Veterinærinstituttet
Norwegian Veterinary Institute

Report 5a/2023

Norwegian Fish Health Report 2022

Parasites and blood cells on the gill surface of a juvenile salmon, magnified 3100 times.
Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

Norwegian Fish Health Report 2022

Norwegian Veterinary Institute Report, series # 5a/2023

The Norwegian Veterinary Institute's annual review of fish health in Norway

Authorship

Authors are credited for each chapter. With the exception of Chapter 9.5 Water Quality, written by employees of the Norwegian Institute for Water Research (NIVA), Chapter 9.7 Algae, jellyfish and fish health co-authored by employees of Patogen and NIVA, and Chapter 6.7 Mycobacteriosis co-authored by employees of Pharmaq Analytic AS, all authors are employees of the Norwegian Veterinary Institute.

The Fish Health Report 2022 is mainly written without references in the text. For information about references, please contact the authors of each chapter.

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Editorial work (Norwegian) completed 08.03.2023
English version 26.05.2022

Suggested citations:

Sommerset I., Wiik-Nielsen J., Oliveira V.H.S, Moldal T., Bornø G., Haukaas A. and Brun E. Norwegian Fish Health Report 2022, Norwegian Veterinary Institute Report, series #5a/2023, published by the Norwegian Veterinary Institute in 2023

Published online in Norwegian 08.03.2023: www.vetinst.no
Published online in English 26.05.2022

ISSN 1890-3290
ISSN #1893-1480 (online version)

Colophon:

Cover design: Reine Linjer
Cover photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

Cover image: The parasite Apiosoma sp. on the gill surface of a juvenile salmon, magnified 3100 times. The hairs (cilia) around the mouth are used to capture and transport food to the mouth. Also visible are two nucleated blood cells. Infections with this parasite are normally associated with poor water quality and high fish densities. The image is photographed with a scanning electron microscope and then colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

Sustainability in the blue

By Edgar Brun

The Fish Health Report for 2022 is the 20th edition of its kind. For 20 years, the Norwegian Veterinary Institute has described the health status within the Norwegian fish farming industry. This annual report has changed over the years, and important improvements include contributions from various industry actors, that have ensured access to nationwide data and information.

Annual reporting allows retrospective comparison of the disease situation with previous years. If we go back 10 years, we can read in the 2012 edition; "Disease problems are still one of the most important challenges for the farming industry.", and "There is an unacceptable loss of fish dying between sea transfer and slaughter. There is a significant difference between (….) regions and individual farmers." Unfortunately, this is still as valid today and the situation may be worsening. "Disease problems" or the overall burden of diseases is increasing. This burden was given an economic face this autumn, described as "biological costs" i.e. the cost linked to diseases and treatments. These costs now equal feed costs. The biological cost of salmon production has in fact doubled since the 2012- report.

In 2022, there is still an "unacceptable loss of fish" and the geographical differences are still "significant". Over the past few years, according to official statistics, the proportion of fish that die before planned slaughter, both for the country as a whole and by production area, shows an increasing trend. In addition, there is a significant number of fish that are considered "non-viable" after e.g. mechanical lice treatments, and are therefore, emergency slaughtered. These fish, which would otherwise probably have died within a short period, are not registered in the "normal" mortality statistics.

Keeping animals for intensive food production necessarily implies that animals will die in the process. It is inevitable. However, no-one wants an industry characterised by disease and large losses. Considerable efforts are being made to limit this situation. However, the overall statistics show that this effort has not been good enough over the years, and some efforts may have made the situation worse. When years of effort do not produce the desired results, common sense dictates that new tools, new methods and new attitudes should be considered, even at politician and top management level.

Biosecurity is an old concept in veterinary medicine, but one that has recently re-emerged as a new and life-saving measure in Norway and internationally. The EU pressures the Norwegian Food Safety Authority to demand the industry to develop biosecurity plans at farm level. The Traffic Light System is in principal, a good system. However, where are the incentives within this system to make the industry work towards sustainability? The aim should be "green". The authorities stop further growth when the traffic light is yellow, and reduce production when the light becomes red. Is it okay that the same authority grants "red" farms compensatory growth?

The result is more lice, increased mortality, poorer finances and a poorer reputation. All areas end up as "red" or "yellow". This is devastating for the whole industry in the long run. The knowledge

Edgar Brun, head of department. Photo: Harrieth Lundberg, Norwegian Veterinary Institute.

generated in the Traffic Light System must actively be used by the authorities to steer development towards a green coast and "blue sustainability".

The industry will at all times maximise production within the framework set by the authorities and politicians. Do we have politicians who sufficiently care about health and welfare to ensure that the industry has, and complies with, good regulations for health and welfare? If so, is there a political will to support strong enforcement of these regulations to ensure sustainability in what is Norway's by far, largest livestock production?

There is great focus on profitability in the industry, often short-term profitability. The quarterly accounts are important. However, not all profitable decisions or projects must, or should, be carried out just because they are economically profitable. Growth is not always in the best interest of the industry and the environment, particularly in a long-term perspective. This is a recognition that requires top management in the various segments to adopt a mature attitude towards the biological aspects of livestock production.

In traditional Norwegian livestock production, there are several examples of eradication of infectious agents that were achieved by setting clear goals and working together to achieve them. The aquaculture industry can also achieve this. We can define barriers and legislation based on new knowledge, technological solutions, infrastructural models and biosecurity measures that are already available. We can reduce the lice challenges, reduce viral diseases and other fish diseases to a minimum, - for some even eradicate them from the farmed salmon population. We can reach a mortality rate down to an average of 5 percent.

Is the will to do this present? Are we mature enough to set real health and welfare targets for the world's largest salmon production - requirements to achieve biological sustainability? Or will we continue to talk about it while we actually remain blinkered with our focus on short-term profits, as long as they last, while sustainability hover in the blue?

Summary

By Ingunn Sommerset

Several reports have highlighted the unprecedented number of farmed salmonids lost in the on-growing seawater farms in 2022. However, high losses also occurred in the land-based juvenile production phase. In total, 92.3 million Atlantic salmon and 5.6 million rainbow trout died before reaching slaughter size in 2022. There is no particular event that can be linked to the high mortality rates, but three health challenges stand out in farmed salmon in 2022: delousing injuries, complex gill disease, and winter ulcer. While the number of detections of serious viral diseases has stabilised, there are concerns about the development of bacterial diseases. In particular, the high prevalence of winter ulcer represents an important animal welfare concern.

Mortality in Norwegian aquaculture

I As in other forms of industrial animal production e.g. broilers and fattening pigs, some individuals will be lost during the production process due to injury, disease or poor environmental conditions. Such losses should be minimised both for animal welfare (ethics) and for economic reasons.

The first stage salmon and rainbow trout production takes place in freshwater (juvenile stage), followed by adaption (smoltification) and transfer to sea water (ongrowing stage). Mortalities in juveniles (larger than 3 grams) reported to the Norwegian Food Authority in 2022 included 35.6 million salmon and 3 million rainbow trout. These numbers exceed reported mortalities in 2021 by 2.2 million for salmon and 1 million for rainbow trout; however, the numbers of smolt transferred to sea have also increased in the same period. The methods of data reporting make it difficult to calculate the percentage of individuals that die in the smolt production phase.

The reported numbers of salmon and rainbow trout that died in the seawater production phase in 2022 were 56.7 and 2.6 million, respectively. For salmon, this is the highest number of lost (dead) individuals registered so far. Other reports may include the category “discards” when referring to mortality, however The Norwegian Fish Health Report uses the numbers recorded in the category “dead fish” when calculating mortality rates, in accordance with previous reports.

Since 2018, we have provided information about mortality of farmed salmonid using mortality rates that are converted into percentages. This method is well suited to assess mortality over a given time period when individuals are removed from and introduced to the production facility. In 2022, mortality in the seawater phase was 16.1 percent for salmon and 17.1 percent for rainbow trout, both increases compared to 2020 and 2021. There is still considerable geographical variation in mortality between the different production areas (abbreviated as PO, see map in Figure 1.1). Production area PO3 comes out worst with 23.7 percent mortality, while PO11 has the best result with 9.1 percent. The total yearly mortality across PO1-5 approximates 20 percent, while in PO6 and the areas north of the region the total yearly mortality is less than 15 percent.

A standardised classification system for cause-specific mortality in farmed salmon has been proposed and the main categories are included in the Norwegian terminology standard NS 9417. Several aquaculture companies are currently in the process of implementing this system, but for the current report, we do not have a quality-assured overview of the causes of mortality.

Mortality data for cleaner fish are still incomplete; however, greater efforts have been made this year to obtain a more reliable basis for estimation (see Chapter 4.12). Based on reports to the Directorate of Fisheries, a total of 36.2 million cleaner fish were stocked in salmon farms in 2022 (data per 28.02.2023). This represents a reduction from 2021 and follows the decreasing trend in the use of cleaner fish to combat salmon lice from the “top year” of 2019, where 60.9 mill individuals were registered transferred to salmon farms.

Notifiable fish diseases

After the implementation of the new Animal Health Regulation 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, the diseases in the previous "list 3" are now included in the national list, category F. The table below shows the annual numbers of detections of listed fish diseases in 2016-2022.

Infectious salmon anaemia (ISA) was confirmed at 15 locations in 2022, a decrease from the previous two years. At the end of the year, five additional locations, including three brood fish farms, were subject to unconfirmed ISA suspicions based on detection of virulent ISA-virus. Suspicion or detection of ISA in brood fish in 2022 has led to challenges in the delivery of roe in Norway. The serious viral diseases IHN and VHS are still not detected in Norway, but detections of IHN in neighbouring countries in 2022 emphasise the need for vigilance.

In 2022, 98 new cases of pancreas disease (PD) were diagnosed, an almost identical number to the 100 cases diagnosed in 2021. Both years represent a marked reduction from 2020, when 158 cases were identified. Comparing the two genotypes of the virus that causes PD, the number of cases associated with SAV2 increased, while there was a marked reduction in the number of cases associated with SAV3. In 2022, there were no detections of co-infections of SAV2 and SAV3 on the same farm, and no PD-virus was detected in the northern surveillance zone.

Of the notifiable bacterial diseases, fewer detections of furunculosis were made in 2022 (two in adult salmon and one in lumpfish) than in 2020 and 2021. Systemic infection with *F. psychrophilum* was identified in four land-based rainbow trout farms, and one case of bacterial kidney disease (BKD) was diagnosed in a salmon

Table 1. Summary of new diagnoses of notifiable fish diseases per farming site or river in Norway for the years 2016-2022.

Disease	Category	2016	2017	2018	2019	2020	2021	2022
Farmed fish: salmonids								
Infectious salmon anaemia (ISA)	C	12	14	13	10	23	25	15
Pancreas disease (PD)	F	138	176	163	152	158	100	98
Furunculosis	F	0	0	0	0	5	5	2
Bacterial Kidney Disease (BKD)	F	1	1	0	1	1	0	1
F. psychrophilum in rainbow trout	F	4	1	4	4	2	1	4
Farmed fish: Marine species								
Francisellosis	F	0	0	0	0	0	0	0
Furunculosis (lumpfish)	F	4	0	0	0	3	0	1
VNN/VER	F	0	0	0	0	0	1	0
Wild salmonids (fresh water)								
Gyrodactylus salaris	F	1	0	0	1	0	0	0
Furunculosis	F	1	2	0	2	0	0	0

ongrowing site. No notifiable disease was detected in farmed marine species (cod, halibut, catfish, and turbot) in 2022.

Non-notifiable fish diseases

The statistical basis for the data concerning non-notifiable diseases is discussed in Chapter 1. Thanks to continuation of agreements between the Norwegian Veterinary Institute and commercial actors that give access to a selection of non-listed disease reports, the numbers for 2021 and 2022 are comparable.

There is a reduction in the occurrence of the viral diseases cardiomyopathy syndrome (CMS), heart and skeletal muscle inflammation (HSMI), and infectious pancreatic necrosis (IPN) in 2022, compared to 2021. CMS: 131 (2022) vs. 155 (2021), HSMI: 147 (2022) vs. 188 (2021), and IPN: 11 (2022) vs. 20 (2021). Results from the annual survey among fish health personnel supports this observation, e.g. CMS, which was reported as the primary cause of mortality in adult salmon in 2019-21, falls to a shared second place in 2022 (see red bars in diagram below). HSMI was also ranked slightly lower in the list of health problems in 2022, compared to 2020 and 2021.

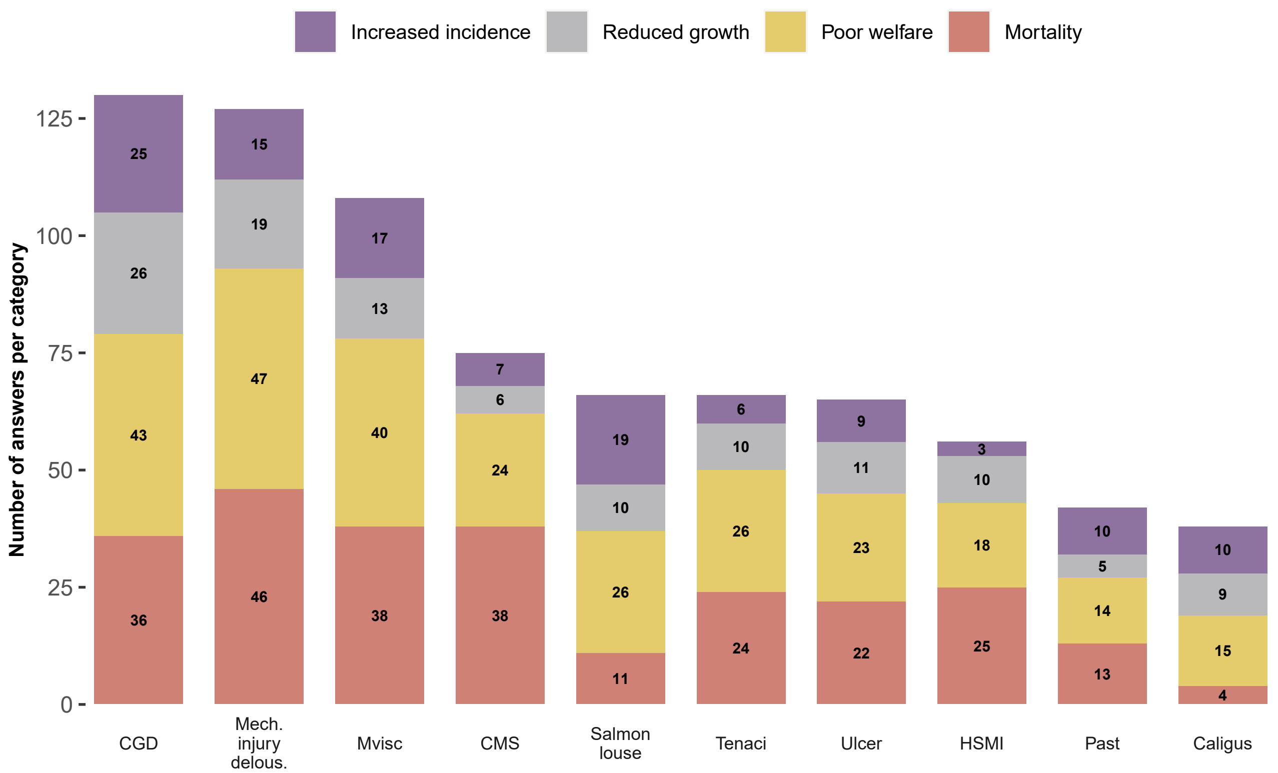


Figure: The 10 most important fish health problems of salmon in ongrowing facilities (sea water sites). Results from the 2022 annual survey among fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents were asked to indicate the five most important health problems on a list of three different problems. The respondents (N = number of persons who answered the question) were asked whether the problems were related to mortality (N=63), reduced welfare (N=63), poor growth (N= 57) or were perceived as a growing problem (N=52).
Abbreviations: CGP = gill disease complex/multifactorial, Mech injury delouse = mechanical damage related to delousing, Mvisc = infection with Moritella viscosa (classic winter ulcers), CMS = cardiomyopathy syndrome, Salmon louse = infestation with salmon lice, Tenaci = infection with Tenacibaculum spp. (non-classical winter ulcers), Ulcer = ulcers unspecified cause, HSMI = heart and skeletal muscle inflammation, Past = infection with Pasteurella sp. (pasteurellosis), Caligus = grazing injuries following infestation with *Caligus elongatus*

In the last two to three years, the Norwegian Fish Health Report has reported a concerning increase in certain bacterial diseases, and this development continues in 2022. Collectively, different forms of winter ulcer may represent the most important bacterial health and welfare challenge to the Norwegian aquaculture industry. The diagnosis was made in 433 different salmon farms in 2022, as well as in other fish species including rainbow trout. Identification of the infectious agent, when performed, typically reveals different genetic groups of *Moritella viscosa* and/or *Tenacibaculum* species, often together.

The ongoing pasteurellosis epidemic along the southwestern coast of Norway worsened considerably in the period 2018-2020. There was a small decrease in 2021, but the number of positive sites is now back to the same level as in 2020. In 2022, Pasteurella infections were detected in 52 marine salmon farms in southwestern Norway (PO2-PO5). As in previous years, most detections were made in PO3 and PO4. The disease primarily affects large salmon and causes abscesses in skin, musculature, and inner organs, among others.

Yersinia ruckeri, the causal agent of yersiniosis, was detected in farmed salmon at 33 locations in 2022, with the majority of cases detected in sea sites between the southwestern coast and county Trøndelag. This is a marked increase from previous years, and comparable to the levels before intraperitoneal vaccination was broadly implemented a few years ago. Although a proportion of the detections in 2022 probably were not associated with clinical symptoms, the disease appears to be re-emerging. Predisposing factors including stressful handling may influence the development of yersiniosis.

Salmon lice and other parasites

The production volume of farmed salmonids is regulated by the Traffic Light System, where the chosen indicator for sustainable production is related to the risk of lice-induced mortality in migrating wild salmon smolts. Considering the country as a whole, the average number of adult female lice per farmed fish was similar in 2021 and 2022. The highest production of larvae occurred in PO2-PO4 and PO6. During the months of wild salmon smolt migration, the production of larvae increased in PO6 and PO12 compared to 2021, and decreased in PO2-

Ingunn Sommerset, main editor of the Fish Health Report 2022. Photo: Eivind Senneset

PO5 and PO8-PO10. Only minor changes occurred in the remaining production areas. The number of non-medicinal delousing operations increased by 11 percent from 2021 to 2022, to a total number of 3145, which is the highest number reported so far. Moreover, the number of medicinal anti-sea lice prescriptions increased slightly in 2022, although still far below the levels prior to 2016.

Caligus elongatus has been a challenge in certain areas, particularly in the North. In the 2022 survey, *C. elongatus* ranks higher on the list of problems than in previous years. For the parasitic diseases AGD and parvicapsulosis, the numbers of detections in 2022 were similar to the previous year. The parasite *Spironucleus salmonicida* has caused sporadic problems in Troms and Finnmark County since its first detection in 1989. In 2022, several farms in this region experienced outbreaks of systemic spironucleosis more serious than previously experienced. Systemic spironucleosis is a serious diagnosis with severe consequences to fish health, welfare, and economy.

Fish welfare

In 2022 as in previous years, non-infectious problems rank as the most important cause of reduced welfare and mortality in both salmon and rainbow trout in fresh water (juvenile) farms. The number of welfare-related adverse events in juvenile production reported to the Norwegian Food Safety Authorities increased from 204 in 2021 to 222 in 2022. Most of these events were categorised as “other” or “unresolved mortalities”.

For adult fish in the seawater phase, the number of delousing operations, as well as the methods used, still represent a major welfare problem for both salmonids and cleaner fish. The number of non-medicinal delousing weeks increased from 2830 in 2021 to 3145 in 2022. The survey of 2022, as in previous years, ranks injuries related to non-medicinal delousing as the number one cause of reduced welfare in both salmon and rainbow trout in the marine phase. For salmon, complex gill disease and winter ulcer rank as number two and three, respectively, on the same list. Both of these diseases are exacerbated by the intensive handling during de-lousing. The Norwegian Food Safety Authorities received 1781 notifications of welfare-related adverse events in adult ongrowers and brood fish in 2022, an increase from the 1617 notifications received in 2021.

For the first time, this year’s report includes data on slaughter quality provided by the Norwegian Food Safety Authority. For the country as a whole, slightly less than 15 percent of the volume of salmon and rainbow trout is downgraded due to defects and other quality issues. “Wounds and injuries” was the most common category of downgrading both in 2021 and 2022. Downgraded fish represents a considerable number of individuals, although it is not possible to determine the exact number from the available slaughter data, which are measured in tonnes.

The use of cleaner fish is still associated with major welfare challenges. The survey shows that non-medicinal delousing, wounds, ’crater disease’, emaciation, and atypical furunculosis are the main causes of mortality and reduced welfare for lumpfish in salmon ongrowing sites. Atypical furunculosis, non-medicinal delousing, and handling stand out as the main causes of mortality and reduced welfare in wrasse, when these species are used as cleaner fish in salmon pens.

Fish used for research purposes are also entitled to good welfare. Because of reporting routines, the number of fish used for research in 2022 in Norway is not yet available, but in 2021, 1.9 million fish were used, of these 96 percent salmon. Quality-assured data show that the majority of experimental fish (77 percent) were used for applied research purposes. Moreover, the data show a marked increase in the number of fish subjected to procedures graded “moderate severity” relative to procedures graded “mild severity”. This development is not positive, and measures to reduce both the number of individuals and the grade of severity deserve greater attention.

The rivers in the Skibotn region were finally declared free of Gyrodactylus salaris in autumn 2022, 43 years after its introduction to the region. From left: Geir Arne Ystmark from the Norwegian Food Safety Authority and Bård Pedersen, assistant state administrator.

Wild salmon

In the autumn of 2022, the rivers Skibotnelva, Signdalselva, and Kitdalselva were finally declared free of *Gyrodactylus salaris* infection, 43 years after its introduction to the region. The combat strategy of the environmental authorities has significantly reduced the nationwide threat from this parasite to wild salmon. The sanitation program for the Fusta river system is still ongoing, sanitation measures have been started in the Driva area and a treatment strategy for the Drammen area is under development.

As one disease-causing microorganism is being defeated, other pathogens may rise in importance. In several river systems, the oomycete *Saprolegnia parasitica* caused a marked decline in the spawning populations in the autumn of 2022. Both salmon, sea-trout and landlocked trout were affected. Classic vibriosis caused salmon mortalities in the inner Oslo fjord in the late summer, most likely related to high sea temperatures and low river water levels. The parasite *Ichthyophthirius multifilis* is also found in Norwegian rivers and infection severity is highly temperature-dependent, with a marked increase in pathogenicity above 15 °C. With climate change, energy crises and other factors affecting river water levels and temperatures, such infections may increase in numbers and severity.

1 Statistical basis for the report

By Victor H S Oliveira, Cecilie Walde and Ingunn Sommerset

The data in the Fish Health Report is mainly taken from official data, data from the Norwegian Veterinary Institute's sample journal system, data from private laboratories and data from a survey among employees in the fish health services and inspectors from the Norwegian Food Safety Authority.

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.

Offisielle data

Norway has a new regulation for animal health since April 28, 2022, which includes lists of diseases and reporting obligations. 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 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.

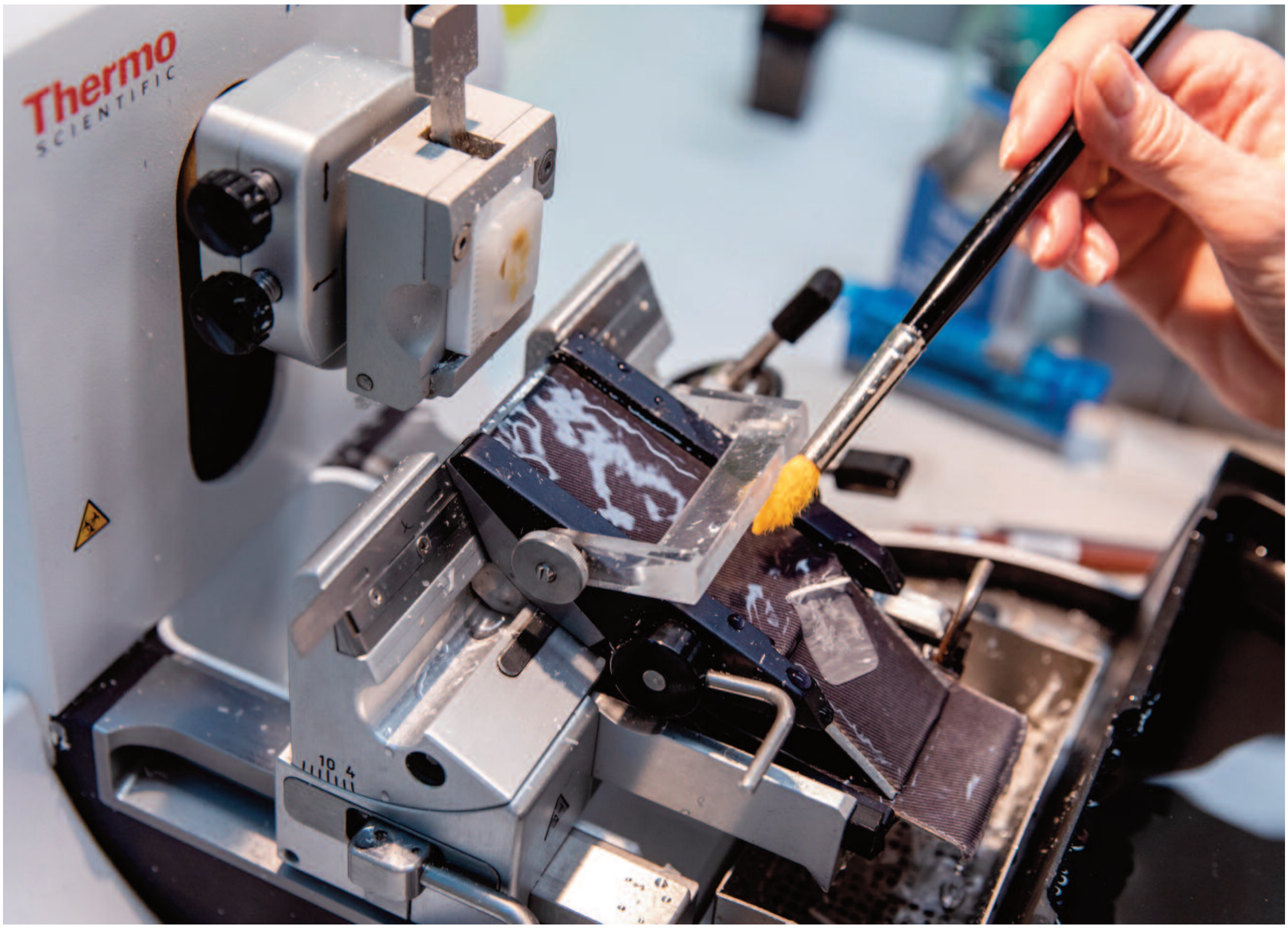
Based on monitoring programmes and ongoing diagnostic examinations, no diseases of category A or B have ever been detected in Norway. Categories C and F diseases with the number of detections are shown in the table on the “Summary” of this report. The figures are based on

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
	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)
	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)
	Infectious salmon anaemia, HPR-deleted	C, D, E	Atlantic salmon, rainbow trout and sea trout
	Koi herpesvirus disease	E	Carp and Koi
Nasjonal (Norway)	Bacterial kidney disease (BKD, *Renibacterium salmoninarum*)	F	Family: Salmonids
	Gyrodactylus salaris infection	F	Atlantic salmon, rainbow trout, arctic char, brook trout, grayling, lake trout and sea trout
	Viral nervous necrosis (VNN)/Viral encephalopathy and retinopathy (VER), Nodavirus	F	Marine fish species
	Furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*)	F	Family: Salmonids
	Pancreas disease (PD, *Salmonid alphavirus*)	F	Atlantic salmon, rainbow trout and sea trout
	Systemic *Flavobacterium psychrophilum* infection	F	Rainbow trout
	Francisellosis (*Francisella* sp.)	F	Atlantic cod
	Lepeophtheirus salmonis (salmon lice) infection	F	Family: Salmonids
	Disease not listed to date	G	

data from the Norwegian Veterinary Institute, which assists the Norwegian Food Safety Authority in keeping an up-to-date overview of the listed diseases. The Norwegian Food Safety Authority notifies the Veterinary Institute of diseases detected by external laboratories such that these are registered alongside detections made by the Norwegian Veterinary Institute. As the National Reference Laboratory, the Norwegian Veterinary Institute 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 is the number of new detections in a site after fallowing. This means that the real number of infected sites in 2022 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 Norwegian Veterinary Institute receives information about the sites’ monthly biomass reports. We also use the “Aquaculture register”, kept by the Directorate of Fisheries, which has an overview of all aquaculture permits, including information about geographical location of the sites, species, type and purpose of production. From the Norwegian Food Safety Authority, the Veterinary Institute receives weekly data on salmon lice counts and number of delousing treatments carried out on sites.



Preparation of a fish tissue sample for microscopy. Photo: Eivind Senneset

Data from the Norwegian Veterinary Institute

The Veterinary Institute receives samples for diagnostic examinations from a number of providers of fish health services. These are examined at the Institute's laboratories in Harstad, Trondheim, Bergen and Ås. All information generated from submitted diagnostic samples is stored in the institute's electronic journal system (prøvejournalsystem/PJS). We extracted and sorted data from PJS so that only samples submitted for diagnostic purposes are in this Report. Exclusions include samples sent for e.g. research purposes and ring tests.

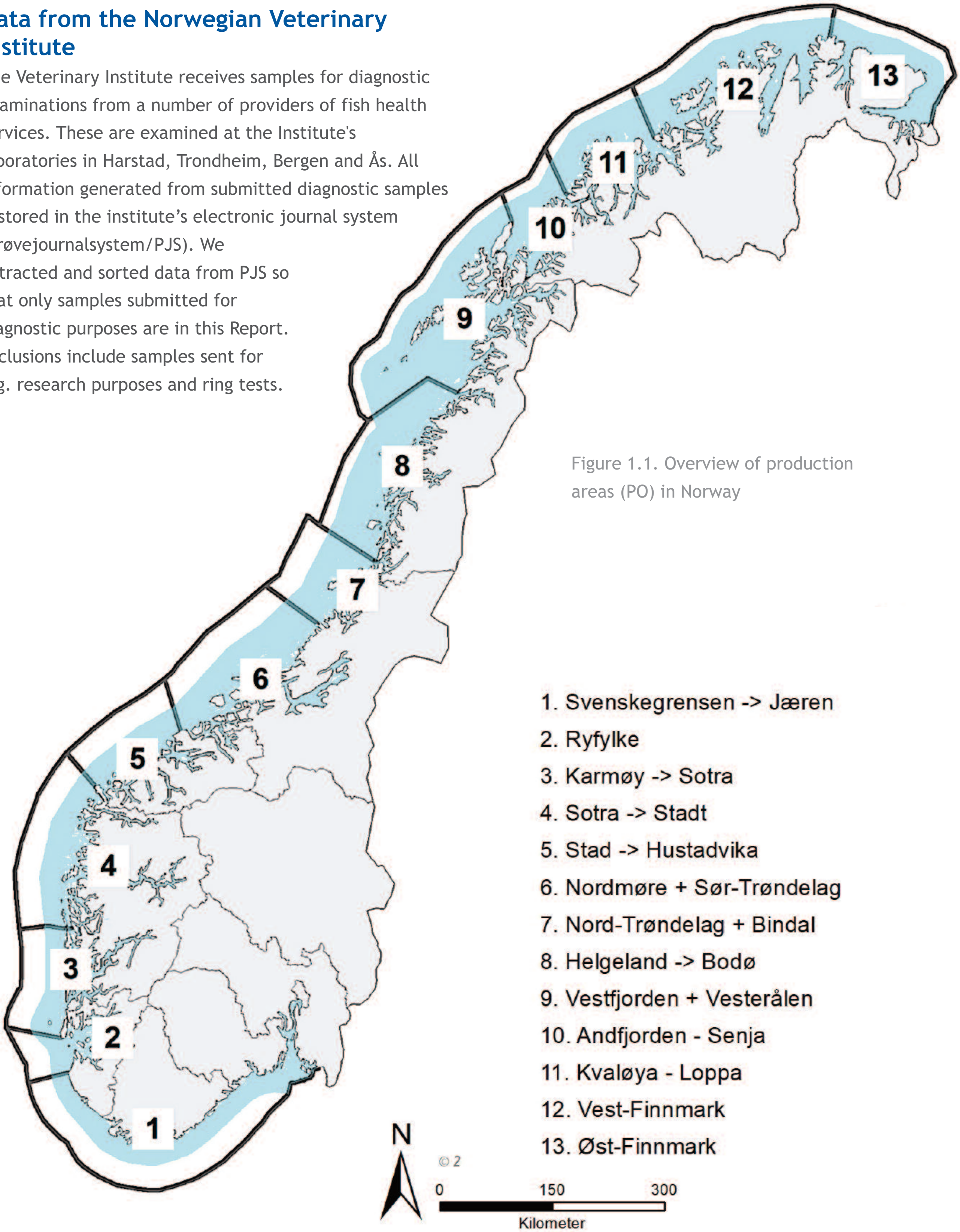


Figure 1.1. Overview of production areas (PO) in Norway

Data from private laboratories and compiling data

Samples for diagnosis of non-listed diseases can be sent to private laboratories as well as to the Norwegian Veterinary Institute. Because of this, data from the Veterinary Institute alone cannot give a complete picture of the national situation for many important non-listed diseases. For the Fish Health Report 2021 and 2022, we have had agreements with several of the largest and medium-sized aquaculture companies in Norway to gain access to data from submitted samples to private laboratories. A total of 23 fish farming companies approved the release of data on the following diseases and associated disease-causing agents:

- Heart and skeletal muscle inflammation (HSMI) and HSMI-like diseases
- Cardiomyopathy syndrome
- Infectious pancreatic necrosis
- Yersiniosis
- Pasteurellosis
- Classical winter ulcer
- Tenacibaculosis/non-classical winter ulcer
- Parvicapsulosis
- Amoebic gill disease
- Infection with lumpfish flavivirus

In 2022, we received data from 20 out of the 23 companies with agreements. Two of the companies had no detection of any of the selected non-listed diseases, and the third had been merged with one of the other companies. Hence, the data of non-listed disease in 2021 and 2022 is overall comparable, in terms of sites and companies providing such data. The selected diseases and disease-causing agents are mainly from the seawater phase of farmed salmon, rainbow trout and to some extent cleaner fish. We also included a few detections in other aquatic environments or other fish species if available.

For an overview of the dataset coverage, we can relate to the proportion of active sites in 2022, obtained from reported biomass via the "Altinn" portal to the Directories of Fisheries. In 2022, there were 878 active sites (grow-out, broodstock and/or R&D) for at least one month, and the monthly average of active locations was 598. We received data regarding the non-listed diseases

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.

from 612 sites in 2022, of which 51 had not reported via “Altinn”. These numbers were close to the received data from 591 sites in 2021, of which 62 had not reported via “Altinn”.

The non-listed diseases data has been extracted from electronic journal systems at the private laboratories PatoGen AS and Pharmaq Analytiq AS. There was verification and authorisation by the farming companies before using the data.

For each disease or agent, we collated the diseases data from the various laboratories, including data from the Norwegian Veterinary Institute, to ensure unique counts of specific diseases or agents per production site. In a few cases, the same disease might have been detected on the same farm in 2021 as well as in 2022, and be part of the same production cycle, so the overview cannot necessarily be used to indicate about the number of new outbreaks in 2022. The exception is for notifiable disease (see description above).

Fish health personnel, in some cases, make diagnosis for non-listed diseases based on characteristic macroscopic findings and agent detection (e.g. by PCR). Based on these diagnoses, we added in this year’s report more information regarding the clinical significance of pure agent detections, i.e. when agents were present without a confirmed histopathological diagnosis of the disease. Fish health officers from each company were asked to record the clinical status of the population from which the relevant positive sample for an agent was taken, as "sick" or "healthy". Information on clinical status was available in approximately 80 percent of the cases where only the agent was detected, and this additional information is used in several of the chapters dealing with the above-mentioned non-listed diseases.

Data from the survey

As in previous years, the Norwegian Veterinary Institute 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 Norwegian Food Safety authority. In the survey, the respondents were asked to rank (among other things) 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 and allowing free text to be entered for some of the topics.

The questionnaire was sent to 260 people, of whom 177 work with fish health inspection, in either private fish health services or farming companies, and 83 as inspectors in the Norwegian Food Safety Authority. There were 74 people who completed the survey (response rate of 28 per cent), which is a slightly lower participation than the previous year. Of these, 68 respondents working in private fish health services or as fish health personnel in farming or breeding companies. The remaining 6 respondents working as inspectors in the Norwegian Food Safety Authority. All respondents were offered to be mentioned by name as contributors, and those who wished to do so are listed on the last page 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.

Geographical distribution

Until 2020, the Fish Health Report showed geographical distributions of data at county level. From 15 October 2017, production of salmon, trout and rainbow trout in sea water sites along the Norwegian coast , became regulated in thirteen geographically defined areas, called production areas (in Norwegian called “produksjonsområder”, abbreviated “PO”), see Figure 1.1. With few exceptions, this year's edition of the Fish Health Report shows aggregate data per production area (abbrevated as PO in the report), instead of per county.

2 Mortality in salmonid production

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

Mortality in farmed salmonid is associated with several determinants, such as adverse environmental events, production characteristics, management-related factors, and diseases. Considerations about fish mortality and diseases appear in several chapters throughout this report, based on information from our annual survey and other sources.

2.1 Some fish production statistics

Preliminary slaughter figures for 2022 indicate a decrease in harvested biomass of just over 10,000 tons for salmon and about 8,000 tons for rainbow trout compared to 2021. Even though the decrease in salmon production was small relative to the total of slaughtered salmon, this is the first time in recent years that we have seen a decrease in harvested biomass in recent years (Table 2.1). The reported biomass at the end of 2022 remained stably high.

In the last four years, the annual number of fish transferred to sea sites has been around 300 million. Preliminary figures for 2022 showed approximately 10 percent increase in the number of transferred smolt, corresponding to approximately 33 million more fish than in 2021. For rainbow trout, the transfers into sea sites were 5 million from 2021 to 2022, which corresponded to a 38 percent increase. Based on figures reported to the Directorate of Fisheries at the end of January 2023, the number of stocked cleaner fish in 2022 was 30.2 million. This was a noticeable drop of approximately 25 percent compared to the previous year, following the downward trend over the past five years. The health situation for cleaner fish is further discussed in Chapter 4 (subheading 4.12) about the welfare challenges for cleaner fish and in Chapter 10 about the health situation for cleaner fish.

2.2 Losses and mortality of fish during the sea phase

Salmonid losses during the production period in seawater are reported to the Directorate of Fisheries, and

Table 2.1 Production data for farmed fish based on available figures from Directorate of Fisheries, as of 30.01.2023, ref. **https://www.fiskeridir.no/Akvakultur,** with corrected figures for cleaner fish as of 28.02.2023. UNK = unknown.

	2018	2019	2020	2021	2022
Number of sites					
Salmonids - hatchery production, number of permits	217	221	227	227	231
Salmonids - grow-out production, number of sites at sea	1015	966	986	990	989
Salmonids - grow-out production, number of sites on land (fresh water and salt water)	UNK	43	48	58	58
Marine fish, number of site at sea	42	64	36	41	48
Biomass at end of year, in tons					
Salmon	813 886	811 958	897 687	870 605	848 927
Rainbow trout	40 364	47 094	40 585	36 984	35 810
Slaughter figures, tons in round weights					
Salmon	1 278 596	1 361 747	1 393 129	1 557 448	1 543 918
Rainbow trout	66 723	79 870	92 864	84 493	76 662
Hatchery fish transferred to sea, in millions					
Salmon	304	288	289	304	337
Rainbow trout	20.0	20.8	17.5	13.0	18
Cleaner fish	UNK	49.4	42.4	40.6	30.2
Post sea-transfer dead fish, in millions					
Salmon	46.3	53.2	52.1	54.0	56.7
Rainbow trout	2.8	3.1	2.8	2.7	2.6

categorised as follows: dead, discarded, escapees or other. The category "dead" defines fish registered as dead for various reasons. "Discarded" are fish not suitable for human consumption. The category "other" would be loss of fish not categorised as dead, discarded or escapees.

We use the number of fish within the category "dead" for mortality calculations. A total of 56.7 million salmon and 2.6 million rainbow trout died in the sea phase in 2022. Overall, these numbers represented approximately 90% of the salmon losses and 80% of rainbow trout losses. See **http://apps.vetinst.no/Laksetap** for details about the distribution of fish losses according to each category over the past 5 years.

Since 2018, we provide information about mortality of farmed salmonid using mortality rates that are converted into percentages. The monthly mortality rate per site is the total number of dead fish divided by the number of fish at risk of dying. The number of fish at risk of dying corresponds to the average number of live fish in the relevant month, calculated as the difference between the number of fish at the beginning of the month and the number of fish at the end of the same month (Bang Jensen et al., 2020). Based on this, we calculate the average monthly rate for all sites. These monthly average values are finally summed and converted to the annual percent mortality, using a formula described by Bang Jensen et al., (2020), and represent the probability of a fish dying during 2022. Mortality was 16.1 percent for salmon and 17.1 percent for rainbow trout in 2022 (Table 2.2), also available at **http://apps.vetinst.no/Laksetap.**

Table 3.2 shows the annual mortality per production area (PO) in the last three years. In 2022, there are still large geographical differences in fish mortality: PO3 with the highest salmon mortality (23.7 percent) and PO9 with the lowest salmon mortality (9.1 percent) (Figure 2.1). Overall, mortality in PO2-PO5 have been around 20 percent, whereas the area from PO6 and northern areas have consistently been below 15 percent. The figures for rainbow trout has naturally varied somewhat more over the years, since there are few sites with this species. For more figures, see **http://apps.vetinst.no/Laksetap.**

Table 2.2 Annual mortality in percentage in the production of salmon and rainbow trout in 2019-2021 by production areas. Mortality is calculated from monthly mortality rates, as described in the text. If you would like to see figures for each county, or for several years back, please refer to the interactive application:
http://apps.vetinst.no/Laksetap/

Salmon				Rainbow trout			
Production - area (PO)*	2020 % mortality	2021 % mortality	2022 % mortality	Production - area (PO)*	2020 % mortality	2021 % mortality	2022 % mortality
PO1	11.3	10.4	18.1	-	-	-	-
PO2	14.4	19.8	19.5	PO2 and PO3	15.0	17.8	15.4
PO3	19.9	19.9	23.7				
PO4	27.2	22.5	22.0	PO4	17.1	15.0	14.5
PO5	15.2	18.7	17.7	PO5	10.4	15.7	21.7
PO6	13.5	14.0	14.9	PO6 and PO7	20.0	10.8	-
PO7	10.5	10.8	11.2				
PO8	9.7	12.1	14.6	-	-	-	-
PO9	9.6	13.6	9.5	PO9 and PO10	9.9	4.8	-
PO10	10.2	10.9	14.4				
PO11	15.7	12.6	9.1	-	-	-	-
PO12	11.1	13.0	11.4	-	-	-	-
PO13	6.7	10.2	9.9	-	-	-	-
Norway	14.8	15.5	16.1	Norway	16.0	14.8	17.1

*Mortality is calculated for POs with more than five sites.
Production areas with fewer than five sites are marked with a "-".

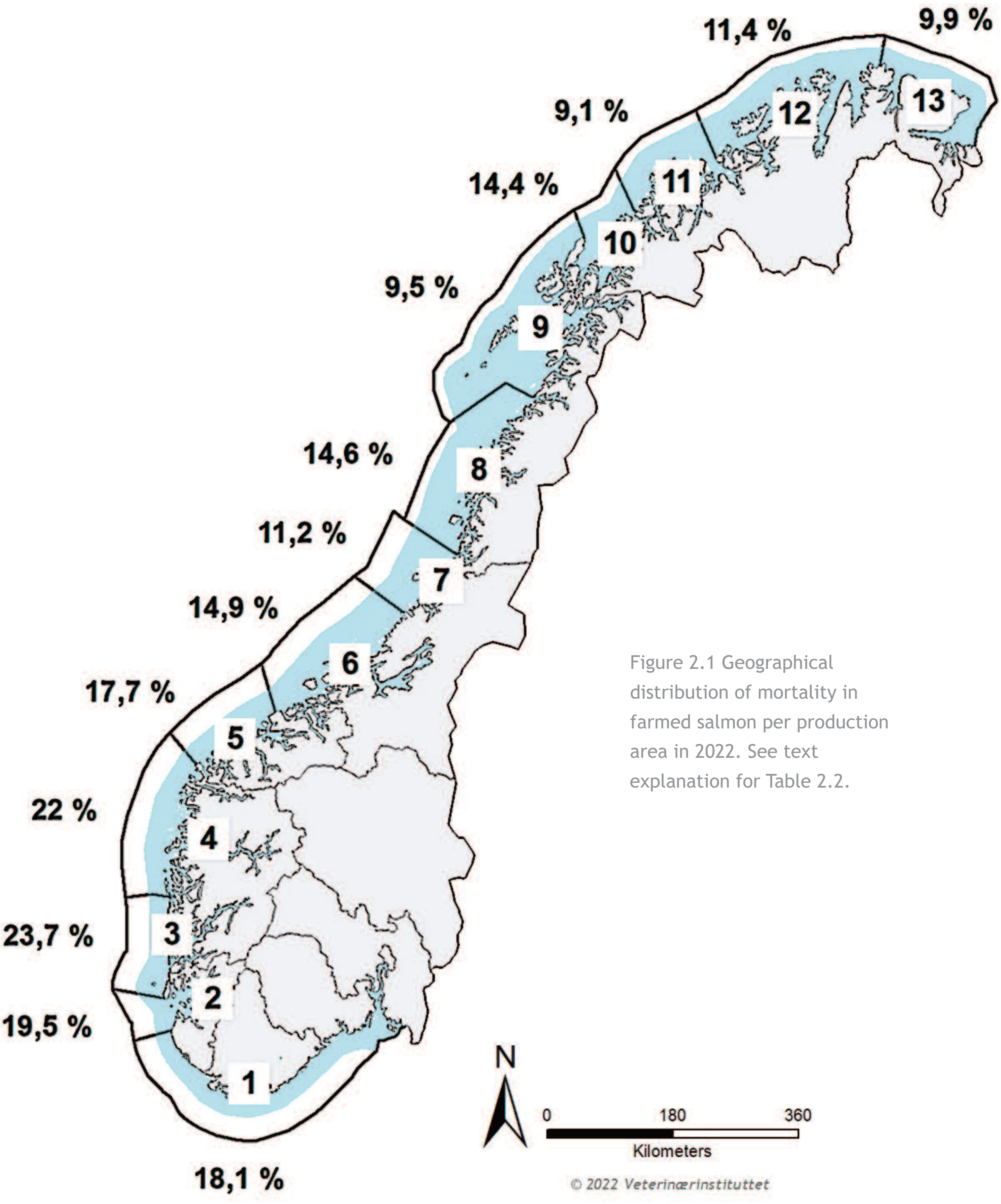


Figure 2.1 Geographical distribution of mortality in farmed salmon per production area in 2022. See text explanation for Table 2.2.

In addition to describing the percentage mortality per year, we also present mortality per production cycle, calculated in a similar way. We calculate the production cycle mortality for sites that have been slaughtered in the respective year, and only included sites that have stocked fish continuously for 12 months or more prior to the harvest. The production cycle mortality summaries does not include sites with broodstock, fish from research and development concessions, teaching concessions, etc.

For production cycles (sites) completed in 2022, the median mortality was 16.6 percent. Median mortality for production cycles has been relatively stable over the past five years, but we see considerable variation among sites. Half of the sites had a mortality between 10.2 and 25.7 per cent (table 2.3). In approximately one quarter of the sites, mortality was 10 percent or lower, while for another quarter had a mortality of 25.8 percent or higher.

Monthly mortality rates per PO over the last three years were included in the report of last year. In Figure 2.2, we present figures for this period between 2020 and 2022. By using monthly mortality rates, it is possible to follow seasonal variations in mortality per PO and compare its deviations from the median mortality at national level. In addition, mortality per PO for given intervals gives us the opportunity to look at which values might be considered above or below the overall mortality rate in different areas. In 2022, there was a mortality peak in PO1 between July and October that stands out. As discussed below, we do not have available data on causes of death, but information from other sources suggests that the peak could be related to high sea temperatures in late summer, which can create a poorer oxygen conditions and problems during handling of fish in delousing operations. It is worth noting that PO1 has relatively few active sites compared to PO2-PO12, and this single events at a smaller group of sites will have a stronger impact on the median mortality than elsewhere.

