexual mat	= sexual maturation
SGPV	= salmon gill pox virus (disease due to SGPV)
Smoltprob	= smoltification problems
Spiro	= infeksjon med *Spironucleus salmonicida* (spironukleose)
Tapew	= Tapeworm
Tenaci	= infection with *Tenacibaculum* spp. (non-classic winter ulcer)
Unspes	= unspecified disease
Ulcer	= skin ulcers and underlying tissues, unspecified cause
Vacc	= vaccine side effects
Yers	= infection with *Yersinia ruckeri* (yersinosis)

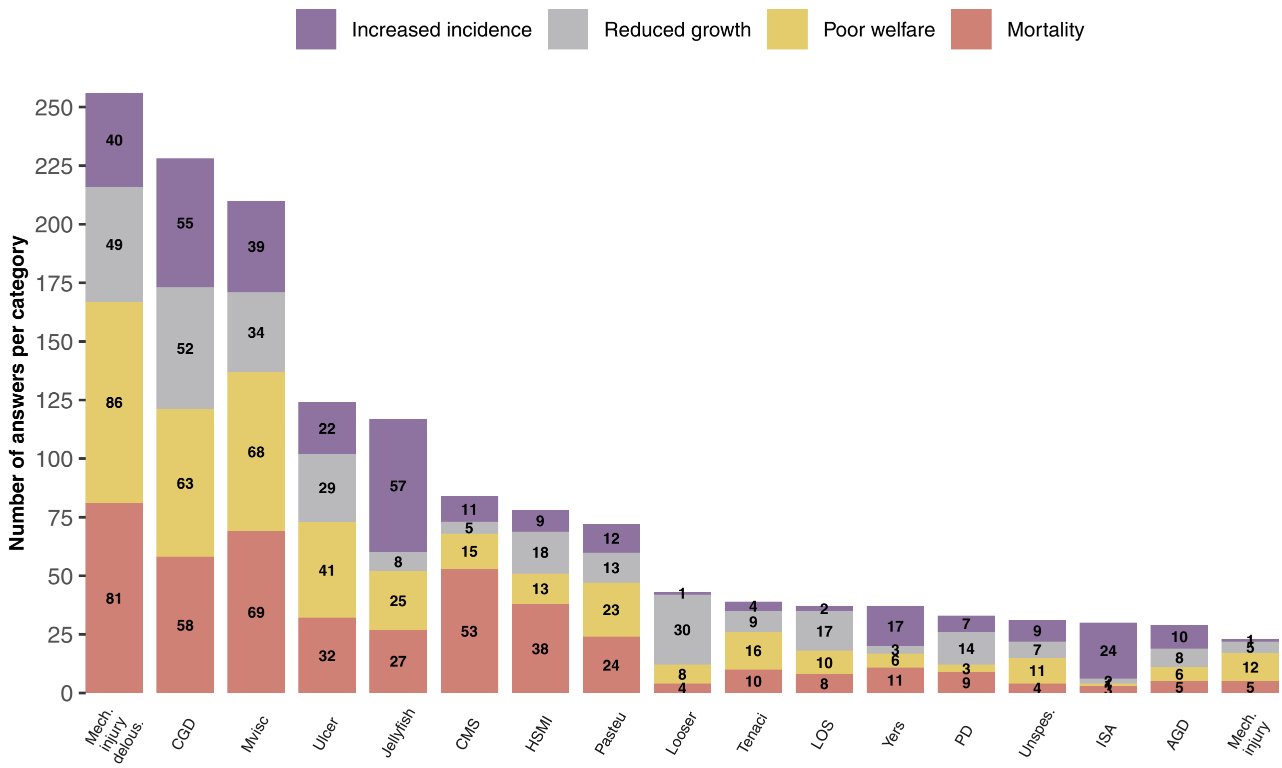


Diagram del 1. De 16 høyest rangerte helseproblemene hos matfisk laks.