For this report, an overview of causes of deaths from reported mortality data is not available. The Norwegian University of Life Sciences (NMBU) has developed a classification system for causes of loss and death, which was commissioned by the industry. This system has been included in the Norwegian Standard NS9417:2022 with importance for aquaculture (see discussion in Chapter 4.1 about welfare indicators). The Veterinary Institute participates in a collaboration with Sjømat Norge (the Norwegian seafood federation) and AquaCloud project (NCE food innovation) on the implementation and digital reporting of standardized causes of death in marine facilities with salmonids. Quality-assured data from this collaboration may provide a better picture of the main mortality causes and differences in time and space (seasonal and geographical variation). Until this is in place, indirect information is obtained from disease statistics, access to welfare incidents reported to the Norwegian Food Safety Authority, the survey among fish health personnel and other sources.

Table 2.3 Mortality in salmon (percentage) for completed production cycles. Only production cycles of 12 months or more are included. For calculation method, see the text.

	2018	2019	2020	2021	2022
Median mortality in percentage for completed production cycles per year	17.4	15.0	17.9	17.4	16.6
1st to 3rd quartile (50% of sites with completed production cycles had mortality within this interval)	10.9-25.2	9.6-25.1	10.9-26.9	10.3-26.7	10.2-25.7

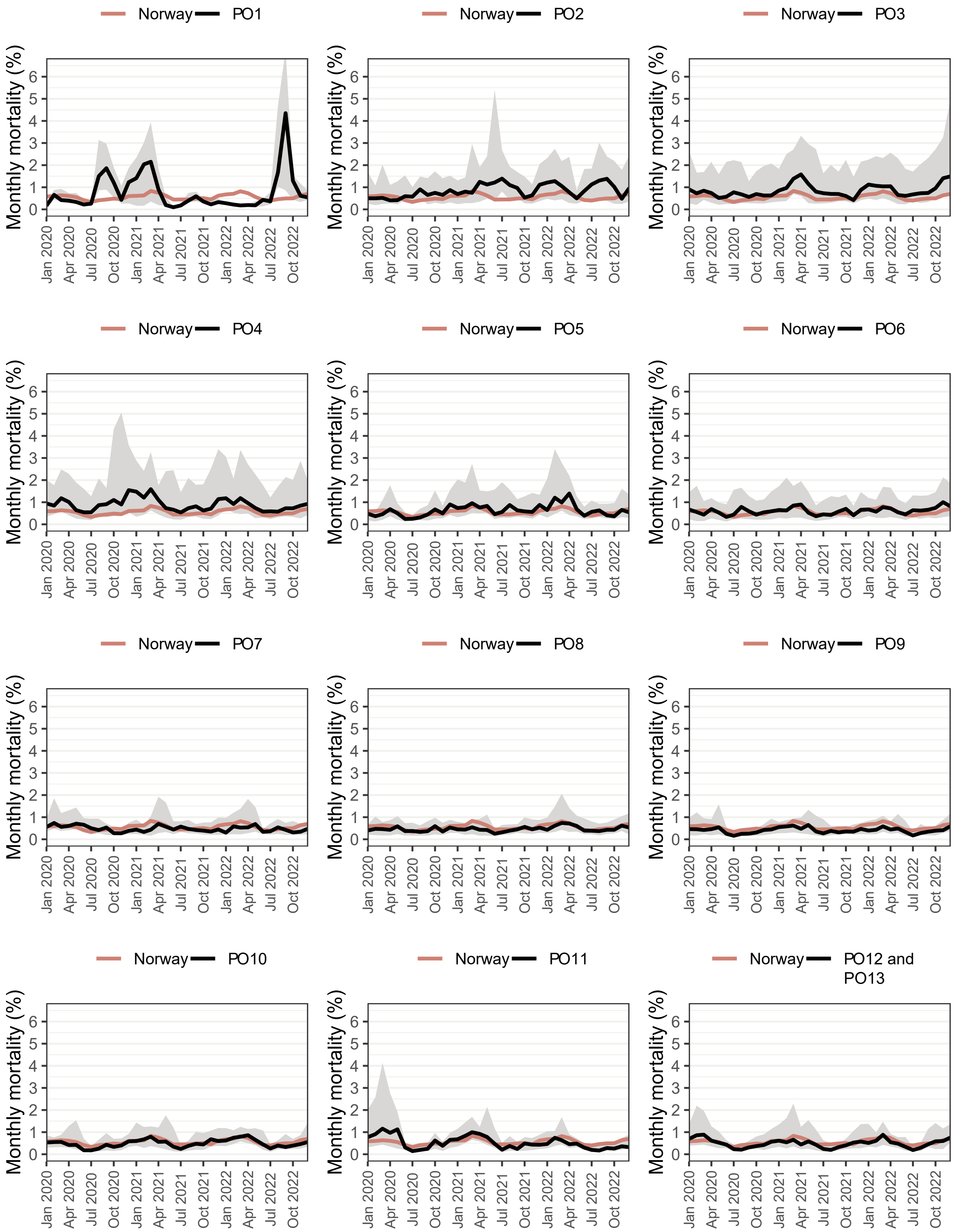


Figure 2.2 Mortality rates development per production areas between 2020 and 2022. Solid lines are medians, grey areas show the interval for 50 percent of sites. There were 25 percent of sites above the grey area, and 25 percent below.

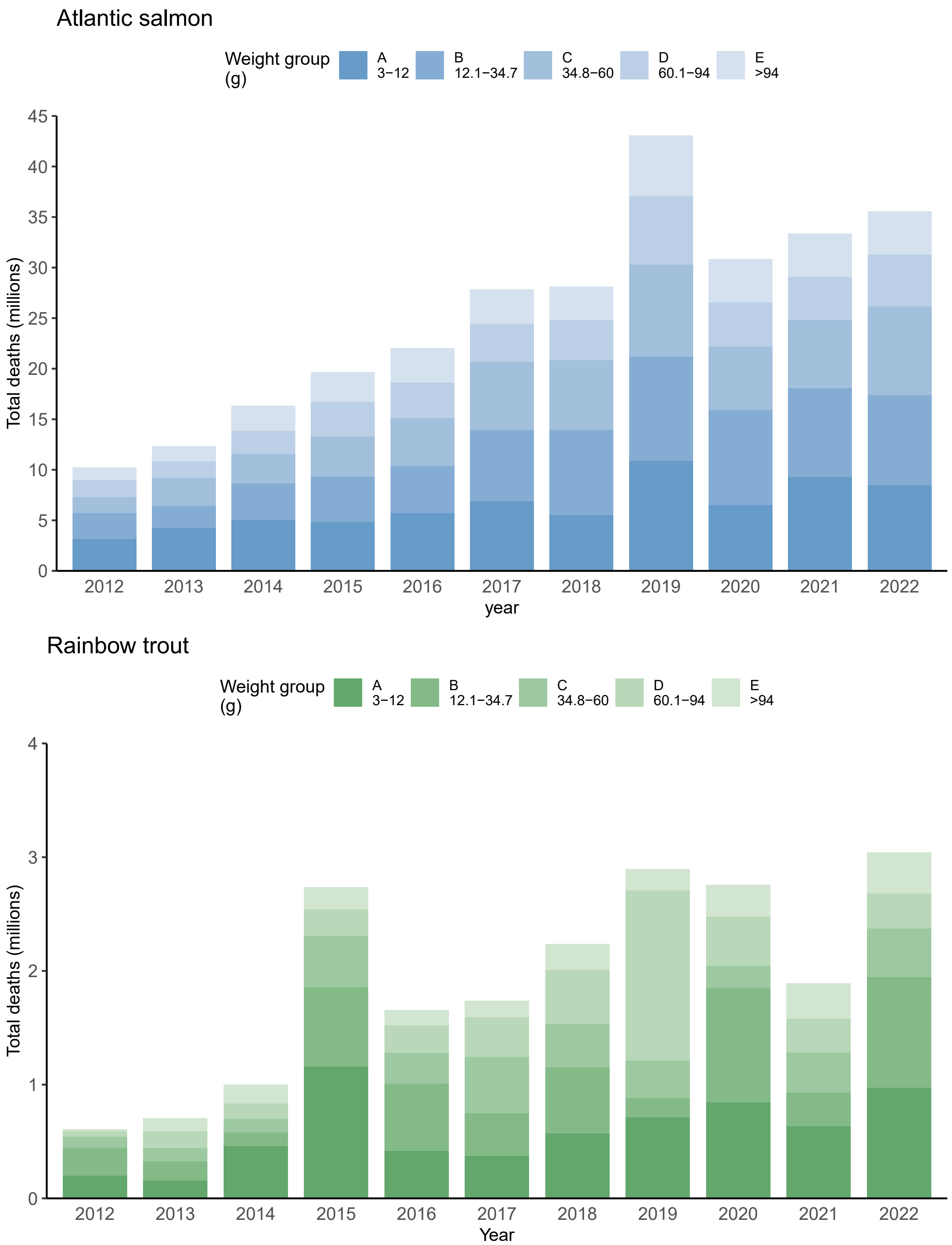


Figure 2.3 Mortality of salmon and rainbow trout in hatcheries (in number of individuals) reported to the Norwegian Food Safety Authority, divided into different weight classes.

2.3 Losses in juvenile production

In the hatchery phase, there is no categorization of fish losses and every lost fish is registered on the same way, here considered as a dead fish, along with total number of fish held and average weight. The quality of the data in the hatchery phase is not as good as for fish in the sea phase, farmed for food consumption. The production routines of hatchery fish make it more difficult to gather data at group level. Therefore, there are limitations to the use of such data for detailed mortality calculations. Proposals for improvements to the reporting are discussed in **https://www.vetinst.no/rapporter-og-publikasjoner/rapporter/2019/dyrevelferd-i-settefiskproduktionen-smafiskvel** (available only in Norwegian).

In the hatcheries, losses related to destruction/departure and mortality is expected at the very early stage, and the figures we use in this year's report therefore do not include the weight class 0-3 grams. Fish in this weight class account for about 45 percent of the total deaths in the hatchery phase. Figure 2.3 shows the numbers of dead fish reported to the Food Safety Authority from 2012 to 2022 in the hatchery phase for salmon and rainbow trout. In 2022, deaths of 35.6 million salmon and 3 million rainbow trout larger than 3g were reported to the Food Safety Authority. For both salmon and rainbow trout, this was an increase in numbers compared to the previous year. A larger smolt production, based on reported figures of the number of salmon smolt put at sea in 2022, may be part of the explanation for such increase (see Table 2.1). Still, the total salmon deaths in hatcheries in 2022 were by far below the peak of more than 43 million in 2019. For rainbow trout, the number of transfers to sea has remained stable.

Salmon fry before smoltification. Photo: Johan Wildhagen

3 Changes in infection risk

By Edgar Brun, Duncan Colquhun, Åse Helen Garseth, Kari Grave, Snorre Gulla, Haakon Hansen, Kari Olli Helgesen, Sonal Patel, Leif Christian Stige and Saraya Tavornpanich

3.1 Biosecurity and disease burden

The overall disease burden in farmed fish is significant, and includes everything from lice and infectious diseases to non-infectious disorders. We do not have a clear estimate of the actual costs, but in the NORCE report "Cost development in salmon and trout farming: what is the cost of biological risk?" by Bård Misund (from November 2022), it has been established that biological costs related to disease and lice are amongst the largest costs in salmon farming. In fact, the biological costs are now on a level with "traditional" production costs. There has been a doubling of the biological costs from 2012 to 2021, and there are also growing differences between the various production areas in Norway.

Given this situation, it is timely that biosecurity has become one of the most central concepts in disease prevention work, both by the public authorities and by industry. The World Organization for Animal Health (WOAH) has devoted biosecurity a separate chapter and since 2019 the FAO has conducted a large NORAD-funded project involving the Norwegian Veterinary Institute, on the theme "Progressive Management Pathway for Improving Aquaculture Biosecurity (PMP/AB)". Biosecurity has a considerable presence in the EU's Animal Health legislation. This obliges the Norwegian authorities and industry to implement biosecurity plans. Groups comprising industry actors with and without the Norwegian Food Safety Authority have been established to work with biosafety. These are highly anticipated and necessary developments.

The aim of biosecurity is to ensure prevention of the most unwanted infectious agents entering farms and fish populations, and prevention of spread of infectious agents; regionally, nationally and globally. Farmers thus have a vested interest in good biosecurity, but it is also of great importance to other actors in the industry and the general public. Implementation and compliance with good individual biosecurity routines is therefore a community task, to protect the industry, jobs and unnecessary waste and misuse of our common resources. Biosecurity requires knowledge of biological risk and measures that can reduce this risk, as well as a willingness to significantly change and incorporate new routines and structures.

The biological risk associated with disease is now showing its costly face. This situation occurs after many years of virtually ignoring this risk due to favourable harvest prices and growth of the industry. Of todays total production costs, close to NOK 60/kg gutted weight, biological costs amount to NOK 14/kg. This is the same order of magnitude as feed costs.

The Norwegian salmon industry has a way to go in relation to sustainability and ethical production of animal protein, considering the disease burden that exists today. The industry's future depends on the industry itself and the public authorities being able to prioritize sufficient resources to take this challenge seriously.

With the focus now directed towards preventive disease work, supported by innovation and effective measures from the authorities, there are signs that fish-farming is starting to mature.

3.2 Antibiotic consumption

The consumption of antibacterial agents, measured in kilograms of active substance, has historically been used as an indicator of the occurrence of bacterial diseases. Vaccines against cold-water vibriosis and furunculosis were introduced in the late 1980s and early 1990s respectively, and since then the consumption of antibiotics has been very low (source: **NORM-VET reports**) despite a considerable increase in production of farmed fish. In the period 2015-2022, antibiotic consumption, in kilograms, was considerably higher in 2017, 2018 and 2021 compared to other years (table 3.2.1). The reason for this were a few treatments in localities with large salmon in these years - for example, in 2021, a single prescription accounted for 240 kg of the total amount (593 kg) of antibacterial agents reported to the Veterinary Medicines Register (VetReg) that year.

The number of treatments is a better indicator of the occurrence of bacterial diseases per fish species and production stage than the total amount (kg) of active

Table 3.2.1 Antibacterial agents used for farmed fish (kg active substance)[1]. Data are calculated from the Veterinary Medicines Register (VetReg). For all years, the figures have been validated against sales figures reported by the Institute of Public Health. VetReg figures as of 27.03.2023. For 2019-2022, the figures include small amounts (0.09 kg-0.23 kg) of antibacterial agents for experimental fish.

Antiobiotic substances	2015	2016	2017	2018	2019	2020	2021	2022
Florfenicol	188	136	269	858	156	113	536	397
Oksolinic acid	84	66	343	54	66	107	57	28
Oxytetracycline				20		0.019		
Enrofloxacin	0.02	0.05	0.01		0.01	0.12	0.44	0.1
Amoxicillin					-	0.09		
Total antibiotics	273	201	612	931	222	220	593	425

[1] Different figures from the 2021 Fish Health Report is due to updates in VetReg and updated routines to identify errors in VetReg-reports.

substance. Figure 3.2.1 shows a considerable increase in the number of treatments for marine species in the 'ongrowing' category in 2022; from 13 in 2021 to 32 in 2022. Of the 32 prescriptions for this group of fish, 24 of the prescriptions were for the treatment of halibut (eight for cod). However, total consumption, in kilograms, of antibacterial agents for marine species was only 20 kg of the total consumption of 425 kg.

In the past, the number of antibiotic treatments in cleaner fish has been considerably higher compared to fish farmed for food. However, there has been a large decrease in the number of antibiotic treatments in cleaner fish. The highest reported number of treatments in cleaner fish was in 2016 when 126 treatments were carried out, while in 2022 10 antibiotic prescriptions were written for cleaner fish.

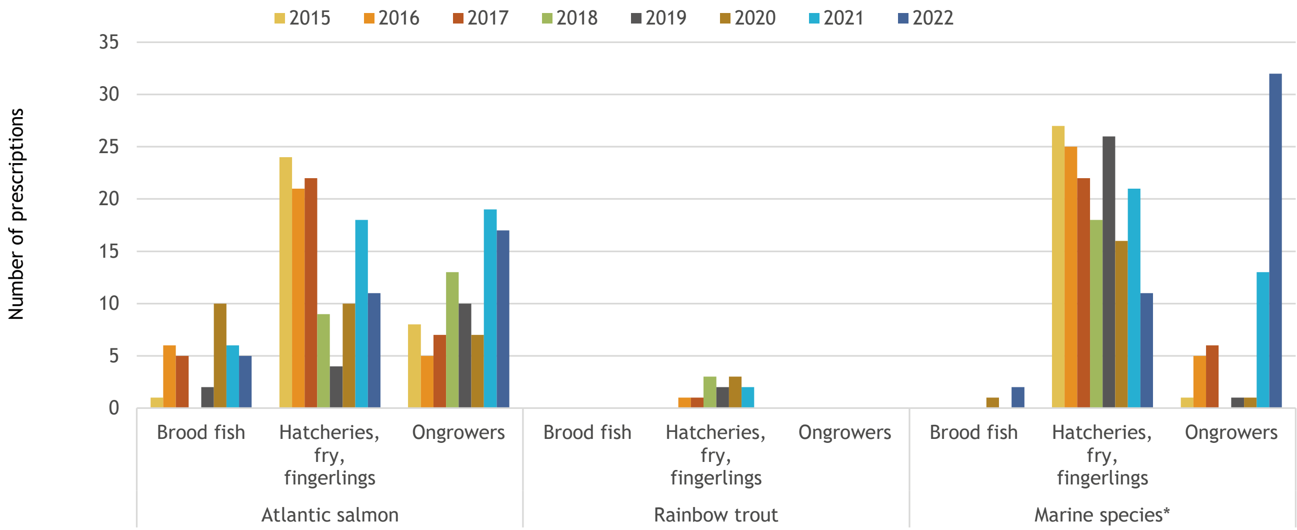


Figure 3.2.1. Number of treatments with antibacterial agents distributed by fish species and production stage in the years 2015-2022 (cleaner fish and experimental fish excluded). The number of treatments is the number of prescriptions from the Veterinary Medicines Register (VetReg figures as of 27.03.2023). * Cod, halibut, turbot

3.3 Salmon lice and louse management

Salmon lice are important for the health and welfare situation in individual farms. This is because the salmon louse is a parasite with a pathological potential for the host, but not least because of the control measures that are put in place to keep the number of lice below the threshold values stated in the salmon lice legislation (https://lovdata.no/dokument/SF/forskrift/2012- 12-05-1140). These threshold values are set lower than the number of lice that result in significant damage to the farmed fish, in order to provide better protection to the wild salmon. In order to comply with the lice thresholds, the fish in most facilities must be treated several times, and each individual treatment has potential side effects. The side effects depend on the fish's state of health, the treatment method that is chosen and implementation of the chosen method (Chapter 4.7 Welfare challenges related to salmon lice).

The total number of medicinal and non-medicinal treatments against salmon lice has increased by 96 per cent from 2012 to 2022, while the number of active fish farms increased by only 2 per cent (Figure 3.3.1). One of the reasons for the increase in the number of treatments is probably that each treatment has become less effective, partly due to the development of resistance, so that more frequent treatments are needed to keep the level of lice down.

Development and use of treatment methods against salmon lice from and including 2016 to 2022 has resulted in increased handling of the fish (figure 3.3.1). The reasons are several. Preventive methods such as lice skirts and continuous delousing using e.g. lasers have long been highlighted as the most gentle methods for lice control, but have not in most farms, proven to result in sufficiently low lice numbers. Medicinal methods are generally gentler on the fish than non-medicinal methods, but widespread development of resistance and environmental aspects mean that their use reduced greatly from 2017 onwards. Non-medicinal methods have dominated from 2017 and their use increases annually. The stabilising observed in 2021 has not continued, and the number of non-medicinal delousings performed in 2022 was higher than ever. The non-medicinal methods that have dominated since 2016 are those that require the most handling (thermal and mechanical delousing), while in-feed treatment, with very few health and welfare-related side effects, dominates non-medicinal methods (Chapter 8.1 The salmon louse *Lepeophtheirus salmonis*). It is, therefore, non-medicinal methods that cause the most negative health and welfare effects on the treated salmon. See chapter 4 Fish welfare for more details on the welfare effects of treatment.

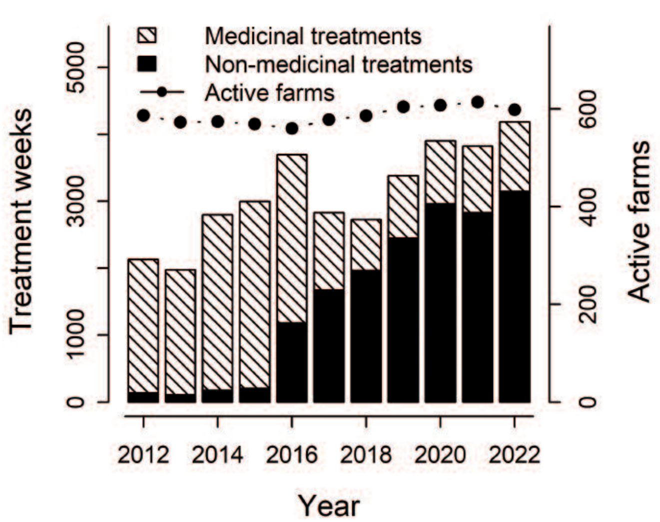


Figure 3.3.1. Number of reported medicinal and non-medicinal treatments against salmon lice and the number of active farms from 2012 to 2022. The treatments are number of weeks in which localities have reported that they have carried out treatment against lice to the Norwegian Food Safety Authority (reported as of 16.01.2023). The number of active facilities is the average number of farms with salmon or trout in the sea in the current year.

3.4 Operating routines – a driver for new bacterial infections

In general, and with few exceptions, the situation with regard to bacterial diseases in Norwegian farmed salmon has been quite good ever since multi-component injectable vaccines with oil adjuvants became widespread from the early 1990s. However, over the past decade, several bacterial infections have again become relevant. Classic winter-ulcer (caused by *Moritella viscosa*) now represents perhaps the most acute disease-related welfare problem in the fish-farming industry, and tenacibaculosis (caused by *Tenacibaculum* species) is also frequently reported. Pasteurellosis (caused by "*Pasteurella atlantica*") has rapidly emerged as an (almost) new and widespread problem, while a new clinical form of yersiniosis (caused by *Yersinia ruckeri*) continues to cause mortality in large fish in the sea, even though vaccination has reduced the problem. At the same time,small increases in the number of outbreaks of furunculosis (caused by *Aeromonas salmonicida* subspecies *salmonicida*) and mycobacteriosis (caused by *Mycobacterium* spp.) have been recorded compared to historical figures.

It is unclear what the underlying causes of this trend are, but there is no indication that changes in either the bacteria or the fish alone can be the cause. Most likely, a complex interaction between several different factors is involved. Most serious bacterial infections occur in the marine phase, where one can imagine possible involvment of climate change and rising sea temperatures. However, historical records along the Norwegian coast show that such parameters have remained relatively stable over the past 10 years. A more obvious connection can then perhaps be found in how today's sea-based salmon farming is practised. Farming operations are constantly being intensified and, not least, non-medicinal delousing methodology has become increasingly widespread and more frequently used since their introduction around 2015. Several of the most commonly used treatment methods can cause significant physical damage and high levels of stress in the salmon both before, during and after the treatment. In recent years, the annual survey of fish health personnel reveals that mechanical damage during delousing is considered one of the most important causes of mortality and reduced welfare in Norwegian food fish production. Clinical histories from diagnostic cases received at the Veterinary Institute further show that bacterial disease outbreaks occur relatively often 2-3 weeks following such treatment or other stress-related event. Another factor that may play a role is increasing intensification in production of hatchery fish on land. Large RAS facilities with year-round production of smolts have been considered as possible contributors due to the risk of smolt being released into the sea at cold temperatures.

The epidemiological triangle is a well-known concept that recognizes that infectious disease occurs as a result of an 'overlap' between the infectious agent (for example bacteria), the host (for example salmon) and the environment (for example a farming cage). The balance in this interaction, and thus the risk of disease, can shift if one or more of these factors undergo change. Bacteria can, for example, acquire new properties that make them more dangerous to the host, or they may become more numerous due to favourable environmental conditions, thereby raising infection pressure. On the other hand, weaknesses in the host, for example due to a harmful or stressful environment, can make the host more susceptible to diseases that would otherwise not develop in healthy individuals. There is now much evidence that stress-activated excretion of bacteria from healthy carriers can help explain several of the large outbreaks of yersiniosis experienced in recent years, late in the marine phase in central Norway. Given that the *Y. ruckeri* strain that causes these outbreaks has been widespread along almost the entire Norwegian coast for several decades, it appears very likely that such healthy carriers must also have been present in the sea for many years without outbreak of yersiniosis.

In summary, the increase in problems related to bacterial disease in sea-based salmon farming over the (roughly speaking) past decade, has occurred in parallel with continual intensification of the farming industry and the introduction of potentially stressful and harmful

Sampling. Photo: Eivind Senneset

delousing methods, which are also associated with high fish densities. It is likely that the accumulated number of repeated, external stress factors to which today's farmed salmon in the sea are exposed may have shifted the balance within the epidemiological triangle in favor of an increased occurrence of bacterial diseases.

Chapter 3.2 Antibiotic consumption shows that antibiotic use in Norwegian salmon farming is still very low. The Norwegian farming industry has so far been "lucky" in relation to bacterial infections. Today's operating systems, with significant physical and physiological stresses on the fish, are a challenge to this favorable situation.

3.5 Viral infections - fight the virus or the disease?

Sustainable development of aquaculture depends on production of fish with a minimum risk of disease outbreak and spread of infection. In recent years, the most commonly diagnosed viral diseases in Norwegian aquaculture have been cardiomyopathy syndrome (CMS), heart and skeletal muscle inflammation (HSMI) and pancreas disease (PD). In addition, infectious salmon anemia (ISA) has shown an increase from between 10 to 15 annual diagnoses, to 23 and 25 detections respectively in 2020 and 2021. For 2022, however, there is a slight decrease in the number of diagnoses of the above-mentioned viral diseases, see Chapters 5.1 – 5.5 . Two of these viral diseases are listed and notifiable: ISA (category C) and PD (category F).

In 2007, legislation was introduced to limit the spread of PD (Chapter 5.1 Pancreas disease (PD)). Stricter legislation (regulation 2017-08-29 no. 1318) and improved compliance from 2017 onwards probably helped contain PD within the PD zone (Jæren in the south to Skjemta in Flatanger in the north). The rest of the coast is PD free and forms two surveillance zones that extend from the borders of the PD zone to the Swedish and Russian borders respectively. PD legislation requires monthly screening for PD virus in sea farms holding salmon, and this has almost certainly increased our knowledge of the disease and the risk of infection.

ISA

ISA is described in more detail in Chapter 5.2 Infectious salmon anemia (ISA). There are two variants of the ISA virus; non-virulent ISA virus (ISAV HPR0) and virulent, pathogenic ISA virus (ISAV HPRΔ). It has been shown that ISAV HPRΔ develops from ISAV HPR0, but knowledge of the probability of ISAV HPR0 developing into ISAV HPRΔ is lacking. Epidemiological data, however, suggests that a small proportion of ISAV HPR0 infections lead to development of ISAV HPRΔ, and that isolated ISA outbreaks can be linked to inadequate biosecurity routines and stress.

Since 2019, a relatively small-scale monitoring program for ISAV HPR0 has been carried out in juvenile production units under the auspices of the Norwegian Food Safety Authority. Farms utilising RAS technology appear somewhat overrepresented among ISAV HPR0 positive farms. ISAV HPR0 has also been detected in fish with no apparent seawater contact. Maintenance of biosecurity between different production departments in modern fish hatcheries is challenging, and introduction of HPR0 can easily contaminate the entire facility. It is reasonable to assume that the more opportunities the virus is given to replicate, the greater the chance of development of mutant variants. Phylogenetic studies of virus strains from 2021 and 2022 identified probable links between juvenile production unit and sea-farm in several cases.

The World Organization for Animal Health (WOAH) has listed both ISAV HPRΔ and ISAV HPR0, and both variants are therefore notifiable in the WOAH system. ISAV HPR0 is, however, not notifiable in Norway or the EU, and detection of ISAV HPR0 is consequently not reported to WOAH (or other body) from the world's largest salmon-producing country.

In relation to animal health legislation, a future management strategy for ISA in Norway is under preparation. The Norwegian Veterinary Institute wrote in its consultation response that ISA must be controlled via a public control programme, including surveillance of HPR0. Consideration should be given to making ILAV HPR0 notifiable, but without administrative consequences. This would be possible by listing ISAV HPR0 in "category G", according to the new "Animal Health Legislation". This would provide an improved overview of the ISAV HPR0 situation in the Norwegian farming industry, while at the same time would not entail significant losses for the industry. The ISA epidemics that have previously affected Norway, the Faroe Islands and Chile illustrate how serious the situation can become if ISA is not controlled. A starting point for improving the current situation could be to demand that all production of salmon broodstock in the sea be stopped and that sea-transferred smolts must be HPR0-free.

Vaccination

Vaccination is one of the most important preventive measures to combat disease. The effectiveness of vaccines against viral diseases compared to that achieved against most bacterial infections has been debated. Several commercial vaccines are marketed against PD, one against ISA, but none against CMS or HSMI in Norway. Most commercial vaccines on the market are documented to reduce mortality, severity of disease and clinical signs. There are several factors that influence the degree of vaccine effect between and within a population (Chapter 9.6 Vaccine effect and side effects).

Vaccinated fish very rarely achieve "sterile" immunity, i.e. the fish can be infected by the infectious agent in question, without necessarily developing clinical disease. In infected vaccinated fish, detection of the virus can be challenging, and it may be necessary to examine a large number of fish with sensitive methodology, for example PCR, to detect infection within a facility. A recently concluded field study with ISA-vaccinated fish in northern Norway showed that vaccinated fish, which had ISA diagnosed relatively shortly after vaccination, did not develop severe disease, but continued to excrete ISA virus. The proportion of fish positive for the virus was low, so it is not unreasonable to assume that virus excretion would have been higher if the fish had been unvaccinated or clinically ill.

Mild clinical signs can mean that viral diseases are not diagnosed (underdiagnosed). This can result in farms with apparently healthy but infected fish, secreting virus over a considerable period. Since ISA is a disease that develops slowly, it is particularly worrying that such fish may be transported and possibly held in 'waiting cages' before harvest, without knowledge of the ongoing ISA infection. This can contribute to the camouflaged spread and creation of endemic environmental ISA reservoirs and increase in recurring ISA problems in the long term. If vaccination is to be actively included in the ISA control program, there will be a need for more knowledge of the effect of the ISA vaccine and the possible effect on virus evolution and shedding in infected individuals. For various reasons, fish can be transferred to sea before the recommended number of post-vaccination degree-days has been achieved. In such cases, vaccination can provide false security as the fish group may not have achieved the expected protection.

Disinfection

Disinfection plays an important role in combating viral diseases at all stages of production. Disinfection of intake water into hatcheries is obligatory, but despite the fact that Water Treatment Legislation allows establishment of requirements for disinfection of waste water from hatcheries and land-based facilities, this has not been done. Hatchery facilities with, for example, ongoing ISAV HPR0 infection, in contact zones with sea-farms, can contribute to horizontal infection, both short- and long-term. Knowledge building and risk assessment around whether untreated waste water can be linked to infection and outbreaks in nearby sea-farms is important. Treatment of both intake and waste water in well boats is obligatory during transport of fish to be released in the sea, delousing and transport to harvest facilities. Control of well boat traffic, disinfection and discharge of the well-water are important infection control measures.

Cleaning and disinfection procedure for well-boats and well-boat equipment are a critical control points in risk management. Photo: Colourbox

3.6 Threats to wild fish populations

In the autumn of 2022, Skibotnelva, Signaldalselva and Kitdalselva were finally declared free of *Gyrodactylus salaris*, 43 years after the parasite was introduced to this region. After these watercourses were declared free, only eight of the original 51 infected watercourses remain infected. Norway has invested large sums of money to combat this deadly parasite in wild Atlantic salmon. The fact that so many waterways in Norway are now free of G. salaris following treatment confirms that the strategy has so far been successful, and that the danger of further spread of the parasite within Norway is significantly reduced.

However, the situation on the Russian side of the border raises concerns. The presence of G. salaris has long been recognised in rivers that drain into the White Sea, but has now quite recently also been detected in two rivers and in several breeding facilities for rainbow trout on the Kola Peninsula, close to the border with Norway. The Veterinary Institute, as a reference laboratory for WOAH, has helped document this situation in close cooperation with Russian researchers and veterinary authorities. After Russia's invasion of Ukraine, contact between Russian academic circles and the Veterinary Institute is currently at a minimum. The situation thus places strict demands both on general vigilance and on active monitoring of the infection situation in the northern areas of Norway. An introduction of G. salaris from Russia would be an extremely negative event.

In 2022, it became known that blocks of ice used to design the ice hotel in Troms county were imported from a G. salaris infected Finnish watercourse. The probability of transmission of G. salaris via the ice blocks to Norway was assessed as low, but the consequences of such an event were assessed as very serious. The status of occurrence of other fish pathogens and alien species in this area of Finland is largely unknown. Finland has a different status with respect to Flavobacterium psychrophilum infection in rainbow trout, infectious haemorrhagic septicemia virus (IHN), crayfish plague and classic furunculosis than Norway, and the import of frozen water is a relevant route of infection for these infectious agents.

The summer and autumn of 2022 gave a foretaste of how climate change, water shortages and the power crisis can affect wild salmon stocks. Classic vibriosis caused mortality in salmon in rivers in the inner Oslo-fjord in late summer. Outbreaks of this disease in wild marine fish at high seawater temperatures in late summer are well known. In farming, this infection is controlled by vaccination. In affected rivers with low water levels, the salmon may concentrate outside the river mouth. Under such conditions, infection is promoted from reservoirs in the marine environment to wild salmon, but also between infected and susceptible salmon.

The fungal disease saprolegniosis contributed to several outbreaks in watercourses with subsequent severe mortality amongst spawning populations in the autumn of 2022. Salmon, sea trout and stationary trout were affected, and the circumstances surrounding the outbreaks made clear the importance of a well balanced interaction between host, agent and environment. Sexually mature fish, and particularly male fish, have reduced immune defences and engage in behavior that makes them more susceptible to close contact with rivals and subsequent injury. In all outbreaks in 2021 and 2022, Saprolegnia parasitica, the most pathogenic species in the saprolegnia family, was detected, and in all affected watercourses there were environmental conditions that complicated the disease picture. In particular, we saw how low water levels, low water flow and low water exchange resulted in concentration of fish stocks. This, combined with higher temperatures, becomes a "certain" driver of disease and high mortality. Diagnostic investigations at the Veterinary Institute are based on submitted material and no serious listed diseases were uncovered in these outbreaks.

In the course of the year, systemic infection with a protozoan in the family Ichtyophonus sp. was identified in humpback salmon. Humpback salmon is an alien species in Norwegian waters, has a generally unknown infection status, and can carry infection between waterways. 2023 is another 'humpback salmon year' and it is expected that the number of invading humpback salmon will increase compared to the previous year. It therefore becomes extra important to implement planned measures that can effectively prevent humpback salmon from entering rivers, while at the same time not preventing upward migration of native salmonids. Humpback salmon can also pose an infection risk to salmon farming along our coast.

Research into infection and disease in wild fish is technically and resource-demanding. There is currently no ongoing research that adequately addresses the most important research questions under this theme. The activities in progress are largely PCR-based mapping of the occurrence of various infectious agents in wild salmon, without associated in-depth pathophysiological or epidemiological analyses.

Fry release in Rauma. Photo: Kristin Bøe

4. Fish welfare

By Kristine Gismervik, Ewa Harasimczuk, Kristoffer Vale Nielsen, Leif C. Stige, Lars Qviller, Brit Tørud and Cecilie M. Mejdell

The Animal Welfare Act (DVL) states that animals, including farmed fish, must be provided with a living environment and husbandry that ensures good welfare throughout their life cycle. The law applies equally to all farmed fish, including lumpfish and wrasse species used as cleaner-fish for removal of salmon lice. Capture of fish must also be performed in a manner resulting in acceptable animal welfare (DVL § 20).

Animal welfare can be evaluated based on 1) the animal's biological function, with good health and normal development, 2) the animal's affective state, i.e. an emphasis on emotions such as fear and pain and 3) natural living, i.e. the ability to express natural behaviours. When animal welfare is measured, these different approaches should be considered. Different definitions of animal-welfare exist, which are based on one or more of these schools of thought. In the list of terminology used in the 'Standard for methods and production of salmon and rainbow trout NS 9417:2022', the term animal welfare is stated as "quality of life as perceived by the animal itself". Examples of positive experiences include safety and satiety, and examples of negative experiences include pain, hunger and fear. Another widely used definition of animal welfare is "the individual's mental and physical state while coping with its environment". Regardless of the definition used, you cannot ask the fish what it experiences and how it feels. Instead, welfare indicators are used to obtain information about the fish's likely perceived quality of life. Good health is a prerequisite for good welfare. Both intensity and duration of pain and discomfort are important when animal welfare is to be assessed. That the fish survive is no guarantee that welfare is good. In practice, fish welfare will be affected by a combination of various factors such as disease, environmental conditions, nutrition and management routines including handling.

It is important that attitudes and wording, both in legislation and in everyday speech contribute to increasing awareness that fish are animals, and that they can experience good and bad welfare. A comparison of legislation relating to the keeping of farmed fish and chickens respectively, shows the use of fewer positively charged words regarding the welfare of farmed salmon. In the mission statement of the operation of aquaculture facilities regulation the, financial goals (profitability, competitiveness, value creation) are the primary purposes listed. Promotion of fish health and welfare starts with "The purpose is also", which gives the impression that this is an additional/secondary objective. This may further give the impression that economics should be emphasized over health and welfare, although the Animal Welfare Act has no dispensation provision. The purpose of the legislation relating to cattle and pigs as far back as 1992 was "to facilitate the good health and well-being of production animals (hereafter referred to as animals) and to ensure that the animals' natural needs are taken into account" (FOR-1992-10-18-779). Such differences and different use of terms can affect the reader, and how the legislation is interpreted. It has been 20 years since the last Norwegian governmental report on animal welfare was published, and a new updated report has been announced for 2024. It is therefore important to ensure that our knowledge-base is continually updated and that current attitudes towards animal welfare are made visible in legislation, public administration and in concrete action plans for improvement of fish welfare.

The Norwegian Animal Welfare Act, § 3, states that animals have an intrinsic value regardless of their utility value for humans. Fish health personnel, research institutions and the public authorities have a particular responsibility to work towards better fish welfare, to disseminate knowledge and to promote good attitudes towards fish both in the industry and in the general population.

4.1 Welfare indicators

Welfare indicators are often divided into environment-based, i.e. measurement of parameters in the fish's environment such as water quality, and animal-based, where parameters related to the fish itself is/are measured. The animal-based parameters can be group-based, such as mortality or schooling behaviour, or 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 of biological variation, threshhold values and identification of suitable parameters that indicate that the fish experience their own welfare as good. Good fish welfare is more than the absence of poor welfare. The ethical norm for what is accepted as a good enough welfare level develops as we gain more knowledge and better assessment methods of how the fish are thriving.

Operational welfare indicators are indicators that can be used during daily operations in commercial fish production. The LAKSVEL project (FHF-901554), published in 2022 a practical protocol for routine welfare monitoring of salmon in Norwegian ongrowing fish farms. It is intended as a framework for daily/regular monitoring of fish health and welfare. Table 4.1.1. shows which indicators were included. A more detailed description, including a scoring sheet and pictorial guide can be found in Nilsson et. al., 2022.

Mortality is perhaps the most reported and utilised welfare indicator (Chapter 2 Mortality in salmon production). At the same time, in the absence of additional information, this indicator says little about the 'load' the fish were exposed to before they died and the likelihood of repeated mortality. Dead fish categorization is a way of indicating probable cause of death. 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 traumas", "D: Physiological causes", "E: Other causes" and "F: Undetermined". The main categories A – E are further divided into various subcategories with specification of cause of death. In 2021, a collaboration was initiated between The Norwegian Seafood Federation, AquaCloud and the Veterinary Institute to produce guidelines and establish a reporting system for cause of death.

4.2 Fish welfare and fish health: legislation and public management

In order for legislation and public management related to fish welfare and health to work as intended, it is important to have a common factual basis built on appropriate data and statistics. On a European scale, Norway has a good foundation for improvement of animal

Table 4.1.1. Welfare indicators in the Laksvel project

Laksvel operative welfare indicators (OVIs)			
Environmental based	Animal based		
	Group based	Individual based	
Oxygen	Behaviour	First impressions	Maxillary lesions
Temperature	Appetite	Skeletal deformity	Jaw deformity
Salinity	Mortality	Emaciation	Cataract
		Sexual maturation	Eye injury
		Scale loss	Opercula
		Skin haemorrhage	Gill status
		ulceration	Fin status

Table 4.2.1 Examples of areas of authority in current legislation, reporting and organisation/resources, with identified risks and proposals for risk-reducing measures for farmed fish

Area	Risk factor	Effect on welfare	Risk reduction
Legislation/ Public management	Animal welfare fish: Not clearly defined/prioritised Non-listed diseases: Poor national statistics Regulation of expansion/technology development: clear welfare targets lacking Little systematized welfare documentation of (new) technology Few control campaigns related to fish welfare	High mortality, suffering, improvement poorly managed Disorders caused by non-notifiable diseases Non-medicinal Delousing: mortality/suffering Large number of welfare related events, complex, unclear cause	Ensure a clear Norwegian animal welfare legislation: easily read, simple to understand and find, for both public servants and animal owners Introduce compulsory reporting for more welfare-related and loss-causing diseases. Can result in better public management follow up and improved prevention measures. Include the animal welfare act as legal basis for further legislation related to health and welfare, to ensure actively use. Amend the mission statement in the aquaculture operation regulation and review wording and attitudes for an increased focus on fish welfare. Specify welfare goals, e.g. animal welfare program requirements Clarify welfare goals before expansion is permitted in the Traffic Light System Clear welfare goals defined regarding development and availability of welfare documentation related to new technology
Reporting to public authorities	Traceability lacking in dataregarding movement of fish, important for detailing national statistics Outdated reporting forms	Difficult to identify cause and risk factors for poor welfare Fragmented data, limited suitability for directed supervision and research	Fish-ID, from egg to slaughter can ensure research over the complete chain Report mortality at the group level (not only tank or cage level) Greater detail in reporting forms: e.g. delousing method Sharing knowledge of causes and risk reduction through follow-up of welfare incidents Increased availability and active use of reported data
Public authority organisation/ resources	Fish welfare is given too low governmental priority Staffing too low to ensure fish welfare	Lack of policing by public authorities results in unreported poor practices Decisions made locally are overturned	Specify animal welfare measures in action plans, including resources for implementation and increased staffing. Ensure that the Norwegian Food Safety Authority has the independent professional capacity and expertise that a premise provider for the ministry and the political environment should have. New animal welfare report, ensuring commitments.... Cases of poor fish welfare should be given higher priority by the police, to force a change in attitude.

welfare in the aquaculture industry, both due to the existence of consensus based statistics and good cooperation between industry and the public authorities. There is, however, potential for improvement in the legislation, reporting by the industry to the authorities and organisation/resource use within the public authorities (Table 4.2.1). It is equally important to retain what is good in the Norwegian Animal Welfare Act, e.g. clear language and ease of reading without too many references (not apparent in EU legislation). It will be natural to review points for improvement in the upcoming governmental report on animal welfare in agriculture, in pets and in fish farming, which should be completed in 2024.

The NFD has established a reference group consisting of the Veterinary Institute, the Norwegian Institute of Marine Research, the Norwegian Food Safety Authority and the Directorate of Fisheries, which will provide input on special matters concerning fish and marine mammals.

The previous government report, written 20 years ago, contained good proposals that have not been implemented/prioritised, including establishment of a 3R center (Chapter 4.5 Welfare challenges in experimental fish). It is important that the report proposes concrete measures, and recommends sufficient resources to implement these measures. Improved data quality and data flow, which can promote more active use of reported data, will contribute to a better national overview of the welfare and disease situation for the public authorities, researchers and industry. In addition, there is a need for more detailed reporting of, for example, the use of delousing technologies, and a unified fish-group ID system that makes it possible to follow the fish from egg to slaughter. Indicators for fish welfare and health must be given higher priority by the public authorities. This is needed to compliment other control systems for growth/development in the farming industry such as the Traffic Light System, which otherwise contributes unfortunately to negative welfare development (Chapter 4.3 Welfare consequences of the Traffic Light System). Systems must be established that reward those who invest in good fish welfare.

A better knowledge-base, based on reporting to the authorities will increase the ability to understand the complex relationships between fish welfare and health. There is great potential for use of reports made to the public authorities more systematically as governmental-based operational welfare indicators (GOWIs). Examples could be: Mortality/emergency slaughter, incidence of disease, delousing operations, use of cleaner-fish, welfare incidents, slaughter quality, regulatory breaches, silage (tonnes), experimental animal reporting.

For salmon farmed in the marine phase, various diseases and welfare problems vary with geography. This is illustrated in Figure 4.2.1, based on this year's survey. However, the trends shown here must be interpreted cautiously, partly because some replies to the survey had to be omitted as the respondent could not be placed in specified production areas. Nevertheless, the figures illustrate that diseases and welfare problems that are prominent in some areas are not so important in others. It is worth noting that it is mainly non-notifiable diseases that are considered most important in relation to reduced welfare and mortality. Pasteurellosis, for example, is a problem in the southernmost areas. Gill disease is and has been problematic in the southernmost areas, but in 2022 gill disease has also become prominent in mid-Norway (PO6-PO9). This is worrying, and together with mechanical damage associated with delousing treatment and ulcer-causing bacteria such as *Moritella viscosa,* has a negative impact on fish welfare. Relative to other diseases, CMS problems have apparently reduced somewhat in mid-Norway, and increased in the south (Chapter 5.5 Cardiomyopathy syndrome, CMS). In the northernmost areas, we still see that mechanical damage during delousing is the greatest concern, as well as infection with *Moritella viscosa* and *Tenacibaculum*, which cause classical and atypical winter-ulcer respectively.

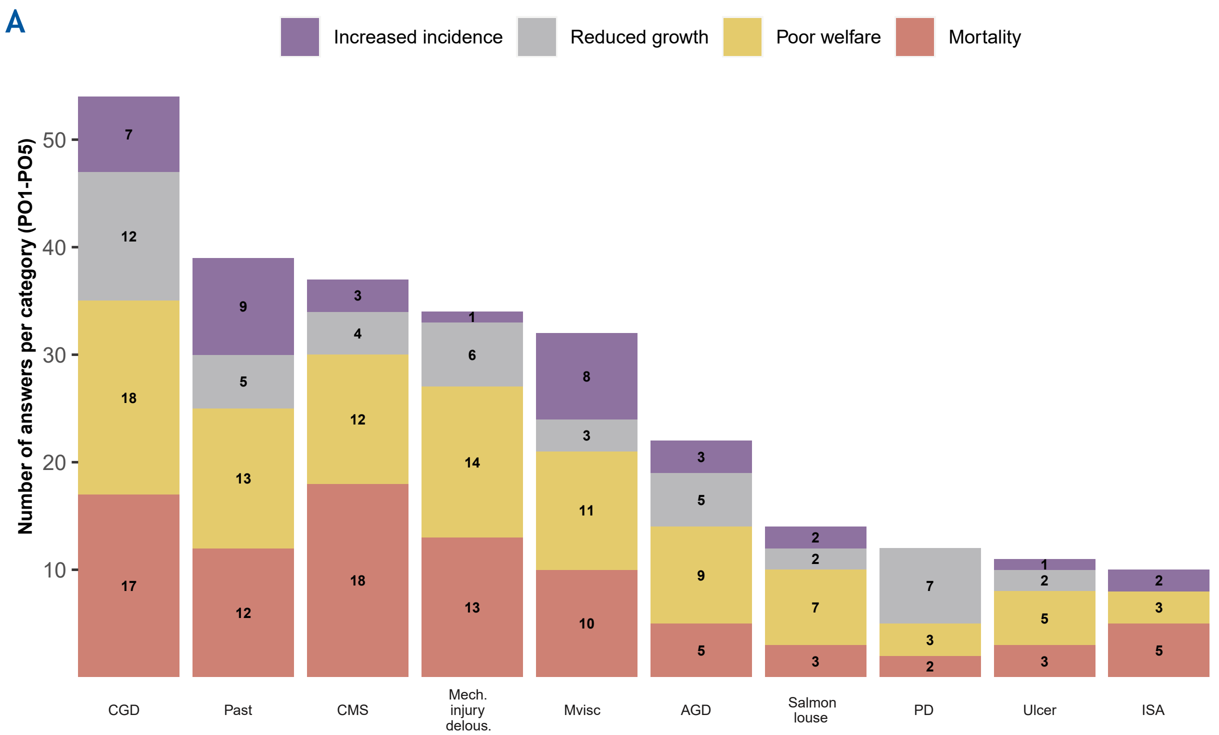
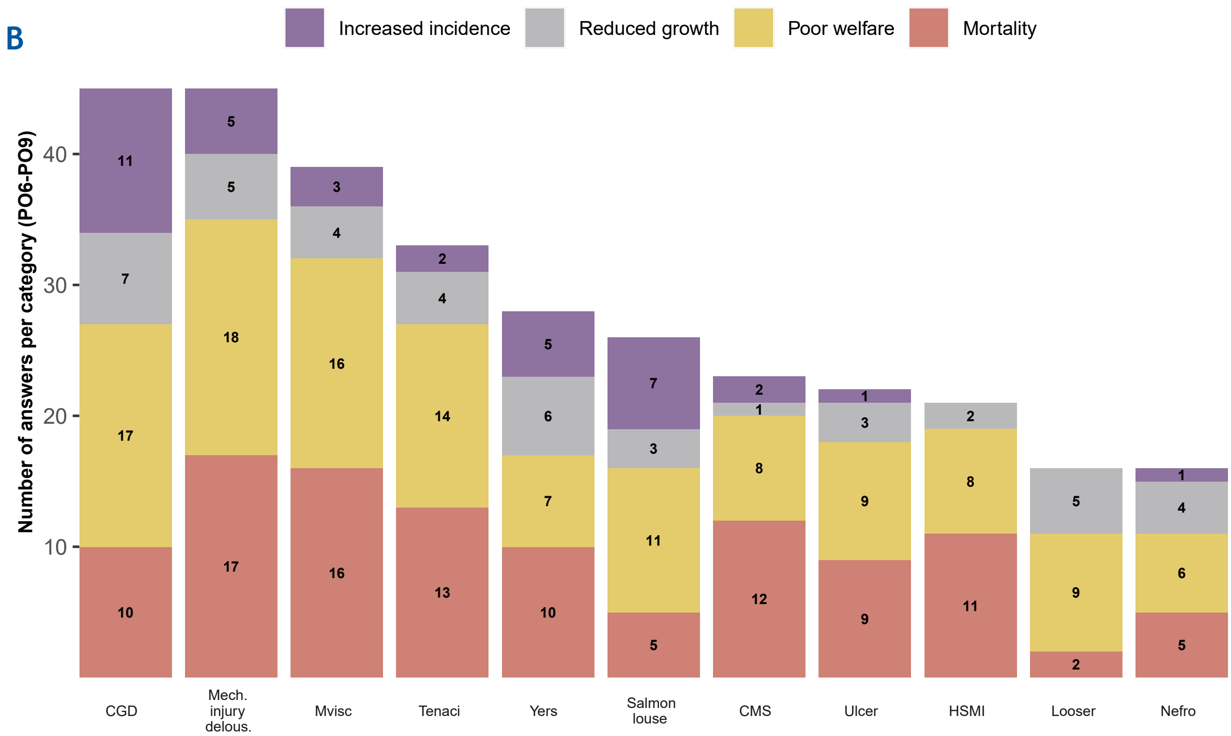


Figure 4.2.1 The ten diseases or welfare problems in ongrowing farms for salmon that received the most crosses for the combined production areas PO1-PO5 (N=20), PO6-PO9 (N=24) and PO10-PO13 (N=10). N= number of respondents, i.e. fish health personnel and inspectors of the Norwegian Food Safety Authority. 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.



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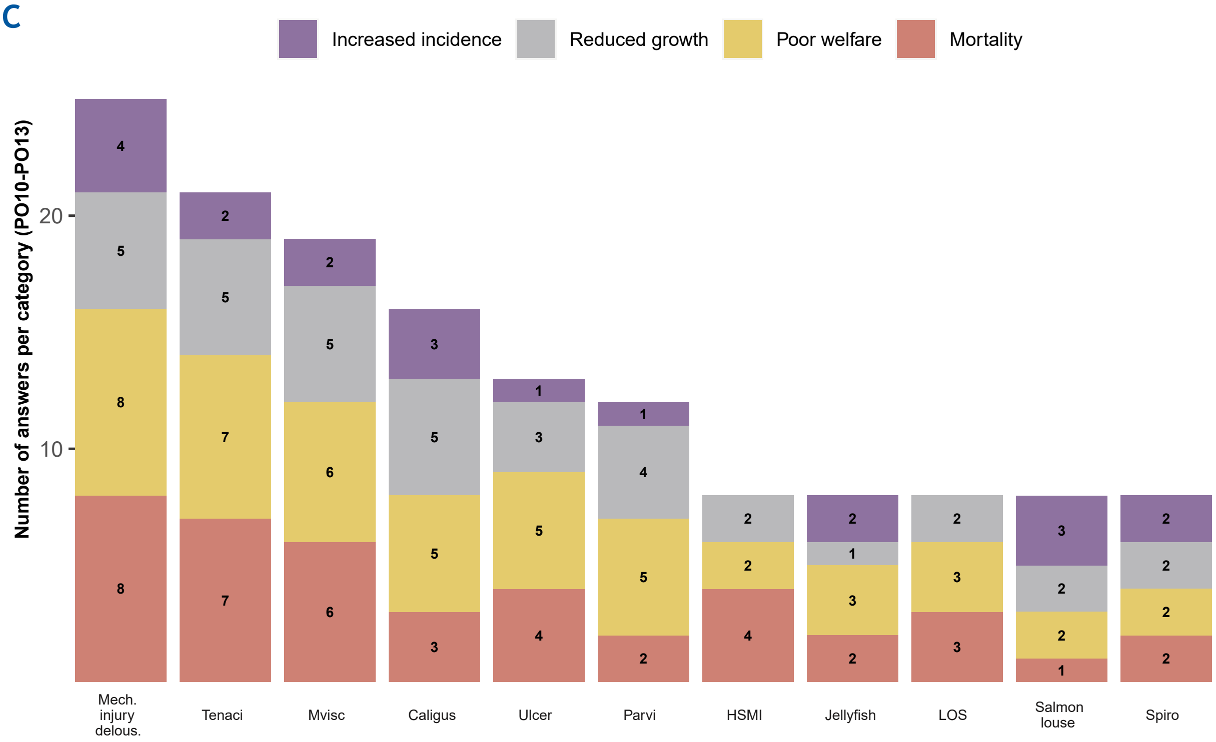


4.3 Welfare consequences of the Traffic Light System

The Traffic Light System of regulating the fish-farming industry was established to provide predictable and sustainable growth. Currently, the sole sustainability indicator is estimated mortality in migrating wild salmon smolts as a result of salmon lice infestation. See further discussion of the Traffic Light System in Chapter 10.4 Salmon lice and sustainability. Production areas experiencing less than 10 percent estimated salmon louse-induced mortality are defined as low risk, 10-30 percent as moderate, and over 30 percent as high risk. An appointed expert group assesses salmon louse-induced mortality every year.

Every other year, on the basis of the expert group's assessments of salmon louse-induced mortality, the steering group's assessments and recommendations, and other relevant societal parameters, the Ministry of Trade, Industry and Fisheries awards a colour for each production area. Red production areas must reduce production, yellow areas remain at present production levels, while green areas can increase production. In addition, Section 12 of the Production Area Regulations allows for departure from these rules under exceptional circumstances. Farmers who apply for and are granted an increase in production capacity are exempted from reduction in red areas or are permitted to expand in yellow areas. The conditions for exceptional growth are, amongst other factors, that the locality has less than 0.1 adult female louse per fish in the period from and including week 13 to week 39, and that a maximum of one medicinal delousing has been carried out during the last production cycle (FOR-2017- 01-16-61). Exceptional growth was originally intended for new forms of operation/technologies that could document lower spread of parasites and disease (Meld. St. 16, 2014-2015), but has not been practiced in this manner to date. For a summary of traffic light colours and trends in treatment against salmon lice, medicated and unmedicated, as well as biomass per production area, see Figure 4.3.1.

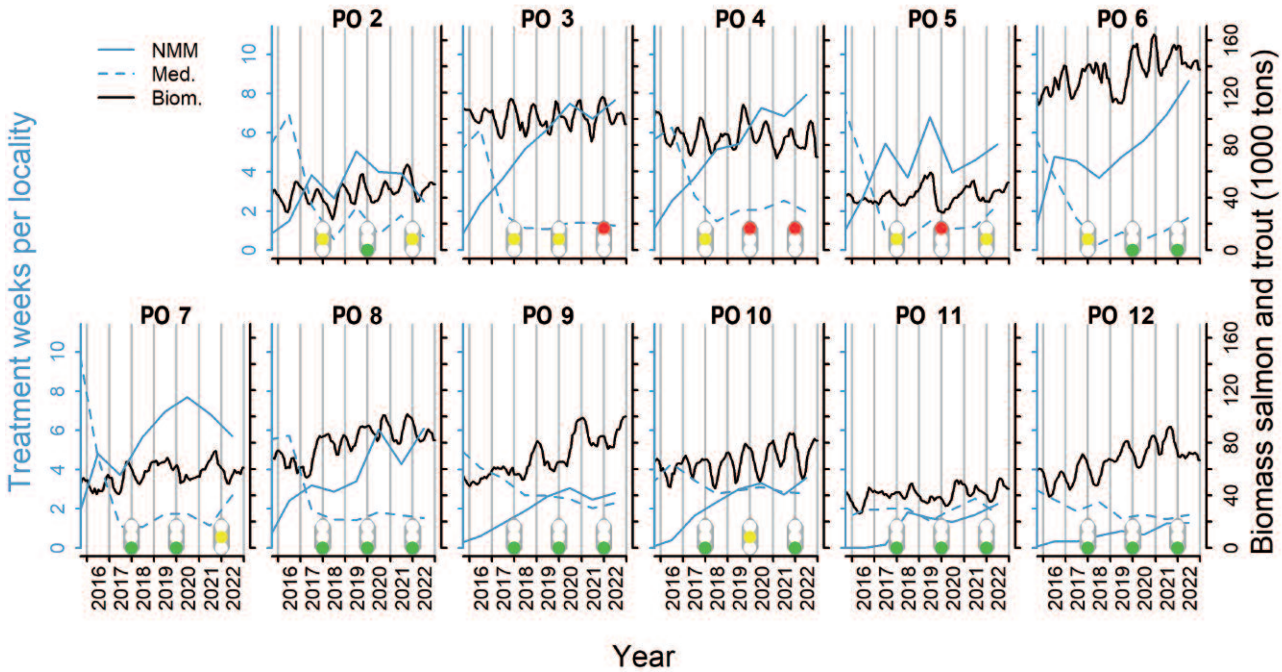


Figure 4.3.1 Chronological trends in salmon lice treatment and biomass of farmed fish in each production area (PO) from 2016 to 2022. The blue solid lines show the number of weeks of non-medicinal delousing (IMM) reported to the Norwegian Food Safety Authority, and the blue dashed lines show weeks of 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 PO3 and PO4 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. PO1 and PO13 are not shown because there were few farms in operation.

From a welfare perspective, the Traffic Light System as practiced today is problematic. The system is set up so that over time the industry grows from green to yellow in all areas, which means 10-30% salmon louse-induced mortality in wild salmon smolts. For wild salmon smolts, this has major welfare consequences. In addition, wild arctic char or sea trout are not included, despite the fact that these species are more stationary than wild salmon, and are severely affected by salmon lice (Chapter 10.4 Salmon lice and sustainability). For farmed fish, high louse-pressure will also have major welfare consequences due, amongst other factors, to the handling procedures associated with non-medicinal delousing (Chapter 4.7 Welfare challenges linked to salmon lice, with the main emphasis on thermal and mechanical delousing). Localities that are granted exceptional growth currently have no limit on the number of non-medicinal delousing treatments.

A review of facilities that have been granted exceptional growth in 2019 and 2021/2022 showed that several have a high number of non-medicinal delousing weeks per year (Figure 4.3.2). This may partly be due to many weeks of single cage treatments. Nevertheless, 37 localities that received exceptional growth in 2021 reported approximately 60 welfare-related incidents the previous year, most of which were related to non-medicinal delousing. Several localities that were awarded exceptional growth also had high mortality in the previous production cycle (Figure 4.3.3).

This shows the need for better safeguarding of fish health and welfare when growth is allocated or exceptions are granted. Requirements related to health and welfare at the locality level, including survival, should be considered before any growth/exceptional expansion is granted. This is to avoid the potential for rewarding poor welfare with growth. Restricting the extent of exceptional growth in general e.g. to new modes of operation/technologies as intended, is another possibility. Limiting the number of non-medicinal delousing treatments is also important, as there is a lack of knowledge of how the total number of treatments, other handling operations and inter-treatment intervals, affect the fish. Knowledge of the negative effects of non-medicinal delousing is increasing. For example, research carried out at the Veterinary Institute shows that non-medicinal methods result in a five to six-fold increase in mortality, as well as reduced growth compared to medicinal delousing.

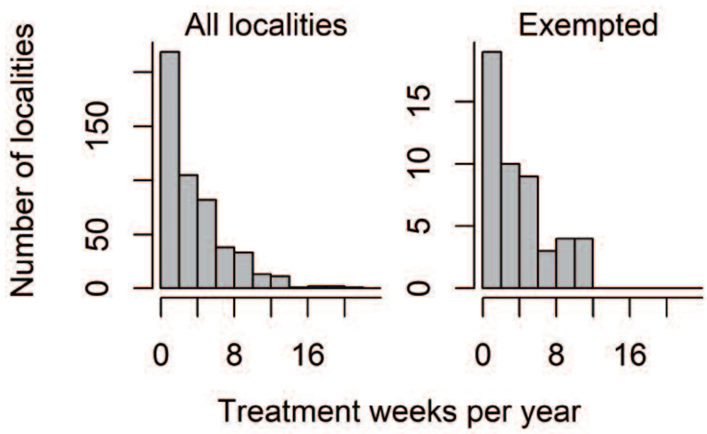


Figure 4.3.2 Total number of treatment weeks per year for all farms (figure on the left) compared with farms that were allocated exceptional growth in 2019 and 2021/2022 (figure on the right). The x-axis shows the number of weeks of non-medicinal delousing reported to the Norwegian Food Safety Authority per year, and the y-axis the number of farms. Only farms in PO3 and PO4 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 (April 2019 and March 2021) for farms with exceptional growth and comparable calendar years for all locations (2017 and 2019).

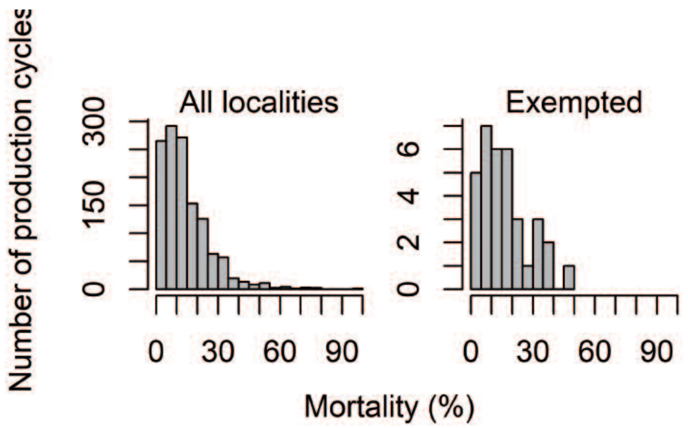


Figure 4.3.3. Mortality in all localities in PO3 and PO4 (figure on the left), compared with localities that were allocated exceptional growth in 2019 and 2021 in the same areas (figure on the right). Mortality is defined here as the proportion (%) of the fish that die between sea-transfer and slaughter, per generation at each location. The x-axis shows mortality per generation, while the y-axis shows the number of generations. The figure on the right includes all production cycles that were fully or partially included in the period that were the basis for the decision on exceptional growth.

4.4 Welfare challenges and new technologies

It is stipulated by law that all technology must be documented as being sound in terms of welfare before it is used (Section 8 of the Animal Welfare Act and Section 20 of the Aquaculture Act). This provision has been in force for a number of years and is repeated in several special regulations regarding aquaculture animals.

When commercializing new technology and methods, both the farmer and manufacturer have a responsibility to update manuals and optimise equipment as new knowledge is generated. It is therefore important that suppliers of machinery secure access to data regarding practical use of the equipment, so that updated knowledge can actually be generated. In some cases, it is a challenge that documentation is not generally available and/or that the documentation does not have sufficient scientific quality.

Much of the technological development in recent years is related to the louse problem, e.g. technology for automatic louse counting, prevention of louse infestation and treatment against lice. In addition, there have been large development projects on farming in more exposed offshore areas. Projects are now underway to facilitate the establishment of offshore aquaculture. Such large units, exposed to strong natural forces, may contribute to a markedly extended response time for the killing/slaughter of fish in the event of, for example, an outbreak of disease. This will lead to greater suffering for the animals that die as a result, with sick or weak fish pressed into the wall of the net. Such developments require the use of experimental fish (Chapter 4.5 Welfare challenges for experimental fish).

All technology development must be followed by step-by-step welfare documentation. It is important to assess whether the method/technology is appropriate for each step (see Figure 2 in the Norwegian Food Safety Authority's Guide on fish welfare when developing and using technology, June 2020).

In 2022, the Norwegian Food Safety Authority received notification of the testing of new technology, in accordance with Section 20 of the Aquaculture Act. The notification concerned (the number of cases in brackets): Automatic counting and weighing (1), delousing methods (7), Land-based facilities – cleaner-fish (1), feeding technology (2), sea-farms – salmonids (4) and land-based farms - salmonids (3). Applications according to experimental animal legislation are not included.

In this year's survey, there were a few free text comments that can be linked to the use of new and/or advanced technologies. There was input that new equipment should not only be approved in terms of fish welfare, but also in terms of biosecurity. It is important that equipment can be satisfactorily cleaned and disinfected. Another respondent believed that there is still room for improvement of existing equipment for non-medicinal delousing, both in terms of fish welfare and efficiency.

Welfare-related incidents reported by the industry to the Norwegian Food Safety Authority reflect that technology is in many cases a contributing factor to negative fish welfare. There are many examples in the categories of vaccination, pumping, handling and delousing. This can be due to equipment design, faults in the equipment, incorrect use or insufficient follow-up, or a combination.

4.5 Welfare challenges for experimental fish

In 2021, over 2 million experimental animals were used in Norway, an increase of over 40 percent from 2020 (Table 4.5.1). Fish, mainly Atlantic salmon, made up 96 percent of these animals. The number of fish used in experiments varies from year to year, probably reflecting the challenges that the farming industry is facing. Norway's use of experimental animals corresponds to a fifth of the total number of experimental animals used in the entire EU. 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". Norway's high consumption can partly be explained by single trials that use a large number of individuals. In 2021, a single experiment was carried out that used just under 500,000 Atlantic salmon. Unfortunately, no decrease in the number of laboratory animals in Norway is expected. As a consequence of the establishment of offshore aquaculture, it is possible that both the number of experimental animals and experiments will increase in the years ahead. For comparison, in 2016, 10.6 million salmon were used in two large field trials in connection with delousing.

Table 4.5.1 Number and distribution of experimental animal use in Norway, from the Norwegian Food Safety Authority's annual reports on the use of experimental animals. For 2020, the figures have been revised in relation to the annual report due to correction of previous errors. The annual report (Food Safety Authority, use of animals in experiments) for 2022 is not available, therefore figures for 2021 are used.

Use of experimental animals		
Year	2020	2021
Number experimental animals	1 422 041	2 008 625
Fish	1 313 565	1 933 511
Salmon	840 678	1 697 816
Cleaner-fish	245 869	39 525

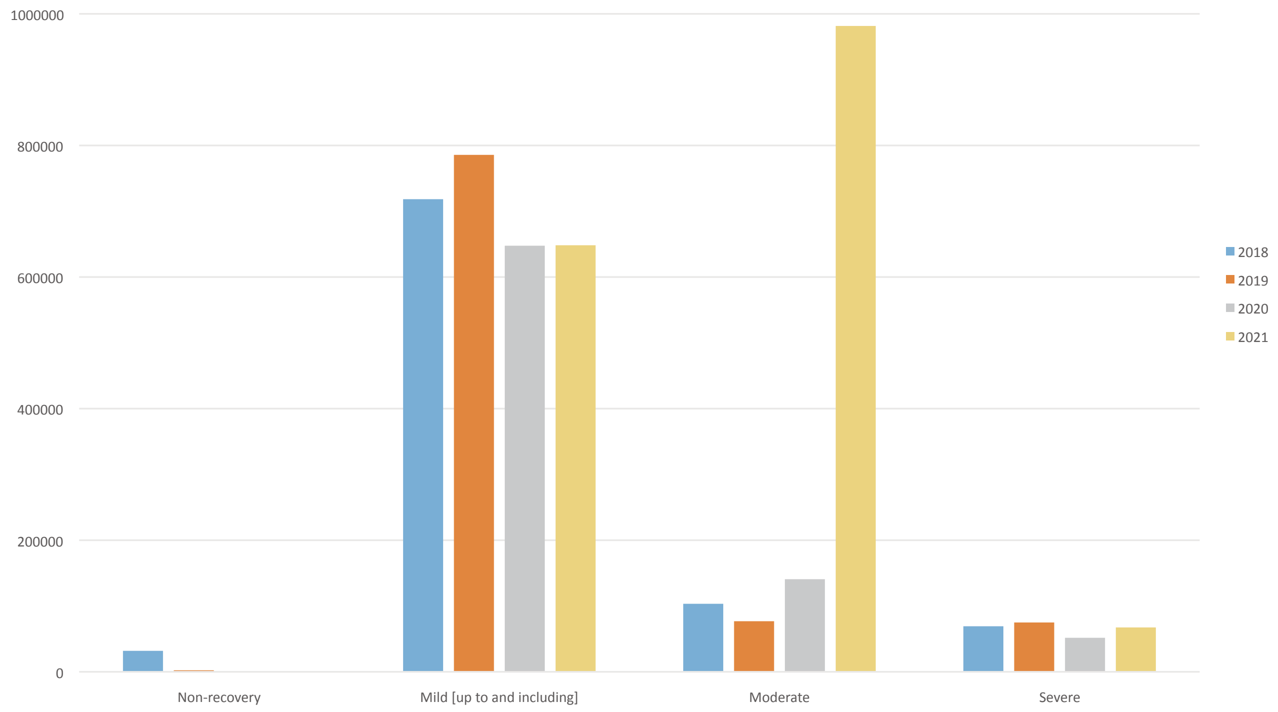


Figure 4.5.1 Number of Atlantic salmon that have been used in trials divided into the four discomfort levels, terminal, mild, moderate and significant from 2018 up to and including 2021 (Champetier A & Smith A, 2023).

Of the nearly 1.7 million salmon that were used in experiments in 2021, 77 percent were used in applied research, while species conservation work accounted for 19 percent (Figure 4.5.2). Whether marking of fish is defined as an experiment or not depends on the situation. For example, marking wild fish (including live gene banks) is defined as experimentation, while marking farmed fish as part of breeding work is exempt. This can partly explain the large number of experimental fish used in species conservation work. 96 percent of the experiments performed in species conservation work are in the "mild" category.

The severity to which experimental animals are subjected is divided into four categories: mild, moderate, severe and non-recovery. Experiments that are carried out exclusively under general anaesthesia, and where the animal will not regain consciousness, are classified as "non-recovery". 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 experimental infection and induction of a disease, is often very burdensome. Other trials involve milder levels of discomfort. Through a special grant from the Animal Welfare Alliance in 2022, Norecopa analyzed the use of laboratory animals in Norway from 2018 to 2021 (Champetier A & Smith A, 2023). This work showed that there has been a marked increase in the number of test fish in the 'moderate' categories compared to 'mild' in 2021 (Figure 4.5.1).

Regulations on the use of experimental animals promote the principle of the 3 R's i.e. "Replacment, Reduction, Refinement". Animal experiments which, as of today, cannot be replaced by alternative methodologies, 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 use of experimental animals (applies also to land animals), Norway still lacks a national 3R centre. This is in contrast to our Scandinavian neighbours and several other countries in Europe. Such a center can promote research into alternatives to animal testing and ensure that knowledge about animal testing is disseminated. Better sharing of knowledge, also negative results, will prevent animal experiments from being repeated unnecessarily.

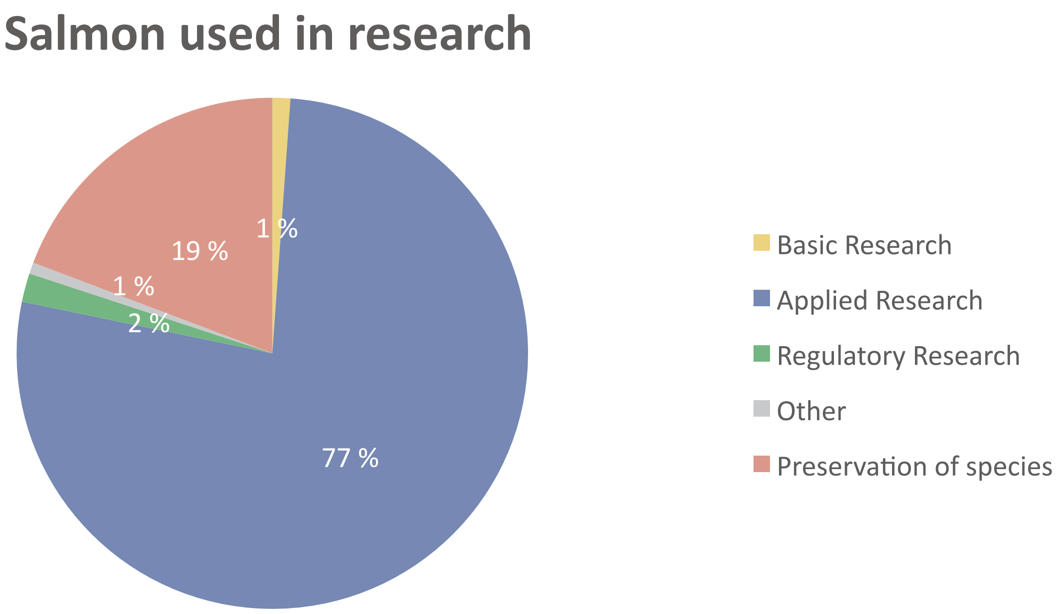


Figure 4.5.2 Percent-wise distribution of the type of experiment salmon have been used in for 2021. Data from the Norwegian Food Safety Authority, compiled by the Norwegian Veterinary Institute.

4.6 Welfare challenges in juvenile salmonid production

The operating conditions in hatcheries are important for the salmon's onward life and performance in the ongrowing phase. The rapid technological development in land-based facilities has not been followed up with correspondingly rapid knowledge building of the biological effects on the fish in the short and long term.

Egg-incubation comes before the fry phase. Egg-production is the domain of the breeding companies, and the 8 ℃ upper temperature limit rule introduced in the nineties remains practiced. Experiments carried out at that time showed that the incubation temperature of salmon eggs is important for the normal development of the heart and skeleton. It is common for hatcheries to order eggs incubated for a certain number of degree-days to be delivered in a specific week. The 2021 Fish Health Report pointed out the need for a more nuanced view of incubation temperature. In experiments carried out at Nofima, the temperature in the period from fertilization to the eyed stage had a major impact on the growth pattern. These experiments showed that eggs incubated at 4°C until the eyed stage resulted in a greater proportion of muscle fibers with a small diameter compared to incubation at 8°C. Although a greater proportion of muscle fibers with a small diameter resulted in reduced growth in the fry phase, this resulted in the best growth after smoltification and until slaughter. Further research is needed to gain knowledge of whether incubating eggs at 4°C until the eyed stage results in a more robust salmon.

Chilling of salmon eggs, in addition to steering maturation of broodstock, is commonly used to extend the spawning season and makes it possible to sea-transfer smolts regardless of season. Rainbow trout producers also want to be able to chill eggs to adjust the hatching time. But rainbow trout and salmon are different species with different tolerances. From nature's point of view, the salmon is an autumn spawner, while the rainbow trout is a spring spawner. This may be part of the reason why rainbow trout eggs do not survive and develop normally at the same temperatures as salmon eggs. The optimal incubation temperature for rainbow trout spawn is 10℃, while the tolerance range is from 8℃ to 12℃. Below 8 ℃, the risk of development of spinal deformities increases. These deformities are visible in X-rays already at the first feeding phase, and may worsen during the production period. The deformities do not necessarily lead to increased mortality, but are a welfare problem. The conclusion is, therefore, that rainbow trout eggs should not be refrigerated to extend the spawning period as is done with salmon eggs.

The large investments made to produce a larger juvenile fish in land-based farms have not always been successful. During the ten generations of such production, the fish themselves may have changed. Smoltification has previously been an important event in the salmon's transition to life in the sea. It is now being discussed whether the salmon has any natural smoltification process at all if allowed to grow past 250 – 300 grams before being transferred to sea. In surveys carried out at the Veterinary Institute, we have found that different methods are used to evaluate whether salmon can withstand the transition to life in the sea. Some producers start careful salt-adaptation already from the age of 5 grams, smolt feed is used alone or together with other methods to synchronize smoltification, while others simply sea-transfer fish when they have reached a certain size. The larger the salmon is when transferred, the easier it is to maintain salt balance. This is because the body surface becomes relatively smaller in relation to its volume as the fish gets bigger. However, some hatcheries still use photoperiod manipulation. In this way, a natural smolt development is imitated with a smoltification signal "from winter to spring".

Legislation does not require anything other than that the fish must be tested before being released into the sea to ensure that they can withstand seawater. The transition from the hatchery phase to the sea is critical with major physiological changes, transport and environmental changes. Several studies have focused on smolt quality, as mortality after sea-transfer can be high. A study from 2021 found that 32 percent of mortality in the first 180 days after sea-transfer is related to smolt quality.

Studies have shown that rainbow trout that have grown rapidly during the early stages of culture are prone to develop more rounded and relatively smaller hearts than in wild rainbow trout. There are strong indications that the same applies to Atlantic salmon. How deviant hearts salmon and rainbow trout can live with under farming conditions is unknown. Fry and parr that have grown slowly due to lower temperatures in the hatchery are reported to be more robust in the sea phase than fast-growing fish. When the salmon, after sea-transfer, are additionally exposed to various viral infections that also attack the heart, the strain can eventually become greater than the salmon can withstand. Both PMCV (Piscine myocarditis virus) which causes CMS and PRV (Piscine orthoreovirus) which causes HSMI (heart and skeletal muscle inflammation) can be detected in hatcheries. We do not know the extent to which gill disease, delousing and ulcer infections can exacerbate the heart problems.

In the annual survey, fish health personnel and inspectors of the Norwegian Food Safety Authority were asked to indicate the conditions they believed had the greatest negative impact on mortality, reduced growth and welfare, and whether the incidence of these conditions is increasing in juvenile production of salmon. As in 2021, the biggest challenges relate to non-infectious diseases and suboptimal production conditions (Appendix A1). For possible geographical differences, see Figures 4.6.1 and 4.6.2, which show the ten highest ranked problems in hatcheries in the southern and central parts of the country respectively. The northernmost production areas are not shown due to few respondents. For PO1-PO5, nephrocalcinosis, haemorrhagic smolt syndrome and fin erosion are ranked highest. In addition, Infectious Pancreatic Necrosis (IPN) may appear to be a greater problem for juvenile salmon in PO1-PO5, although the concerns related to IPN are somewhat less this year. For PO6-PO9, nephrocalcinosis, haemorrhagic smolt syndrome and poor water quality are ranked highest. Compared to 2021, water quality has moved up to third place from seventh place, which indicates that water quality may have had a greater importance in 2022 than 2021.

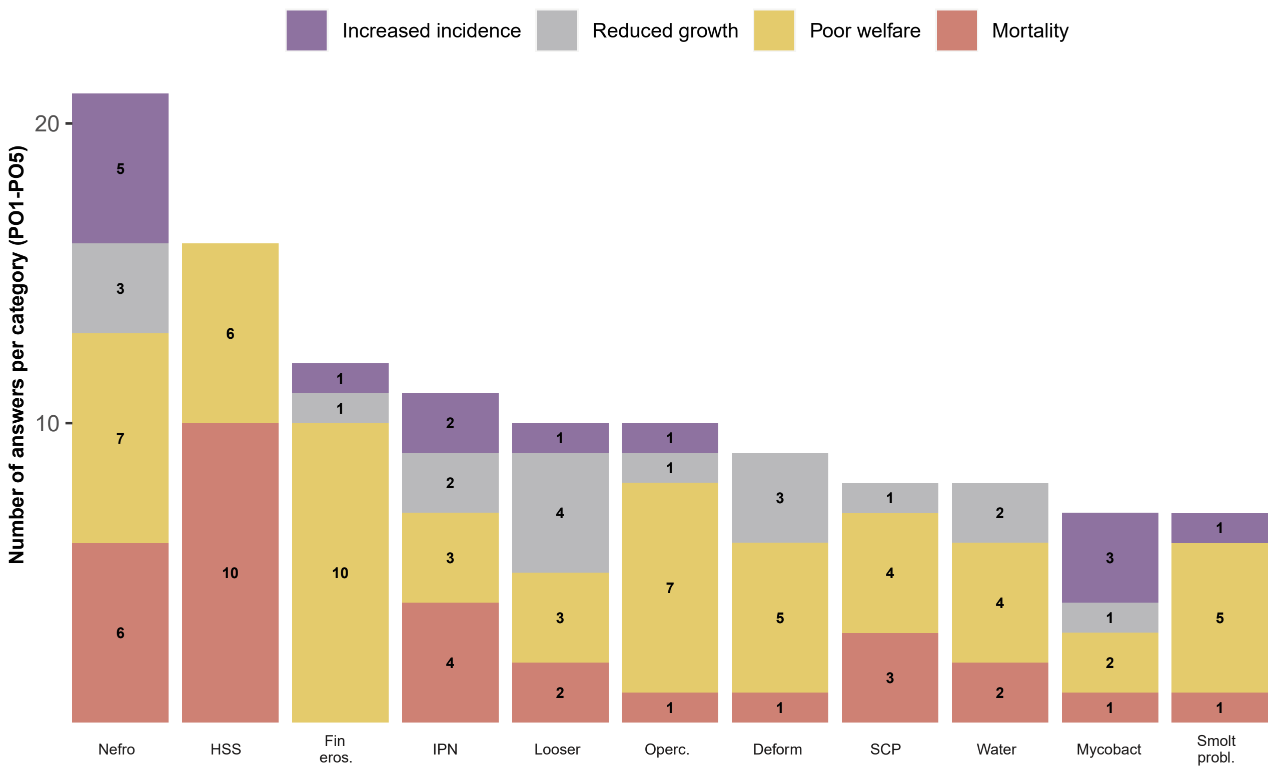


Figure 4.6.1 The diseases or welfare problems in hatcheries that received the most crosses in the combined production area PO1-PO5 (N=15). See Appendix A1 for explanations and abbreviations for each disease/problem on the x-axis, as well as the overview for the whole country.

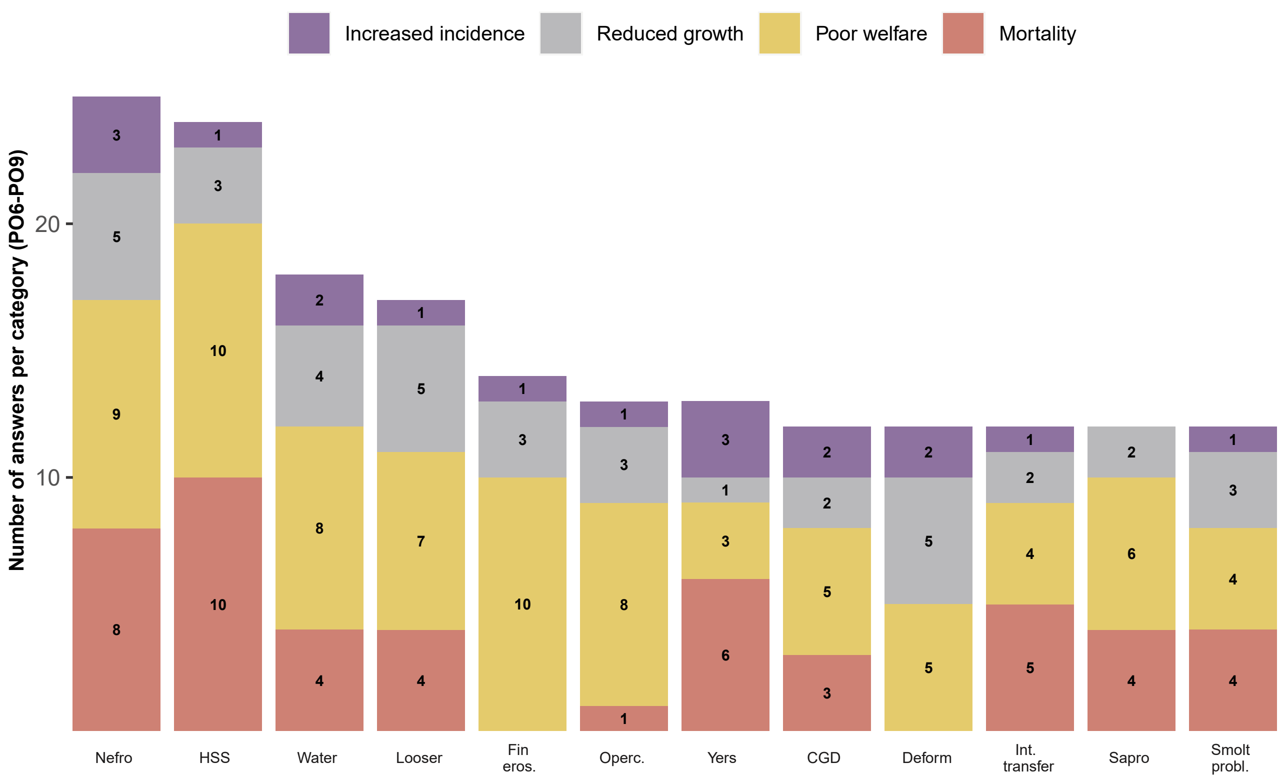


Figure 4.6.2 The diseases or welfare problems in hatcheries that received the most crosses in the combined production area PO6-PO9 (N=18). See Appendix A1 for explanations and abbreviations for each disease/problem on the x-axis, as well as the overview for the whole country.

When asked about changes in mortality patterns in salmon in -flow-through hatchery facilities, 75 percent answered that the situation was approximately the same as previously, while 12 percent said they did not know, and respectively 3 and 9 percent answered that mortality was higher or lower (N= 32). For RAS facilities, 72 percent answered that the mortality rate was approximately the same, 12 percent answered they did not know, and 8 percent answered that the mortality rate was higher or lower (N=25). For salmon in facilities with a combination of flow- through and RAS, 60 percent answered that the mortality was about the same, 30 percent said they did not know, and 5 percent that it was higher or lower (N=20).

The number of welfare-related incidents reported to the Norwegian Food Safety Authority has increased in the last four years for hatchery fish (Table 4.6.1). It is unclear whether this increase is a real increase in the number of incidents, or whether it is due to better notification routines, increased production in general or other factors. In 2022, the Norwegian Food Safety Authority prioritised analysis of such reports, and a larger proportion of hatchery incidents have been assessed as serious and should be followed-up. It is therefore important to find the causes of such incidents with a view to prevention.

4.7 Welfare challenges related to salmon lice

Non-medicinal delousing (also called IMM in Norwegian), which requires handling of the fish, has proven to be a major welfare challenge. If the salmon are sick or weakened by infections, they cannot withstand additional handling. This also applies to cleaner-fish, which are intrinsically sensitive to this type of handling, and should therefore be fished out in advance. However, since removal of cleaner-fish is also challenging, the combination of cleaner-fish use and non-medicinal delousing has proven to be demanding in terms of fish welfare (Chapter 4.12 Welfare challenges for cleaning fish).

Non-medicinal delousing is mainly based on three different principles; thermal (warm water), mechanical (water-based flushing and brushing) and use of fresh water. In addition, there is an increasing number of methods that combine the various principles. Non-medicinal combination methods came into use around 2020. During thermal delousing, the temperature in the water bath is adjusted (approx. 28-34 °C for approx. 30 seconds) based on the sea temperature, treatment effect and fish welfare.

Table 4.6.1 Number of welfare-related incidents reported to the Norwegian Food Safety Authority based on incident type in the years 2018-2022. The reports concern hatchery fish. Data from the Norwegian Food Safety Authority is presented as registered in their electronic reporting system (MATS). The differences in figures from the Fish Health Report 2021 are due to updated figures from the Norwegian Food Safety Authority.

Welfare related incidents hatchery fish					
Cause	2018	2019	2020	2021	2022
Other	26 (45%)	46 (47%)	84 (52%)	112 (55%)	101 (45%)
Unexplained mortality	27 (47%)	46 (47%)	50 (31%)	51 (25%)	76 (34%)
Pumping	1 (2%)	2 (2%)	13 (8%)	23 (11%)	20 (9%)
Vaccination	2 (3%)	3 (3%)	12 (7%)	17 (8%)	19 (9%)
Natural forces - storm, electricity	1 (2%)	-	3 (2%)	1 (0,5%)	2 (1%)
Fire	-	1 (1%)	-		
Counting	1 (2%)	-	-		4 (2%)
Total	58	98	162	204	222

A common factor for all non-medicinal delousing methods is that the fish must be crowded before they are pumped into the delousing systems. This in itself has proven to be a major welfare risk. Thermal and mechanical treatments, and combinations of these, involve a lot of handling and a number of situations where stress and physical damage may occur. In addition, harmful changes in water quality e.g. drop in oxygen saturation, gas supersaturation etc. may occur (Chapter 9.5 Water quality).

Thermal delousing is debated, as the water temperatures used have been shown to be painful to the fish (see Table 4.7.1). Recently published research shows a worryingly low delousing effect of hot water. The consequence of this new knowledge for current practices should be assessed in more detail. A ban was on the horizon in 2019, with a phasing out within two years should acceptable welfare not be documented. Such documentation remains lacking, but the ban has not been implemented. In 2022, the Norwegian Food Safety Authority has published a guide for animal health personnel regarding IMM use, which, amongst other things, describes responsibilities and practices. The duty to notify of incidents that result in poor welfare is specified. It is important that such incident reports contain sufficient information, so that experiences can be shared with a view to development of preventive measures. These reports are now systematically collated, and the Veterinary Institute is involved in gathering more information about these incidents.

The number of delousing weeks with non-medicinal methodology has increased annually, with the exception of a small decrease from 2020 to 2021 (Table 4.7.2). Thermal delousing, although reduced in the last two

Tabell 4.7.1. Welfare consequences in salmon exposed to warm water in controlled trials.

Findings	The fish/trial	References
Behavior 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 endpoint1 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 behavioral reaction/panic behavior 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 behavioral 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

years, remains the most used method since its commercialization around 2015. However, combination treatments are increasing, including thermal combined with mechanical or freshwater treatment. Table 4.7.2 shows combination treatments reported for the same farm in the same week. Not all are real combinations, for example a farm may have deloused one cage with thermal and another cage with mechanical treatment in the same week. Real combinations are nevertheless increasing from 2022. In the case of fresh water, this treatment is somewhat reduced and replaced with combined thermal/mechanical treatment. Different methods are used per PO, illustrated in Figure 4.7.1. For example, PO4 has almost exclusively used thermal treatment or combinations including thermal, while PO6 had the most mechanical treatment weeks in 2022. Other areas such as PO9 have a more even distribution between the treatment principles. There are also large differences in the number of delousing weeks between the various production areas. The three areas with most delousing in 2022 were, as in 2021, PO6 (675), PO4 (603) and PO3 (551), all of which have high biomass and over 80 active farms (Figure 4.7.1). PO6 has the highest biomass, but also the most sea area per fish. The fact that the use of medicinal delousing increased in some areas in 2022 may be partly due to introduction of a new drug with the active ingredient imidacloprid in 2021 (Figure 4.7.1 and Chapter 8.1 Salmon lice - Lepeophtheirus salmonis).

In 2022, the Norwegian Food Safety Authority received 1,781 notifications related to welfare-related incidents in ongrowing and broodstock farms (Table 4.7.3). Of incidents reported in 2022, 752 (42 percent) were linked to non-medicinal delousing, which requires handling, which suggests that the slight trend in reduction in the number of incidents involving non-medicinal delousing continues. The seriousness and extent of reported incidents vary, and different companies may have different thresholds for notification. The summary does not specify fish species, and while reports primarily involve salmon, cleaner-fish are also included. On collection of statistics for 2022 from the Norwegian Food Safety Authority, a major adjustment to the 2021 statistics were made (over 80 notifications were added). The reason was delayed reporting/missing updates.

To better prevent incidents with a negative effect on fish welfare, work is now being done to systematize data from reported welfare incidents. As part of this work, the mortality rate at the farm level has been examined this

Table 4.7.2 Number of weeks of non-medicinal delousing reported to the Norwegian Food Safety Authority as of 16.01.2023[1]. The treatment methods are divided into four categories: Thermal (hot water), mechanical (various water based flushing), fresh water and other. The combination categories indicate whether several delousing methods have been reported for the same farm in the same week. The category "other" covers reports that have not been able to be categorized in one of the other categories based on free text fields in the reporting form.

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Thermal	0	0	3	36	685	1246	1327	1449	1723	1456	1357
Mechanical	4	2	37	34	311	236	423	674	823	862	1074
Fresh water	0	1	1	28	73	75	84	148	220	286	225
Thermal and mechanical mekanisk	0	0	0	0	12	42	35	56	59	30	47
Thermal and fresh water	0	0	0	0	16	21	17	27	20	63	141
Mechanical and fresh water	0	0	0	0	7	1	7	7	24	56	153
Thermal + mech + FW	0	0	0	0	0	0	1	0	1	5	9
Other	132	107	136	103	75	52	69	87	92	72	139
Total weeks	136	110	177	201	1179	1672	1963	2446	2962	2830	3145

[1]Differences in figures from the Fish Health Report 2021 are due to updated routines for identifying erroneous reports, updated routines for identifying treatment type based on text descriptions in reporting forms and forms received late.behandlingstype utfra tekstbeskrivelser i rapporteringsskjema og seint innkomne skjemaer.