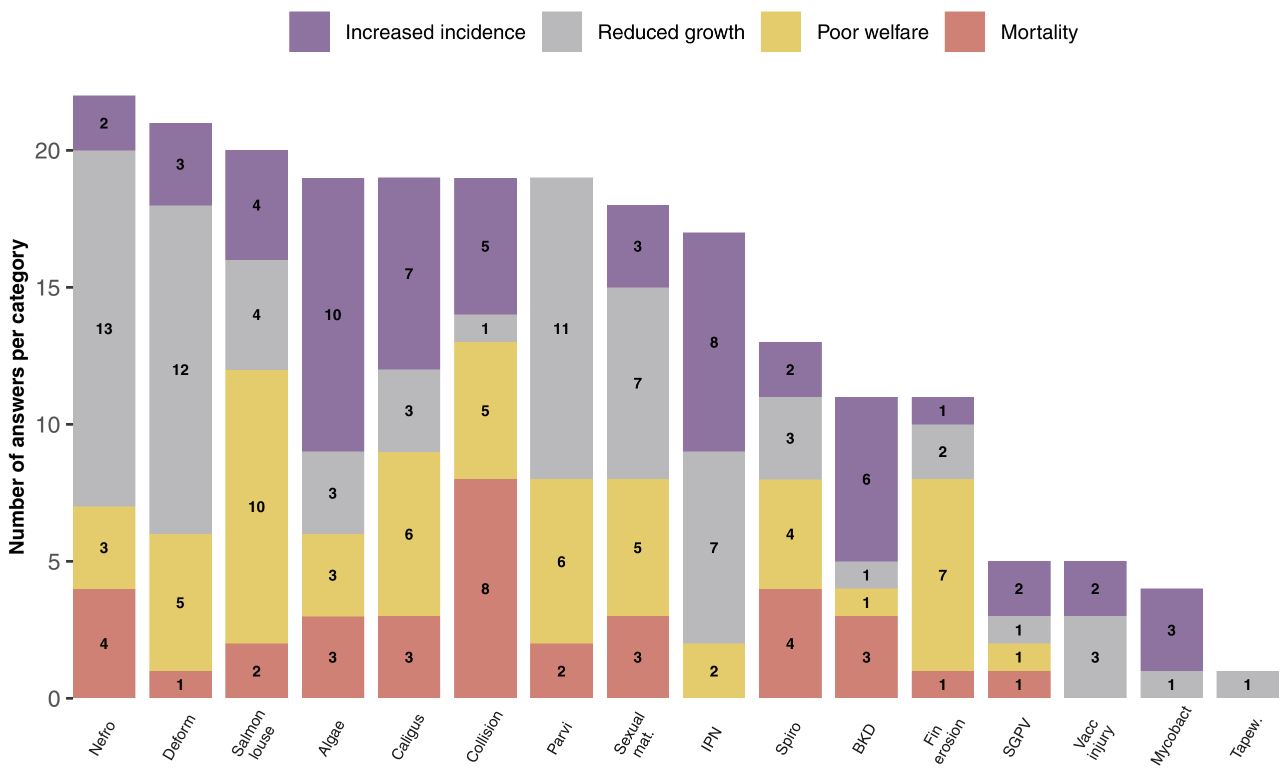


Diagram del 2. Rangering av helseproblem 17-33 hos matfisk laks.

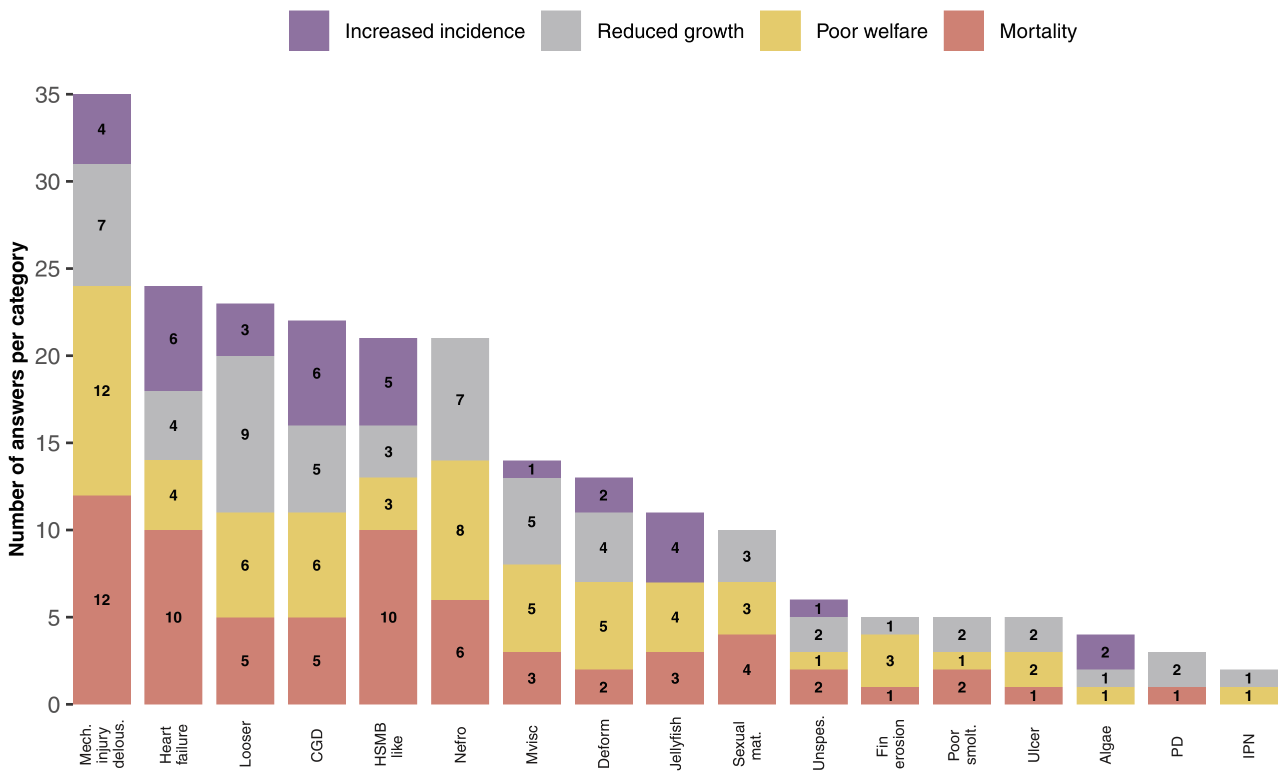
Appendix B2:

Health problems during ongrowing rainbow trout

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in salmon ongrowing facilities were asked to cross off the five most important of 30 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=14 respondents who responded on increasing prevalence, N=19 on reduced growth, N=19 on reduced welfare and N=19 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Algae = algae
CGP = gill disease complex/multifactoral
Deform = deformities
Fin eros = fin erosion
Heart failure = heart failure, not related to known infectious disease
HSMI-like = heart and skeletal muscle like inflammation
IPN = infectious pancreas necrosis
Jellyfish = jellyfish
Looser = runted fish, runt syndrome, emaciation
Mech injury delouse = mechanical harm related to delousing
Mvisc = infection with *Moritella viscosa* (classic winter ulcer)
Nefro = nephrocalcinosis
PD = Pancreas disease
Poor smolt = Poor smoltification
Salmon louse = salmon lice (grazing injuries following infection with *Lepeoptheirus salmonis*)
Sexual mat = sexual maturation
Unspes = unspecified disease
Ulcer = skin ulcers and underlying tissues, unspecified cause



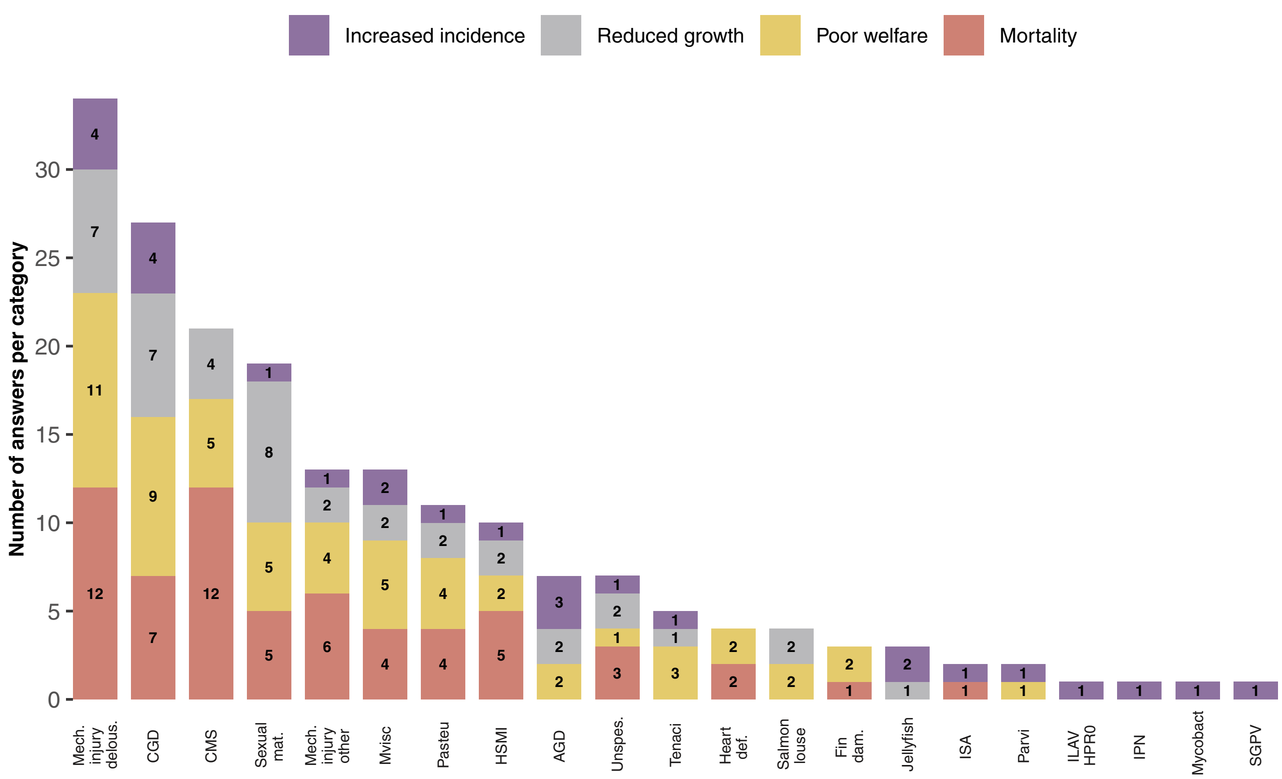
Appendix C1:

Health problems in broodstock salmon production*

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in broodstock salmon were asked to cross off the five most important of 29 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=14 respondents who responded on increasing prevalence, N=17 on reduced growth, N=20 on reduced welfare and N=20 on mortality. *The results for health problem in broodstock rainbow trout production is not presented (only one respondent).

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

AGD	=	amoebic gill disease
CGP	=	gill disease complex/multifactoral
CMS	=	cardiomyopathy syndrome
Fin eros	=	fin erosion
HSMI	=	heart and skeletal muscle inflammation
IPN	=	infectious pancreas necrosis
ISA	=	Infectious salmon anaemia (infection with ISAV HPR-deleted)
ISAV HPR0	=	infection with non-virulent ISAV (ISAV HPR0)
Jelly	=	jellyfish
Mech injury delouse	=	mechanical harm related to delousing
Mech injury	=	mechanical harm not related to delousing, e.g. after manual handling, transport
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Mycobact	=	infection with Mycobacteria
Nefro	=	nephrocalcinosis
Parvi	=	infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Pasteu	=	infection with *Pasteurella* sp. (pasteurellosis)
Sexual mat	=	sexual maturation
Tenaci	=	infection with *Tenacibaculum* spp. (non-classic winter ulcer)
Unspes	=	unspecified disease



Appendix C2:

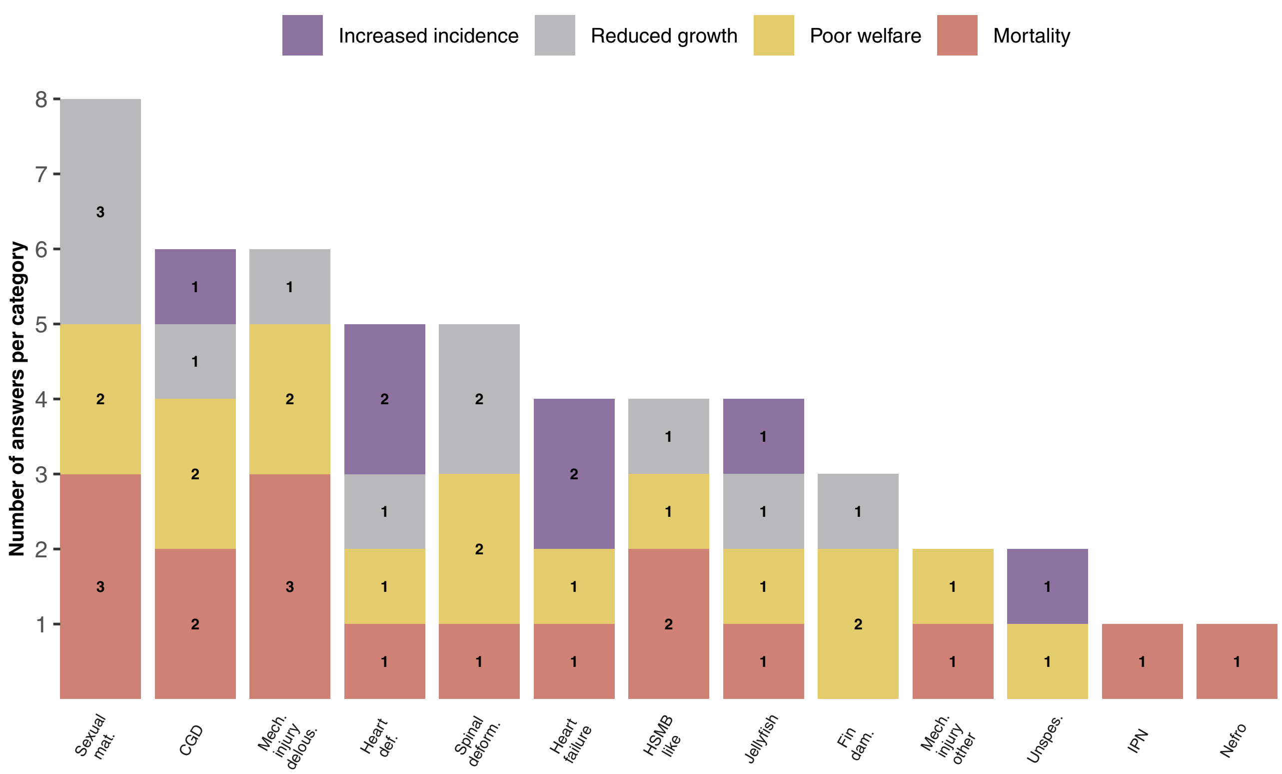
Health problems in broodstock salmon production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in broodstock salmon were asked to cross off the five most important of 25 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence).