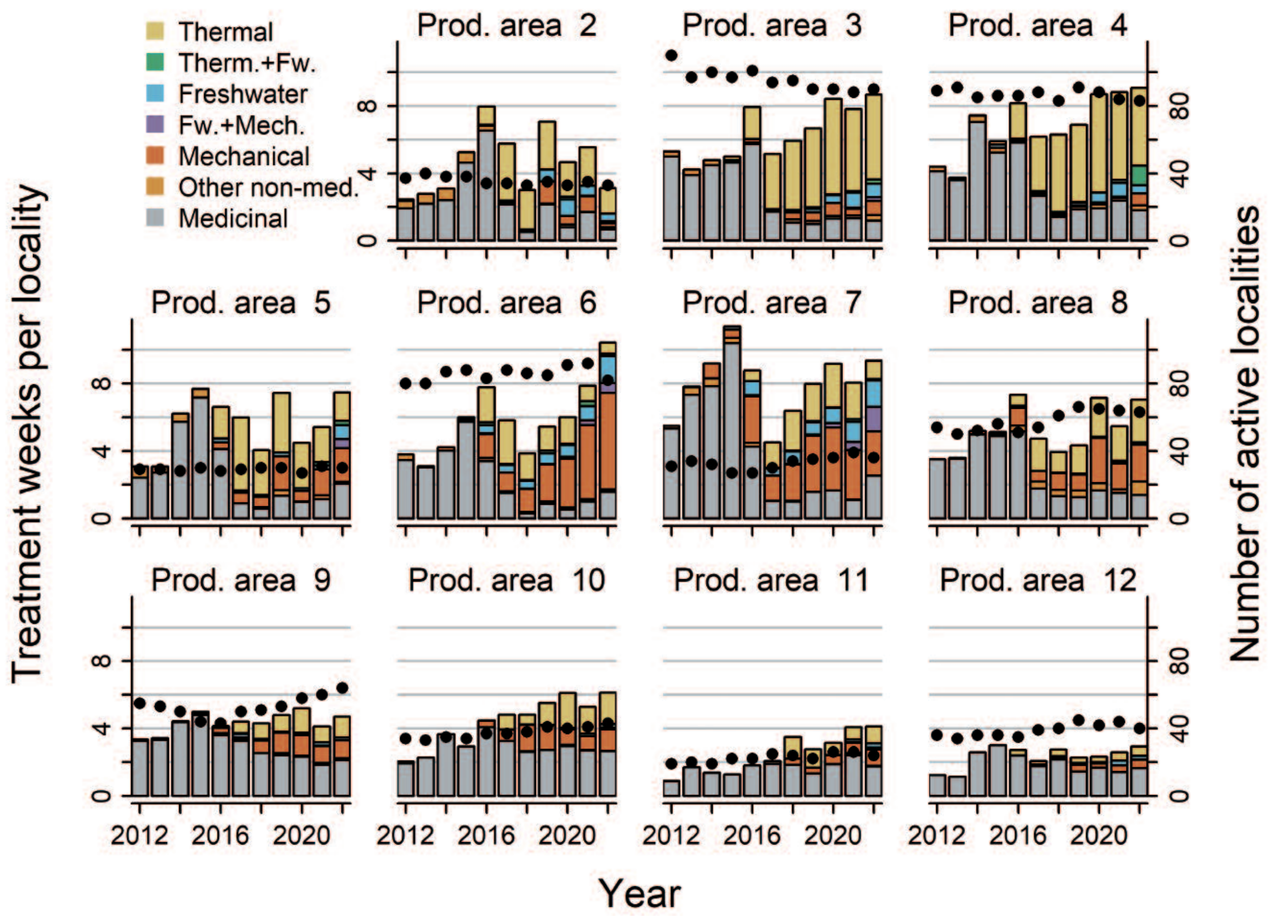


Figure 4.7.1 Trends in the number of treatment weeks per farm in the various production areas (PO). The columns show the number of weeks of treatment for various delousing methods, including medicinal delousing (scale on the left y-axis). The number of active farms per PO is shown with black dots (right axis). PO1 and PO13 are omitted due to few active farms.

year based on the type of incident (Figure 4.7.2). The figure shows that there is a high mortality associated with many incident reports, particularly in the categories "Other", "Non-medicinal delousing with handling" and "Undetermined mortality". Two outliers with a mortality of 39 percent (undetermined mortality) and 54 percent (other and handling) were removed to improve the readability of the figure. 'Mortality in percent', which is indicated in Figure 4.7.2, must be considered a probable underestimate. Incidents that, for example, concern one or a few cages will be underestimated since the calculation is calculated at the farm level. In addition, mortality is calculated in the month of 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. Amongst the welfare-related events reported, there were four reports of jellyfish attacks in 2022, with a significant number of fish affected (Chapter 9.7 Algae, jellyfish and fish health).

The mortality in events "Delousing IMM with handling" was linked to the free-text field in louse-reporting and compared with use of thermal or mechanical delousing. In the absence of text, the data is lost. In addition, a criterion was set that there should be a maximum of one month between the incident and identification from the

Table 4.7.3. 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 ongorwing/broodstock fish	2018	2019*	2020*	2021*	2022
Non-medicinal delousing with handling	629 (61%)	906 (61%)	873 (54%)	774 (48%)	752 (42%)
Undetermined mortality	196 (19%)	251 (17%)	282 (17%)	270 (17%)	332 (19%)
Other	112 (11%)	178 (12%)	312 (19%)	384 (24%)	445 (25%)
Handling	40 (4%)	60 (4%)	78 (5%)	71 (4%)	93 (5%)
Medicinal delousing with handling	40 (4%)	55 (4%)	19 (1%)	38 (2%)	86 (5%)
Grading/pumping	7 (1%)	18 (1%)	16 (1%)	15 (1%)	14 (1%)
Natural forces	0	9 (1%)	25 (2%)	23 (1%)	31 (2%)
Medicinal delousing without handling	9 (1%)	9 (1%)	6 (0%)	10 (1%)	7 (0%)
Non-medicinal delousing without handling	3 (0%)	3 (0%)	9 (1%)	31 (2%)	17 (1%)
Jellyfish			3 (0%)		4 (0%)
Reduced susceptibility/resistence	1 (0%)	0	0	1 (0%)	0
Total	**1037**	**1489**	**1623**	**1617**	**1781**

* Minor changes from the Fish Health Report 2021 are due to delayed reporting/updated figures.

louse-report that mechanical/thermal delousing had been used. This is to weed out possible faulty associations and reduce the impact of other contributing causes. As Figure 4.7.3 shows, there were more episodes with higher mortality associated with thermal than mechanical delousing, despite the reporting of fewer incidents related to thermal. It is nevertheless important to consider that use of thermal and mechanical delousing varies with geography, and that the individual production areas have different underlying disease status and mortality (see e.g. Figure 4.2.2 and Chapter 2 Mortality).

Despite the underestimation, the calculated mortality associated with various events is high. The Norwegian Food Safety Authority has developed an inspection template for its follow up work on welfare-related incidents. The Norwegian Veterinary Institute will contribute by mapping causal relationships and possible preventive measures.

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 the survey, respondents were asked how often they had experienced use or stanby of an emergency slaughter boat during

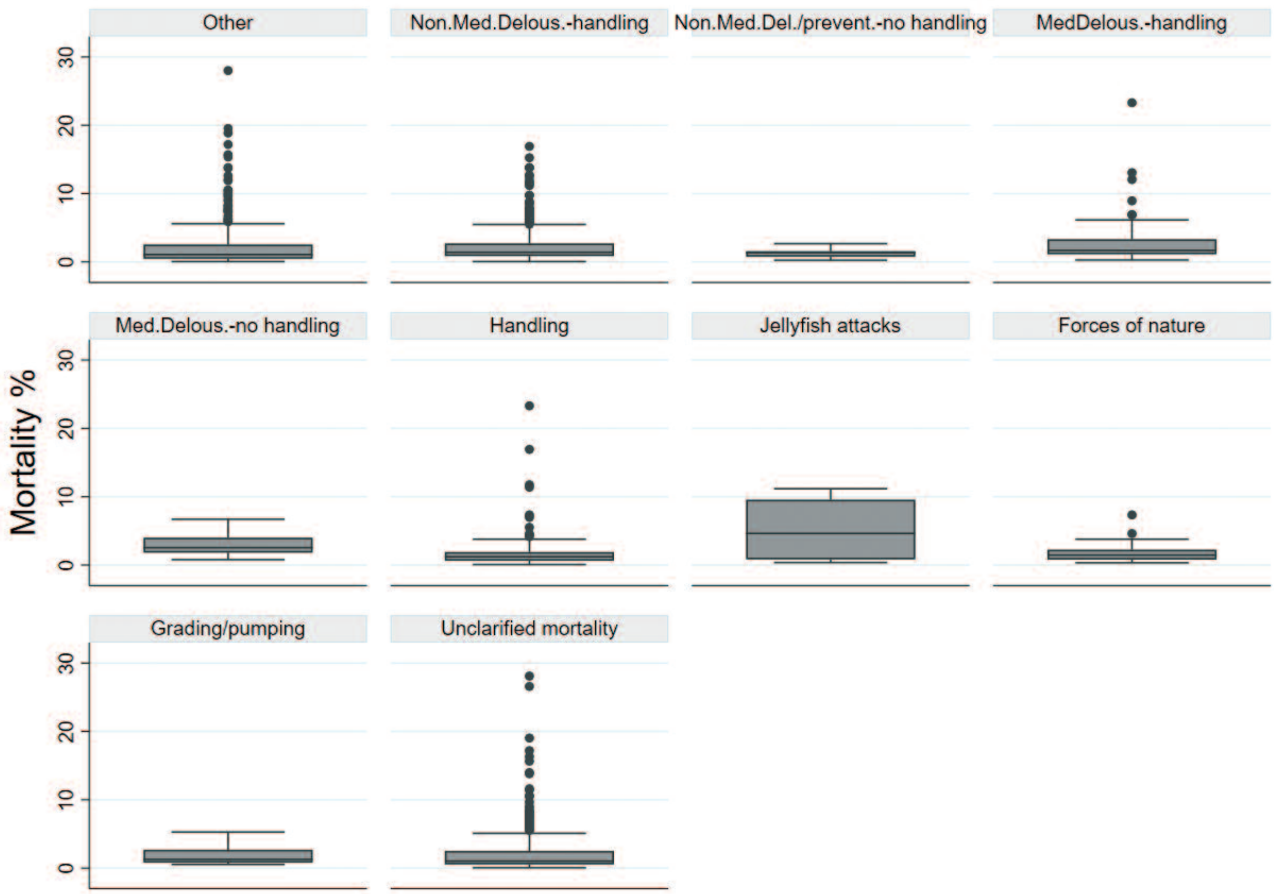


Figure 4.7.2 Overview of mortality (%) based on incident type as reported in MATS to the Norwegian Food Safety Authority for ongrowing and broodstock fish. Data are shown as boxplots of mortalities in the month the event occurred. N=1681 reports, after excluding 100 reports due to incomplete data, including the removal of two outliers of 39 and 54% to improve readability of the figure. Also note that the "Jellyfish attack" category only has four events.

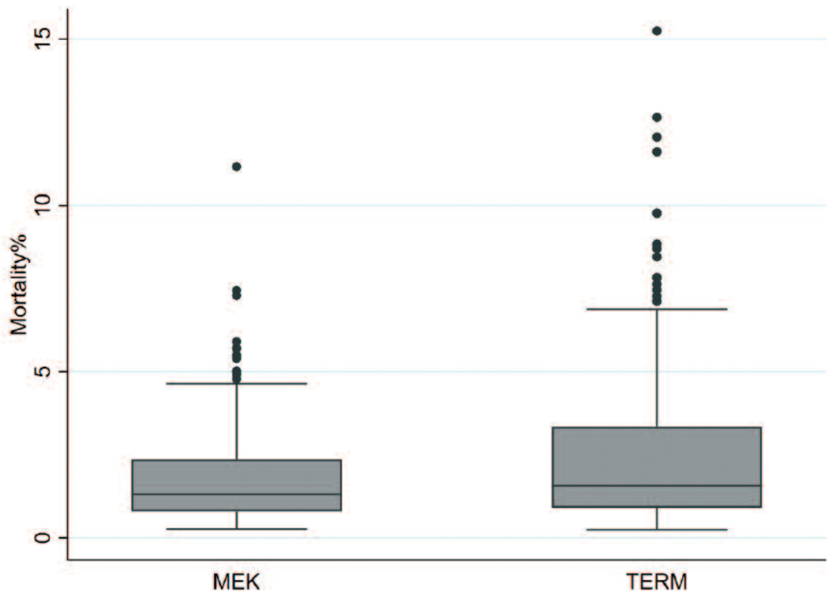


Figure 4.7.3 Mortality (%) at farm level in months in which a welfare incident in the category "non-medicinal delousing with handling" was reported to the Norwegian Food Safety Authority with incidents classified as either mechanical (N= 312) or thermal (N= 244) based on the free text fields shown.

delousing in 2022. Of 67 respondents, 60 percent answered "never/very rarely", nine percent "rarely", eight percent " occasionally', twelve percent 'often', and eight percent answered 'very often'. Five percent answered "don't know". Those who answer "often" and "very often" state in 2022, as in 2021, were based in PO3-PO6. It is important that such a practice does not increase 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.

There is still a lack of knowledge of how the total number of lice treatments or handling in general, and the interval between treatments, affect the fish. At the same time, a high and increasing number of delousing weeks is observed. With increasing use of combination methods, the picture becomes more complex and computationally difficult to analyse. The importance of stress on the skin and mucus layer as well as the gills caused by frequent delousing or combination methods is still poorly documented. However, the knowledge base regarding non-medicinal associated mortality is increasing. In the survey for 2022, "Mechanical damage related to louse removal" is again ranked at the top as a cause of reduced welfare in both ongrowing and broodstock salmon and rainbow trout (Appendices B1, B2, C1 and C2).

A total of 67 respondents shared their experiences of welfare associated with various delousing methods in this year's survey, eleven fewer than the year before. An overview of the methods the respondents had experience with in 2022 is shown in Figure 4.7.4. In relation to the survey in 2021, the trend continues with fewer people having experience with "Optilicer" (from 50 to 42 percent). Far more have experience with combination methods in 2022. Despite the fact that combination methods such as "Freshwell" and "Optiflush" are now separate categories, "Other" has increased from 10 to 24 percent. In the free text field, ‘fresh water and

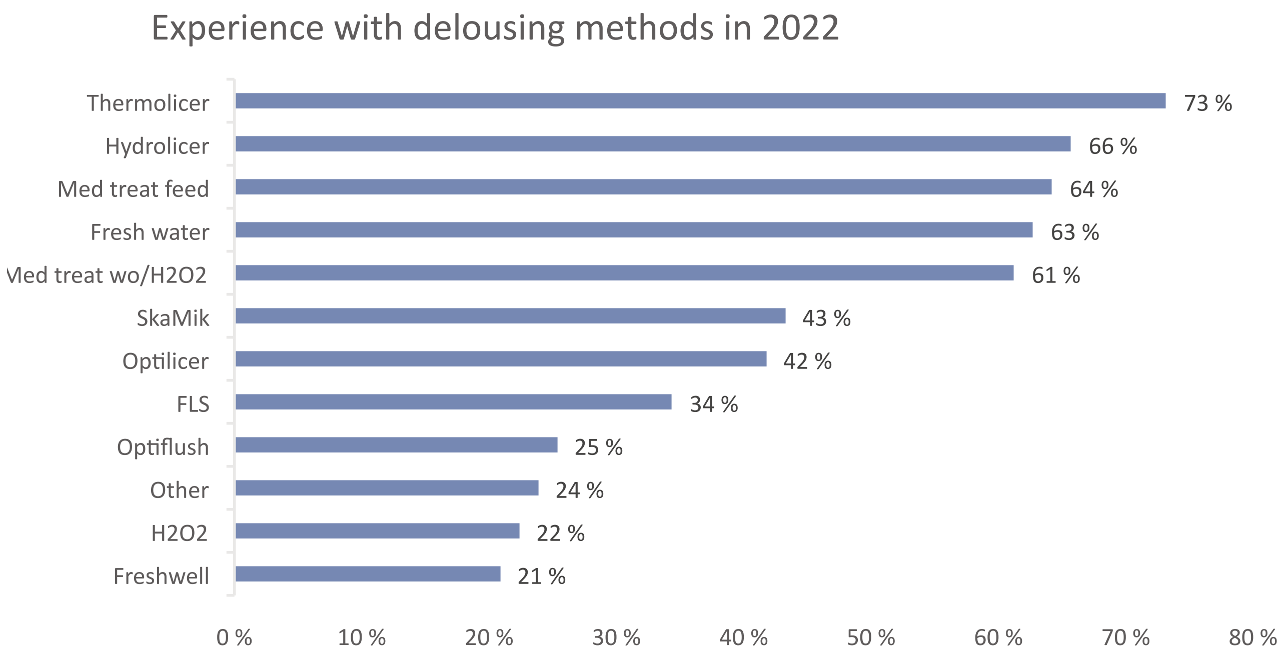


Figure 4.7.4 Overview of the delousing methods fish health personnel in the survey had experience with in 2022 (N=67).).

Thermolicer', 'fresh water and Hydrolicer", and other combinations were mentioned.

How effectively non-medicinal delousing removes salmon lice can depend on many factors. Examples are pressure, temperature, treatment time and crowding, but effectiveness can also be affected if tolerance to the treatment develops due to selection pressure in the louse population. The survey asked whether the respondents had observed any changes in the effect of non-medicinal treatments. Of 63 respondents, 75 percent reported no change in effect, 18 percent reported reduced effect and 13 percent reported increased effect. Of the 24 free text responses received, nine reported a reduced effect and/or seasonal variation in thermal delousing as problematic, one suspected a reduction in effect involving water-based flushing, five reported an increased or good effect related to combination methods, while one experienced that the delousing effect was reduced using a combination method. One mentioned that increased use of IMM leads to reduced welfare and increased mortality, while another mentioned a case of vertebral injuries and mortality after non-medicinal delousing. Three mentioned the importance of biological expertise in the development of new delousing technology, a current shortcoming.

When asked about the most common treatment temperature used for thermal treatments in 2022, 33 percent answered 33-34 °C, 48 percent 31-33 °C, 12 percent 29-30 °C, 2 percent 28 °C and 5 percent answered "do not know" (N=58). When asked of the highest temperature used, no one stated higher than 34 °C. Of 51 respondents, approx. 71 percent stated that the highest temperature was approx. 34 °C (from 33.5-34.0), an increase from 50 percent in 2021. The lowest treatment temperature used was stated as 18 °C at a sea temperature of 4 °C, but 77 percent report that the lowest treatment temperature was 28 °C or higher.

The survey asked how often injuries or mortality occur in connection with different delousing methods (Figure 4.7.5). The trends in the injuries fish health personnel register most frequently are about the same as last year, perhaps with slightly lower scale-loss following thermal

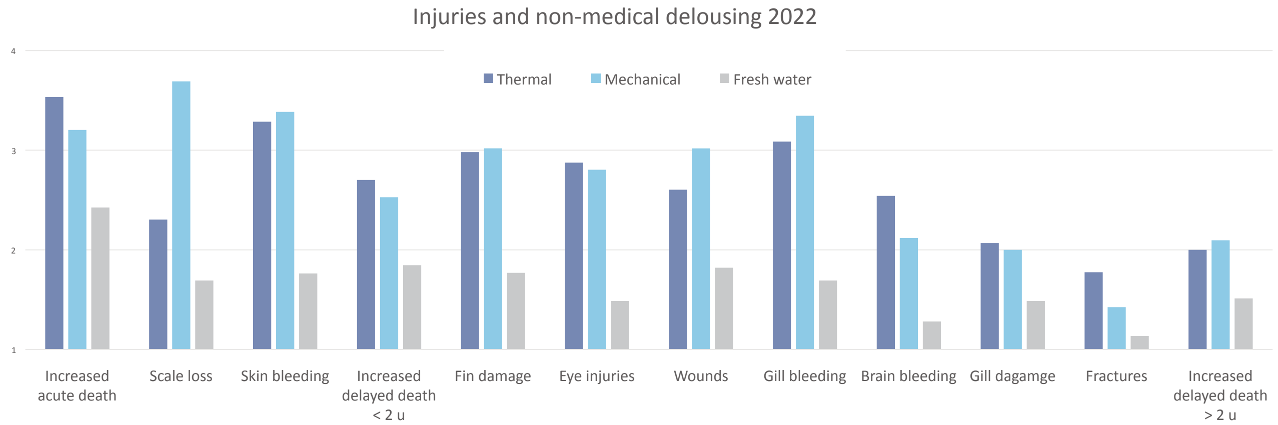


Figure 4.7.5 Average frequency of injuries or mortality in connection with various delousing methods, where frequency is graded on a scale from 1 (never seen/very rarely) to 5 (seen in almost all fish). For the two questions about mortality, answer option 5= corresponds to almost all delousing. The "don't know" option is not shown here. Increased acute mortality means > 0.2 per cent in the first 3 days following delousing, increased delayed death <2 u means up to 2 weeks after treatment. Increased delayed death > 2 u means increased mortality 2 weeks to one month after treatment. The number (N) who shared their experiences varies slightly between the various injury categories, and is between 49 and 58 for thermal, 49 and 56 for mechanical and 40 and 41 for fresh water.

treatment. This may be due to introduction of scale-loss of a moderate/severe degree as a parameter in the survey for 2022. Other trends may include a reduction in delayed mortality and that freshwater in general has a somewhat lower injury frequency. The figures must be interpreted with caution and only as trends. Increased use of combination methods, locally adapted delousing equipment, different methods used in the same week, very frequent delousing and method rotation make it increasingly difficult to keep track of and find trends from year to year. This particularly applies to causal relationships around delayed mortality.

In the survey, fish health personnel were also asked whether there had been a change in the severity of external injuries in connection with non-medicinal delousing in 2022, compared to 2021. 56 percent answered that there had been no change, 16 percent that there had been an improvement, 8 percent that there had been a deterioration, while 20 percent answered "don't know" (N=64).

Several respondents commented that decisive factors for fish welfare related to delousing are the general health of the fish and the processes leading up to and during the delousing itself, such as crowding and pumping. Fish with circulatory disorders and poor gill health are said to tolerate thermal treatment poorly. Of related injuries, there are comments on impact related injuries including eyes, brain haemorrhages and wounds (thermolicer) and gill haemorrhages. The "FLS delouser" is mentioned by three as being more gentle than other flushing based treatments. Combined methods are highlighted as positive by nine respondents, one mentions that mortality is also seen there, another that the effect is uncertain. The survey in 2021 showed that underlying or active diseases, such as CMS, HSMI, PD, AGD and generally poor gill health, are reported to result in major welfare challenges in relation to non-medicinal delousing, while skin-ulcers were reported as the most common disease problem following non-medicinal delousing (corresponding questions were not asked in the survey for 2022).

4.8 Welfare challenges associated with transport

Farmed fish are transported as fry, smolt, harvest-ready fish and as broodstock. Many transports are large operations that require good preparation, experience and advanced technology to be successful. In general, all handling is stressful for the fish. Physical damage occurs easily when fish are crowded, handled or experience panic. In addition, the transport of fish poses a significant biosecurity risk, and is thus also an indirect welfare threat.

Many transports are carried out today with an apparently acceptable impact on fish welfare, but occasionally transport does not go according to plan, with negative impact. The Norwegian Food Safety Authority received ten notifications of welfare incidents related to transport in 2022, a 50 percent reduction from 2021. Three incidents were categorized as transport injury, one as water quality and six as "other". See also section on water quality during wellboat operations in Chapter 9.5 Water quality.

4.9 Welfare challenges associated with slaughter

All killing of animals entails a risk of suffering, and there is a requirement that livestock and farmed fish are stunned and rendered unconscious before they are killed. The slaughter of farmed fish is largely automated. The likelihood that the fish will suffer damage, pain and other stresses is not only affected by how well the stunning works, but also how careful prior handling has been. Crowding, pumping, live chilling (if used), time out of water and the design of slaughter equipment are all relevant.

The stunning methods permitted for salmonids are electricity and by a physical blow to the head (i.e. percussive stunning using a non-penetrating captive bolt), or a combination of these. The stunning shall to render the fish unconscious and thus unable to experience discomfort, pain and fear when sticked and during bleeding until death. Thus, the fish should remain unconscious until it dies from anoxia due to blood loss.

Previous research shows that both methods can work satisfactorily regarding fish welfare, provided that the systems are used and maintained properly. For the physical method, the fish must be struck with sufficient force in the right place, in the skull slightly behind the eyes, such that the fish is rendered unconscious. The blow should cause a severe concussion and preferably bleeding in the back/lower area of the brain where the blood vessels enter. In percussive stunning machines, the fish must all have roughly the same size and head shape, and must enter the stunning site correctly oriented. In the case of semidry electrical stunning, the fish must be oriented head first, or the current must not activate until the fish's head is inside the stunner. Electric shocks prior to loss of conciousness are painful. In the case of electrical stunning, the current strength through the brain must be sufficient to cause immediate unconsciousness. If the current is too weak, it may take longer for the fish to become unconscious, or in the worst case that only the muscles are paralysed so that the fish lies still without being unconscious (electroimmobilisation). Visual assessment of stunning quality can be challenging. Electrical stunning is most often reversible and of short duration, and it is therefore absolutely essential that the fish is bled immediately after stunning. Cutting the gill arches on one side results in slower bleeding than if the gill arches on both sides or the main artery are cut.

Consideration of product quality and consideration of fish welfare often coincide at the slaughterhouse. Fish that are stressed before slaughter go into rigor mortis faster after slaughter and develop a harder rigor mortis compared to fish that are not stressed. This reduces the possibility of pre-rigor filleting. In addition, the final pH of the fillet becomes higher, which reduces its shelf life as a fresh product.

It may be beneficial for fish welfare that slaughtering takes place on a boat directly from the cage, provided that stunning and killing are practised satisfactorily. The welfare consequences of pumping to a well boat, transport to the slaughterhouse, a period in a waiting cage followed by pumping to the slaughterhouse itself are relatively significant, particularly for sick fish. Slaughter boats where the fish are pumped up straight from the holding cage, stunned and killed on board and transported to shore for further processing are now in use (see Chapter 4.7 Welfare challenges related to salmon lice, for welfare concerns).

Measures to improve fish welfare in slaughterhouses must also include fish that are sorted out. This includes cleaner-fish, ‘stowaways’ such as small pollock, but also salmon that have to be sorted out/discarded. These fish have the same rights to good welfare as fish with economic value.

In the survey, 20 respondents answered that they had supervised slaughterhouses in 2022. Most (14 of 20) had supervised only a single slaughterhouse, and four respondents had two. One had supervision over four and the last over five facilities. To the question: "Do you have supervision or experience with emergency slaughter boats in 2022?" 22 people answered "yes" and 52 people answered "no". In this year's survey, there were slightly fewer specific questions than in previous years regarding slaughter. Twenty people answered the question "Do you find that stunning and killing of cleaner-fish at the slaughterhouses results in satisfactory fish welfare?" Seven answered "yes", eight answered "no" and five answered "don't know".

Twelve free text responses were received regarding welfare challenges at slaughter. The comments concerned: 1) Inadequate stunning and/or bleeding, among other things related to equipment not being adapted to fish size, low voltage level on electric stunners, incorrect orientation of fish into equipment and inadequate control regimes, 2) Emergency slaughter boats; both that their use is positive in terms of welfare, but also that their use masks the real extent of delousing related mortality, as well as concerns over slaughter quality, 3) Cleaner-fish and other fish from the cages (for example pollock); no approved methods of stunning/killing and generally poorly adapted equipment.

4.10 Slaughter data as a welfare indicator

After slaughter, the fish are often quality sorted into superior, ordinary and production grades. When a batch of fish is slaughtered, there are usually fish that are not processed further, but are sorted out (discard). The use of the various quality classes varies between slaughterhouses/boats. There can be various reasons for downgrading a fish, such as sexual maturation, lesions, injuries and deformities. Common to a large proportion of the fish that are downgraded is that they have undergone a period of reduced welfare prior to being killed.

The proportion of fish attaining 'Superior grade' is a commonly used parameter in the industry to describe the quality of a batch of fish after slaughter. Usually, the superior share is stated as a percentage of the total quantity slaughtered, calculated on the basis of weight, and thus indicates the proportion of fish in the best quality class, that is, the proportion of fish that have not been downgraded. From a welfare perspective, the superior share should be calculated based on the number of fish, rather than the weight of the fish. This is because the individual weights for an average superior fish are probably higher than for an average downgraded fish from the same batch. Presumably, therefore, a superior proportion based on weight will often be higher than a superior proportion based on number, for the same batch of fish.

Norwegian fish slaughterhouses and emergency slaughter boats submit data to the Norwegian Food Safety Authority for each week and each farm. The slaughter data contains information on species and quantity slaughtered (gutted weight), and on quantities of fish in the various quality classes. Information is also provided for each slaughter week identifying the most important reason for downgrading (ordinary and production) and the most important reason for discard.

The Norwegian Veterinary Institute has been given access to the slaughter data sets for 2021 and 2022, for salmon, rainbow trout and trout. Obvious typos, as well as rows where a unique locality could not be identified, have been removed (75 rows in total). Numbers marked rainbow trout and numbers marked trout are combined in the further processing, since both are assumed to represent rainbow trout. The material covered 10,393 rows of slaughter weeks (fish of the same species, from the same locality and slaughtered at the same slaughterhouse/boat within the same week). These data represent 89 percent of the salmon and 78 percent of the rainbow trout that were slaughtered in Norway in 2021 (cf. statistics published by the Directorate of Fisheries, assuming that the given quantities are gutted weight),

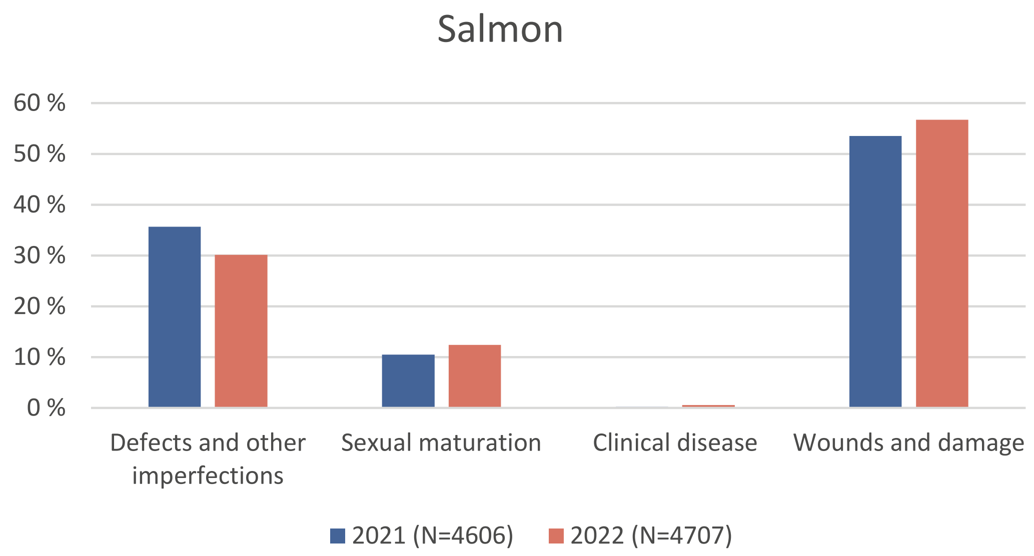
Table 4.10.1. Summary of slaughter data for 2021 and 2022 in the material from the Norwegian Food Safety Authority, as reported from slaughterhouses/boats. Number of slaughter weeks, total volume slaughtered (gutted weight), and quantity classified as superior, ordinary, production and discard, respectively.

	Salmon		Rainbow trout	
	2021	2022	2021	2022
Number of slaughter weeks (farm)	4 606	4 687	585	515
Total slaughter, tonn	1 227 994	1 253 560	58 122	58 838
Total superior, tonn	1 067 371	1 071 658	49 712	51 363
Total ordinary, tonn	21 842	20 233	3 159	1 825
Total production, tonn	128 964	155 743	4 993	5 389
Total discard, tonn	9 817	5 949	256	263
Proportion superior of total (weight)	86.9 %	85.5 %	85.5 %	87.3 %

and 100 percent of the salmon and 95 percent of the rainbow trout for 2022 (figures reported to the Norwegian Directorate of Fisheries as of 20/12/2022), when corrected for gutting related discard (12.5 percent added for salmon and 13.5 percent gut discard to gutted weight). The data are summarized in Table 4.10.1.

In the material, fish that were discarded in 2021 and 2022, and the reasons for discard, are not dealt with further here. Discard makes up a small percentage by weight, but many in number (2.66 million salmon in 2022, according to the Norwegian Directorate of Fisheries' biomass statistics as of 23/02/2023).

When reporting each slaughter week, the "most important reason for downgrading" of fish to ordinary and



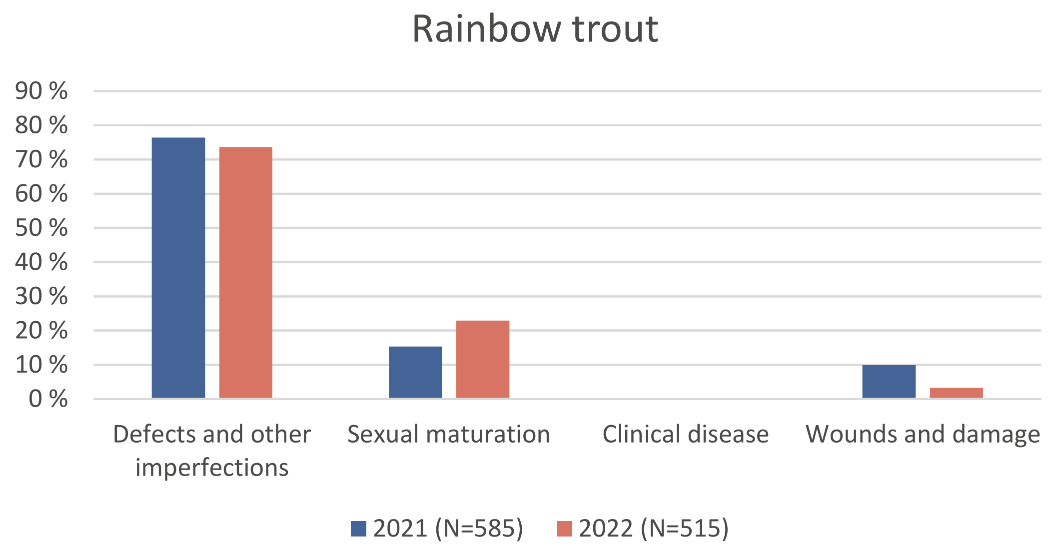
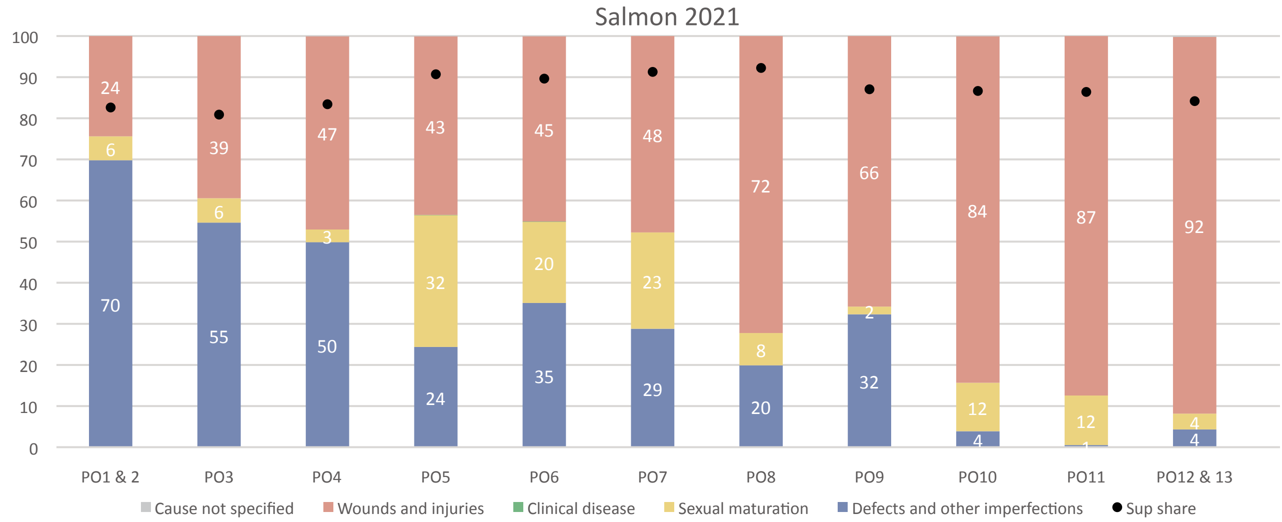


Figure 4.10.1 Proportion of slaughter weeks (salmon and rainbow trout) for 2021 and 2022, respectively, where the down-classification categories "defects and other imperfections", "sexual maturation", "clinical disease" and "wounds and injury" were chosen as the most important cause of slaughter quality categories "ordinary" and "production".



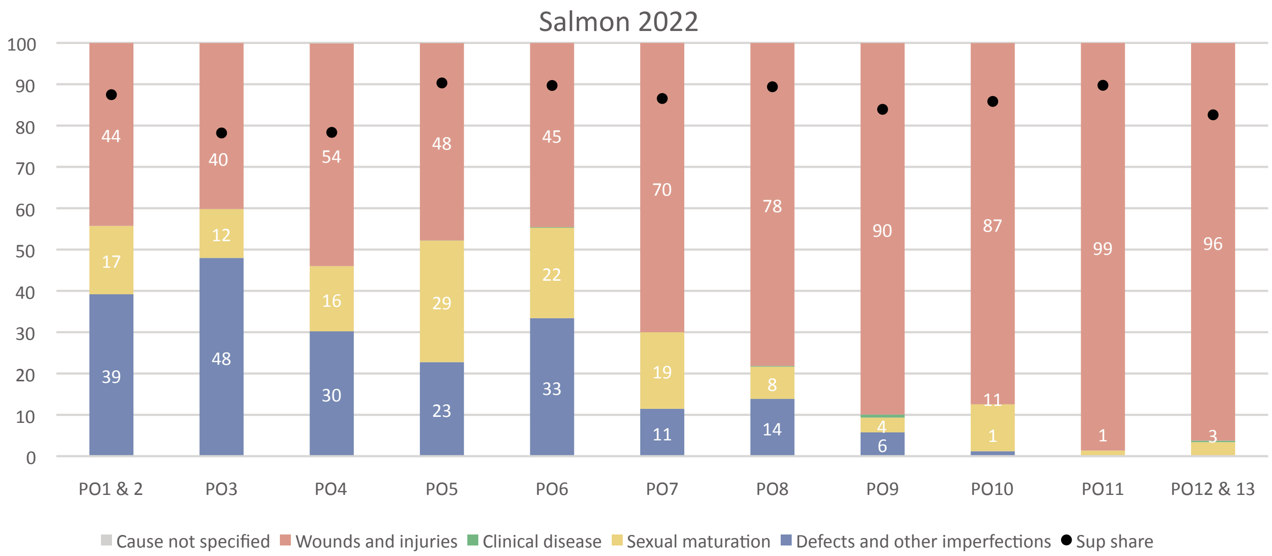


Figure 4.10.2 Superior share per production area in 2021 and 2022, as a percentage of the total volume of salmon slaughtered (black dots), and distribution (%) of the most important reasons for downgrading shown in different column colours. Data from PO1 and PO2 are combined, and the same applies to data from PO12 and PO13.

production is indicated. The choice of cause is predefined with four different options: "Defects and other imperfections", "Sexual maturation", "Clinical disease" and "Wounds and damage". It is only possible to enter one reason per slaughter week.

The most common choice of "most important reason for downgrading" in 2021 and 2022 for salmon was the category "wounds and damage", while for rainbow trout was "defects and other imperfections" (Figure 4.10.1). "Wounds and damage" was chosen to a lesser extent for rainbow trout, and "Clinical disease" is generally little used. There is roughly the same pattern in the selection of the most important reason for downgrading between 2021 and 2022 within salmon and rainbow trout respectively.

The superior share (%) for salmon slaughtered in the various production areas (PO) is shown in figure 4.10.2 for 2021 and 2022. Data for PO1 and PO2 have been combined and the same applies to PO12 and PO13, due to the few farms located in PO1 and PO13. The same figures also show the percentage distribution of the most important reason for downgrading, calculated on the volume (by weight) of fish (not on the number of slaughter weeks as in Figure 4.10.1). There is some variation in the superior share between production areas within the same year, but also variation between 2021 and 2022. The main reasons for downgrading vary more between the different production areas. The option "Defects and other imperfections" is most frequently chosen in the south of the country, while the option "Wounds and injuries" is most important in the north. "Sexual maturation" apparently has the greatest relative importance in central Norway. Corresponding figures have not been drawn up for rainbow trout, since the production of this species is significantly smaller and the number of producers is few in the various production areas. For the same reason, Figure 4.10.1 must not be interpreted uncritically as species specific differences.

The data material contains statistics relating to the slaughter of salmon and rainbow trout in 2021 and 2022 from a total of 841 farms. By summing up the data for each farm, a total superior share was calculated. This then expresses the average of all fish harvested (and reported) in the period for each farm. The average superior share for the 841 localities was 85 percent (the

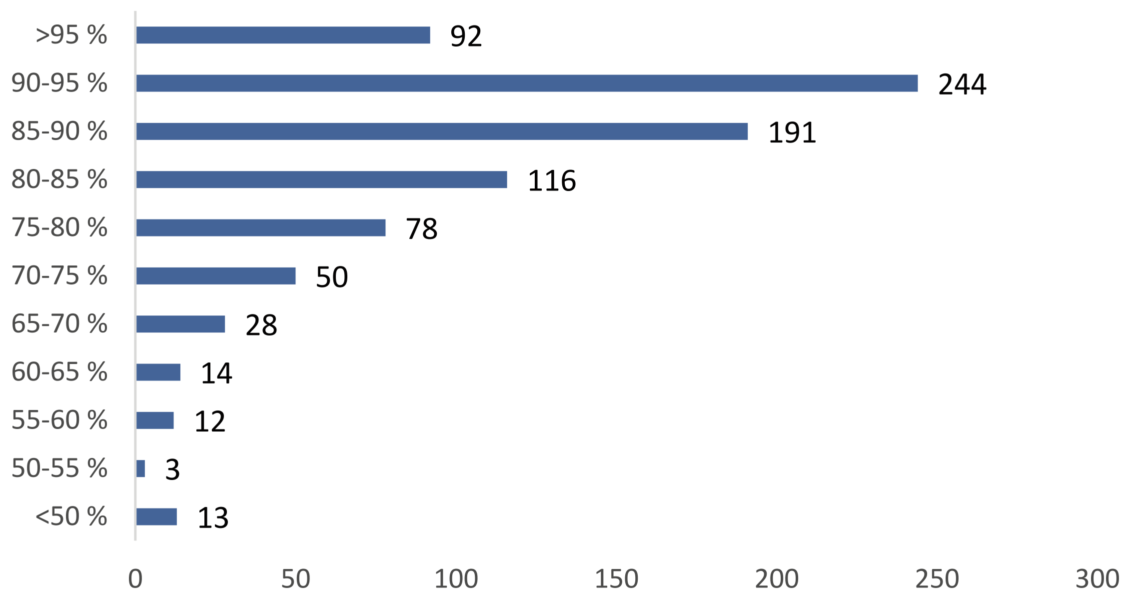


Figure 4.10.3 Number of farms with a superior share within different percentage intervals, for farms with slaughter of salmon and/or rainbow trout in 2021 and 2022. Total number of farms in the material (N) = 841.

25th percentile was 81 percent, the median 88 percent and the 75th percentile was 93 percent). Figure 4.10.3 shows the number of localities with a superior proportion within different percentage intervals.

In assessment of harvest data as an indicator of fish welfare, it is important to recognise both strengths and weaknesses. The reporting of slaughter data provides large enough data sets to be able to say something overall about trends between species, years and production areas. Overall trends can, together with other welfare indicators such as mortality, dead fish classification, welfare incidents etc. be used to systematically measure changes in fish welfare. At farm and cage level, the degree of downgrading and culling, as well as the reasons behind this, will provide valuable information about welfare at the end of the production cycle. Weaknesses may be that the use of the various quality classes varies, for example the class "ordinary" is apparently not used at a number of slaughterhouses. It is also a weakness that only one downgrading reason can be reported per week, which gives an unnuanced picture of the real situation, since it must be assumed that the situation is often more complex. As mentioned earlier, it would have been an important supplement if the number of fish had been added to the data set. In comparison, discard data from e.g. poultry slaughterhouses provides valuable information of the state of health in the flock, which can be used in production planning and welfare work.

4.11 Welfare challenges related to feed and feeding

Feeding methods and amount of feed affect fish welfare, amongst other things, by influencing the behaviour of the fish. For example, using a suboptimal feeding method, or too little feed, can lead to competition for feed between the fish. Aggressive behaviour in turn leads to fish being injured, and fins, gill covers and eyes are often exposed in such situations. On the other hand, too much feed can affect water quality negatively, and it is not sustainable to waste feed.

Starving or fasting the fish (the latter is a more correct term, see NS 9417:2022), is routinely done before transport and prior to various handling operations. Cessation of feeding does not cause aggression in the same way as too little feed over a longer period of time. Fasting is done to empty the gut and to reduce the fish's metabolism, both of which contribute to better water quality and a decrease in the fish's oxygen consumption. This helps the fish tolerate handling better. Fasting is also done for quality and hygienic reasons before slaughter. Recent research on post-smolt Atlantic salmon has failed to demonstrate negative welfare effects of four to eight week periods of withholding feed.

Proper nutrition is essential for normal development and growth in all animals. Nutritional requirements change throughout the life cycle, and there may also be individual differences. Commercial feed is adapted to the nutritional needs of the majority of fish in an age group, and will rarely have large safety margins in expensive feed ingredients. Changes in feed composition, due to e.g. fluctuating raw material prices or environmental concerns, can have side effects on health and welfare, and must therefore be carefully monitored both in the short and long term. Since the 1990s, there have been major changes in the raw materials, and in the relative proportions of the various raw materials, used in standard feed for salmon and rainbow trout. The amount of fishmeal and fish oil has been greatly reduced as the content of vegetable based materials increased.

In addition to standard feed, suppliers often have a wide range of so-called ‘health feeds’ or ‘functional feeds’. Such types of feed are marketed as having an effect against e.g. gill problems, lice, ulcers, heart problems, etc. There is limited available documentation on the real effect of these feed types, but there are some positive indications of effect. If a health feed has a good effect on fish with an infectious disease, it must be assumed that the overall mechanism is based on supplementation of nutrients of which the fish do not have sufficient stores, to the fight against the agent.

In the Norwegian farming industry, some health problems of a complex nature have had an increasing trend in recent years. It is reasonable to suspect that nutrition may be part of the overall picture. A relevant question may then be whether today's standard feed provides the fish with too little of a safety margin in terms of important nutrients to cope with the challenges the fish are, at times, exposed to.

4.12 Welfare challenges related to cleaner-fish

Cleaner-fish are lumpfish and various wrasse species that are used as part of the control strategy against salmon lice. According to the Norwegian Fisheries Directorate's biomass register, 36.2 million cleaner-fish were used in 2022 (reported figures as of 28.02.23). It is the third year in a row that a decrease in number of cleaner-fish used has been recorded. The decrease in use reflects the views of fish health personnel who state in this year's survey 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.

Of the wrasse species, it is corkwing wrasse, goldsinney wrasse, ballan wrasse and rock cook that are used to control salmon lice. They are mostly wild caught. The catch quota is 18 million wrasse, and the fishery is divided into three geographical areas: Southern Norway, Western Norway and north of 62°N. In addition, wrasse are also imported from Sweden. In 2022, two concessions were granted for a total of 1.13 million wrasse. It has not been possible to obtain the actual figures for imported wrasse, which illustrates the lack of an overview and basis for statistics. The majority of the wrasse released in

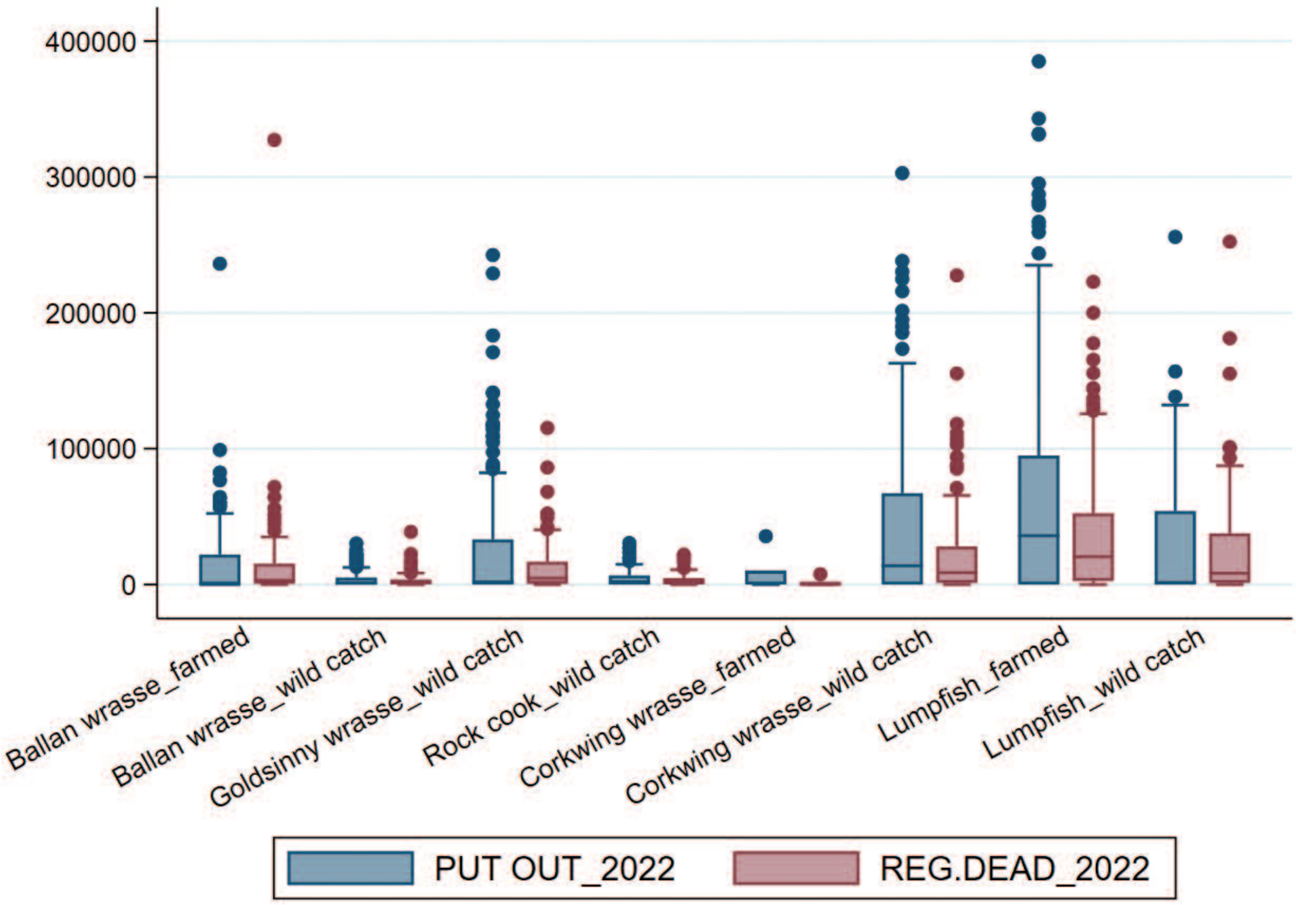


Figure 4.12.1 Number of registered utilised and dead cleaner-fish per species, as reported to the Directorate of Fisheries in 2022. During the processing of the figures, incorrect reports were discovered which have been removed. Data are not further quality assured and must be interpreted with caution.