There were N=4 respondents who responded on increasing prevalence, N=3 on reduced growth, N=5 on reduced welfare and N=5 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

CGP	=	gill disease complex/multifactoral
Fin eros	=	fin erosion
Heart def	=	Heart deformities
Heart failure	=	heart failure, not related to known infectious disease
HSMI like inflammation	=	heart and skeletal muscle like
IPN	=	infectious pancreas necrosis
Jelly	=	jellyfish
Mech injury delouse	=	mechanical harm related to delousing
Mech injury	=	mechanical harm not related to delousing, e.g. after manual handling, transport
Nefro	=	nephrocalcinosis
Sexual mat	=	sexual maturation
Spinal deform	=	spinal deformities
Unspes	=	unspecified disease



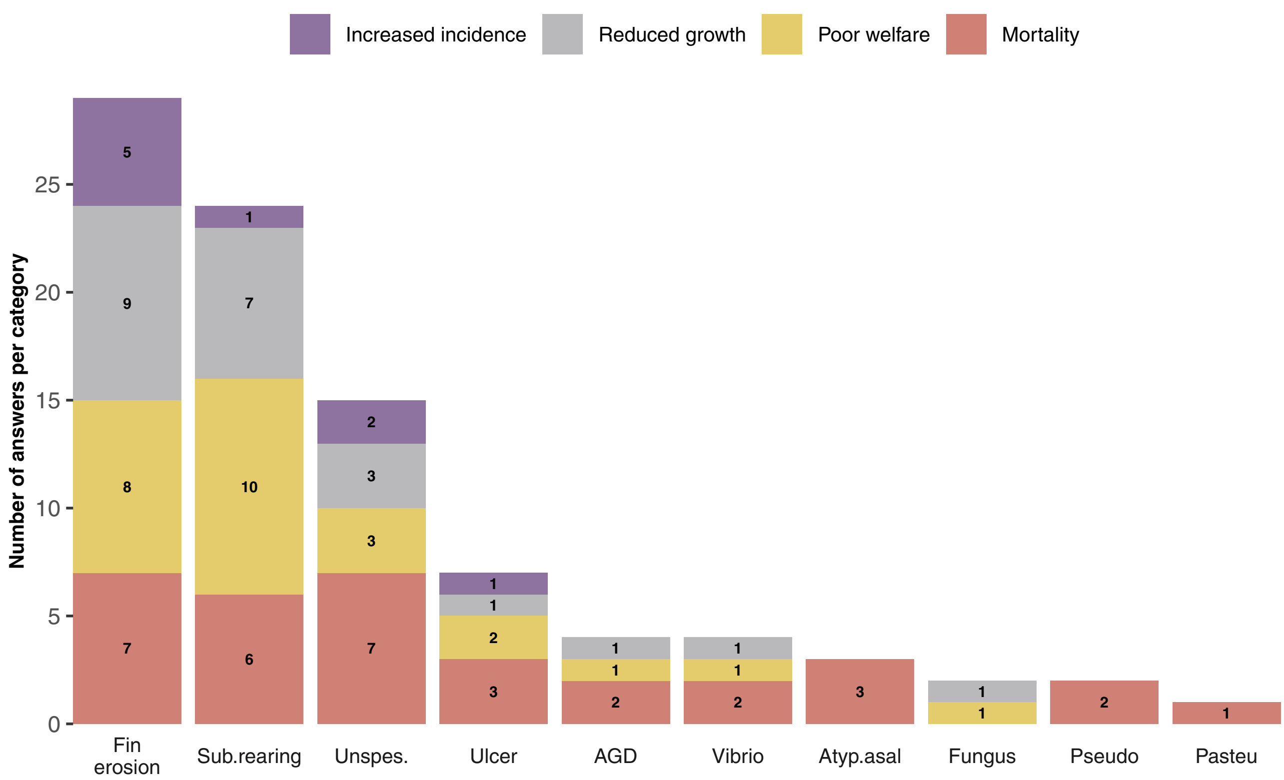
Appendix D1:

Health problems in juvenile lumpfish production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in juvenile lumpfish production were asked to cross off the five most important of 12 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=7 respondent who responded on increasing prevalence, N=15 on reduced growth, N=14 on reduced welfare and N=15 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

AGD	=	amoebic gill disease
Atyp furunc	=	atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Fin eros	=	fin erosion
Pasteu	=	infection with *Pasteurella* sp. (pasteurellosis)
Pseudo	=	infection with *Pseudomonas anguilliseptica*
Sub rearing	=	suboptimal care
Unspes	=	unspecified disease
Ulcer	=	skin ulcers and underlying tissues, unspecified cause
Vibrio	=	vibriosis (Infection with *Vibrio* spp.)



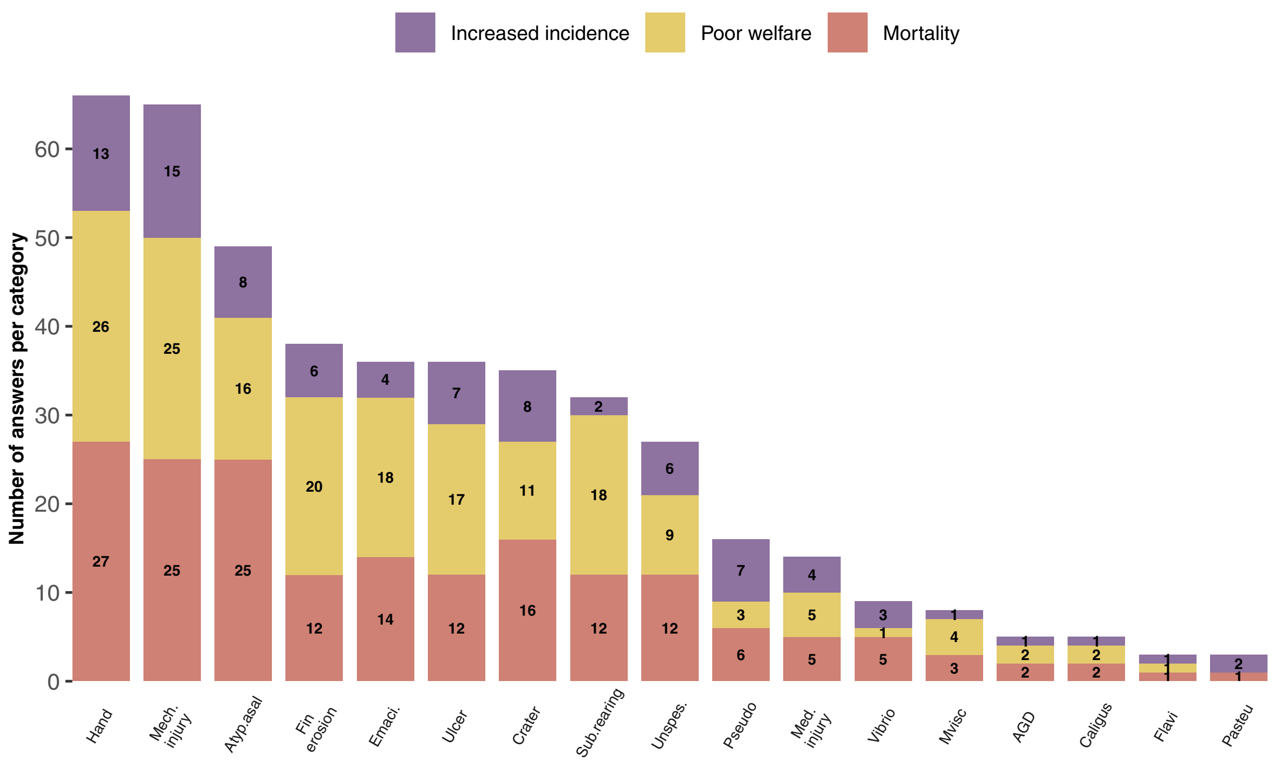
Appendix D2:

Health problems in lumpfish held with ongrowing salmon

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in lumpfish held in ongrowing facilities were asked to cross off the five most important of 20 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=41 respondents who responded on increasing prevalence, N=65 on reduced welfare and N=65 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

AGD	=	amoebic gill disease
Atyp asal	=	atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Caligus	=	infestation with *Caligus elongatus*
Crater	=	crater disease (infection with *Tenacibaculosis* spp.)
Fin eros	=	fin erosion
Flavi	=	lumpfish flavivirus
Hand	=	mortality rate as a consequence of handling
Med injury delouse	=	mortality related to medicinal delousing
Med injury	=	mortality not related to medicinal delousing
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Pasteu	=	infection with *Pasteurella* sp. (pasteurellosis)
Pseudo	=	infection with *Pseudomonas anguilliseptica*
Sub rearing	=	suboptimal care
Ulcer	=	skin ulcers and underlying tissues
Unspes	=	unspecified disease
Vibrio	=	vibriosis (Infection with *Vibrio* spp.)