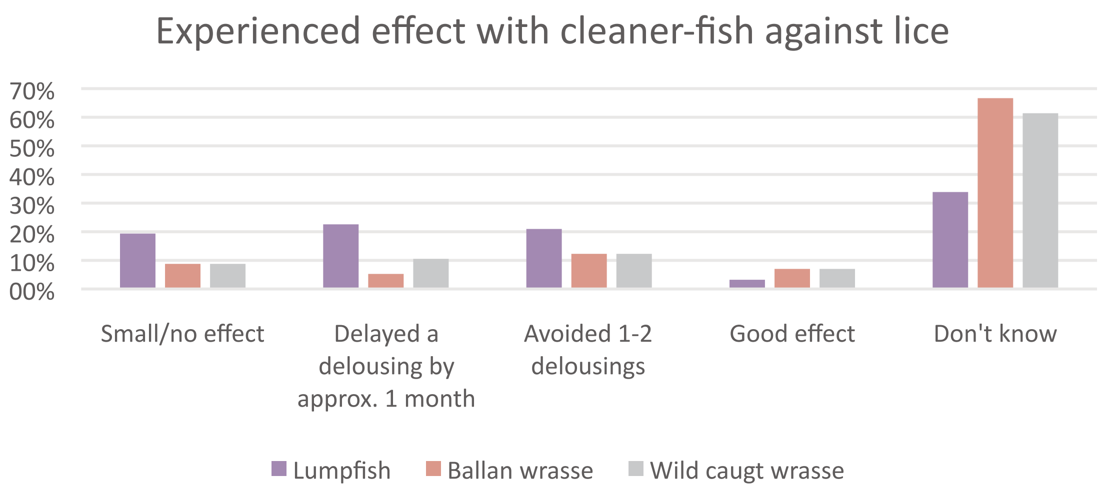


Figure 4.12.2 Fish health personnel experiences of the delousing effect of lumpfish, farmed ballan wrasse and wild-caught wrasse on a scale from little/no effect to good/significant effect and don't know. N=62 for lumpfish and N=57 for farmed ballan wrasse and wild-caught wrasse.

farms are caught locally, but transport over greater distances also occurs. Studies have shown that genetic contamination has occurred from Skagerak corkwing wrasse in PO6-PO7 (Risk report Norwegian fish farming 2023). For wild-caught cleaner fish, there are major welfare challenges linked to capture, storage, transport and the risk of infection. The significance of fishing on wild stocks, and on the ecosystem from which they are removed, is unknown, but in 2018 fishing was regulated in the form of quotas.

Lumpfish make up the majority of farmed cleaner-fish, and are Norway's second largest farmed species in terms of number. The advantages of farmed cleaner-fish include a lower risk of disease transmission, more stable quality, and reduction in risk of overfishing. Unfortunately, there are few available vaccines for farmed cleaner-fish, and vaccines with better efficacy are required. This year, the Norwegian Veterinary Institute has received statistical data from the Norwegian Directorate of Fisheries (sourced 24.01.23) based on production and mortality statistics provided by the producing farms in 2022. During data processing, a number of misreportings were discovered. These were removed and remaining data for the most common species are compiled in figure 4.12.1. For better scale, two outliers, > 400,000 sea-transferred lumpfish, are not shown in the figure. The figures are not further quality assured, but may indicate trends. Wild-caught lumpfish appear to have a slightly higher recorded mortality, compared to farmed. Subject to uncertainty in the reporting, approx. 20.6 million cleaner-fish were recorded dead in 2022. It is known that reporting of losses per species of cleaner-fish in salmon farms is challenging.

The cleaner-fish's natural habitat differs considerably from the environment in the cages used in salmon farming. The salmon is an athletic fish with a high swimming capacity, while the lumpfish is a poor swimmer. The ballan wrasse also has poor swimming capacity, and will not thrive in moderate to strong currents. Strong currents and exposed locations are therefore a major challenge. In the free text field in the survey, several respondents mention that it is necessary to determine whether the environmental conditions in the locality are suitable for cleaner-fish before release. We know from previous investigations that cleaner-fish are used in locations with strong currents, even if breeders and fish health personnel assume that the cleaner-fish cannot tolerate it. This practice must change.

In addition, lumpfish do not tolerate high sea temperatures, and summer temperatures in southern Norway pose an additional stress. Although lumpfish are usually used at lower temperatures, sea-transfer of lumpfish has been recorded in the summer months in

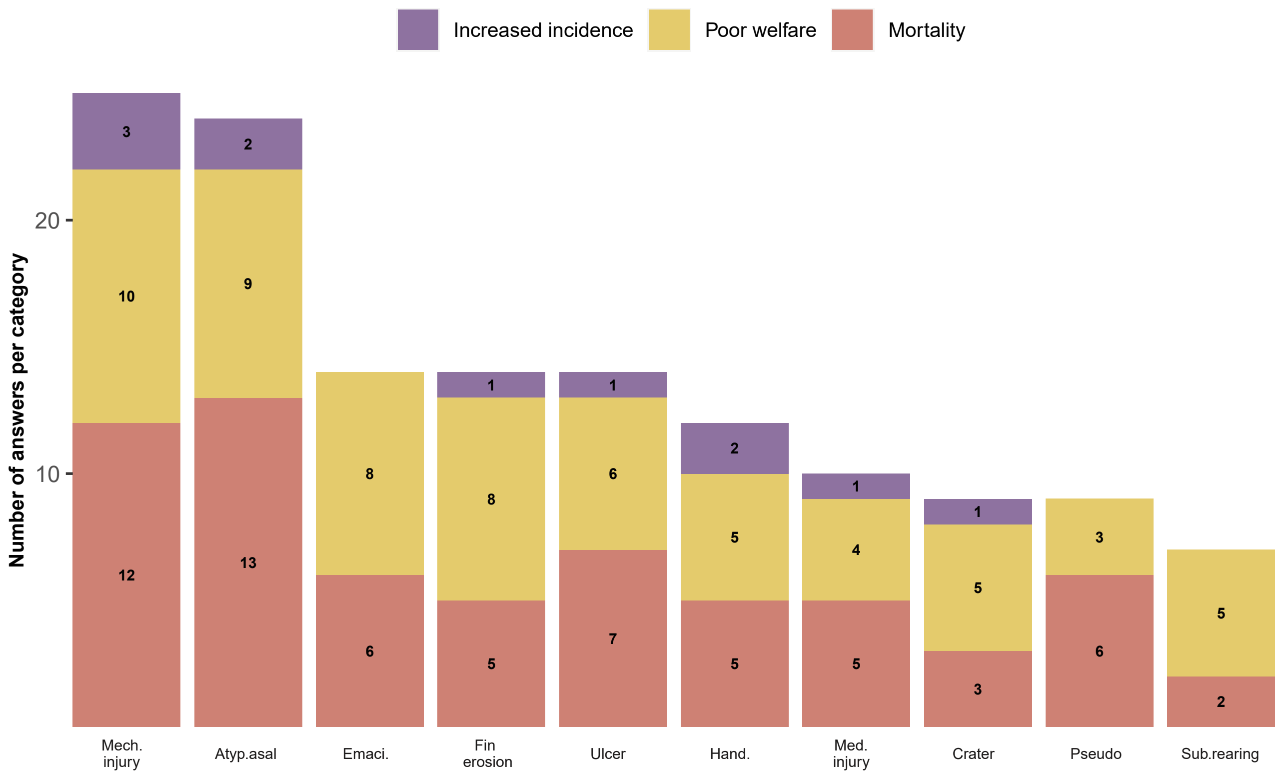


Figure 4.12.3 Fish health personnel and inspectors of the Norwegian Food Safety Authority have ranked the three most important causes of mortality, welfare, and increasing incidence in lumpfish held in cages with salmon in PO1-PO5 (N=20).

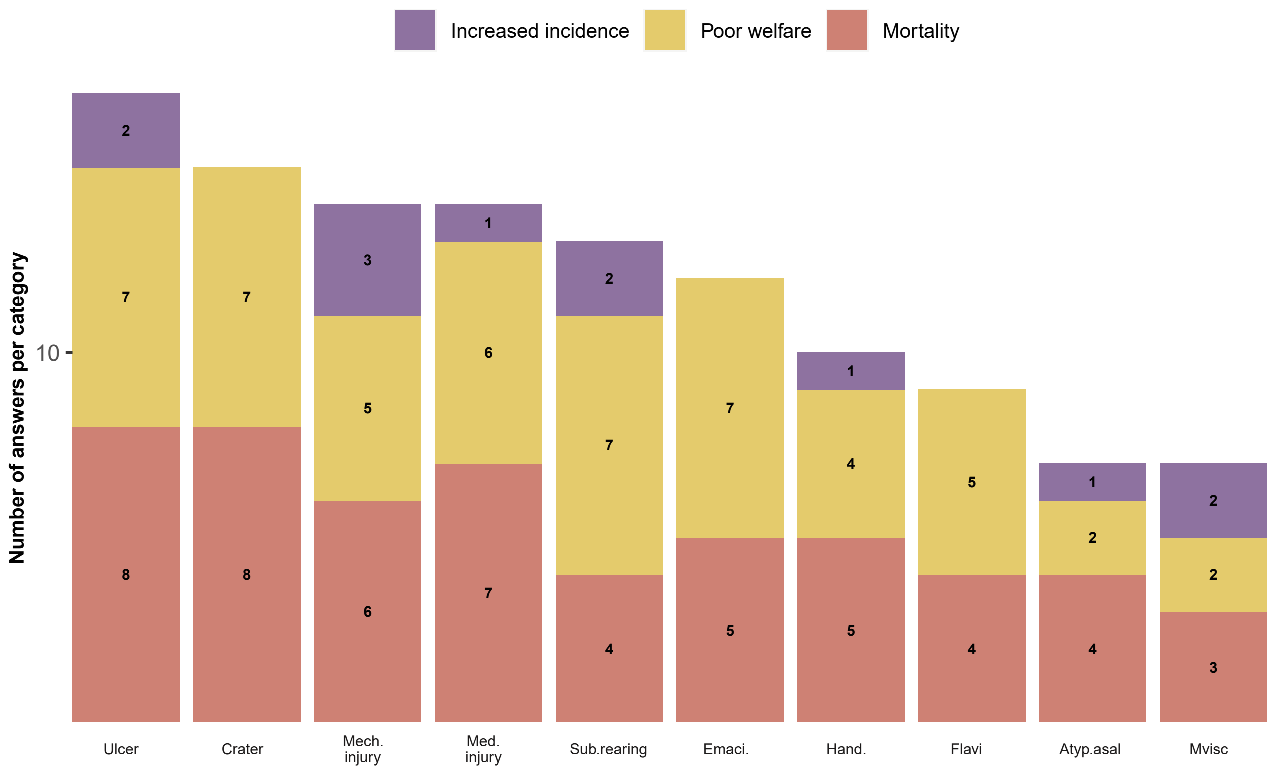


Figure 4.12.4 Fish health personnel and inspectors of the Norwegian Food Safety Authority have ranked the three most important causes of mortality, welfare and increasing incidence in lumpfish held in cages with salmon in PO6-PO9 (N=16).

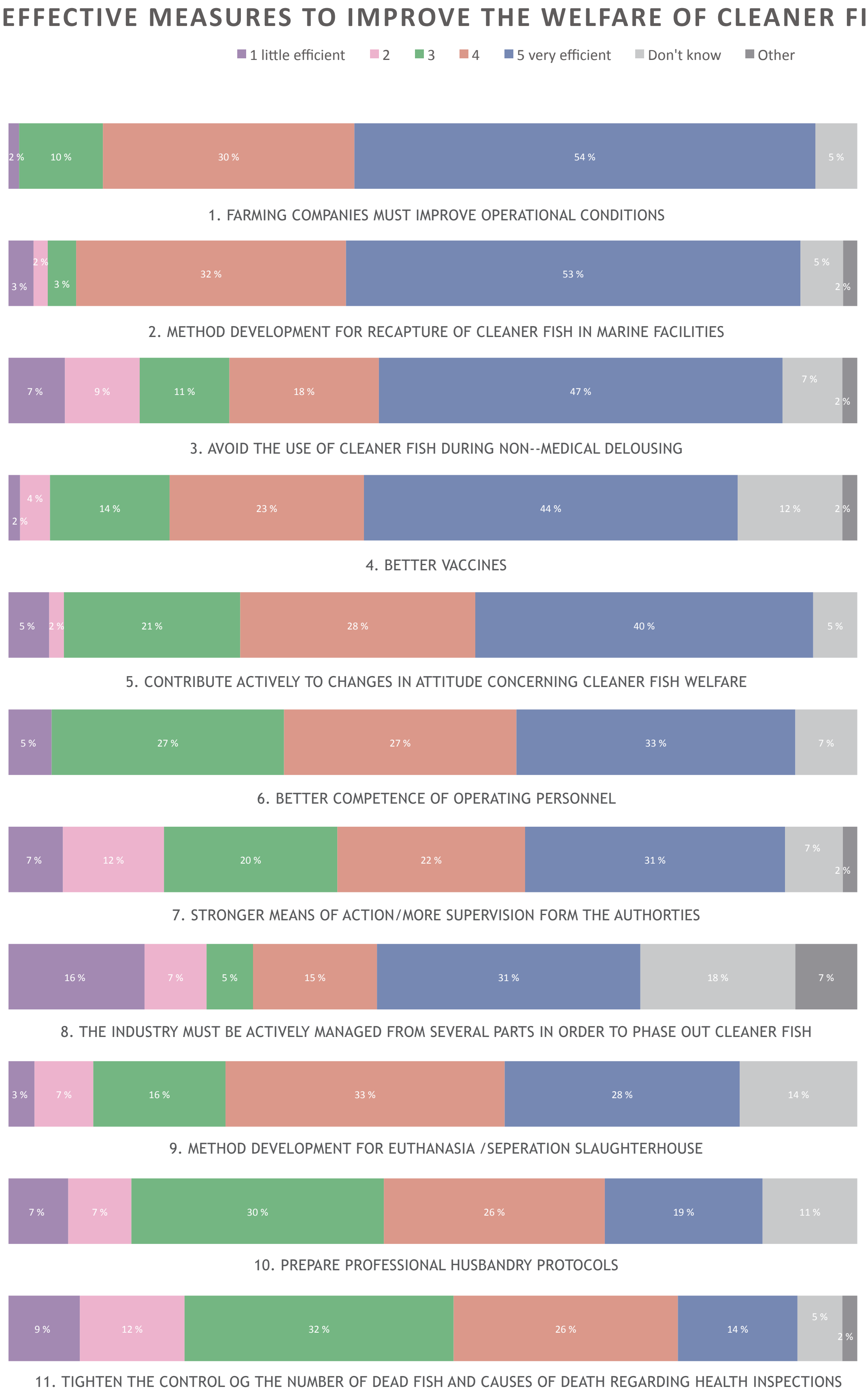


Figure 4.12.5 Fish health personnel opinions on effective measures to improve the welfare of cleaner-fish. They were asked to rate the measures from 1 (poor) to 5 (very effective), as well as to use the entire scale (N=55-61 depending on the measure)

southern Norway. This practice has not been documented in terms of welfare, and is therefore unjustifiable. Wrasse, on the other hand, are relatively heat tolerant and have low activity at 5-10 °C. It is therefore positive that wrasse are not used in the northern production areas (PO8-PO13). Skeletal deformities in farmed ballan wrasse are common and are thought to affect both welfare and their efficiency as delousers.

The effect of cleaner-fish against salmon lice is debatable. Despite the fact that several breeders believe that cleaner-fish have an effect, the scientific documentation is poor. In this year's survey, fish health personnel and inspectors from the Norwegian Food Safety Authority were asked about their experience of the delousing effect of lumpfish, farmed ballan wrasse and wild-caught wrasse (Figure 4.12.2). For lumpfish approx. 3 percent said that they registered a good effect, 34 percent did not know. For each of the categories "small/no effect", "delayed a delousing by approx. 1 month" and "avoided 1-2 delousings per sea-cycle", there are approx. 20 percent who experienced these. For farmed ballan wrasse and wild-caught wrasse, over 60 percent answered "don't know", while 7 percent said they have a good effect. The proportion who say they didn't know, as well as low numbers for good effect, illustrate the great uncertainty surrounding the effect of cleaner-fish.

Vaccination of farmed cleaner-fish, provision of suitable shelter, suitable feed and feeding strategies are measures used to improve their welfare. Nevertheless, the mortality rate is persistently unacceptably high and the welfare and disease challenges are great (see Chapter 10 The health situation for cleaning fish). It is likely that cleaner fish do not have the ability to either adapt to or master salmon farming conditions.

In the survey, atypical furunculosis, non-medicinal delousing and handling are highlighted as the major causes of mortality and reduced welfare in wrasse held in salmon cages. For lumpfish held with salmon, non-medicinal delousing, 'crater disease' and ulcers are highlighted as the most important and increasing causes of mortality and reduced welfare. There are nevertheless geographical differences: In PO1-PO5 non-medicinal delousing, atypical furunculosis and emaciation are indicated as the most important causes of mortality and reduced welfare (Figure 4.12.3). For PO6-PO9, wounds, 'crater disease' and medicinal delousing are indicated as

Lumpfish. Photo: Rudolf Svendsen, UW Photo the most important causes of mortality and reduced welfare. PO10-PO13 are not shown due to few respondents.

When commenting on the general health situation for cleaner-fish, fish health personnel are also critical of current practices in 2022. Many comment that removal of cleaner-fish before delousing is either too demanding or simply not done, which directly or indirectly results in poor welfare and mortality. A desire to ban cleaner-fish use was also mentioned this year. On the other side, there were comments that cleaner-fish use is now more successful than previously. Increased focus on and better capture practices prior to delousing were mentioned. Capture and removal of lumpfish at rising temperatures and on detection of disease was also mentioned. The partly contradictory feedback regarding the fishing out of cleaner-fish before delousing may indicate major differences among the farmers approaches. In addition, there may be different perceptions of what fish health personnel consider a successful capture/removal.

In this year's survey, fish health personnel were asked to rank various measures to improve the welfare of cleaner-fish according to effectiveness (Figure 4.12.5). As can be seen from the figure, the two most effective measures highlighted are: "Farming companies must improve operational conditions such as planning, logistics, harvesting, feeding and care", and "Method development for recapture of cleaner fish in marine facilities". When asked what other measures could improve welfare, 13 comments were received, including two who mentioned that they had no experience with cleaner-fish. Five believe the best thing is to discontinue cleaner-fish use. Of the remaining comments, awareness-raising around the choice of the locality in terms of environmental conditions is mentioned. It was also mentioned that lumpfish are best suited for winter use, and should be fished out and destroyed before release of wrasse, which work better in summer and autumn. Knowledge exchange and the sharing of husbandry protocols for cleaner-fish hatcheries are also mentioned as measures.

There were 18 responses to free-text questions related to discontinuation of cleaner-fish use. There were five who mentioned that no difference in lice burden has been recorded. It is also pointed out that this may be related to unsuitable site condictions i.e. current strength and weather conditions. Several also mentioned that they now have more time to focus on the salmon. Two mention that suspension of cleaner-fish use has led to poorer welfare and increased mortality in salmon due to an increased number of lice. Furthermore, it is highlighted that 2022 has been a challenging louse year. Two also mentioned that suspension has led to good experiences, and that lumpfish have been replaced with lasers.

As in previous years, it was asked whether the mortality in cleaner-fish after stocking in sea cages with salmon was approximately the same level, higher or lower or not known. There continues to be a disturbingly high percentage who answer "don't know"; 39 and 56 percent for lumpfish and wrasse, respectively. The high proportion who answer "don't know" shows that it is difficult for fish health personnel to have a good overview of survival in cleaner-fish in the cages, and thus any measures to improve their survival and welfare.

4.13 Welfare challenges in wild fish - increased focus

Wild fish are not given the same welfare consideration as farmed fish. A change in attitude is nevertheless underway, for example when it comes to commercial fisheries as well as the handling and killing of fish in recreational fishing (see the Fish Health Report 2019-2021 for details). Where better solutions in terms of fish welfare are available, however, awareness clearly needs to be improved. One such example is the development and operation of hydro electricity power stations. When damming up, the habitat changes in lakes and rivers. Large and rapid fluctuations in water levels can have major welfare consequences when fish becomes stranded or the river dries up. There are examples where turbines in power plants injure and kill fish, including the endangered eel. Physical barriers to prevent wild fish from entering turbines exist, but their installation and

Table 4.13.1. Risk factors, welfare effects and risk-reducing measures for wild fish

Area	Risk factor	Effect on welfare	Risk reduction
Commercial fisheries: Capture method	Sufficient stunning/killing of fish Temprary storage of live, wild-caught fish Large fish numbers in, nets -longer pumping times	Exhaustion Suffocated to death (e.g. in a trawl) Dying in capture equipt. (e.g. gill net) Fish with capture injuries, longer suffering, wound infections and downgrading Stress Burst swim-bladder	Develop better killing methods (particularly for schooling fish) Acceptable supervision frequency, more welfare-friendly capture equipment Daily health control of live stored wild fish, satifactory capture method
By-catch		Drowned marine mammals e.g. whales and seals	Use of 'pingers' Avoid benthic trawling
Ghost fishing		Fish and crustaceans trapped and die of starvation	Pots/creels made of degradable materials Removal of ghost equipment Guidelines on placement of capture quipment Increased traceability of capture equipment and policing
Angling: Catch and release	High water tempertaure (summer)	Stress, injury to skin and jaws, subsequent infection, possible death	Compulsory use of particular hook designs, handling procedures, water temperature limits, ban
Hydro power	Environmental changes to lakes and rivers Large, rapid changes in water level Turbine damage to fish	Fish are stranded or isolated in small pools, results in suffocation, fear response, population reduction Migration/spawning hindered Wounds and death Gas supersaturation Low water levels: Increased density of fish resulting in poor water quality, less food, increased infection risk	Minimum water level Functioning fish ladders Barriers to prevent fish entering turbines
Control of alien species	e.g. humpback salmon and pike outside natural range	Capture and killing may result in negative welfare both for the species intended controlled and other native species	For humpback salmon: Frequently supervised live capture systems that allow removal of Atlantic salmon
Eradication of fish disease e.g. G.salaris	Some methods kill all organisms with gills	Suffocation	Develop methods which kill the parasite without harming the host organism

maintenance are costly. It must be ensured that the Animal Welfare Act is prioritized and used to prevent damage and safeguard the welfare of wild fish.

Research is ongoing to examine how fishing gear such as gillnet, demersal seine and longline in commercial fisheries affect fish welfare and product quality (Ethicatch, NFR-301951). Such research can contribute to improvement of capture methods and management/practices and the development of better welfare options. In fisheries, it is common for fish that are caught to die of suffocation. There is a need for method development so that even wild fish that are caught in large numbers e.g. herring and mackerel, are anesthetized before bleeding or that they can be killed quickly. More knowledge of welfare-acceptable killing of crustaceans (lobster, crab, crayfish, shrimp), including practical implementation, is needed.

Live storage of captured wild fish, such as mackerel or cod, must occur in a welfare acceptable manner. An example from 2022 showed mackerel in temporary storage displaying large wounds. There has been a focus on reduction of "ghost fishing", i.e. abandoned nets and pots, in which stray fish and crabs are caught and slowly starve to death. The animal welfare unit of the Norwegian National Authority for Investigation and Prosecution of Economic and Environmental Crime (Økokrim) is investigating such a case. However, this is a continuous task, as fishing gear constantly goes astray. Another area is the prevention of bycatch of e.g. whales and seals, and avoiding damage to coral reefs and benthic vegetation, which is important for wildlife.

Regarding catch and release angling, the Norwegian Food Safety Authority has made some clarifications. Pure catch and release, where the only goal is to experience the joy and excitement of fishing and then release the fish again, is in violation of the Animal Welfare Act and is prohibited in Norway. Furthermore, "it is politically determined that limited catch and release of salmon and trout is temporarily permitted". Releasing fish without serious damage, below the minimum size, or species that are not considered food fish, has been practiced for many years. Catch and release practices for salmon nevertheless appear unclear and ethically difficult, and there are significant differences between fisheries in how catch and release is practised. In combat of alien species, such as humpback salmon, there are many welfare considerations to take into account. Other species, such as Atlantic salmon, must be unharmed, and animal welfare-acceptable killing of the humpback salmon must be ensured.

It is particularly important for the welfare of wild fish that all actors, agencies, administrators and researchers promote good welfare solutions where they exist (Figure 4.13.1). At the same time, problems must be acknowledged and research efforts increased where solutions are currently lacking.

4.14 Overall assessment of fish welfare in 2022

Several hatchery projects have stressed the importance of considering the entire life course of the salmon when assessing welfare and mortality. However, the requirements for reporting mortalities to the Norwegian Food Safety Authority (see Fish Health Report 2019) have not changed. In addition to the use of standardized categories of mortality, it is necessary to be able to follow groups of fish from hatch to slaughter. This is to identify measures targeted towards the biggest challenges in production. Non-infectious problems are also ranked in 2022 as the most important cause of reduced welfare and mortality in both salmon and trout hatcheries. The number of reported welfare incidents from hatchery production continues to increase: In 2022, the Norwegian Food Safety Authority received 222 reports (most in category ‘other’ and ‘undetermined mortality’), compared with 204 in 2021.

For fish farmed in the sea, the number of delousing treatments and the methods used are still a major welfare problem, both for salmon and cleaner-fish. The number of non-medicinal delousing weeks has markedly increased in 2022, with an increase from 2,830 weeks in 2021 to 3,145 weeks in 2022. Thermal delousing is still the most used treatment method, despite the fact that both pain and panic behaviour have been documented with this type of treatment. Experience shows that fish recognised in advance as having e.g. poor gill health or circulatory disorders, tolerate this treatment very poorly. For the mechanical delousing machines, which are recognised as causing scale loss, treated fish will be particularly exposed to winter ulcer at cold water temperatures. Both classical and atypical winter ulcers are ranked high as a cause of reduced welfare and mortality in farmed salmon in the sea phase in this year's survey, which is supported by the high number of locations diagnosed with winter ulcer in 2022 (Chapter 6.4 Winter ulcer).

In total, the Norwegian Food Safety Authority received 1,781 reports of welfare incidents from fish farms in 2022, an increasing trend from 2021, which had 1,617 reports. The proportion of reports concerning non-medicinal delousing with handling shows a slightly decreasing trend. Use of thermal delousing alone is also decreasing, while combination methods are increasing considerably, including fresh water combined with either thermal or mechanical treatment. In 2022, important work has been initiated to better systematize welfare incidents and generate knowledge of preventive measures.

It is important that the practice of having a slaughter boat present during delousing for the emergency slaughter of morbid fish does not increase the willingness to take risks in relation to delousing. In addition, it is important that the number of fish slaughtered in this way is reported and made available in order to increase the knowledge base around delousing operations, so that the risk of mortality during delousing is not underestimated.

New for this year's report is that statistics have been obtained from the Norwegian Food Safety Authority that describe slaughter quality in the industry. On a national basis, just under 15 percent of the volume of salmon and rainbow trout is downgraded due to deformities and imperfections. The most frequently used reason for down-classification in both 2021 and 2022 was "wounds and injuries", which represents fish that have probably lived with reduced welfare for shorter or longer periods prior to slaughter. Fish classified as "ordinary" and "production" represent a significant proportion. Exact identification of the number of fish involved (rather than weight in tons) would have been valuable, particularly in relation to using this type of data as a welfare indicator. At the farm level, there is great variation in the proportion of fish that are downgraded. By analyzing slaughter data, an indication can be gained of whether work is progressing in the right direction in relation to systematic improvement of operations with a view to welfare. Concrete, measurable parameters can contribute to greater welfare focus, not least regarding technology development.

For cleaner-fish, there are still major welfare challenges related to disease, delousing and a lack of control over mortality in the cages. There has been a recorded decline in use of cleaner-fish over the past three years. Several comments have also been received in the free text field this year where it is suggested that the use of cleaner-fish should be banned. The Government's Aquaculture Strategy from 2021 states that if it good welfare and effectiveness against salmon lice cannot be documented in the near future that the use of cleaner fish must be discontinued. There is still a great deal of uncertainty related to their delousing effect. In this year's survey, 34 percent (for lumpfish) and over 60 percent (for wrasse) of fish health personnel who supervise cleaner-fish answer that they do not know what delousing effect the cleaner-fish provide. A lack of control over stocking, mortality and imports of wrasse from Sweden, illustrate that there are still major challenges linked to the use of cleaner-fish.

When it comes to the use of new and complex technology in, for example, delousing, technical problems and human failure remain challenging. Such events are of great importance, as many personell are often involved in operational failure. When planning operations, ample safety margins should be included, and both daily management and particular practices should be risk assessed and managed with a view to minimizing risk. Camera-based solutions for automated lice counting can also provide information on external welfare indicators. Hopefully, in the long term, these can be good tools for monitoring and improving welfare.

Fish health personnel are committed promoters of fish health, welfare and general biosecurity, and face different challenges in the various production areas. The public management system should ensure that good health and welfare pay off, while the opposite does not.

When it comes to the Traffic Light System, growth and exceptional growth, corrective measures and clear welfare targets must be introduced in public management to ensure low mortality rates, that the areas remain green in relation to survival and welfare of wild salmon, and that non-medicinal treatments requiring handling are only used in exceptional cases. The coming parliamentary report on animal welfare will hopefully contribute to improved welfare, by facilitating action plans that deal with cleaner-fish problems, infectious diseases and the number of non-medicinal delousing events. It is important that business development is based on good health and welfare, for both farmed fish, wild fish and cleaner-fish, and that good indicators are found to achieve welfare targets.

5 Viral diseases of farmed salmonids

By Torfinn Moldal

Infectious salmon anaemia (ISA) was confirmed at 15 locations in 2022. In addition, ISA was suspected at five sites based on detection of virulent ISA-virus. ISA was confirmed or suspected at one or more locations in every production areas, from PO2 in the South-west to PO10 in the North. There was at least three cases where virus likely had been transmitted between neighbouring sites, while two confirmed outbreaks at ongrowing sites could be linked to the smolt farms that had delivered fish to the respective sites and two confirmed outbreaks in brood fish farms could be linked to relocation of fish from a third brood fish farm where ISA is suspected.

Pancreas disease (PD) was confirmed at 98 sites in 2022. All detections were within the endemic zones for SAV2 and SAV3, and there were equal numbers of detections of each genotype. It is worth noting that there was a marked increase of detections of SAV2 in PO6 and a pronounced decrease of detections of SAV3 in PO3.

Infectious haematopoietic necrosis (IHN) was confirmed at several locations in Denmark and Finland in 2022. Surveillance of brown trout and rainbow trout at freshwater sites as well as Atlantic salmon and rainbow trout at marine sites revealed neither IHN nor viral haemorrhagic septicaemia (VHS) at Norwegian farms with salmonids last year. Given the serious consequences of an outbreak of IHN or VHS, surveillance of farmed fish in Norway is important to enable infected fish to be removed as quickly as possible, in the event of an infection.

In 2022, cardiomyopathy syndrome (CMS) and heart and skeletal muscle inflammation (HSMI) were detected at fewer sites than in 2021. However, these are among the most frequently detected diseases in Atlantic salmon in the sea phase, and are linked to high mortality in association with sea lice treatment. Regarding infectious pancreas necrosis (IPN), the situation is relatively stable and with a low number of cases, as for previous years.

Table 5.1 The number of sites with farmed salmonids where viral diseases were detected in the period 2013-2022. *For the period 2013-2019, the numbers of sites with CMS, HSMI and IPN are based on samples submitted to the Norwegian Veterinary Institute, while data that are made available from the owner companies via the private laboratories are included since 2020 (see Chapter 1 Statistical Basis for the report).

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ISA	10	10	15	12	14	13	10	23	25	15
PD	99	142	137	138	176	163	152	158	100	98
CMS	100	107	105	90	100	101	82	154*	155*	131*
HSMI	134	181	135	101	93	104	79	161*	188*	147*
IPN	56	48	30	27	23	19	23	22*	20*	12*

5.1 Pancreas disease (PD)

By Hilde Sindre, Sonal Patel, 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 has been present in Norway since the late 1980s, and 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 can be 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 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 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 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 utilising 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 favourable.

Several commercial vaccines against PD are available, and vaccination is commonly used in the SAV3 zone on the Western coast (PO2–PO5). In Trøndelag, PD vaccination has been less frequent. 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 (PO6 and PO7), however this requirement was withdrawn with no time frame for implantation.

The effect of vaccination has been debated, and vaccination against PD has had limited effects compared to the vaccines against most bacterial infections. However, studies have shown positive effects on the number of outbreaks and lower mortality within outbreaks, In addition, vaccination may contribute to lowering the presence of infectious virus in the water, and consequently also the infection pressure to other site, especially in combination with other biosecurity measures.

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 (**www.barentswatch.no**), and monthly status reports are published on the NVI website.

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

The Health Situation in 2022

Official data

In 2022 98 new cases of PD was registered (49 SAV2 and 49 SAV3) (Figure 5.1.1), and the total number of cases is similar to last year with 100 cases, but a significant reduction compared to 2020, with 158 cases. There is an increase in the number of SAV2-cases (Figure 5.1.2), and a marked decrease in the number of SAV3-cases (Figure 5.1.3). No coinfections with both SAV2 and SAV3 were detected in 2022, and also no detections of SAV north of Trøndelag.

Implemented control areas to prevent, decrease and control PD in farmed aquaculture animals in the area Flatanger (now Namsos), Nærøysund, Leka, Bindal, Brønnøy and Sømna municipalities in Trøndelag and Nordland and similarly for SAV3 in Smøla, Aure, Heim and Hitra municipalities in Møre og Romsdal and Trøndelag have been removed. This also applies for the control area for SAV2 in municipalities Tysvær, Vindafjord, Suldal, Stavanger and Hjelmeland in Rogaland.

In February 2020 a control area for SAV2 was established for the municipalities Stadt, Kinn and Bremanger in Vestland fylke, and this area was still in place by the end of 2022.

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 2021 are not included in the data for PD for 2022. Consequently, the number of infected sites within the PD zone is higher than the reported number, as infected fish from 2021 may remain at sea in the following year.

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, 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

The main area for SAV2 is PO6 (Nordmøre and southern part of Trøndelag), with 46 of 49 cases, while the remaining three were detected in PO5. For SAV2 there was a marked increase in the number of new cases from 29 in 2021 to 49 in 2022. September and the end of the year represents peaks in number of detections (Figure 5.1.4).

SAV3

PD caused by SAV3 is mainly detected in PO2-PO4 covering Ryfylke to Stadt, the southern part of the PD zone. A significant reduction in the number of detection of SAV3 infections was observed in 2021, and this trend continued in 2022, with a reduction from 71 to 49 cases. Previously, a peak in cases of PD caused by SAV3 has typically been observed in the early summer (June-July). In 2020 the detection peak was in April, and in 2021 February/March. In 2022 two peaks of detections are observed, in February and in May/June (Figure 5.1.5). In PO2 a marginally increase in detections from 15 in 2021 to 17 in 2022. In contrast, PO3 had a marked reduction in cases from 22 in 2021 to three in 2022, while PO4 had a reduction from 32 in 2021 to 28 i 2022. More than 50 percent of the SAV3-detections are now within the area from Nordhordland to Stad. The positive trend from 2021 continued in PO5 (Stadt to Hustadvika) with only one detection of SAV3 in 2022. SAV3 was not detected in PO6 to PO13 (Nordmøre to Øst-Finnmark).

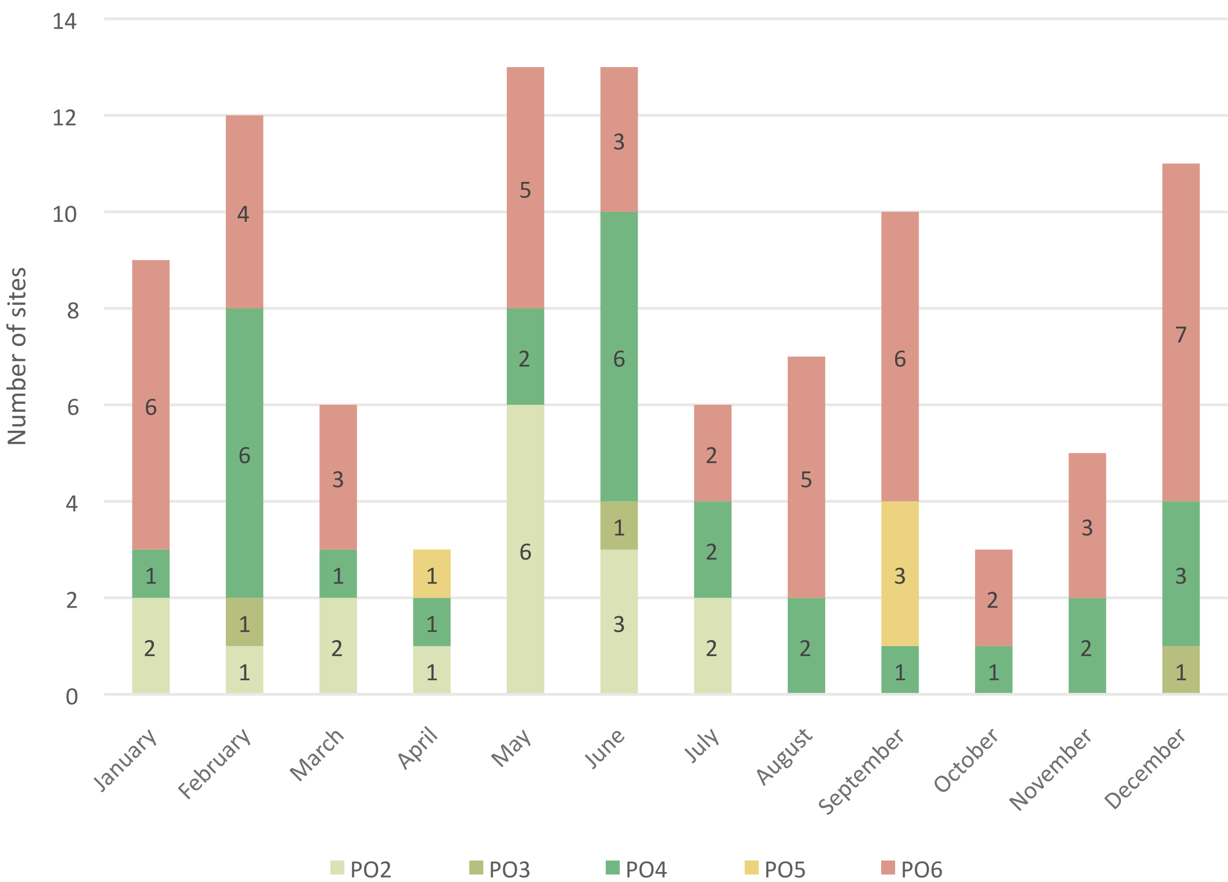


Figure 5.1.1 New PD cases in 2022 per production area (PO) and month.

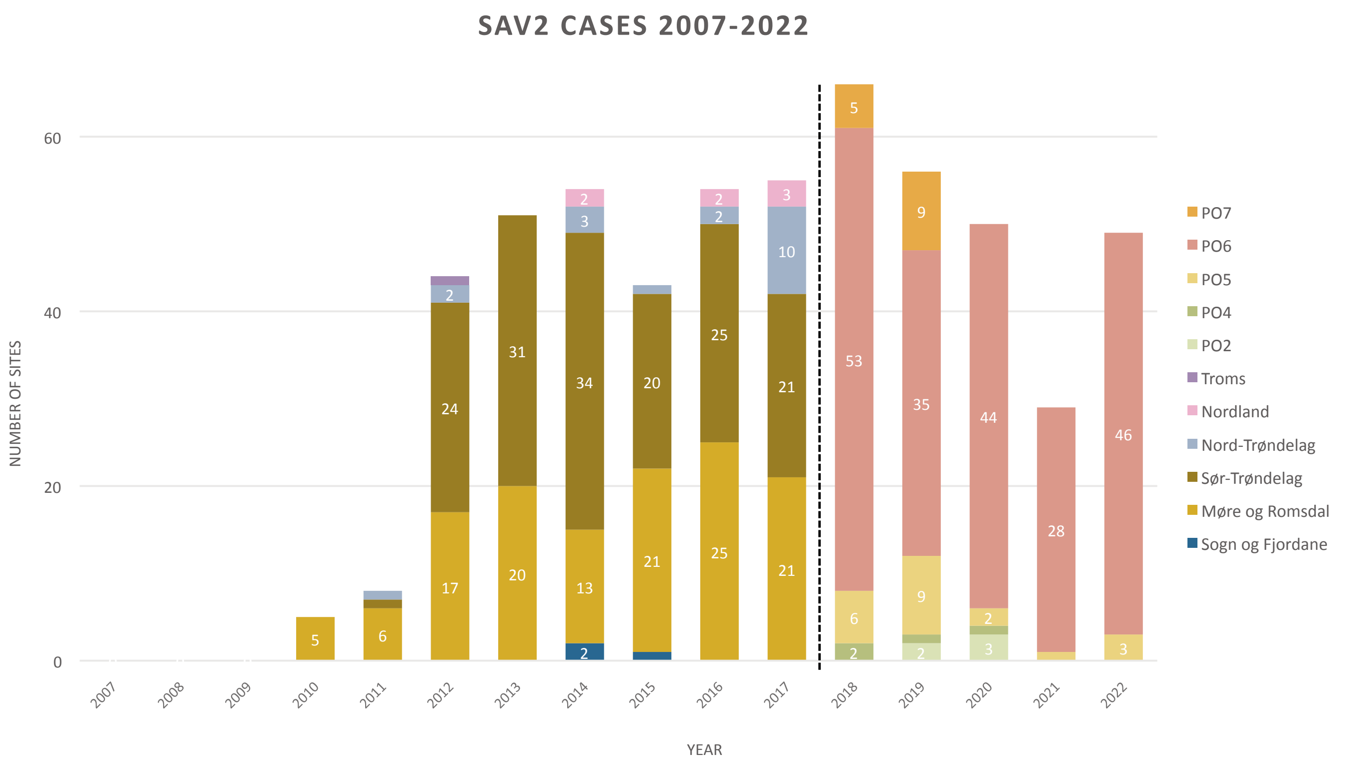


Figure 5.1.2 New SAV2 cases each year per county (2007-2017) and per production area (PO) (2018-2022). Areas without SAV2-cases are not included in the figure.

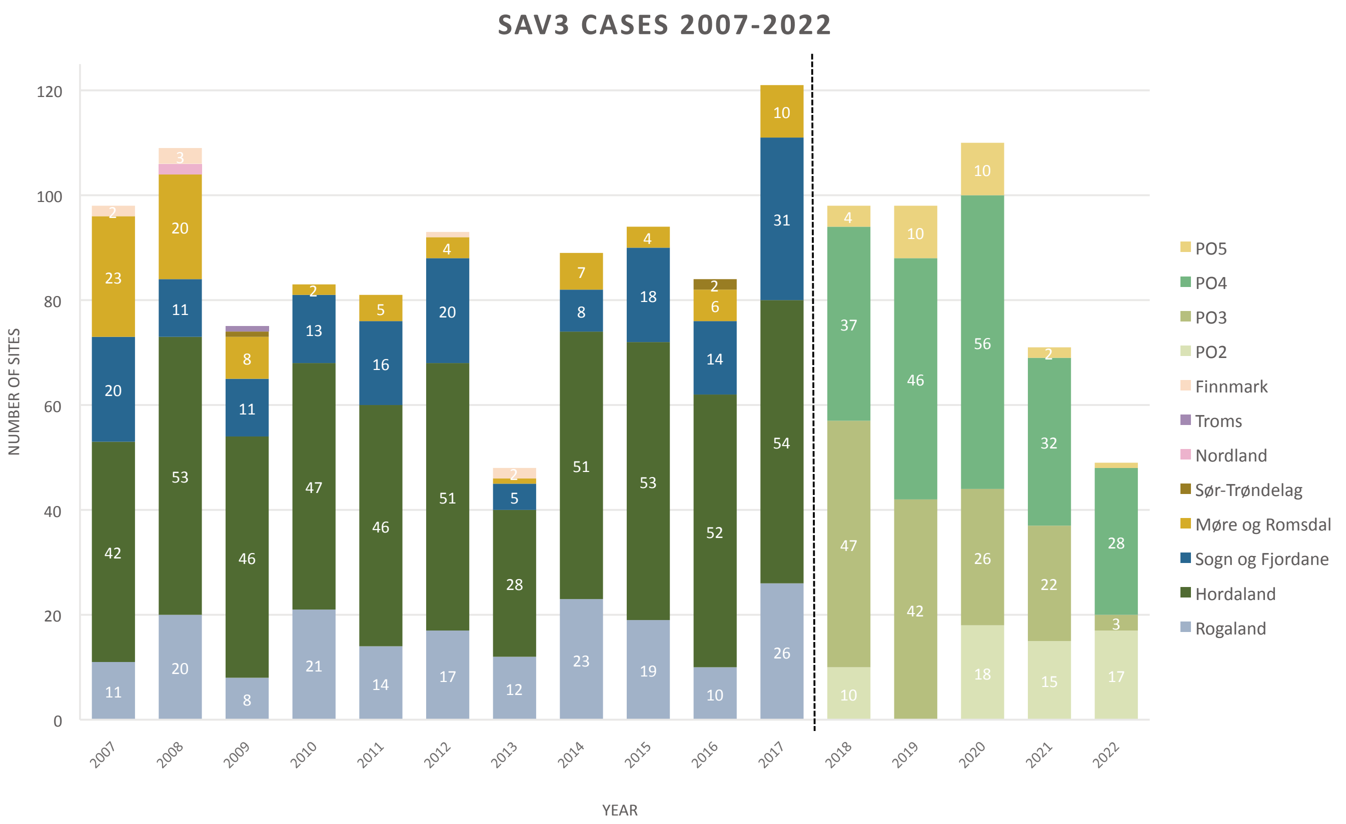


Figure 5.1.3 Monthly new SAV3 cases each year per county (2007-2017) and per production area (PO) (2018-2022). Areas without SAV3-cases are not included in the figure.

All detections of both SAV2 and SAV3 in 2022 were within the described endemic areas for the two genotypes as stated in the current legislation (Figure 5.1.6).

The Annual Survey

Many respondents still considered PD as an important viral disease in marine finishing sites for both Atlantic salmon and rainbow trout in 2022. (Appendix B1 og B2). As previous years, the disease was associated with low feed conversion for both species. 42 percent of the respondents (13 of 31) with experience in vaccination against PD had not observed PD after vaccination, whereas 39 percent (12 of 31) reported reduced occurrence of disease. The remaining 19percent reported no changes. Some respondents noted that fewer clinical signs were observed in vaccinated fish compared to non-vaccinated although virus has been detected on site. Also noted by some was that outbreaks occurred later in the production period and with shorter duration, and respondents connected these observations to vaccination with DNA vaccine. For information regarding vaccine side effects and evaluation of vaccination efficacy of PD vaccination, read Chapter 9.6 Vaccine efficacy and side effects.