Appendix E1:

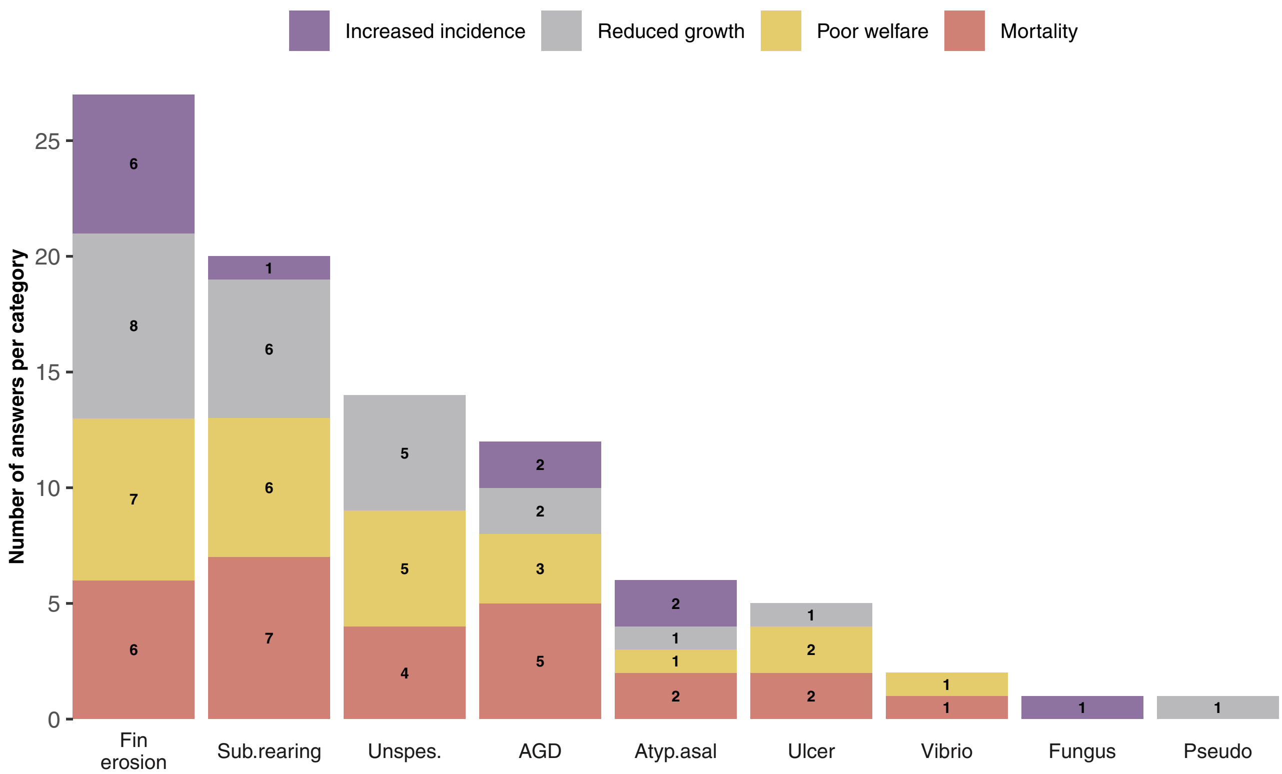
Health problems in juvenile wrasse production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in wrasse hatcheries were asked to cross off the five most important of 11 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence).

There were N=6 respondent who responded on increasing prevalence, N=11 on reduced growth, N=11 on reduced welfare and N=11 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

AGD = amoebic gill disease
Atyp asal = atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Fin eros = fin erosion
Sub rearing = suboptimal care
Ulcer = skin ulcers and underlying tissues
Unspes = unspecified disease
Vibrio = vibriosis (Infection with *Vibrio* spp.)