Evaluation of the PD situation

The number of PD-cases is still high, and constitutes a considerable challenge to the aquaculture industry, connected to increased production costs and welfare challenges for the fish. Fish may be sub-clinically infected with SAV for a long time before visible disease is observed, Consequently, frequent screening for SAV is important to detect infection 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 be spread directly in seawater, or by transport of fish for slaughtering or moving of infected fish between sites.

When the northern bondery 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. However, no new cases have been reported from 2019, which is very positive with regards to preventing the transmission of SAV to the PD free zone in the north of Norway. This demonstrates that spread of PD can be prevented by improved biosecurity measures and cooperation within the industry and between the industry and the authorities.

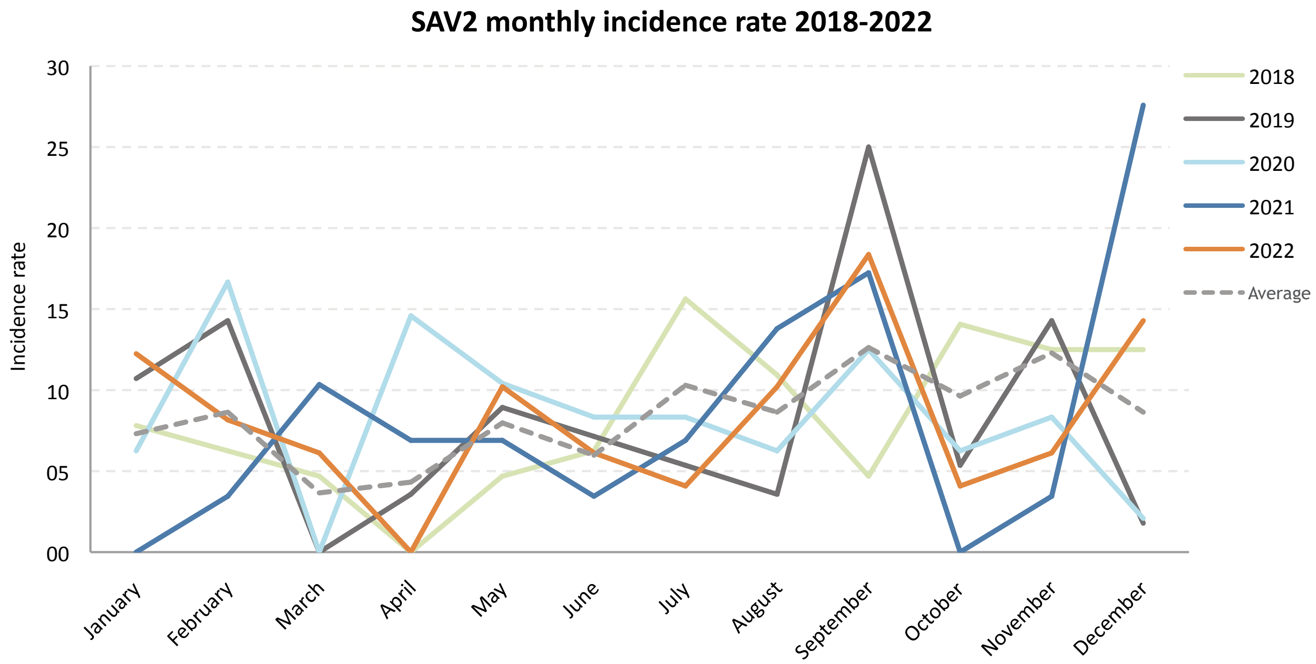


Figure 5.1.4 Monthly incidence rate for SAV2 from 2018 to 2022. The incidence rate for each month is calculated by dividing the number of cases for the specific month with the number of total cases each year, and multiplying with hundred.

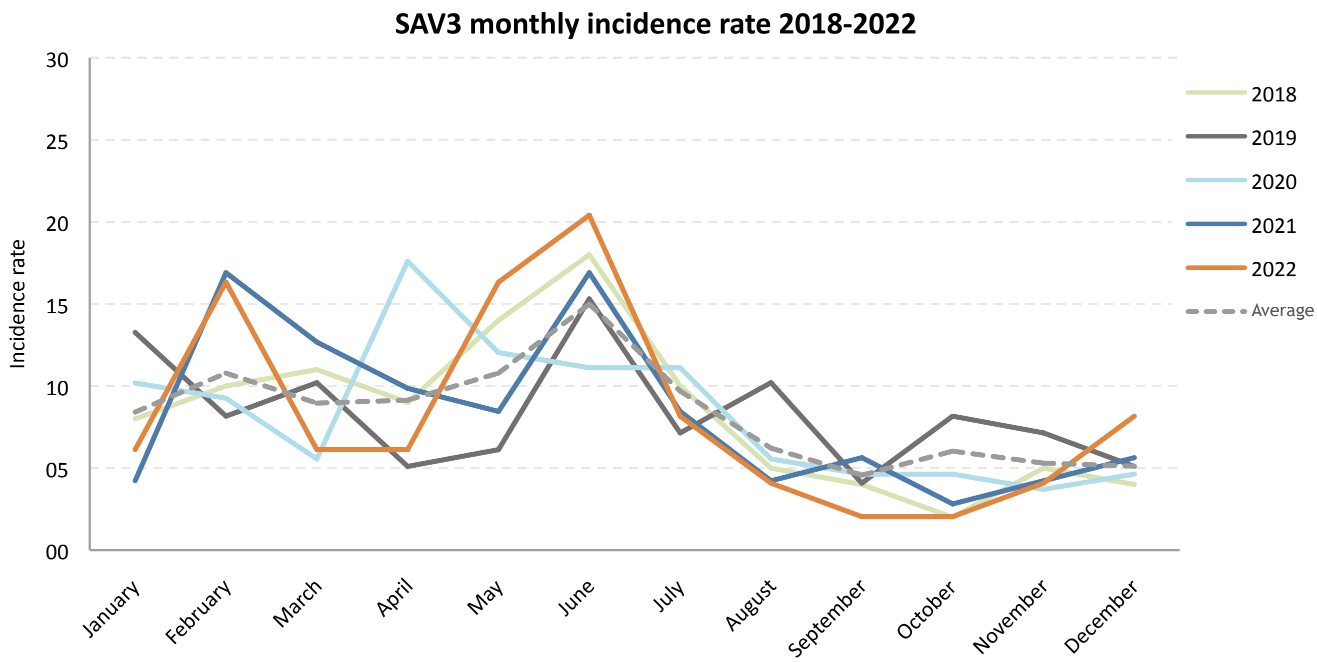


Figure 5.1.5 Monthly incidence rate for SAV3 from 2018 to 2022. The incidence rate for each month is calculated by dividing the number of cases for the specific month with the number of total cases each year, and multiplying with hundred.

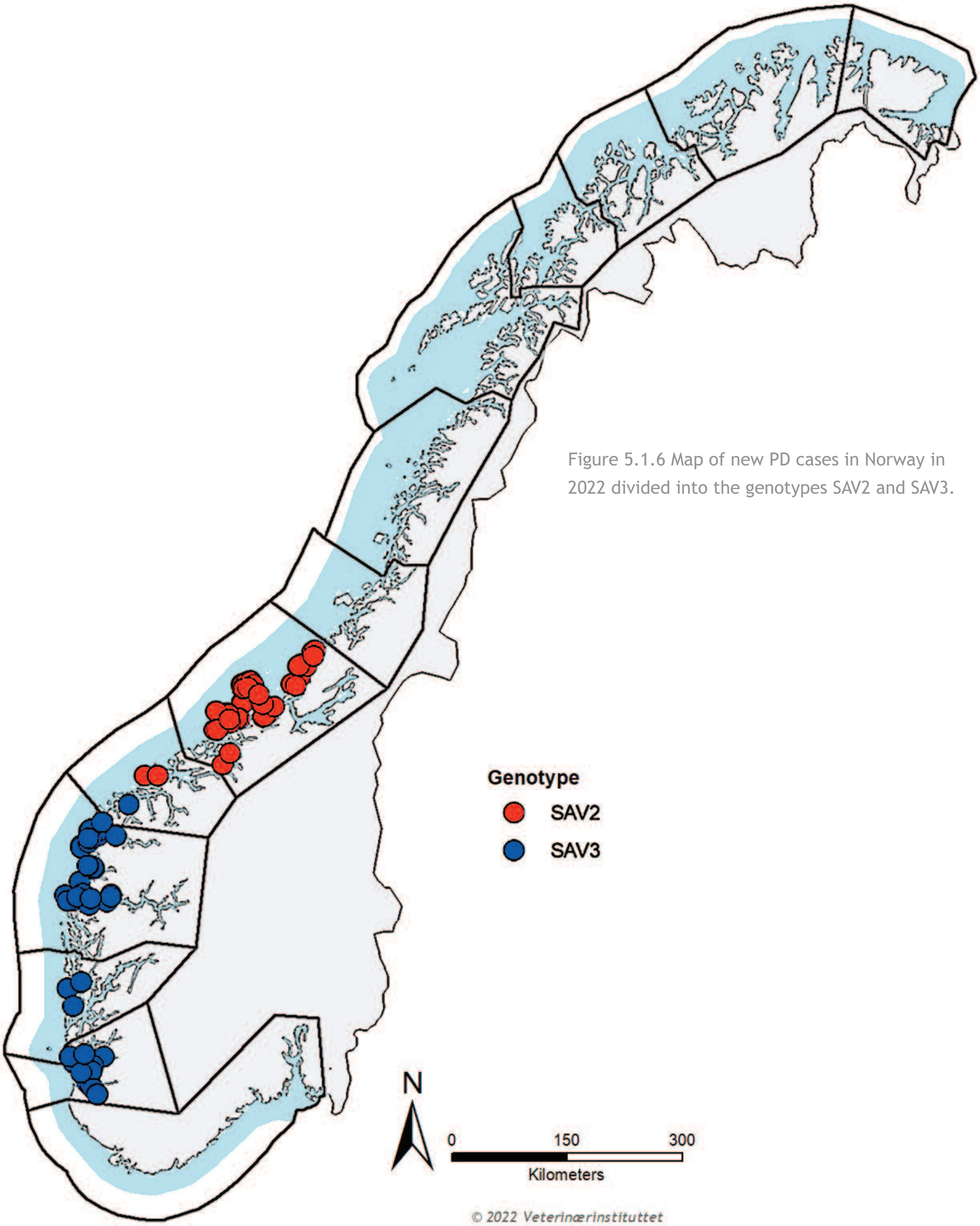


Figure 5.1.6 Map of new PD cases in Norway in 2022 divided into the genotypes SAV2 and SAV3.

5.2 Infectious salmon anaemia (ISA)

By Torfinn Moldal, Hege Løkslett, Geir Bornø, Monika Hjortaas, Johanna Hol Fosse and Ole Bendik Dale

The Disease

Infectious salmon anaemia (ISA) is a serious viral disease caused by the infectious salmon anaemia virus (ISAV). Naturally occurring ISA outbreaks have only been reported in farmed Atlantic salmon; however, both rainbow trout and brown trout are considered susceptible. The infection initially affects the surface of the fish (gills and skin), before disseminating to the circulatory system. Post mortem examination typically reveals pale gills, suggestive of severe anaemia (reduced red blood cell numbers), as well as clinical signs compatible with vascular and circulatory dysfunction, including free abdominal fluid, oedema, necrotic lesions, and haemorrhages in eyes, skin, and internal organs (Figure 5.2.1).

ISAV may be present on a farm for a considerable time period before characteristic clinical and pathological signs of disease become evident. Typically, only a small proportion of the fish becomes infected and develops disease; hence, the daily mortality rate in affected pens is low, in the region of 0.5-1‰. In this early phase of infection, the detection of the virus can be challenging and require PCR examination of a large number of fish.

ISAV is classified into two main variants according to the ability to cause disease, non-virulent (ISAV HPR0) and virulent (ISAV HPRΔ). ISAV HPRΔ evolves from ISAV HPR0 through pathotypical changes in the amino acid sequence of the hypervariable region (HPR) of the haemagglutinin esterase protein (HE, encoded by genomic segment 6) and around the cleavage site of the fusion protein (F, encoded by genomic segment 5). The prevalence of ISAV HPR0 is high, with frequent, transient infections affecting all three production stages. Moreover, a recent study from the Faeroe Islands suggests that ISAV HPR0 can establish persistent "house-strains" in land-based smolt farms. The same study revealed that ISAV HPR0 variants detected in smolts were not closely related to strains detected in brood fish that had delivered eggs to the hatcheries, suggesting that true vertical transmission of ISAV HPR0 via eggs is not a frequent occurrence. In agreement with the Faeroese study, data from Norwegian smolt farms suggests that the same ISAV HPR0 strain may persist at land-based locations for years and contribute to subsequent outbreaks in sea. Within the last decade, ISA outbreaks have been confirmed at two land-based Norwegian smolt farms, both of which had delivered fish to several ongrowing sites that also developed ISA. On both occasions, the ISAV detected in the smolt farms and at the ongrowing sites were identical or closely related. In addition, around ten smolt farms have delivered fish to ongrowing sites that subsequently experienced ISA outbreaks caused by ISAV HPRΔ variants closely related to ISAV HPR0 detected on the smolt farm that had delivered the fish.

Our knowledge of the risks associated with the detection of ISAV HPR0 has several gaps, including information about possible reservoirs, how often new ISAV HPRΔ variants arise, and the factors that drive the transition from ISAV HPR0 to ISAV HPRΔ. Nevertheless, epidemiological data suggests that a small proportion of ISAV HPR0 infections gives rise to new ISAV HPRΔ variants. Transitions from HPR0 to HPRΔ remain the most likely cause of solitary ISA outbreaks. Such transitions have been documented in the field. Furthermore, solitary outbreaks can be associated with insufficient biosecurity and increased stress.

Disease control

ISAV HPRΔ is notifiable both 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 location 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 location (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

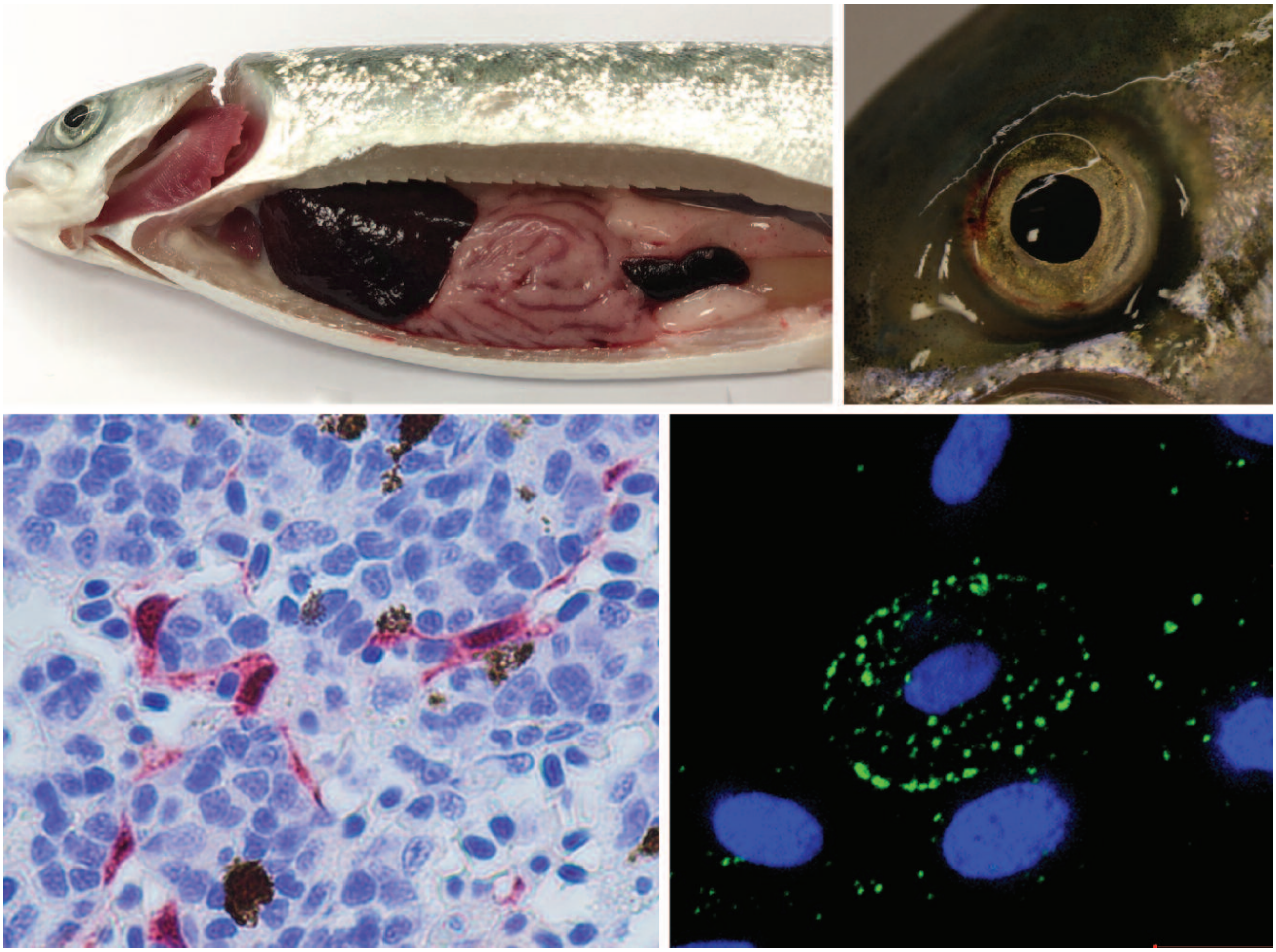


Figure 5.2.1 Typical signs of infectious salmon anaemia (ISA) include pale gills, dark liver, and bleedings in internal organs and eye (top panel). ISAV replicates in the thin cell layer lining Atlantic salmon blood vessels (lower left panel, the virus is coloured red by immunohistochemical staining). When new virus particles are released to the blood stream, they attach to red blood cells (lower right panel, the virus is coloured green by immunofluorescent staining). Photo: Frieda Betty Ploss, Adriana Magalhães Santos Andresen og Johanna Hol Fosse.

The Health Situation in 2022

Official data

In 2022, ISA outbreaks were confirmed at a total of 15 locations, three in PO2, one in PO3, three in PO4, one in PO5, three in PO6, one in PO7, two in PO8, and one in PO10. One of the confirmed outbreaks in PO2 was recorded as a suspicion in December 2021, based on the detection of virulent ISAV. At the end of 2022, five detections of virulent ISAV had not yet been confirmed and were classified as suspected outbreaks, including two in PO2 and one each in PO5, PO8, and PO9. For one of the unconfirmed cases in PO2 and the unconfirmed case in PO8, the fish was slaughtered without the suspicion being confirmed. The remaining three suspected cases concerned brood fish farms.

The Annual Survey

The annual survey shows that both ISA (infection with ISAV HPRΔ) and infection with ISAV HPR0 are considered high on the list of increasing challenges on brood fish farms in 2022 (Appendix C1).

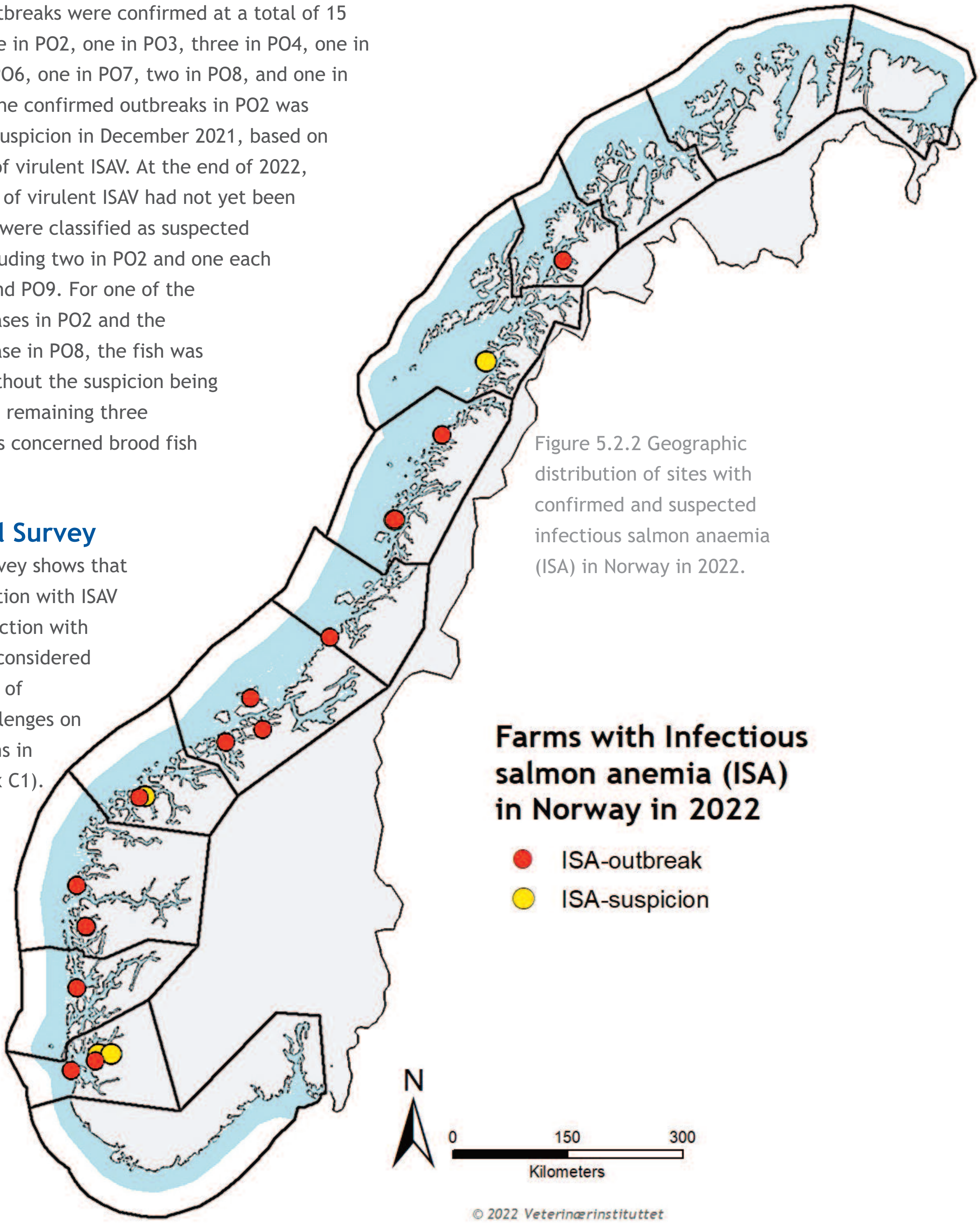


Figure 5.2.2 Geographic distribution of sites with confirmed and suspected infectious salmon anaemia (ISA) in Norway in 2022.

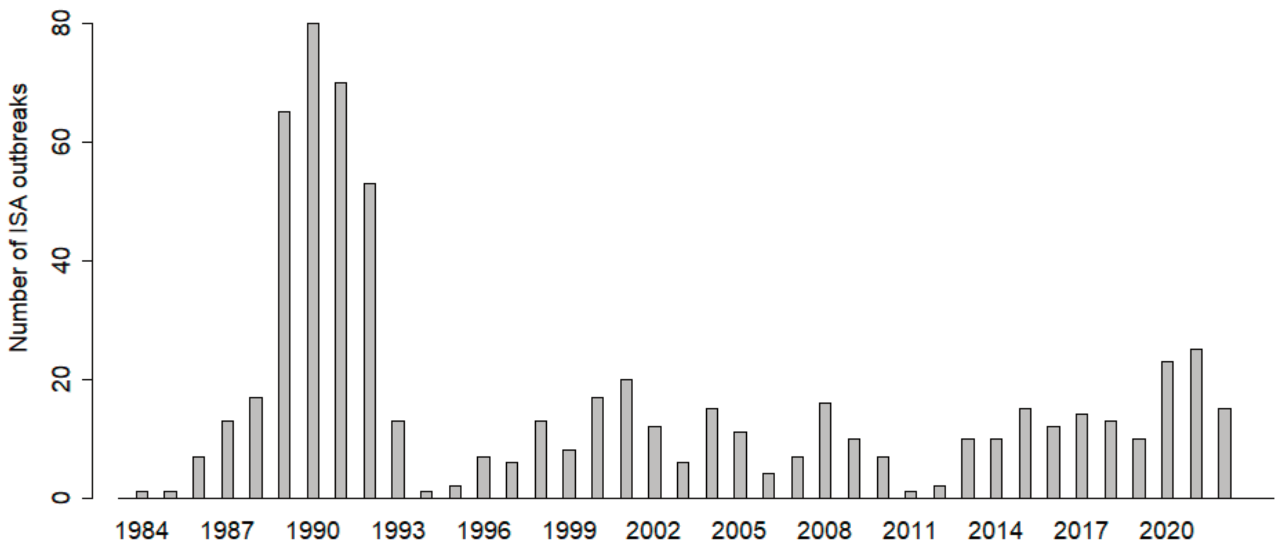


Figure 5.2.3 Annual numbers of confirmed infectious salmon anaemia (ISA) outbreaks in Norway from 1984 to 2022.

On smolt farms, infection with ISAV HPR0 is considered the second most important of increasing challenges, while infection with ISAV HPRΔ is not considered high on the list of increasing challenges (Appendix A1). At ongrowing finishing sites, ISA is considered the 11th most important cause of mortality (9/63 responders), but is lower on the list of increasing challenges (Appendix B1).

Evaluation of the ISA situation

ISA was confirmed or suspected at one or more locations in every production area, from PO2 in the South-west of Norway to PO10 in the North (Figure 5.2.2). Two outbreaks were confirmed at brood fish farms, while the remaining outbreaks were confirmed at ongrowing sites. At the time when the ISA suspicion was recorded, nine locations were already affected by ISA restricted zone regulations, two in protection zones and seven in surveillance zones. One location had vaccinated the fish against ISAV; moreover, the fish in this location was triploid. Between 1993 and 2021, the yearly number of ISA outbreaks varied from one (1994, 2011) to 25 (2021), with an average of 10 outbreaks per year (Figure 5.2.3). Hence, the number of confirmed outbreaks in 2022 is considerably lower than the previous year, but relatively high when the last 30 years are considered together. The geographic distribution of confirmed ISA outbreaks in Norway between 2018 and 2022 are shown in Figure 5.2.4. The number of outbreaks in the northern production areas was noticeably lower in 2022, compared to the three previous years. This can at least in part be related to increased vaccination against ISAV.

Phylogenetic analyses based on genomic segments 5 and 6 show that ISAV HPRΔ detected at two of the ongrowing finishing sites with confirmed ISA outbreaks in PO2, is identical or closely related to ISAV HPR0 detected at two of the smolt farms that had delivered fish to the respective sites. ISAV HPRΔ detected on the third marine finishing site with confirmed ISA in PO2 is related to virus detected at several locations in the South-west of Norway in recent years; however, no connection to previous outbreaks was identified. Sequences retrieved from the two sites with suspected ISA in PO2 and the site with confirmed ISA in PO3 were insufficient for phylogenetic analyses.

ISAV detected at two neighbouring sites in PO4 last autumn are closely related to each other, but not to virus detected at other sites in recent years. Virus detected at the third site with confirmed ISA in PO4 last autumn is related to ISAV detected at a site further south in the same production area in the spring of 2021. No further connection between the two outbreaks has been identified.

Virus detected at a brood fish farm in PO5 where ISA was not confirmed and two brood fish farms in PO6 where ISA was confirmed last spring are identical in the areas of segment 5 and 6 included in the phylogenetic analysis. The fish on the farms in PO6 had been relocated from the farm in PO5. Virus detected at three ongrowing sites in PO5, PO6, and PO7 are not closely related to virus detected in recent years; these outbreaks appear to be solitary.

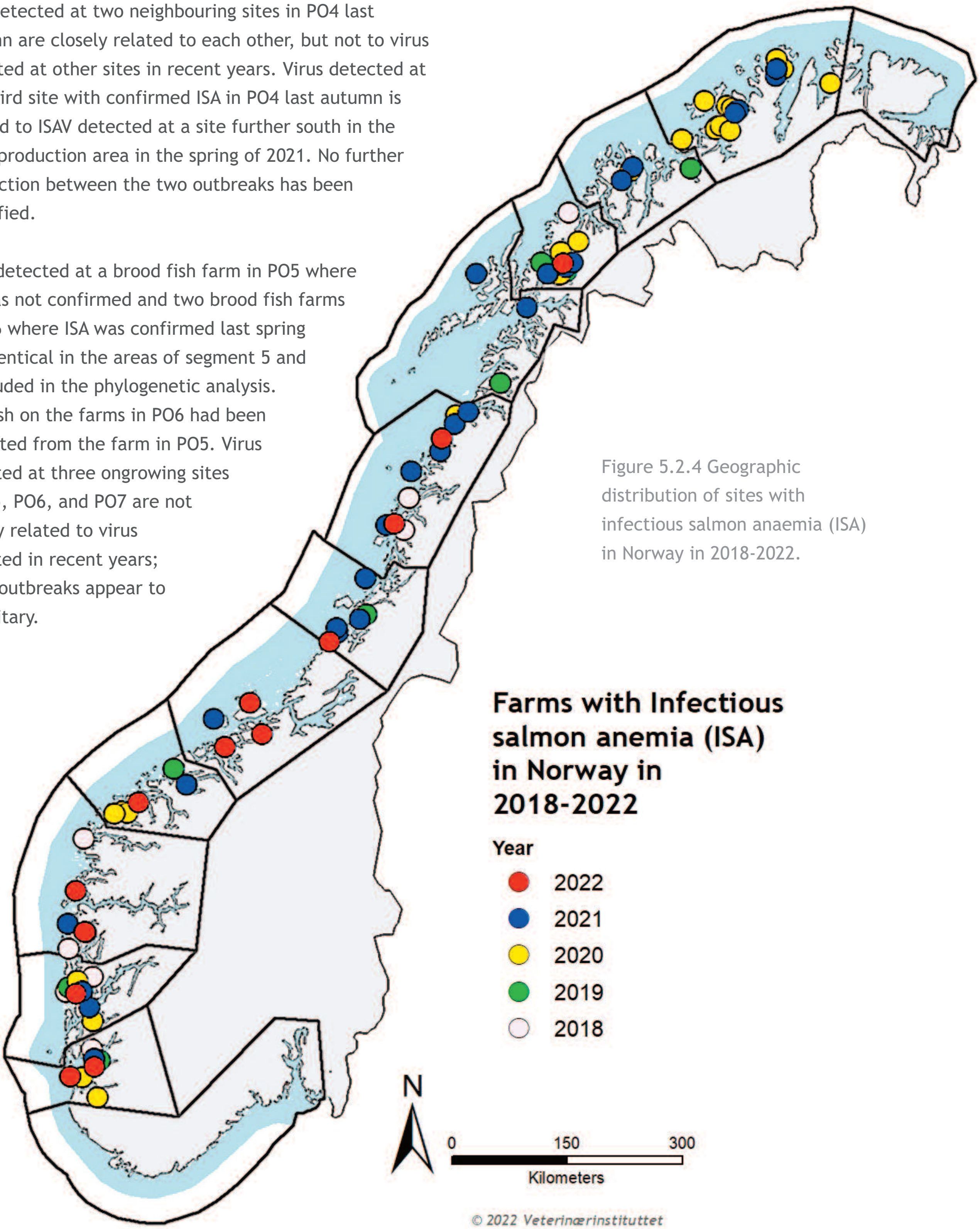


Figure 5.2.4 Geographic distribution of sites with infectious salmon anaemia (ISA) in Norway in 2018-2022.

Virus detected at two neighbouring sites in PO8 last summer are identical to each other and closely related to virus detected at a site further north in the summer of 2020. Virus detected at a third site in PO8 last year is not closely related to recently detected viruses, based on a total evaluation of segment 5 and 6 sequences. No sequences were retrieved from the virus detected on a brood fish farm in PO9. Virus detected on an ongrowing site in PO10 at the end of last year's summer is closely related to a virus that was detected for the first time at a nearby site with vaccinated fish in the summer of 2021. The vaccinated fish at this site was permitted to remain in sea by the Norwegian Food Safety Authorities, closely supervised by the Norwegian Veterinary Institute and the vaccine company. Virulent ISAV was detected again at the site in the summer of 2022, and the site was emptied of fish last autumn.

In conclusion, the ISA outbreaks in 2022 were broadly distributed along the coast, with no widespread epidemics caused by the same virus variant. The most noticeable findings are the relatively few outbreaks in the North and the relatively many confirmed outbreaks and suspicions at brood fish farms. At least three outbreaks are likely to have resulted from transmission from neighbouring sites; two confirmed outbreaks at ongrowing sites can be associated with the smolt farms from which the fish originated; and two confirmed outbreaks on brood fish farms can be associated with movement of fish from a third brood fish farm with suspected ISA based on detection of virulent ISAV.

In compliance with the Norwegian Veterinary Institute's commitment as the international and national reference laboratory for ISA, quality-assured sequences of genomic segments 5 and 6 detected in conjunction with surveillance and suspected outbreaks are deposited in GenBank. The sequences are named based on their geographic origin and year of detection, as well as the Norwegian Veterinary Institute record number. The GenBank entry also includes the name and number of the location, the date of sampling, and the species that was sampled.

Since 2019, the prevalence of ISAV HPR0 in Norwegian smolt farms has been documented in a surveillance program. Approximately half of Norwegian smolt farms are screened for ISAV HPR0 by a single sampling every other year. In 2022, ISAV HPR0 was detected in nine out of 78 smolt farms (11.5 percent) sampled in the program. In comparison, ISAV HPR0 was detected in 7 percent (five out of 74), 14 percent (six out of 42), and 10 percent (eight out of 78) of sampled farms in 2019, 2020, and 2021, respectively. Based on the assumptions that ISAV HPR0 causes a transient infection of a relatively short duration; that the farms have only been sampled on a single occasion; and that sampling have only been performed in a subset of cages at each smolt farm; the true prevalence of ISAV HPR0 on smolt farms in Norway is probably considerably higher. Final numbers and conclusions will be made public in the report of the ISAV HPR0 surveillance program in Norwegian smolt farms 2022.

No official surveillance program has been implemented to evaluate the prevalence of ISAV HPR0 at ongrowing sites, and per today, the Norwegian Veterinary Institute does not have a complete overview of ISAV HPR0 detections in fish kept at sea. Through surveillance in control areas and diagnostics, the Norwegian Veterinary Institute has detected ISAV HPR0 at a total of 36 ongrowing sites in 2022. As for smolt farms, the true prevalence of ISAV HPR0 at ongrowing sites is assumed to be considerably higher.

The successful control of ISA outbreaks and the prevention of further spread of the infection depend on early detection of infection and efficient removal of infected fish. Moreover, if ISAV HPRΔ is detected in fish products intended for export, trade restrictions with severe consequences to the Norwegian salmon farming industry may be imposed, as illustrated by the reactions to such findings in fish exported to China in 2015. Since the autumn of 2015, the industry, fish health services, and the Norwegian Food Safety Authorities have together implemented systematic surveillance measures in restricted zones created in conjunction with ISA outbreaks (earlier referred to as control areas). This surveillance involves monthly inspections and sampling to facilitate detection at the earliest possible time point.

Successful prevention of ISA is better than control. It is reasonable to assume that the presence of ISAV HPR0 represents an important risk factor for ISA outbreaks. Increased knowledge of possible reservoirs of ISAV HPR0, as well as the factors that predispose for the transition to ISAV HPRΔ, will be important to design improved strategies for future control and eradication.

Successful control of ISA is based on prevention of spread through early diagnosis and rapid removal of diseased fish from the affected farm. Photo: Lisa Furnesvik, Stim AS

5.3 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.

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 2022

Data from the Norwegian Veterinary Institute and other laboratories

Compiled data from the Norwegian Veterinary Institute and the private laboratories (see Statistical Basis in Chapter 1) show that IPN was detected in 12 different sites in 2022. This is at a similar level as in previous years. IPN has been detected along most of the coast (Figure 4.3.1), distributed as follows, with the number of positive locations in parentheses: PO1 + PO2 (1), PO3 (0), PO4 (1), PO5 (3), PO6 (2), PO7 (1), PO8 (1), PO9 (2), PO10 (1), PO11 (0) and PO12 + PO13 (0). From surveys based solely on agent detection (mainly analyzed by real-time RT-PCR), IPN virus has been detected on 21 sites divided from PO1-PO11. Of these sites, about 50 percent state that these have no clinical significance.

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QTL stocks are widely used for both salmon and rainbow trout, and almost all fish are vaccinated against IPN. IPN is perceived as an important problem in 2022 and IPN is ranked among the ten most important increasing problems in the hatchery phase for salmon and among the five most important problems in rainbow trout. For hatchery fish, IPN is reported as an increasing problem in the form of increased mortality, reduced growth and, to a certain degree, reduced welfare. For fish farms with salmon, it is reported that reduced growth and welfare associated with IPN is a problem, and that IPN results in a slight increase in mortality. For more details from the survey, see Appendix A1-A2 (hatcheries) and B1-B2 (ongrowing).

Evaluation of the IPN situation

It is disturbing that breeders still experience outbreaks in IPN QTL fish, but it is positive that the number of recorded outbreaks remains at a relatively stable, low level. IPN used to be one of the most common diagnoses. The Norwegian Veterinary Institute collects IPN-virus samples from outbreaks in order to monitor the situation.

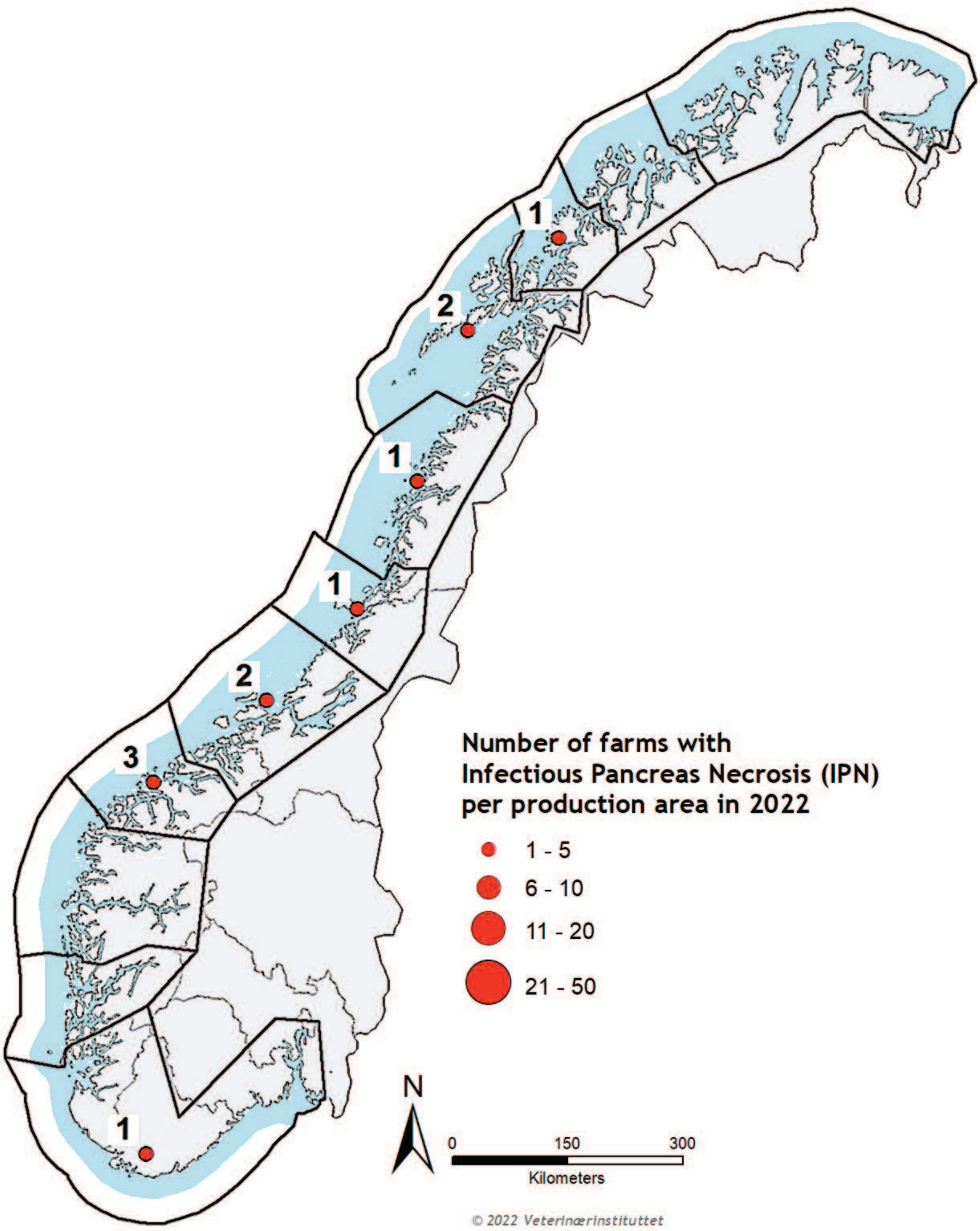

Figure 5.3.1 Distribution of registered IPN outbreaks in Norway 2022.

5.4 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) is one of the most common viral diseases of farmed salmon in Norway, and was first reported in 1999. The disease is most common in the first year at sea, but outbreaks occur throughout the marine production phase and can also be detected in smolt farms. The heart muscle inflammation develops gradually (Figure 5.4.1 a and b) in the time before and during the clinical outbreak, which can last for several weeks. Within the outbreak period, red skeletal muscle inflammation is also common. The mortality rate associated with HSMI can be highly variable, ranging from no increase to near 20 percent. Losses are often reported in conjunction with operating measures that may have caused stress to the fish. Salmon that die from HSMI commonly show signs of severe circulatory disturbances (Figure 5.4.2).

In 2013-2014, a HSMI-like disease with heart inflammation was detected in Norwegian rainbow trout. Outbreaks were recorded in freshwater and at marine sites in fish transferred from infected smolt farms. Diseased rainbow trout could present very pale, as a manifestation of severe anaemia. In comparison, HSMI in salmon is usually not associated with anaemia.

Piscine orthoreovirus (PRV) was first identified in tissues of HSMI-affected salmon in 2010 (PRV-1). In 2015, another PRV genotype was detected in rainbow trout with HSMI-like disease (PRV-3, earlier referred to as virus Y or PRV-Om). An additional PRV variant (PRV-2) was described in Japanese Coho salmon. Genetically, PRV-1 from salmon and PRV-3 from rainbow trout are approximately 90 percent similar, but some parts of the genome show less than 80 percent similarity. The association between PRV-1 and HSMI in Atlantic salmon was established experimentally in 2017; the association between PRV-3 and HSMI-like disease in rainbow trout was established in a similar manner in 2019.

PRV-1 is highly prevalent in farmed salmon in Norway and has also been detected in wild salmon; however, not all infected salmon develop disease. In later years, several genetic variants of PRV-1 have been identified, and these variants have been shown to vary in virulence. Early variants from the time preceding the first HSMI outbreaks in 1999 belong to the genetic group perceived as low virulent. In contrast, virus isolates from recent outbreaks confer experimental HSMI and belong to the virulent genetic group. It is likely that the overall condition of the salmon contributes to determining the outcome of infection, and that stress may trigger or increase mortality in infected fish. Infections with PRV-3 are still detected in Norwegian rainbow trout; however, after 2015, no serious disease outbreaks have been recorded. PRV-3 is also detected in wild sea trout (Chapter 10.2 The health situation in the wild salmonid brood fish).

All characterised genotypes of PRV infect red blood cells and can be detected in most blood-filled organs of the fish from the early stages of infection. PRV-1 in salmon can also be detected in blood and blood-filled organs for a long time after the resolution of disease, often all the way to slaughter. In contrast, rainbow trout appear to eliminate PRV-3 after infection. In fish that develop HSMI, the levels of virus in heart and muscle cells are high, but fall as the tissues heal. This suggests a link between the inflammation and the destruction of infected cells by the immune system.

Disease control

Norway has no official eradication strategy for HSMI, and the disease has not been notifiable since 2014. The reason for this is that the virus is highly prevalent in farmed salmon, and that the detection of the virus is often not associated with clinical disease. PRV-3 in rainbow trout is less prevalent, but can also be detected without clinical signs of disease. As for HSMI in salmon, PRV-3-mediated HSMI-like disease in rainbow trout is not notifiable.

No commercial vaccine against PRV is available, although a few experimental vaccine studies have shown effect. Treating HSMI with anti-inflammatory feed components has been reported to modulate disease development to some extent, and QTL-salmon with increased resistance to HSMI has been introduced. HSMI-related losses can be reduced by avoiding operating measures associated with stress. Experimental studies have shown that salmon with HSMI are sensitive to reduced water oxygen saturation; such conditions can arise after crowding of the fish, transport, or de-lousing. This may relate to decreased haemoglobin levels in virus-infected red blood cells that reduce their ability to carry oxygen, or to heart failure.

Most HSMI outbreaks occur after the fish has been transferred to sea, and the most important reservoir of PRV-1 in the marine environment is probably the farmed salmon itself. However, both the virus and the disease are also detected in smolt farms. For PRV-3 in rainbow trout, efficient surveillance of smolt health appears to be important to detect the infection.

Some smolt farms go through repeated episodes of PRV infection. PRV is a non-enveloped virus and can be challenging to eliminate by standard sanitation measures. Some operators have initiated campaigns to eradicate PRV infections from their smolt farm. The virus appears resistant to high temperatures and UV-treatment, but is susceptible to extremely acidic or basic detergents. Seawater intake without sufficient disinfection appears to increase the risk of PRV infection. There may be reason to believe that efficient control of PRV in smolt farms could affect the prevalence in the marine environment.

For more information about HSMI and HSMI-like disease (in Norwegian): see fact sheet: **https://www.vetinst.no/sykdom-og-agens/hjerte-og-skjelettmuskelbetennelse-hsmb**

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

In 2022, heart and skeletal muscle inflammation was diagnosed at 147 sites harbouring Atlantic salmon (Figure 5.4.3). The number of cases is based on coordinated data from the Norwegian Veterinary Institute and private laboratories (Chapter 1 Statistical basis for the report). Most detections were at marine finishing sites. Occasionally, HSMI is also detected before transfer to sea, and the Norwegian Veterinary Institute's data material from 2022 included four detections at smolt farms (in comparison, seven in 2020 and six in 2021). In previous years, most detections of HSMI were recorded in and north of PO6 (Nordmøre and Sør-Trøndelag). In 2022, the detections were spread relatively evenly along the coast, but as in 2021, with a clear accumulation of cases in PO6. PO9 (Vestfjorden and Vesterålen) also stood out last year. HSMI is diagnosed throughout the year, but in 2022, around 60 percent of the Norwegian Veterinary Institute's cases were registered in the first six months, reaching a peak in June. On many occasions, PRV-1 was detected without a diagnosis of HSMI being made.

PRV-3 in rainbow trout was detected at ten sites in 2022, compared to five in 2021. In four of the cases, the virus detection was associated with disease, compared to three in 2021. The detections were in PO3-PO5 (Karmøy-Hustadvika).

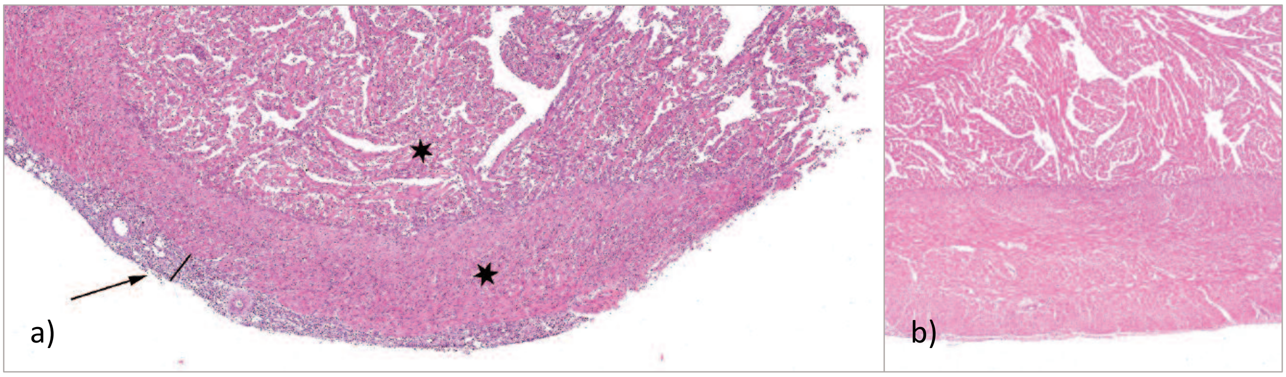

Figure 5.4.1 Heart from salmon with heart and skeletal muscle inflammation (HSMI). a) Histopathological image showing Inflammatory cells in the thickened epicardium (arrow and line) and in the compact (outer) and spongy (inner) layers of the cardiac ventricle (stars). b) Normal cardiac ventricle. Photo: Mona Gjessing and Anne Berit Olsen, Norwegian Veterinary Institute.

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Altogether, HSMI ranges relatively low on the list of health challenges for salmon in smolt farms in 2022 (Appendix A1). Nevertheless, some respondents (7 out of 42) rank HSMI as an important cause of death in the pre-smolt stage.

At marine finishing sites, HSMB is ranked high on the list of the causes of increased mortality, reduced growth, and reduced welfare in 2022, and is considered the number eight health problem in the marine phase for salmon (Appendix B1). This is slightly lower than in 2021, when HSMI was ranked number six on the list. HSMI also has some impact on reduced welfare and mortality in salmon brood fish (Appendix C1).

HSMI-like disease is ranked as a small to moderate health challenge in rainbow trout in different production stages in 2022 (Appendix A2, B2, and C2).

Evaluation of the HSMI situation

The number of recorded HSMI cases declined in 2022, with 147 detections compared to 188 in 2021 and 161 in 2020. Although the datasets for 2022 and 2021 are comparable (Chapter 1 Statistical Basis for the report), it is difficult to determine if the number reflects a true reduction. The survey supports a certain stabilisation of the HSMI situation, as only a few respondents perceived HSMI as an increasing problem in 2022.

In 2022, like previous years, certain marine finishing sites suffered from repeated HSMI episodes over several months. Fish with HSMI appear to be less tolerant to non-medicinal delousing and other handling, and these operating procedures may result in significant mortalities. Similarly, some smolt farms experienced repeated HSMI detections over several months. HSMI in smolt farms may be due to virulent “house strains” that cause repeated disease outbreaks. This is congruent with the hardy nature of the virus, among other resistant to UV-treatment.

As in previous years, a number of detections of PRV-1 were not associated with disease and mortality, possibly explained by the prevalence of genetic PRV-1 variants of low virulence.

The number of sites with rainbow trout in which PRV-3 was detected doubled in 2022 compared to 2021. It is not clear whether this is due to a greater awareness of the infection in rainbow trout or reflects a true increase. Indications for examining rainbow trout for PRV-3 include heart and/or skeletal muscle inflammation (red muscle) and/or pallor.

PRV-associated disease has a great impact also outside of Norway, and PRV has been reported to cause other diseases than HSMI. In particular, PRV-1 has been associated with liver necrosis in Chinook salmon in Canada, and PRV-2 has been associated with anaemia in Coho salmon in Japan. PRV-3 has been associated with disease in rainbow trout in Denmark and Great Britain,

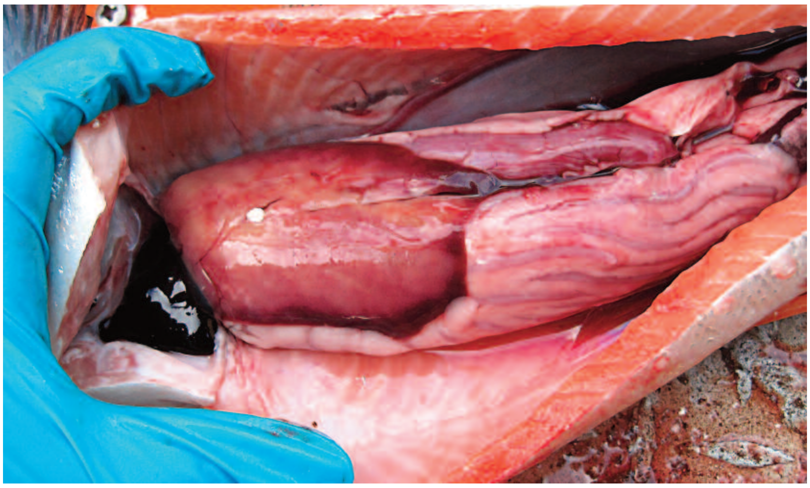


Figure 5.4.2 Salmon with heart and skeletal muscle inflammation (HSMI) with free abdominal fluid, liver fibrin deposits, and pericardial haemorrhage. Photo: Labora

and the virus has been detected in wild brown trout in several European countries. Relatively small variations in the PRV-1 genome have been found to affect its ability to cause disease, and diagnostic methods that distinguish between low and high virulent variants of PRV may become relevant in the future.

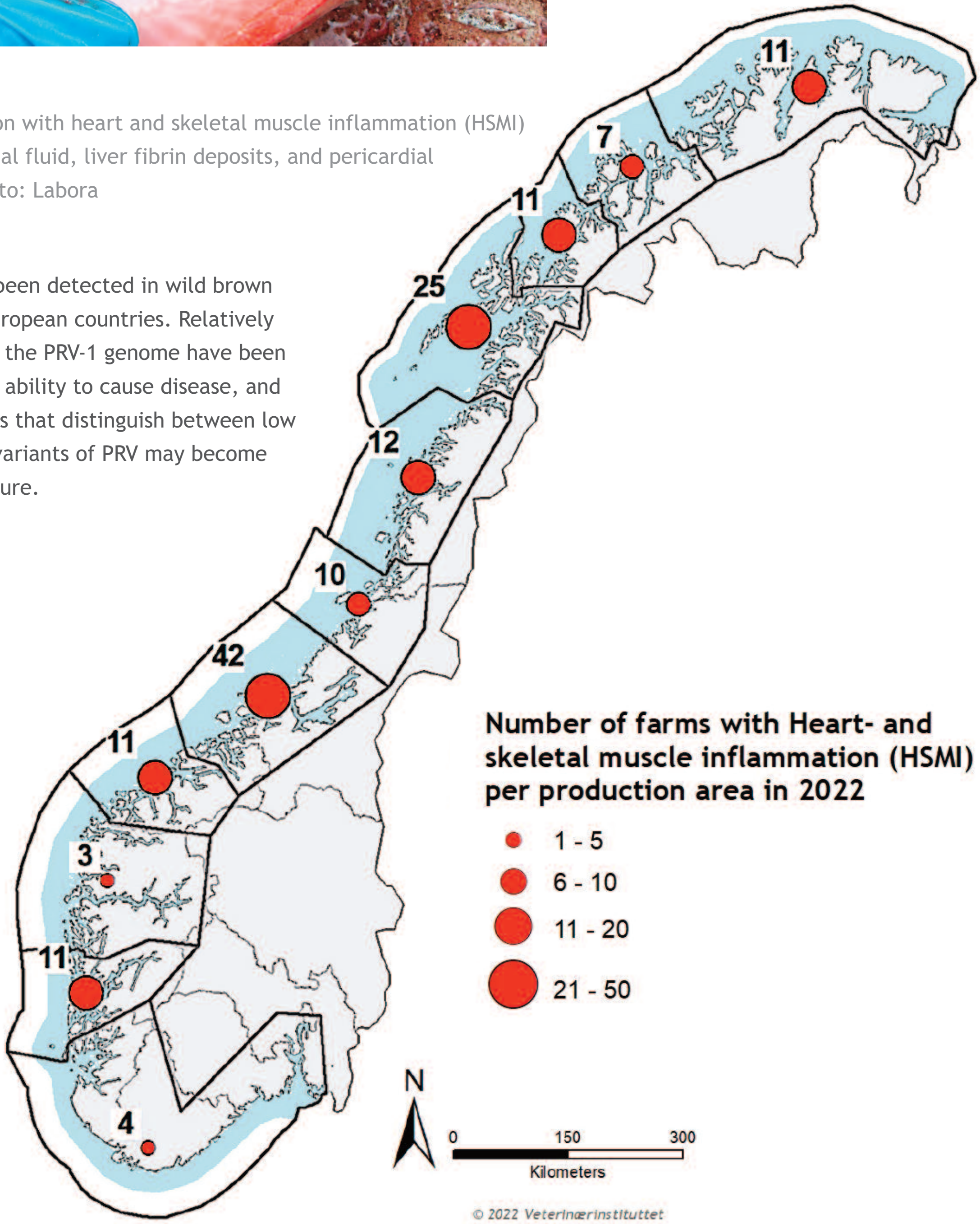


Figure 5.4.3 The number of sites diagnosed with HSMI in 2022 in the different production areas, based on coordinated data from the Norwegian Veterinary Institute and private laboratories.

5.5 Cardiomyopathy syndrome (CMS)

By Camilla Fritsvold and Raoul Valentin Kuiper

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 (POs). 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, associated with substantial economic losses too. Because CMS tends to affect large salmon close to harvesting, when most of the producing costs have been invested, 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 as acute outbreaks, often triggered by a stressful event for the fish. In recent years, CMS is also more frequently diagnosed in younger fish shortly after sea-transfer, and mortality has been reported in fish as small as 100-300 g. Introduction of CMS this early is particularly unfavourable as the production facility will be affected during the entire production cycle, often resulting in higher cumulative mortality.

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 5.5.1). 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. In severe cases, the atrial wall may rupture. 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 unenveloped, 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 hit 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 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 diseases like PD. Within the same production facility, fish in a single or several cages can have PCMV and CMS, 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 strengthen a histopathological diagnosis. PCR for PMCV is being used increasingly in disease diagnostics as well, and is useful for distinguishing CMS from differential diagnoses in uncharacteristic cases or in mixed infections. Newer in-situ techniques also look promising in terms of distinguishing the different inflammatory heart diseases by histological examinations, which are being set up for diagnostic use at the Veterinary Institute (Figure 5.5.2). New research on non-lethal 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.

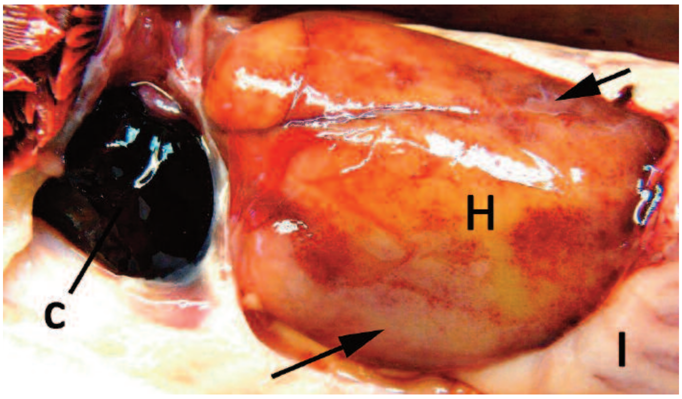
There is a general lack of knowledge on the virus, infection pathways and development of CMS (pathogenesis). How fish are infected, when the fish shed the virus, and what causes the development of clinical disease in fish infected with PMCV, is still unknown. PMCV cannot be cultured for a long time in the commonly used fish cell lines for fish viruses.

Disease control

CMS is not a notifiable disease in Norway or by the World Organization for Animal Health (WOAH), nor is there a public control programme for CMS in Norway. The virus and the disease are present along the entire Norwegian coastline.

There are no available vaccines against CMS, but research for vaccine development continues. CMS-QTL-smolt (smolt from QTL-selected strains with increased resistance to disease) are commercially available. 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



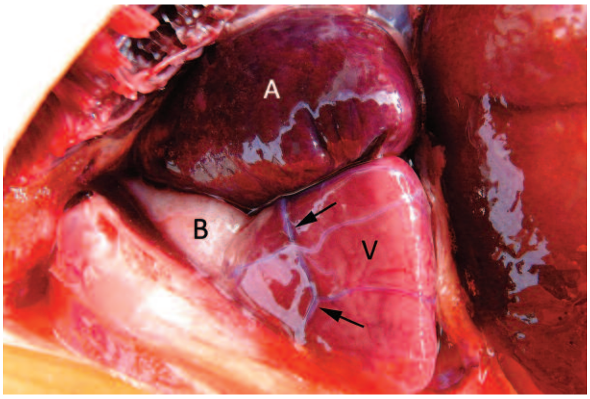


Figure 5.5.1 Cardiomyopathy syndrome (CMS). a) Necropsy findings in a fish with CMS: Ruptured heart (C), almost completely covered by a blood clot filling the entire pericardial space, liver (H) with multifocal hemorrhages, discolouration, and fibrinous pseudomembranes on the surface (arrows). I = pyloric caeca with adipose and pancreas tissue. The swim bladder can be seen as grey-white field above the liver and adipose tissue. Photo: Brit Tørud, Norwegian Veterinary Institute. b) Severely distended atrium, (A) in a fish with CMS. B= Bulbus arteriosus, V = cardiac ventricle, arrows indicate coronary vessels. Gills are to the left, and liver to the right of the heart. Photo: Trygve T. Poppe.

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

The figures for 2022 are, as for 2021, based on data available from private laboratories, coordinated with the Veterinary Institute's own figures (see Chapter 1 Statistical Basis for the report). According to these data, CMS has been diagnosed at 131 individual sites in 2022, compared to 155 in 2021(Figure 5.5.3). PMCV was detected at 123 sites in 2022, compared to 139 in 2021 and 121 in 2020. The majority of diagnosed CMS cases is still not confirmed by simultaneous detection of PMCV, which is essentially explained by the fact that CMS is a histopatological diagnosis without requirement for confirmed detection of PMCV, even if that can be a useful additional analysis. For those cases where PMCV was detected without a confirmed CMS diagnosis in 2022, i.e. production sites where only the virus PMCV was detected, clinical disease was registered in 61 percent (45 sites) and 23 percent was reported as clinically healthy, while clinical information was missing for the remaining 16 percent. The numbers may indicate that PCR for screening of PMCV in fish stocks with no clinical signs of CMS is commonly being used.

Because CMS is not notifiable, it is reasonable to assume that the disease has been, and is, underreported, i.e. self-diagnosis is done 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 will in such cases, without histopathologic confirmation, not be registered as a formal CMS diagnose in the Norwegian Fish Health Report. Thus, there is a certain risk for inaccurate diagnosing, as other diseases causing circulatory failure, like various variants of HSMB and PD are missed and/or erroneously interpreted as CMS.

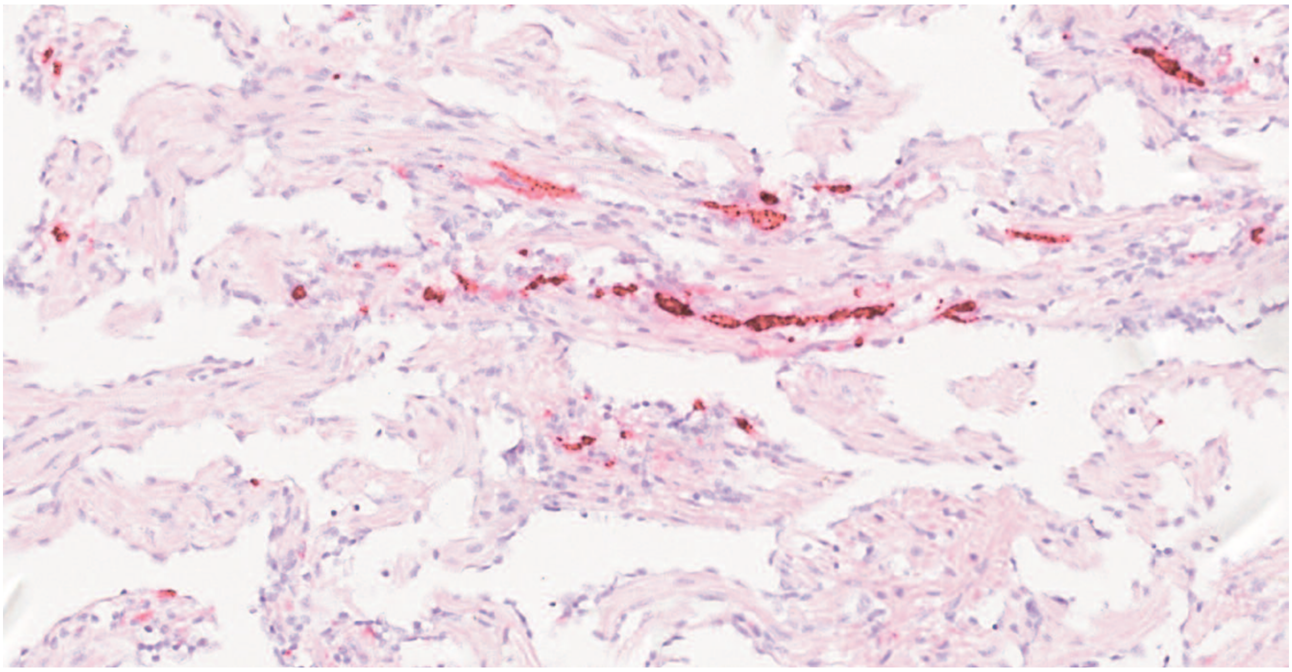


Figure 5.5.2. Detection of PMCV (ORF-1) using RNAscope® in situ hybridisation on a histological section of the atrium of an Atlantic salmon with CMS (experimental infection). PMCV specific RNA is marked with a dark red staining in regions with inflammation, degeneration and necrosis. Conventional light microscopy, 200x. Photo: Camilla Fritsvold, Norwegian Veterinary Institute.

Diagnoses by production areas

The number of confirmed CMS diagnoses for the individual production areas (POs) is not directly comparable to last year's figures, since the basis for the data is somewhat larger, but differences can serve as an indication for trends over time (Figure 5.5.3.).

Generally, there was a clear reduction of the number of CMS diagnoses from northern Trøndelag, and further north: the three northernmost production areas (PO11-PO13) had fewer cases of CMS in 2022, with a reduction from 15 cases in 2021 to four in 2022. Four cases were registered for PO10 (Andøya to Senja) half of the eight cases in 2021. PO9 (Vestfjord and Vesterålen), PO8 (Helgeland to Bodø) and PO7 (Northern-Trøndelag including Bindal) all showed a clear decrease in cases of CMS last year, from respectively 13, twelve and ten cases in 2021 to six, four and eight in 2022.

PO6 (Nordmøre and Sør-Trøndelag) is historically a hotspot for CMS, and the observed increase from 2020 to 2021 continues, from 39 diagnoses in 2021 to 44 in 2022.

For Western Norway south of Hustadvika, it generally looks like the increase in diagnosed cases of CMS that was observed the previous three years has levelled off or turned around with some variation between the POs: In PO5 (Stadt to Hustadvika) there is a reduction from nine in 2021 to five in 2022, while in PO4 (Nordhordaland to Stadt) there was an increase from 15 diagnosed cases in 2021 to 19 in 2022. PO3 (Karmøy to Sotra) remains stable at a similar level as in the last three years, with 29 diagnosed cases in 2022, and 30 and 32 in 2020 and 2021, respectively. A strong reduction in diagnosed CMS cases continues in the combined PO1 and PO2 (from the border with Sweden to Jæren) for the last two years: From 25 in 2020 and 16 in 2021, to eight in 2022.

The Annual Survey

CMS is pointed out as one of the most important problems for both ongrowing and broodstock facilities for Norwegian salmon farming in 2022, as in 2018-2021 (Appendix B1 and C1).

Mortality

As in 2021, CMS was also in 2022 ranked as the most important cause of mortality in salmon broodstock facilities, by 83 percent of the respondents (ten out of twelve). This is consistent with CMS predominantly being a disease in larger fish. In salmon grow-out facilities, CMS was ranked second as a cause of mortality in 2022, together with winter ulcers caused by infection with *Moritella viscosa*.

Reduced growth

As CMS most commonly affects large fish in the sea, it is not surprising that disease is not considered one of the primary causes of reduced growth in ongrowing facilities for salmon. None of the respondents for broodstock facilities indicated CMS as a contributor to reduced growth.

Reduced welfare for the fish

For 2022, CMS was ranked the second most important cause of reduced welfare of salmon broodstock, next to mechanical damages related to delousing. In contrast to broodstock, CMS was not considered to contribute as much to reduced welfare in on-growing facilities as mechanical damage related to delousing, gill disease, louse infestation and infections with *Moritella viscosa* and *Tenacibaculum* spp..

Increasing problem

For ongrowing facilities, CMS ranked a bit lower on the list of increasing problems in 2022, in line with the reduced number of diagnosed cases compared to the two previous years. CMS has not been noted as an increasing problem for salmon broodstock but has remained a persistent problem for many years.

Non-medicinal delousing and CMS

The number of non-medicinal treatments for salmon lice has increased sharply in recent years (Chapter 4 Fish Welfare and Chapter 8.1 Salmon louse - *Lepeophteirus salmonis* and Chapter 8.2 Caligus elongatus), and the average farmed salmon is deloused three times a year. All non-medicinal treatments in use in Norway today involve some kind of crowding, pumping and other stresses for the fish. Various stressful events have been identified as risk factors for CMS outbreaks, and stress related to delousing is likely to contribute to subclinical, latent PMCV infections developing into clinical CMS and mortality. Large numbers of inflammatory cells in the heart with CMS, especially in the atrium, render the wall of the atrium fragile, and fish with such severe degrees of CMS therefore have a very low tolerance of stress. Moreover, a farmed fish group often has a complex overall disease picture, e.g. gill disease combined with HSMI and/or CMS, which in some cases contribute to a disproportionately large "treatment mortality" following delousing. CMS now occuring in smaller fish, with a considerable amount of time left in the sea phase prior to slaughter, magnifies and prolongs the problems related to frequent delousing.

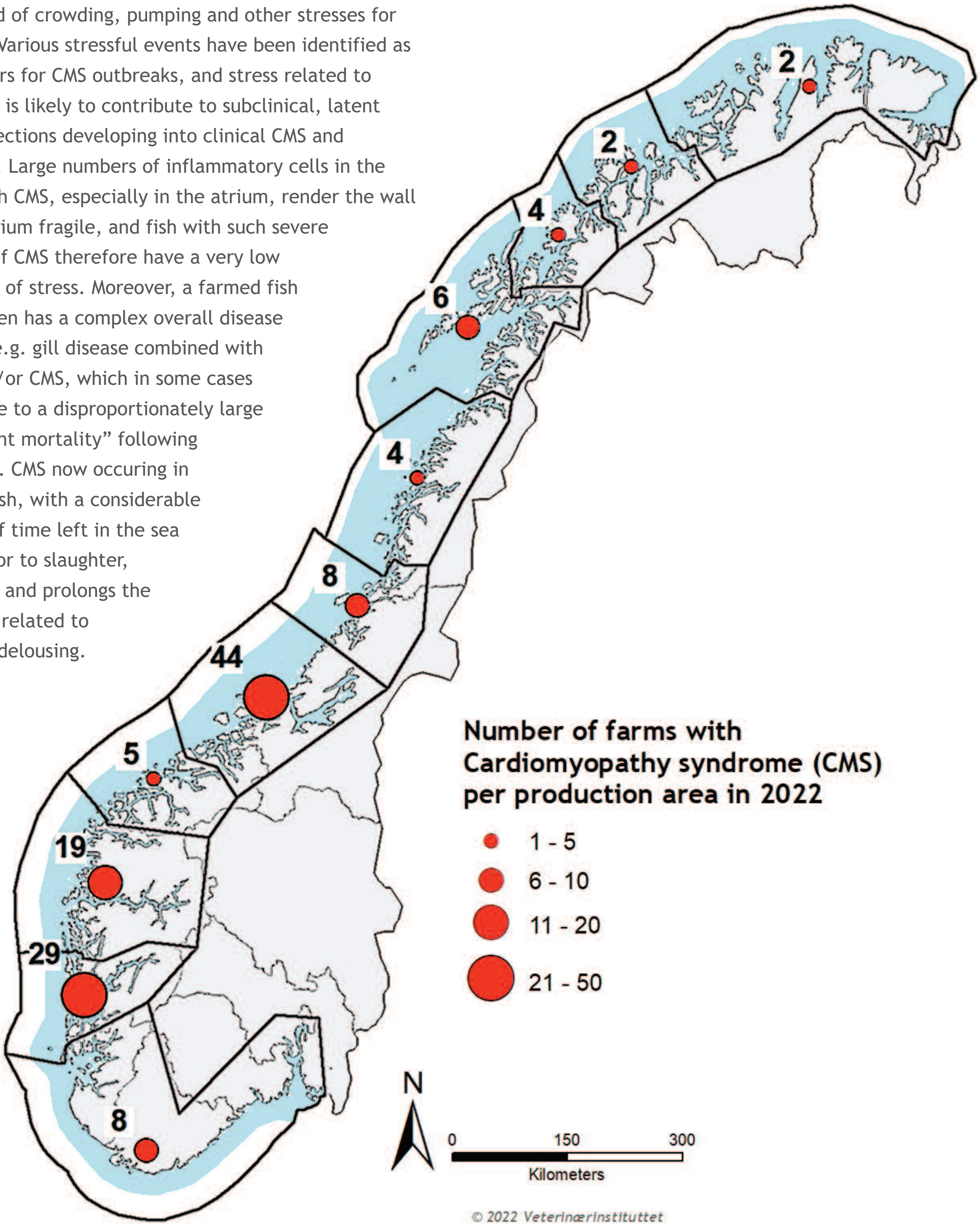


Figure 5.5.3. Number of CMS diagnoses in 2022 by production area, based on coordinated figures from the Norwegian Veterinary Institute and private laboratories.

Evaluation of the CMS situation

The comprehensive statistical basis for the 2022 Fish Health Report allows for a better overview then what the Norwegian Fish Health report could present before 2020, including more precise numbers of confirmed diagnosed cases. This is because possible double registrations has been removed, and the contributions from both large and small operators results in more than 80 percent of all farming locations being included in the report.(Chapter 1 Statistical Basis for the report). Because the data base has been further expanded from 2021 to 2022, and the number of detections is stated per PO since 2020, it is more challenging to evaluate trends in CMS cases in these last few years in Norway as a whole. Based on the number and geographic distribution of CMS diagnoses (Figure 5.5.3), it looks like the prevalence of CMS stays relatively stable, even if there is a small reduction in diagnosed cases in 2022 compared to recent years: 131 cases in 2022, compared to 155 in 2021 and 154 in 2020. In the survey of 2022, fish health workers from along the entire Norwegian coast ranks CMS as the most important cause for mortality in salmon broodstock facilities and the second most important cause of mortality in ongrowing facilities in the marine phase.

In five out of 26 of the free text comments relating to ongrowing fish, respondents experience a decrease in the incidence of CMS, fewer clinical or severe cases, and/or reduced mortality related to CMS compared to earlier years, while 1 recons CMS as a primary challenge. Taken together with a minor reduction in the number of registered diagnosed cases, this could be the beginning of a new trend with fewer cases of CMS per year. At the same time, there are still reports of major lice problems, frequent delousing and many incidents of high mortality in the period after delousing. It is encouraging to read that two of the 26 free text comments for ongrowing salmon in the survey do report reduced mortality related to handling and delousing, and indicate that more knowledge, experience and improved practise of the methods can be the cause. The management and stress of non-medicinal delousing methods appears to be essential as a triggering factor for many post-treatment CMS outbreaks and related mortality (see Chapter 4 Fish Welfare), and any measure that reduces this impact is welcome. Whether repeated lice treatments of salmon with established diseases like CMS or severe gill diseases can be justified from a fish welfare perspective remains a topic for debate.

The CMS situation in Norway is largely unchanged compared to the previous years, and continues to represent a significant challenge for the Norwegian aquaculture industry.

5.6 Viral haemorrhagic septicemia (VHS)

By Torfinn Moldal, Åse Helen Garseth and Ole Bendik Dale

The Disease

Viral haemorrhagic septicemia (VHS) is characterised by high mortality, protruding eyes, distended abdomen, bleeding and anaemia (Figure 5.6.1). 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

VHS is a notifiable disease both in Norway and the EU (category C+D+E), and outbreaks will be controlled by destruction of all fish on the infected location («stamping out»). Further, a restricted zone divided into a protection zone and a surveillance zone will be established. Vaccination is not relevant 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 2022

Official data

A risk-based monitoring programme is in place in Norway, based on PCR examination of samples from Atlantic salmon, rainbow trout and cleaner fish submitted to the Norwegian Veterinary Institute for diagnostic investigation. In 2022, brown trout in cultivation and ongrowing facilities as well as rainbow trout in inland farms were also included in the monitoring programme. In the monitoring programme for wild fish, samples from diseased fish were inoculated in cell lines that are susceptible for VHSV. Samples from some fish were also examined by PCR due to high mortality or histological findings. VHS was not detected in 2022 in Norway. The last detection in farmed fish in Norway was in rainbow trout in Storfjorden in Sunnmøre, in 2007-2008.

Evaluation of the VHS situation

In 2022, only Germany notified outbreaks of VHS to EU's Animal Disease Notification System (ADNS). Previous identification of VHSV in various wrasse species in Shetland in 2012 and lumpfish in Iceland in 2015 highlights the need for vigilance, as these fish species are used as cleaner fish in Norwegian salmon farming. The Norwegian Scientific Committee for Food and Environment (VKM) has evaluated the risk (probability x consequence) for transmission of disease between wild cleaner fish and farmed fish to be high. Given the serious consequences of a VHS outbreak, surveillance for VHS is important for removal of infected fish as quickly as possible.

For many years, VHS was endemic in Denmark, but the virus has not been identified in the country since 2009, following a successful eradication programme. In Finland, VHS outbreaks have been detected from the early 2000s in connection with production in open cages in brackish water and sea in both Åland and the mainland. In Åland, the combat programmes took a long time to succeed, with the last detection made in 2012. In 2017, France presented a plan to combat VHS, but two VHS outbreaks still occurred in the country both in 2019 and in 2020, and one outbreak occurred in 2021.

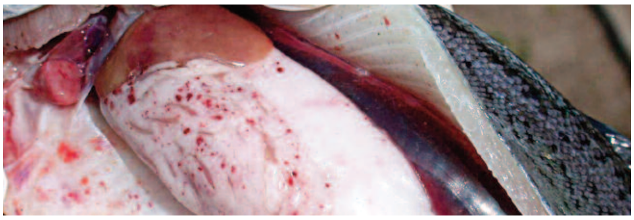


Figure 5.6.1 VHS in rainbow trout with multiple small haemorrhages. Photo: Ole Bendik Dale, Norwegian Veterinary Institute.

5.7 Infectious haematopoetic necrosis (IHN)

By Torfinn Moldal, Åse Helen Garseth and Ole Bendik Dale

The Disease

Infectious haematopoietic necrosis (IHN) is a viral disease that primarily affects salmonids. The IHN-virus belongs to the genus *Novirhabdovirus* in the family *Rhabdoviridae*. Traditionally, fry has been most prone to infection, and outbreaks occur most commonly during the spring and autumn at temperatures between 8 and 15°C.

Protruding eyes are often observed clinically, and post mortem findings include haemorrhages in internal organs, swollen kidneys and ascites (Figure 5.7.1). Histologically, damage of haematopoietic tissues can be observed, and the disease is classified as a haemorrhagic septicaemia.

IHN was first isolated from sockeye salmon (*Oncorhynchus nerka*) in a hatchery in Washington state, USA, in the 1950s. The virus has since been detected in a number of salmonid species including Atlantic salmon and rainbow trout. High mortality rates are reported in big salmons in British Columbia. Based on a fragment of the virus genome, the virus can be divided into five main types (U, M, L, J and E) that reflect their geographic origins. The genotypes U, M and L account for the upper, middle and lower parts of North America's west coast. Genotype E (Europe) has its origins in North America, as does genotype J (Japan). The latter genotype has spread to much of Asia.

In November 2017, IHNV was detected in Finland for the first time, and the virus was detected in six rainbow trout farms over the next few months. The infection was detected in the frame of surveillance and spread from a state-owned location with brood fish and a hatchery that had delivered fish to ongrowing facilities in Bottenviken. The source of infection remains unknown, and the virus did not belong to any recognised genotype and did not result in clinical disease in infected fish.

In May 2021, IHN was detected in Denmark for the first time. The virus belonged to genotype E and was assumed to have been introduced from Germany. During the summer and early autumn, the virus was detected in a total of eight fish farms and three facilities for recreational fishing (so-called put & take lakes). In December 2021, Denmark informed the European Commission that it was giving up its free status for IHN. Denmark thus became one of 23 EU countries without free status. During the spring and summer last year, IHN was detected in an additional ten locations.

As a result of fish imports from Denmark, IHN was detected in five farms in Åland, Finland, in the period from May to October 2021. During the summer of 2022, IHN was detected at one more farm in Åland. The virus was of the same type that was detected in Åland and Denmark in 2021. The site that experienced an outbreak last year is located relatively far from the farms that experienced IHN in 2021 and has not received fish from any of these. However, rainbow trout was imported from a Danish farm reported to be free of IHN, as well as from other countries. All rainbow trout from the infected farm have been harvested or destroyed, and according to the EU legislation, Finnish authorities have established a restricted zone around the infected farm, which can resume its production of fish in March 2023. The restrictions due to IHN can be lifted during the winter 2024/2025 at the earliest. The ongoing control programme for VHS in Åland has meant that the relocation of live or ungutted fish from Åland to VHS-free areas in Finland has been limited for more than 10 years. Further spread from Åland is therefore considered unlikely.

Disease control

IHN is a notifiable disease both in Norway and the EU (categori C+D+E), and outbreaks will be controlled by destruction of all fish on the infected location («stamping out»). Further, a restriced zone divided into a protection zone and a surveillance zone will be established. Vaccination is not relevant 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 2022

Official data

A risk-based monitoring programme is in place in Norway, based on PCR examination of samples from Atlantic salmon, rainbow trout and cleaner fish submitted to the Norwegian Veterinary Institute for diagnostic investigation. In 2022, brown trout in cultivation and ongrowing facilities as well as rainbow trout in inland farms were also included in the monitoring programme. In the monitoring programme for wild fish, samples from diseased fish were inoculated in IHNV-susceptible cell lines. Samples from some fish were also examined by PCR due to high mortality or histological findings. IHN has never been detected in Norway.

Evaluation of the IHN situation

IHN is endemic in western 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 2022, IHN outbreaks were notified in six European countries, among them Denmark and Finland, according to EU's Animal Disease Notification System (ADNS).

Loss of free status has major trade consequences for Danish breeders. The aquaculture industry associations have therefore drawn up a combat plan with a view to reclaiming Denmark's free status. Denmark's loss of free status also has consequences for Norway. Once the free status is removed, the restricted zones cease so that there is greater freedom for both the transport of fish and recreational fishing within Denmark. This can make the infection situation more disorganized.

The spread of infection is to a significant degree related to the trade of infected eggs or juvenile salmonids. The virus has, however, also been identified in marine fish species following experimental infection and in wild marine fish. Such fish may therefore act as a reservoir of infection.

The introduction of new species such as pink salmon into Norwegian coastal waters and rivers is a potential source of infection, despite the fact that this species is considered to have a low susceptibility to IHN. Given the serious consequences of an IHN outbreak in Norway, constant vigilance is important to ensure the rapid detection and destruction of infected fish. Furthermore, all imported fish, including rainbow trout, from areas officially free of IHN should be subject to a risk analysis in light of the Finnish and Danish situations. The possible negative consequences of an introduction include ‘stamping out’ and the spread of infection to wild fish that potentially could lead to IHN becoming endemic, also in Norway.

Figure 5.7.1 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.

5.8 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. The diseased fish had circulatory disturbances and abnormal clumping of red blood cells in addition to the gill changes. After sequencing of the virus in 2015 improved diagnostics showed that several other disease manifestations existed. An important finding was that the SGPV is often involved in what we now call complex gill disease (see Chapter 9.1 Gill health).

The salmon gill pox virus has many genes with unknown functions, but mapping gene expression in both virus and host through the disease course, we have begun to understand some of the disease mechanisms. The gene expression in the gills during the disease outbreak show that the virus disturbs the protective function of the gill mucus and that the recruitment of inflammatory cells is abnormal. 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 is 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 if the newly developed 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, so closely related that they are of the same species (SGPV), have been detected in Atlantic salmon from Norway, the Faroe Islands, Scotland and Iceland. Isolates from the same country are more closely related than isolates from different countries. Some fjord systems and hatchery facilities seem to have their own “house strains". We do not yet know to what degree recurring infections are repeated introductions from the same source, or one and the same strain can cause persistent infection on site; this is an important distinction in terms of countermeasures.

A somewhat genetically different pox virus from the SGPV in Europe 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 pox-virus-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. To monitor outbreaks measuring virus levels in water by PCR have been shown to be a good alternative to test fish samples. 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 indicate that the farm has 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, and it was the same MLVA type as before. 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 was followed further and, surprisingly, a new type of MLVA was identified, suggesting a new introduction to the farm.

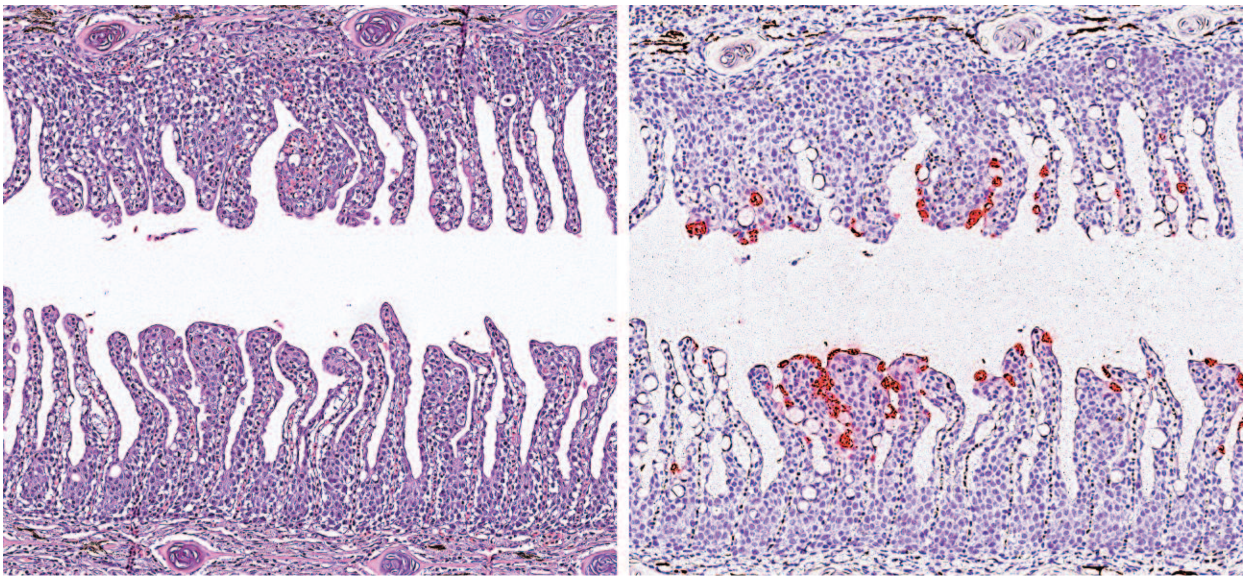


Figure 5.8.1 Gill tissue from complex gill inflammation has changed greatly due to several infections that cause a mixture of lesions and host responses. using standard HE staining (left), it is very demanding to pick out cells that are infected and altered due to the salmon gill pox virus, while In Situ Hybridisation (ISH) allows us to see cells clearly, in a visible red colour (right). Photo: M Gjessing, Norwegian Veterinary Institute.

The Health Situation in 2022

Data from the Norwegian Veterinary Institute

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 the Norwegian Veterinary Institute detects the virus DNA which indicates the amount of pox virus in the sample. We have seen a strong link between symptoms, disease changes and the amount of virus in the same individual. A PCR method detecting virus RNA show transcripts from an infection that may, or may not, lead to new viruses, and thus not necessarily correlated to the amount of virus eventually produced.

Infection with the salmon gill pox virus 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, a newly established in-situ hybridisation method (ISH) is very effective in showing the salmon gill pox virus in gill changes (Figure 5.8.1).

Information about SGPV is not part of the information shared by the private laboratories in 2022. Among cases submitted to the Norwegian Veterinary Institute in 2021, salmon gill pox virus was detected in one hatchery and two ongrowing facilities. This year's figures represent probably only a minor part of the problem; in 2020, salmon gill pox virus infection was detected in 10 hatcheries, at 51 ongrowing sites, in one cultivation plant and in one broodstock facility. A better nationwide overview of the SGPV cases would be helpful to address the increasing gill problems.

The Annual Survey

In the survey, the SGPV in terms of mortality and reduced welfare was assessed to be small and not an increasing problem in hatcheries or ongrowing facilities.
In the survey gill disease in ongrowth farms is ranked as the most important health problem, and the most important cause of reduced growth. Gill disease is also the problem that has increased the most, but the current status of knowledge makes it difficult to pinpoint exact causes

Evaluation of the SGPV situation

The major outbreaks of SGPV disease in hatcheries are thankfully rare, but consequences in these cases makes it well worth to map sources of infection work purposefully to stop the infection. The SGPV is sporadically detected in complex gill disease in ongrowing facilities at sea. Here it is important to find out if the smolt carry the infection from the hatchery, and if so, what it means for development complex gill disease in the sea. Better knowledge about infection and reservoirs for the 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.

For more information on SGPV (in Norwegian):
see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/laksepox

6. Bacterial diseases of farmed salmonids

By Snorre Gulla

A range of previously detrimental bacterial diseases among farmed salmonids in Norway have now for several decades been efficiently controlled by the use of oil-based injection vaccines, which has caused the use of antibiotics to plummet. Some bacterial diseases, however, remain uncontrolled via vaccination and/or available vaccines do not provide full protection. Overall, the total number of bacterial disease cases in Norwegian aquaculture has increased over recent years, and this situation warrants close monitoring in the years to come.

Winter ulcers constitute perhaps the most significant health- and welfare-challenge in relation to bacterial disease in Norwegian aquaculture today, and affects sea-farms along the entire coastline. The disease was diagnosed at 433 salmon farms through 2022, and also occurs in other fish species such as rainbow trout. Among such cases involving identification of the causative agent(s), different genetic groups of *Moritella viscosa* and/or *Tenacibaculum* spp. were by far the most prevalent, often as mixed infections. Winter ulcer is not, however, a notifiable disease and it is relatively easily diagnosed on-site, which together with high scores in the annual quest-back makes it likely that it is underreported. Operational procedures which can cause harm to the skin, for example during physical delousing, may have a strong predisposing effect with regard to winter ulcer development.

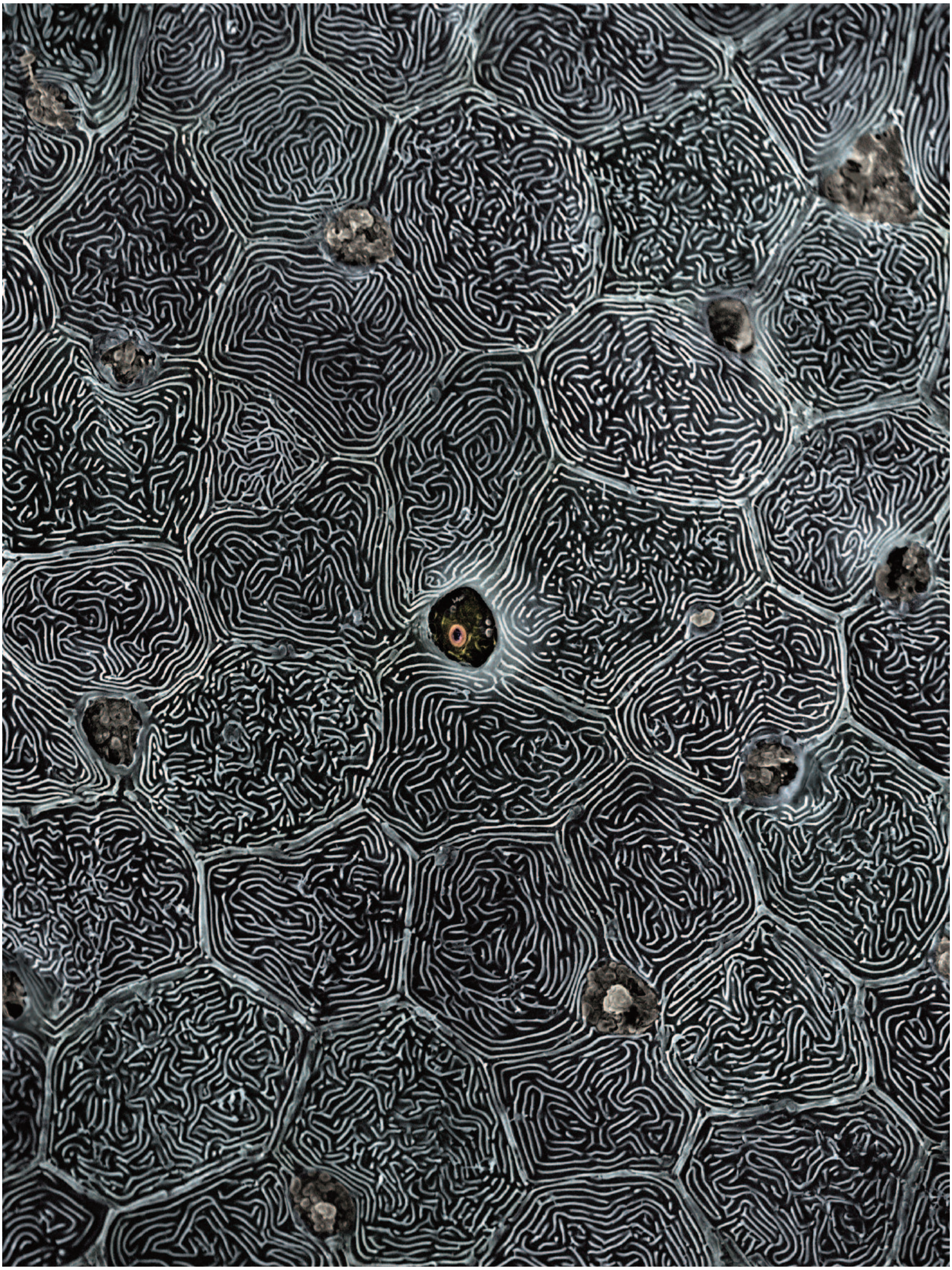
Pasteurellosis in large sea-farmed salmon has been a problem in Western Norway since 2018, and this was also the case through 2022, when the causative bacterium was identified at 52 different salmon farms. For comparison, registered detections were made at 45 farms in 2021 and 57 in 2020. A high prevalence of co-infections involving other agents, and reports of extensive handling prior to outbreaks, may point to external factors increasing the risk of pasteurellosis outbreaks occurring.

Yersinia ruckeri, the causative agent of yersiniosis, was registered at 33 different salmon farms through 2022, with the majority of cases occurring at sea from Western- to Mid-Norway. This constitutes quite a significant increase compared to preceding years and is on par with the period immediately prior to injection vaccines against yersiniosis being put into wide use a few years ago, although we currently possess no good overview with regard to the overall vaccine coverage. While some registrations for 2022 were likely not associated with clinical disease, it appears fairly clear that the disease is yet again on the rise. It has been established that stress-associated handling etc. may contribute to the development of yersiniosis.

Among the notifiable bacterial diseases (category F) diagnosed in farmed salmon through 2022, furunculosis was detected at two neighbouring sea farms in Nord-Trøndelag, and bacterial kidney disease (BKD) was detected at one sea farm in Trøndelag. Systemic flavobacteriosis was detected in rainbow trout at four landlocked farms within an endemic area. None of these diseases were detected in wild fish through 2022.

Mycobacteriosis was detected in farmed salmon at eight different sea farms through 2022, from Rogaland to Nordland. A slight, gradual increase in the number of cases registered annually at the Norwegian Veterinary Institute has occurred over recent years, and a similar trend has also been reported from private laboratories.

Among other known bacterial pathogens of salmonids detected in 2022 were *Vibrio anguillarum* in salmon and rainbow trout respectively at three and one farm(s), atypical *Aeromonas salmonicida* in salmon at four farms, and *Pseudomonas anguilliseptica* in salmon at one farm. A range of other bacteria, e.g. associated with poor water quality or normal gut microbiota in fish, are also regularly detected from diseased farmed fish, but are not considered of significant importance as primary pathogens. Among such agents which were again detected in varying numbers from farmed salmonids through 2022 were motile *Aeromonas* spp., *Pseudomonas fluorescens* and *Carnobacterium maltoaromaticum*.