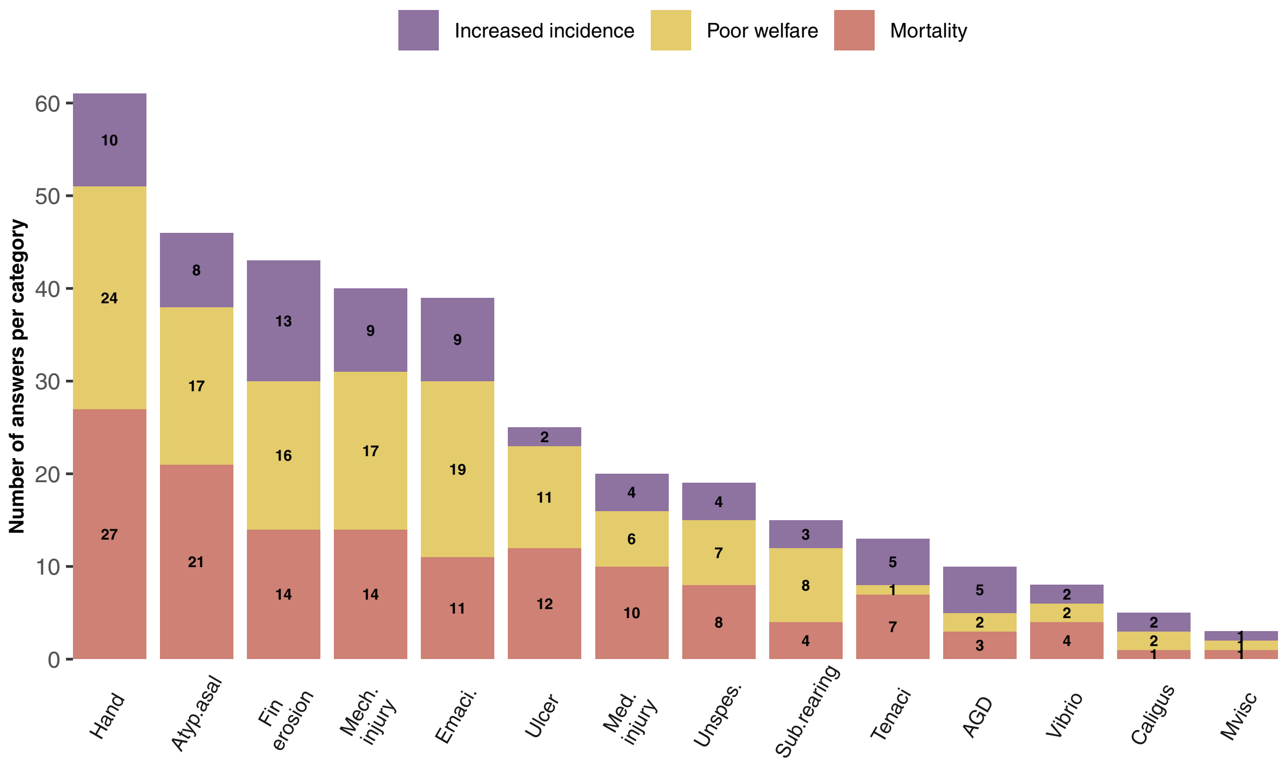
Appendix E2:

Health problems in wrasse held with ongrowing salmon

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2023. Respondents with experience in wrasse held in ongrowing facilities were asked to cross off the five most important of 15 fish health problems based on whether they contributed to mortality, reduced welfare, reduced growth or were considered to be an increasing problem (increased prevalence). There were N=34 respondents who responded on increasing prevalence, N=49 on reduced welfare and N=50 on mortality.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

AGD	=	amoebic gill disease
Atyp asal	=	atypical furunculosis (infection with atypical Aeromonas salmonicida)
Caligus	=	infestation with Caligus elongates
Fin erosion	=	fin erosion
Hand	=	mortality rate as a consequence of handling
Med injury delouse	=	mortality related to medicinal delousing
Med injury	=	mortality not related to medicinal delousing
Sub rearing	=	suboptimal care
Ulcer	=	skin ulcers and underlying tissues
Unspes	=	unspecified disease
Vibrio	=	vibriosis (Infection with Vibrio spp.)



For 20 years, the Norwegian Veterinary Institute has described the health status within the Norwegian fish farming industry. Photo: Rudolf Svensen

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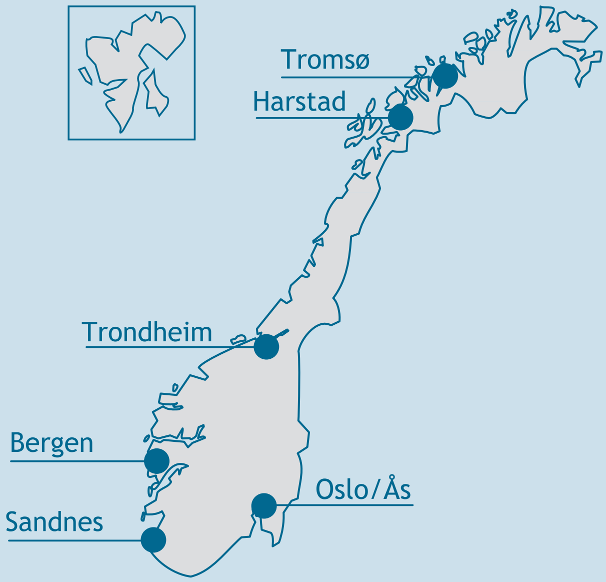

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