Mucus cells on the surface of salmon skin magnified 2500x. These cells produce a special type of mucus with antimicrobial properties. The mucus covers the surface of the skin and acts as a protective barrier against infectious agents and mechanical injury (The micrograph shows an area of skin between the scales around the size of a pin-head). Photo: Jannicke Wiik-Nielsen, Veterinærinstituttet

6.1 Flavobacteriosis

By Hanne K. Nilsen

The Disease

The bacterium *Flavobacterium psychrophilum*, is a serious fish pathogen associated with disease in several fish species worldwide, in different life stages from fry to broodstock and in fresh and brackish water. Clinical signs vary between fish species and life stage and include spiral swimming, skin ulcers (typically in the peduncle area), fin rot, fluid filled distended abdomen, enlarged spleen and anemia. The disease is also associated with vertebral deformities. An acute disease course with high mortality is common in rainbow trout fry. Rainbow trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) are considered particularly vulnerable to serious outbreaks. Phenotypic and genetic characterization reveals strain variation within *Flavobacterium psychrophilum* as a species. Some variants are associated with a severe disease course with high mortality, while other variants are more often associated with external lesions such as ulcers and fin rot.

In Norway today, the disease is recognised as an important cause of mortality, representing major welfare issues in large rainbow trout farmed in brackish water. Previously, the disease has caused high mortality in rainbow trout fry and smolt in several hatcheries in Norway, and the disease is considered a potential threat to rainbow farming in Norway. The bacterium may be associated with ulcers and fin rot in salmon (*Salmo salar* L.) and brown trout (*Salmo trutta* L.) in fresh water.

Disease control

F. psychrophilum is transmitted horizontally from fish to fish, and fish suffering from the disease secrete large numbers of bacteria into the water. Vertical transmission from broodstock to roe is likely, especially in rainbow trout. Biosecurity measures such as frequent removal of fish with signs of disease during outbreaks, washing and disinfection of equipment, avoidance of transport of diseased fish as well as disinfection of eggs to reduce possible transmission, are important preventive measures.

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

For more information about flavobacteriosis, see fact sheet (in Norwegian): **https://www.vetinst.no/sykdom-ogagens/*flavobacterium-psychrophilum***

The Health Situation in 2022

Data from the Norwegian Veterinary Institute

Rainbow trout

In 2022, systemic infection with *F. psychrophilum* was detected in rainbow trout at four inland facilities in an area where the disease has been previously detected. Genotyping revealed the variants ST92, ST168 and ST181 in fish with systemic infection. These genotypes have previously been detected in the same area. ST23 was isolated from one of several outbreaks involving ulcers and fin rot in the same area. Spine and head deformities were also identified. ST 92 belongs to a group of closely related variants of the bacterium that are associated with high mortality in rainbow trout worldwide. As before, this variant showed reduced sensitivity to quinolone antibiotics. ST168, ST181 and ST23 belong to other genetic sub-populations.

Other fish species

Flavobacterium psychrophilum was not detected in material sampled from salmon, brown trout and wild fish submitted to the Norwegian Veterinary Institute, in 2022.

The Annual Survey

For rainbow trout in hatcheries, ongrowing farms and broodstock farms, none of the respondents considered flavobacteriosis as one of the five main causes of mortality, reduced welfare, reduced growth or as an increasing problem. However, the number of respondents was low, below ten.

For salmon in the fresh water phase, flavobacteriosis was considered one of the five main causes of mortality by two of 42 respondents, while five of 43 believed it was an important cause of reduced welfare. No one considered the disease as an increasing problem or as a problem that causes reduced growth.

Evaluation of the Flavobacterium situation

In the area where *F. psychrophilum* genotype ST2 in recent years has been common, flavobacteriosis was not detected in large rainbow trout in 2022. The disease appears to represent a recurring problem in inland facilities with rainbow trout.

In salmon, the submitted material does not provide a complete overview of the situation, but the results of the survey show that the disease, as before, can be a challenge in the hatchery phase.

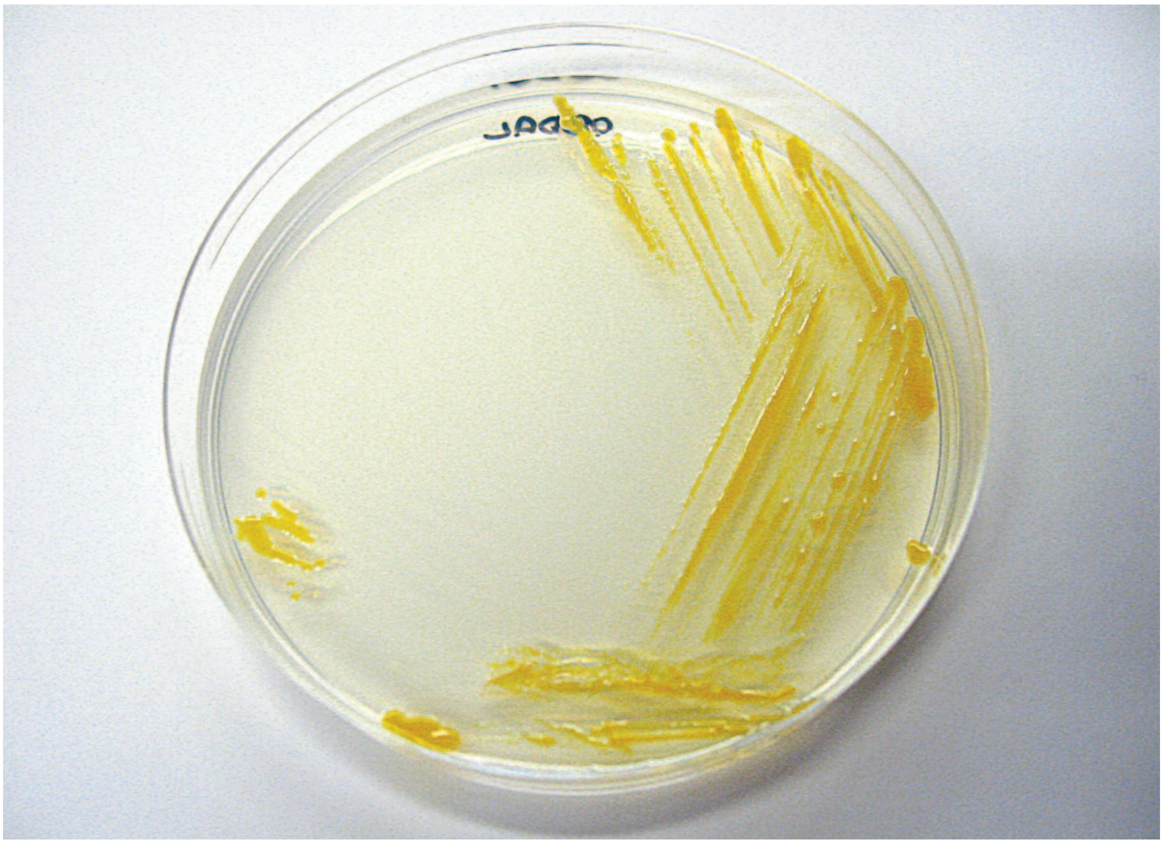


Figure 6.1.1 *Flavobacterium psychrophilum* in Anacker and Ordal medium (AOA). Photo: Hanne Nilsen, Norwegian Veterinary Institute.

6.2 Furunculosis

By Duncan J. Colquhoun

The Disease

Classical furunculosis (infection caused by *Aeromonas salmonicida* subsp. *salmonicida*) is an infectious disease which can result in high mortality in salmonid fish both in freshwater and in seawater. Other fish species such lumpfish and turbot have occasionally also been affected.

A. salmonicida belongs to the Family Aeromonadaceae. Five subspecies have been described, *salmonicida, achromogenes, masoucida, pectinolytica* and *smithia*. Recent work performed at the Norwegian Veterinary Institute has shown that the diversity within the species may be described more exactly based on sequence variation in the vapA gene, an important virulence gene coding for the A-layer protein found on the surface of the bacterium. Twenty-three different A-layer types have now been identified, which in most cases show a significant degree of host specificity for various fish species.

A. salmonicida subsp. *salmonicida* is commonly called 'classical' *A. salmonicida* while non- subsp. salmonicida subspecies and other strains are commonly referred to as 'atypical' *A. salmonicida*. The resulting infections are generally referred to as either 'classical furunculosis' or 'atypical furunculosis'. The most common symptoms in larger fish suffering classical furunculosis are skin lesions and bloody 'boils' or 'furuncles' in the musculature (see Figure 6.2.1).

All variants of *A. salmonicida* pathogenic for fish are non-motile short rods. *A. salmonicida* subsp. *salmonicida* produces rich quantities of water-soluble brown pigment when grown on media containing tyrosine and/or phenylalanine. Atypical variants most commonly grow more slowly, with smaller colonies and produce smaller quantities of pigment or do not produce pigment at all. Non-pigment producing *A. salmonicida subsp. salmonicida* have been registered.

The main mode of transmission is assumed to be horizontal, from fish to fish. In Norway the disease affects mainly Atlantic salmon, brown trout (including seatrout) and Arctic char. Although outbreaks of furunculosis in Norway have, in the main been associated with the marine phase of culture and in hatcheries utilising seawater, outbreaks have also been registered in farms utilising only freshwater. Rainbow trout are considered less susceptible to furunculosis and the disease has not been identified in rainbow trout farmed in Norway in recent years. Furunculosis is, however, a considerable problem in rainbow trout farming in other countries, including Denmark. Salmonid fish may also be asymptomatically infected with *A. salmonicida* subsp. *salmonicida*. Such 'hidden' infections may be difficult to diagnose and result in outbreak of disease following stress events such as handling, transport, grading etc.

Disease control

Classical furunculosis is a notifiable disease (category F) in Norway. Atypical furunculosis i.e. infections caused by other subspecies and strains are not notifiable.

Generally, good hygiene combined with vaccination introduced in the early 1990's has contributed to the effective disappearance of the disease from Norwegian aquaculture. The disease is currently under good control due to vaccination, but occasional outbreaks still occur from time to time.

For more information, see fact sheet (in Norwegian): **https://www.vetinst.no/sykdom-og-agens/furunkulose**

The Health Situation in 2022

Official data

Furunculosis (*A. salmonicida* subsp. *salmonicida*) was identified in 4-5 kg farmed salmon in to neighbouring ongrowing farms in Nord-Trøndelag in 2022. The Norwegian Veterinary Institute also diagnosed the infection in lumpfish on one of these farms, and information was received that the infection had also been previously diagnosed in lumpfish on the other farm. *A. salmonicida* subsp. *salmonicida* was not identified from wild salmonids in 2022.

The Annual Survey

The results of the survey mirror the diagnostic situation and support the conclusion that furunculosis is an uncommon disease in farmed salmon. All respondents consider furunculosis to represent an insignificant threat in regard to mortality, reduced growth, reduced welfare or as an increasing problem in juvenile salmon production. Only one of 63 respondents concluded that the disease represents a welfare concern in ongrowing salmon (ref. ranking in Appendix B1).

Evaluation of the furunculosis situation

The furunculosis situation in Norwegian aquaculture remains favourable, thanks to extensive use of effective vaccines. That occasional outbreaks continue to be irregularly identified in both wild and farmed salmon, and that the disease is expected to increase in importance in a warmer climate, means that we must strive to keep the disease under strict control. Vaccination against furunculosis must therefore continue.

Figure 6.2.1 Atlantic salmon with furunculosis, displaying typical bloody furuncles. Photo: Geir Bornø, Norwegian Veterinary Institute

6.3 Bacterial kidney disease (BKD)

By Duncan J. Colquhoun

The Disease

Bacterial kidney disease is a serious, notifiable and chronic disease of salmonid fish caused by the bacterium *Renibacterium salmoninarum* (see Figure 6.3.1).

R. salmoninarum is a gram positive, non-motile and slow growing bacterium. It does not grow on standard agar types and requires special media containing the amino acid cysteine e.g. Kidney Disease Medium, KDM.

Bacterial kidney disease is a disease of salmonid fish around the world, both farmed and wild. BKD was first identified in Norway by the Norwegian Veterinary Institute in 1980 in juvenile fish parented by wild caught broodstock. BKD outbreaks are most frequently identified in western Norway where several rivers are most probably endemically infected. The bacterium may be transmitted from one generation to the next via infected eggs (vertical transmission). The infection can also transmit horizontally and infected wild salmon are considered the main source of infection to the few outbreaks diagnosed in Norwegian farmed salmonids in recent years.

Only salmonid fish are affected and susceptible species include salmon and brown/seatrout (*Salmo* spp.), Pacific salmon and rainbow trout (*Oncorhynchus* spp.), char (*Salvelinus* spp.) and grayling (*Thymallus thymallus*). BKD may result in acute mortality, particularly in younger fish, but is usually associated with chronic disease. Life-long latent infections occur.

Disease control

BKD is a notifiable (list F, National) disease in Norway. As no effective treatment or vaccine exists, strict biosecurity and broodstock testing are the primary elements of BKD prevention. The alternative is destruction of affected stocks.

For more information, see fact sheet (in Norwegian): **https://www.vetinst.no/sykdom-og-agens/bakteriell-nyresjuke-bkd**

The Health Situation in 2022

Official data

Bacterial kidney disease (BKD) is now only sporadically identified in Norway with between none and three cases occurring annually. BKD was diagnosed in one ongrowing site for salmon in PO6 in 2022. Macroscopically, white nodules in the liver, spleen and kidney were observed. Mortality levels were not increased. BKD was not identified in wild salmon in 2022.

Evaluation of the BKD situation

The current BKD situation is favourable. It is, however, important that we remain vigilant, particularly during broodstock health surveillance.

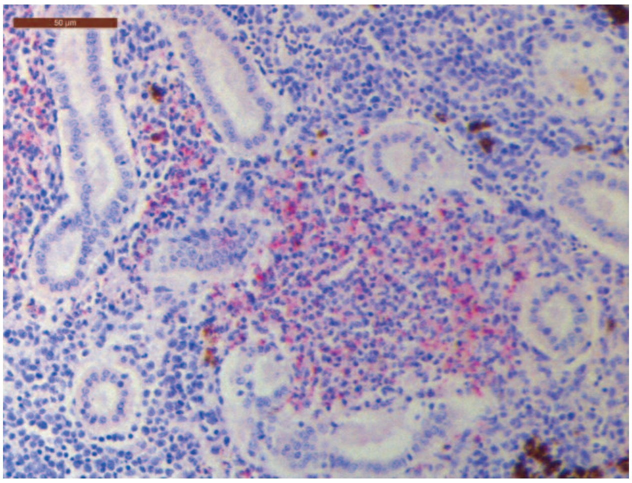


Figure 6.3.1 *Renibacterium salmoninarum* in the kidney of Atlantic salmon (The bacterial cells are stained red using an immunohistochemical technique). Photo: Hanne Nilsen, Norwegian Veterinary Institute

6.4 Winter ulcer

By Duncan J. Colquhoun and Anne Berit Olsen

The Disease

Ulcer development during the sea phase is a serious animal welfare problem and results in both increased mortality and reduced quality at harvest. While development of skin ulcers are a typical autumn and winter problem, the problem can occur all year round.

The term 'winter ulcer' is primarily associated with infection with the bacterium *Moritella viscosa* (Figure 6.4.1), while the term 'tenacibaculosis' is used in cases primarily associated with *Tenacibaculum* spp. infection (Figure 6.4.2). *M. viscosa* infections may be systemic i.e. the inner organs are affected, while tenacibaculosis in Norwegian salmonids occurs almost exclusively as surface or topical infections.

Winter ulcer develops mainly on the lateral surfaces of the fish, while tenacibaculosis most commonly manifests as deep lesions around the jaw (mouth rot) and head, and as tail and fin erosion (fin rot) (Figure 6.4.3). Although both types of infection occur throughout the whole sea phase, tenacibaculosis is most commonly associated with acute disease in smolts recently transferred to the sea at low temperatures. Tenacibaculosis is less common than winter ulcer but can be very severe. Mixed infections with *M. viscosa* and *Tenacibaculum* spp. are not uncommon.

Development of skin lesions can often be linked to previous handling, such as mechanical delousing.

While *M. viscosa* and/or *Tenacibaculum* spp. may cause ulcers alone or as mixed infections, other bacteria such as *Allivibrio (Vibrio) wodanis*, *Aliivibrio (Vibrio) logei* and *Vibrio splendidus* are also commonly cultured from skin lesions. In particular, systemic infections with Aliivibrio wodanis in apparent pure culture are relatively common in fish displaying winter ulcer. The importance of A. wodanis in development of this condition remains, however, unclear. Despite the fact that the disease could not be recreated following exposure of salmon to this bacterium in early infection trials, it cannot be discounted that the bacterium plays a role in development of skin lesions.

M. viscosa was for many years perceived as a genetically conserved species, but genetic analyses have revealed the existence of several closely related sub-populations (clonal complexes, CC), where winter ulcer in salmon is mainly associated with members of CC1 and CC3. It is not uncommon to find both clonal complexes involved in an individual outbreak.

Tenacibaculum spp. are naturally widespread in the marine environment, where they have an important ecological function in decomposition of organic material. Recent research indicates that different *Tenacibaculum* species and strains differ in their ability to cause skin disease in farmed Atlantic salmon. A study performed in 2018/2019 found that tenacibaculosis in newly sea-transferred smolts was

Figure 6.4.1. *Moritella viscosa* cultured from the kidney of salmon displaying winter ulcer (blood agar supplemented with 1.5% NaCl). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

mainly associated with *T. finnmarkense*. This species consists of two very closely related genomovars i.e. gv. *finnmarkense* and *gv. ulcerans*. While both genomovariants may be involved in outbreaks of tenacibaculosis, it appears that gv. *finnmarkense* is the main contributor to ulcer development. Although *T. piscium* may be cultured from and identified histologically within ulcers, it does not appear to be related to serious ulcer development. The fact that several genetic variants of *Tenacibaculum* are usually detected within outbreaks indicates that colonisation of fish from the environment is more important than direct infection from fish to fish.

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 tenacibaculosis, see the fact sheets (in Norwegian):

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

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

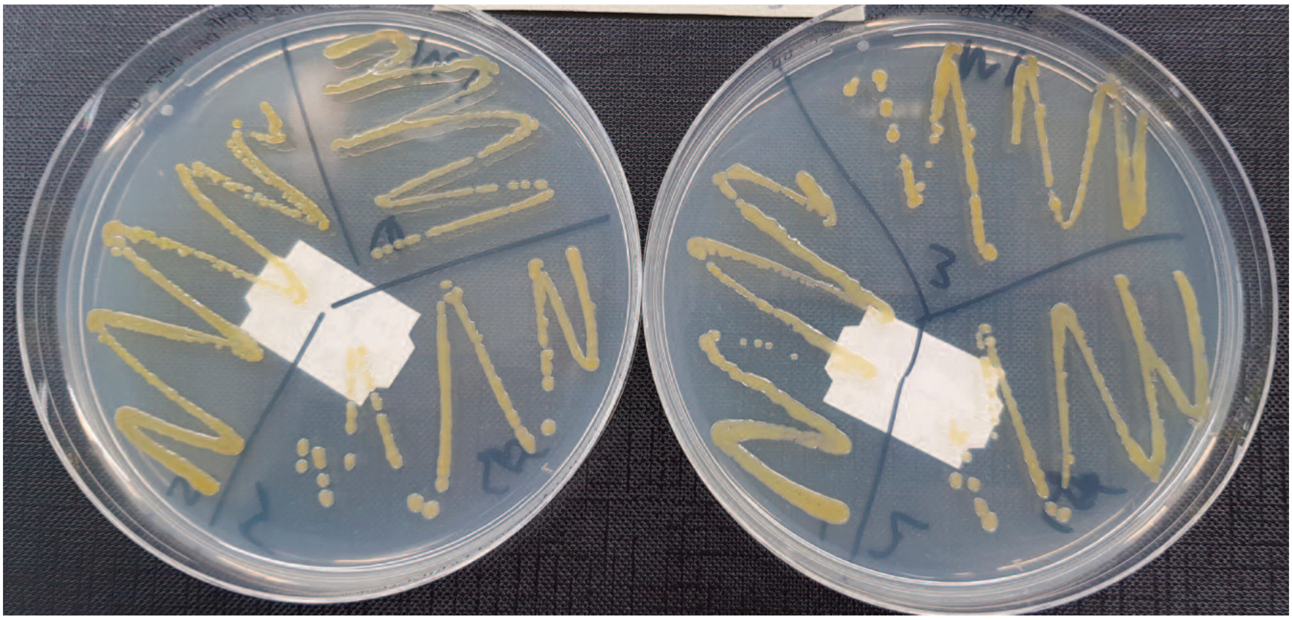


Figure 6.4.2. *Tenacibaculum finnmarkense* cultured from an Atlantic salmon with 'mouth rot' (marine agar). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

Figure 6.4.3. Skin lesions in the head/jaw region are commonly infected with *Tenacibaculum finnmarkense*. Photo: Geir Bornø, Norwegian Veterinary Institute

The Health Situation in 2022

Data from the Norwegian veterinary Institute and private laboratories

In 2022, skin ulcer development was again identified in salmon farmed along the entire coastline. Due to the need for specific PCR or other molecular biological analyses, subtyping of *M. viscosa* and *Tenacibaculum* spp. is normally not performed during routine diagnostic investigations.

Combined data from the Norwegian Veterinary Institute and private diagnostic laboratories (Chapter 1 Statistical basis for the report) revealed that winter ulcer, irrespective of underlying cause, was diagnosed in 433 salmon farming localities during 2022. The underlying causes of skin lesion development are not always identified, and *M. viscosa* and *Tenacibaculum* spp. may be diagnosed alone, together or in the presence of other bacteria. In those cases where a bacteriological diagnosis was made, *M. viscosa* was identified in 296 salmon farms, while *Tenacibaculum* spp. were identified in 205 salmon farms. *M. viscosa* and *Tenacibaculum* spp. were identified in four (PO3-PO5) and two (PO3) rainbow trout ongrowing farms respectively. The geographical distribution of cases indicates, as for 2021, that *M. viscosa* infections in salmon are relatively evenly spread along the entire coastline (Figure 6.4.4). Of the ~60% of the *Tenacibaculum* isolates that were identified to species/genomovariant level, ~50 percent and ~33 percent were identified as *T. finnmarkense* gv. *finnmarkense* and *ulcerans*, respectively. The remaining isolates comprised *T. dicentrarchi* (~4 percent), *T. piscium* (~2 percent) and *T. maritimum* (~3 percent). Both genomovariants of *T. finnmarkense* were identified in all production areas with the exception of gv. *finnmarkense*, which was not identified in PO1 and PO2. No obvious geographic pattern was observed amongst the various *Tenacibaculum* spp. (Figure 6.4.5). As in 2021, most diagnoses involving *Tenacibaculum finnmarkense* and *M. viscosa* were made in the first half of the year, particularly January – March. Although both types of

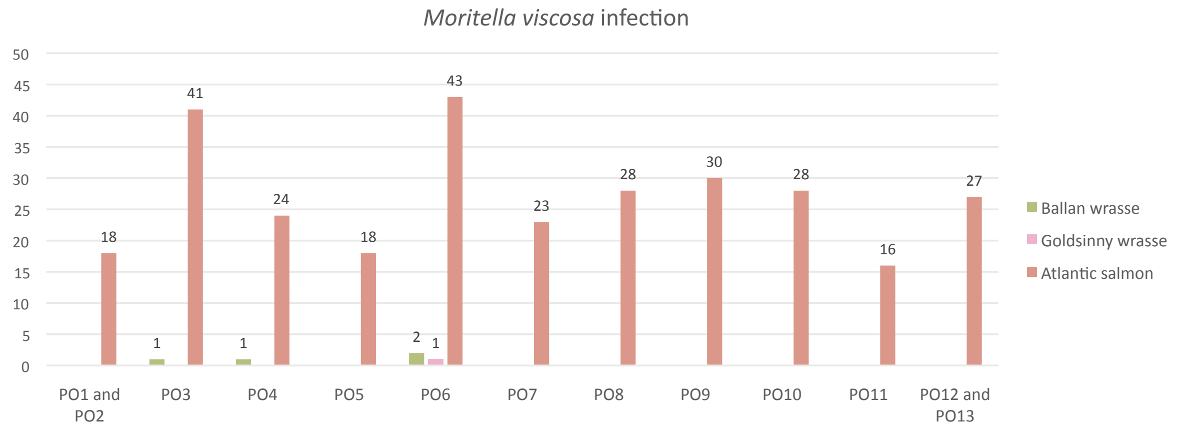


Figure 6.4.4. Salmon farms with diagnosed *Moritella viscosa*-infection per production area (PO) in 2022

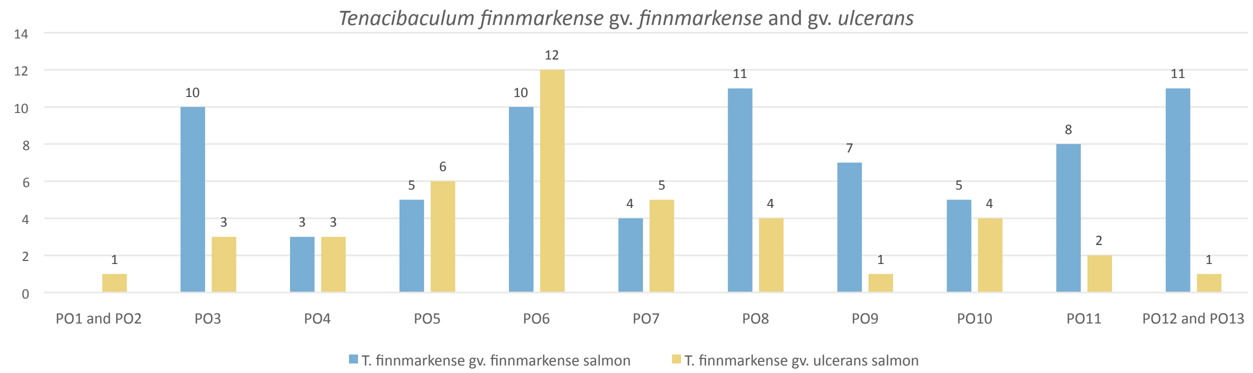


Figure 6.4.5. Salmon farms with diagnosed *Tenacibaculum finnmarkense* genomovar finnmarkense og genomovar *ulcerans* infections per production area (PO) i 2022

bacteria were also diagnosed late in the year, in the cases investigated by the Norwegian Veterinary Institute, *M. viscosa* appeared to dominate in this period, with relatively few *Tenacibaculum* diagnoses in the period October – December (Figures 6.4.6 and 6.4.7).

The Annual Survey

In the annual survey, *M. viscosa* and *Tenacibaculum* related diseases were ranked in third and sixth place respectively, closely followed by non-specific skin lesions, in regard to the most important health challenges in sea-farmed salmon (Appendix B1). Both types of infection are considered particularly important in terms of reduced welfare, being ranked in third and fourth place respectively. While both infections are listed amongst increasing causes of mortality in brood stock salmon, only *Tenacibaculum* spp. were linked to reduced growth (Appendix C1). Classic winter ulcer was mentioned as a cause of mortality, reduced growth and reduced welfare in ongrowing rainbow trout (Appendix B2). *Tenacibaculum* spp. were not mentioned as a challenge in rainbow trout farming.

Delousing related injuries were considered the most important cause of reduced growth and welfare, the second most important cause of mortality and were ranked in fourth place as an increasing problem in ongrowing salmon. Delousing injuries are considered the most important underlying cause of mortality and reduced welfare in ongrowing rainbow trout. There can be little doubt that injuries resulting from mechanical delousing predispose for skin lesion development. Avoidance of all production related factors that damage the skin barrier should be avoided.

Evaluation of the winter ulcer situation

Estimation of the impact and prevalence of both *M. viscosa* associated winter ulcer and tenacibaculosis is challenging due to the fact that these diseases are non-notifiable and relatively easy to diagnose in the field. The true prevalence of these diseases, based on submissions to diagnostic laboratories is, therefore, almost certainly under estimated. That *M. viscosa* infection was nonetheless identified in 296 farms (48 percent of all participating farms), indicates that the situation is serious. This is further supported by the fact that fish health personnel rank winter ulcer, together with delousing injuries amongst the most important current health challenges in ongrowing salmon.

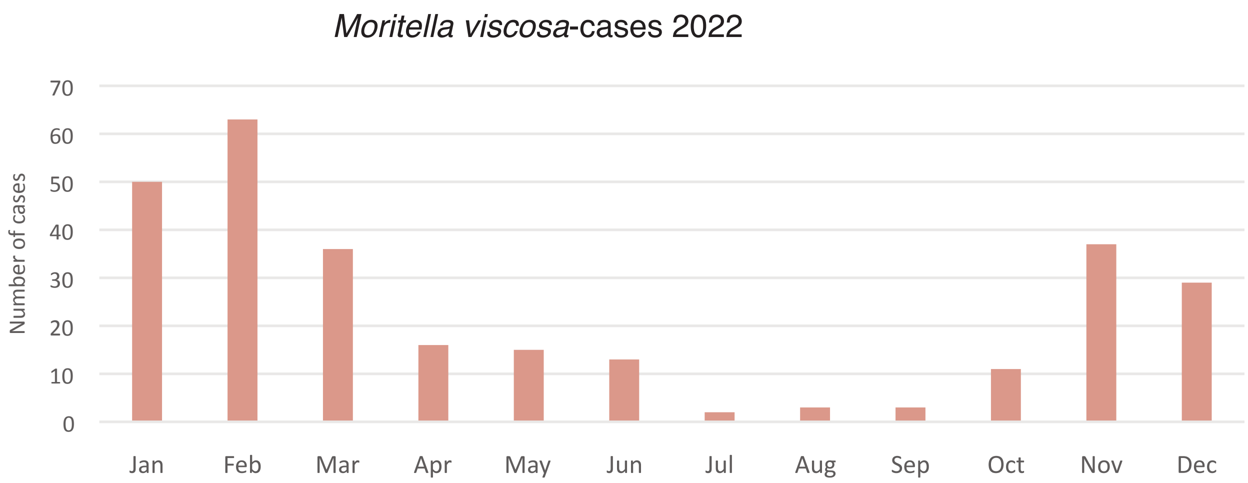


Figure 6.4.6. Monthly distribution of *Moritella viscosa* cases diagnosed by the Norwegian Veterinary Institute in 2022 (three cases in rainbow trout, the remainder salmon)

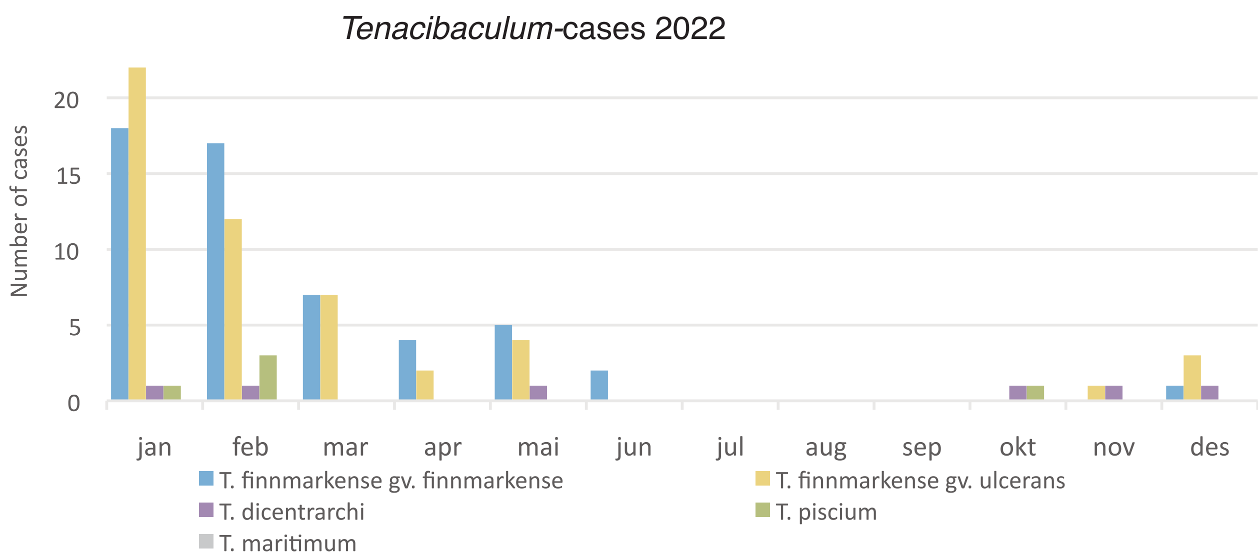


Figure 6.4.7. Monthly distribution of *Tenacibaculum* cases at the species and genomovar-level diagnosed by the Norwegian Veterinary Institute in 2022 (one case involved rainbow trout, the remainder salmon)

6.5 Pasteurellosis

BY Hanne K. Nilsen, Duncan Colquhoun og Snorre Gulla

The Disease

The term pasteurellosis includes diseases caused by different variants within the bacterial genus *Pasteurella*. In Norwegian salmon, a variant currently known as *Pasteurella "atlantica* genomovar *salmonicida*" (not yet officially named), has since 2018 been associated with disease outbreaks in Atlantic salmon along the western coast in Norway. Another species within the genus, *Pasteurella skyensis* has caused recurrent problems in salmon farming in Scotland. In Norway in 2020, two neighbouring sites were diagnosed with *P. skyensis*, but the bacterium has not since been detected.

Another genetic variant, *P. «atlantica* genomovar *cyclopteri»*, is associated with disease in lumpsucker used as cleaner fish in salmon farms (Chapter 11 The health situation in cleaning fish).

Historically, bacterial isolates now retrospectively identified as *P. "atlantica* genomovar *salmonicida*" were isolated from individual, widely geographically and chronologically separated disease outbreaks in salmon. The first recognised outbreak of the disease was in Northern Norway at the end of the 80s. The disease, first known under the name 'Varracalbmi' – the Lappish term for “bloody eye”, reoccurred in single outbreaks registered in 2000 and 2012 in Western Norway. From 2018, the disease has, however, remained one of the major disease and welfare challenges in salmon aquaculture in this area. The disease primarily affects large fish, at the end of the production cycle.

In salmon with pasteurellosis caused by *P. "atlantica* genomovar *salmonicida*", typical clinical macroscopic findings are pus-forming inflammation in the pericardium, abdominal wall and pseudobranch, as well as findings of pus-filled areas in skeletal muscles and at the bases of the pectoral fins. Protruding, sometimes bloody and inflamed eyes are common (figure 6.5.1), but do not occur in all fish. Histopathological changes reflect the macroscopic picture with findings of acute and more chronic inflammation, abundant inflammatory cells, tissue fluid, and short bacterial rods in affected organs. Reported clinical findings at one farm with *P. skyensis* infection in Norway had a slightly different picture, with bleeding in the swim bladder and fatty tissues, in addition to pericarditis and protruding eyes.

P. "atlantica genomovar *salmonicida*" displays low virulence in challenge trials. PCR has detected the bacteria's genetic material (DNA) on gill surface and skin of fish in fish farms, as well as in water when examining environmental DNA. The bacterium is demanding to cultivate, as it is dependent on blood products in culture media, and preliminary results from investigations carried out at the Veterinary Institute indicate that they probably have a poor ability to survive freely in seawater.

Disease control

The disease is not notifiable In Norway. Knowledge gaps exists about routes of infection, and the reservoir is unknown. Concurrent outbreaks at nearby salmon sites, combined with a high degree of genetic similarity between isolates, may point to a common source of infection. Hygienic measures, such as disinfection of equipment, personnel and frequent changes of de-lousing water during thermal IMM treatment to prevent possible concentration of infectious agents secreted from diseased fish, may be useful. Autogenous vaccines against the disease have been developed, but the degree of possible protection in the field has not yet been documented.

For more information about *Pasteurella*, see the fact sheet (in Norwegian): https://www.vetinst.no/sykdom-og-agens/pasteurellose-hos-fisk

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

In 2022, the disease was detected in salmon at 52 sites. All positive sites were located in the south-western coastal area (PO1-PO5), and as earlier, the highest number of affected sites were in PO3 and PO4 (Figure 6.5.2). Detections of bacteria have for most cases been made fish displaying signs of disease, but in a few cases the bacterium has been isolated from apparently healthy fish. Common findings have, as in the past, included pericarditis and peritonitis, and purulent inflammation in muscle, internal organs and at the bases of the pectoral fins. The disease continues to primarily affect large fish (2-5 kg), but the bacterium has also been detected in fish of around 1 kg. Increased mortality is reported and, as earlier, handling procedures such as delousing, are commonly registered in the period prior to outbreak of disease. The clinical picture may be complex. Co-infections with *Yersinia ruckeri, Moritella viscosa* and *Tenacibaculum finnmarkense* have been detected, and fish with pasteurellosis are commonly co-diagnosed with the viral diseases PD, HSMB and CMS.

The Annual Survey

For salmon in sea water sites, 13 of 63 respondents indicated that the disease was associated with increased mortality, 14 of 63 reported reduced fish welfare, and ten of 52 that the disease represents an increasing problem at the national level. Pasteurellosis is a disease that strikes late in the production cycle, which is reflected in the fact that there are few respondents, five of 57, who stated that the disease is associated with reduced growth.
For salmon in broodstock farms, two of twelve respondents indicated that the disease causes mortality and reduced fish welfare. No respondents considered the disease to represent an increasing problem or a cause of reduced growth.

Figure 6.5.1 Eye damage in salmon with pasteurellosis. Photo: Hanne Nilsen, Norwegian Veterinary Institute

Evaluation of the Pasteurella situation

The number of diagnoses in 2022 remains high, and the disease has been detected in 52 locations, which is a slight increase compared to last year (45). The commonly complicated disease picture with several infectious diseases involved combined with the association with handling procedures, which cause stress, may indicate a generally weakened defence status in the fish.

Pasteurellosis in salmon is now an established bacterial disease that threatens fish welfare and sustainability in the industry. Until now, the disease has spread along the south-western coast of Norway, but there may be a risk of spread to new areas.

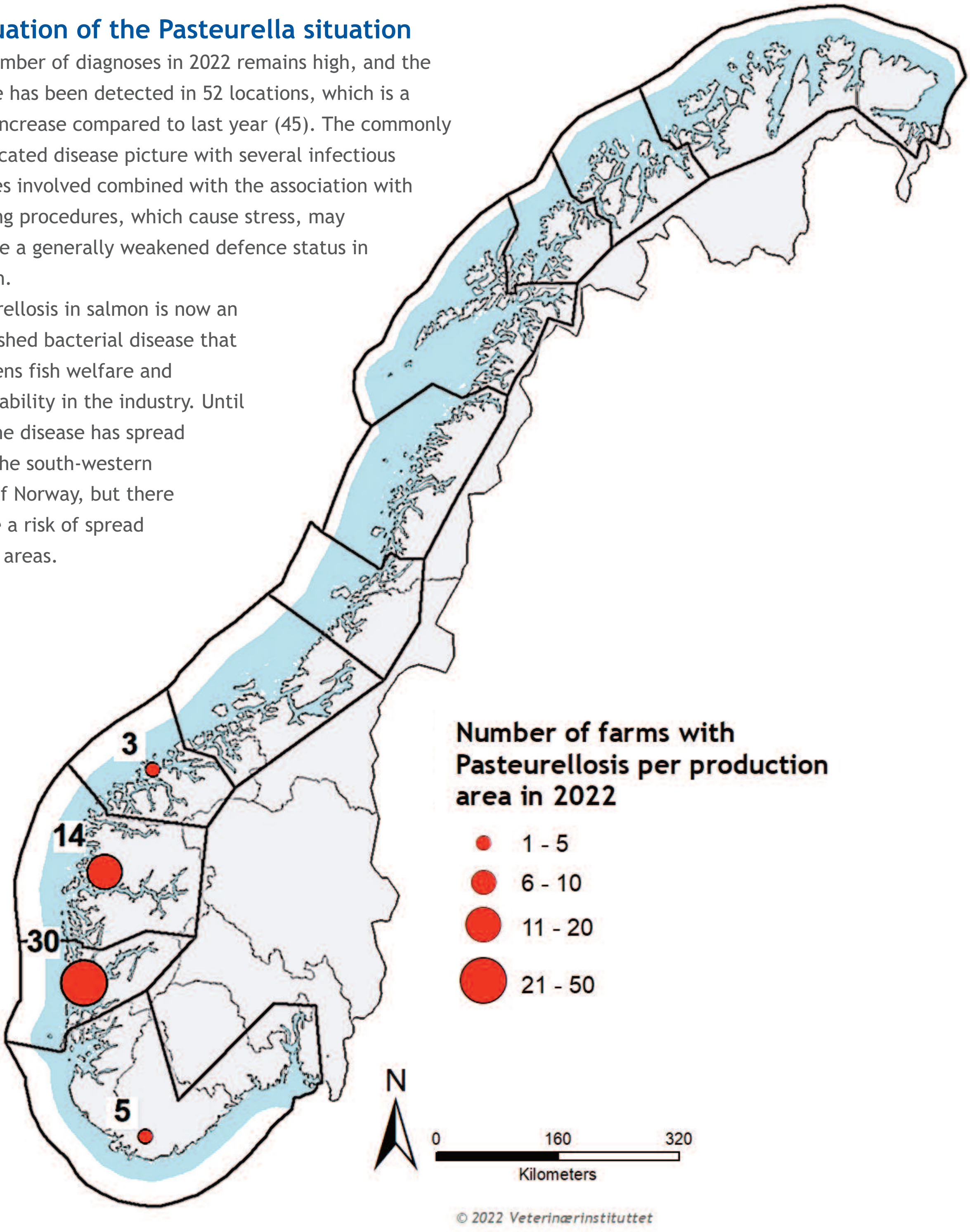


Figure 6.5.2 Number of pasteurellosis diagnoses in 2022 by production areas, based on figures compiled from the Norwegian Veterinary Institute and private laboratories

6.6 Yersiniosis

By Snorre Gulla og 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, and to a lesser extent redness around the mouth (Figure 6.6.1).

The disease may manifest both before and after sea transfer, but it is likely that the infection is primarily transmitted 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 originated from sub-clinical infections becoming activated due to handling and stress 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).

Research at the Norwegian Veterinary Institute has shown that one specific genetic variant (clone) of *Y. ruckeri*, displaying the O1 serotype, has been responsible for nearly all major yersiniosis outbreaks in Norway since the mid-90s. Distinct local clones of the O1 serotype dominate in other countries. Moreover, a diverse range of other clones, e.g. belonging to serotypes O1 and O2, are also found in Norway. This latter group, however, are seldom linked to clinical disease, and are instead isolated primarily from other sources such as clinically healthy fish and biofilm in hatcheries free of clinical yersiniosis.

Disease control

Due to disease problems in salmon at sea, water-based injection vaccines against yersiniosis prior to sea transfer have become relatively widespread in some parts of Norway. Some hatcheries also appear to have succeeded in eradicating virulent strains of *Y. ruckeri* from their facilities by sanitation. Yersiniosis may be confirmed by cultivation of the bacterium e.g. from the head-kidney of affected fish, and acquisition of bacterial isolates is also necessary in order to enable monitoring of resistance towards antimicrobials, which are used to a limited extent for combatting outbreaks. Such treatments may cause development of resistance, and reduced sensitivity towards some antimicrobials is occasionally documented in strains of *Y. ruckeri*. Products based on bacteriophages, i.e. viruses specific to *Y. ruckeri*, are also available for controlling the bacterium in fish farm environments.

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

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

Through 2022, detection of *Yersinia ruckeri* (by culture and/or PCR) was registered from a total of 36 different sites. This includes 33 detections in farmed Atlantic salmon (12 hatchery-, 18 ongrowing-, two broodstock- and one cultivation-sites), with six in PO3, four in PO4, one in PO5, four in PO6, twelve in PO7, three in PO8, one in PO10 and two in PO12. The bacterium was also detected in one wild Atlantic salmon, one lumpfish used as cleaner fish, and one farmed sea trout.

Overall, these numbers constitute a relatively marked increase compared to preceding years (14 and 19 affected sites respectively in 2020 and 2021), and actually surpasses the peak years of 2015 and 2016, each with 34 positive sites. These numbers are not, however, necessarily comparable, both because statistics from multiple laboratories have only been compiled in recent years, and due to PCR screening for the bacterium becoming more prevalent. In this regard, clinical reports from the positive sites were largely lacking, although to the extent that such information existed, most detections were made in association with clinical disease. The compiled registrations are based on data from the Norwegian Veterinary Institute in addition to private laboratories (see Chapter 1 Statistical basis for the report).

The Annual Survey

Overall, the respondents rank yersiniosis in «12th place» among problems both for salmon hatcheries (Appendix A1) and ongrowing farms (Appendix B1), and as in 2021, it achieves the second highest score when considering only the specific infectious diseases listed for the hatchery phase (Appendix A1). When asked if they have experienced yersiniosis outbreaks in vaccinated fish, six respondents reply «yes», while 27 reply «no». In the comments section it is remarked that outbreaks seldom occur in vaccinated fish, although one is mentioned that affected newly vaccinated fish in the freshwater phase, but was of shorter duration than what is usually experienced in unvaccinated fish.

Evaluation of the yersiniosis situation

After 2016, increased vaccine coverage was accompanied by a steep decline in the number of yersiniosis cases diagnosed at sea, but this trend appears now to have turned. Considering the number of positive sites registered annually, we are currently back on par with the levels observed prior to vaccination against the disease becoming widespread. The statistical basis for 2022, however, covers more laboratories than previous years and also likely includes some PCR-based detections from clinically unaffected fish. But while the numbers should thus be interpreted with some caution, it appears evident that yersiniosis (yet again) constitutes a growing problem within Norwegian salmon farming.

As of today, no comprehensive overview exists with regard to the proportion of sea transferred salmon that are vaccinated against *Y. ruckeri*, but any decline in this rate could potentially contribute towards explaining the increased incidence of yersiniosis. Recent research done at the Norwegian Veterinary Institute has shown that stressful handling, e.g. during thermal delousing, will stimulate *Y. ruckeri* shedding from sub-clinically infected carriers. This may potentially constitute a biosecurity risk towards naïve fish treated simultaneously and/or subsequently in the same water. Regardless, yersiniosis is a disease warranting close attention in the years to come.

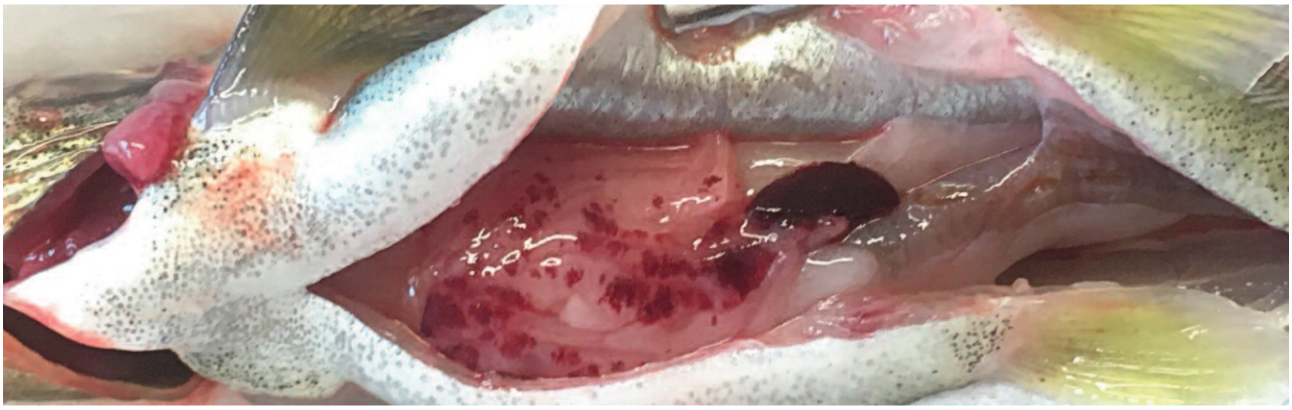


Figure 6.6.1: Yersiniosis in hatchery salmon with bleedings in the liver and enlarged spleen.
Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

6.7 Mycobacteriosis

By Julie Christine Svendsen, Toni Erkinharju and Hanne Nilsen, 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 6.7.1) 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 2022

Data from the Norwegian Veterinary Institute

In 2022, bacterial cultivation led to the detection of mycobacterial infection in atlantic salmon originating from five sites, as well as in one wild caught cod. In addition to this, *Mycobacterium* sp. was detected through immunohistochemical examination on three sites, and there was suspicion of infection with the bacteria on one site based on detection of acid-fast, rod-shaped bacteria. The geographical origin of these cases spanned from PO2 and northward toward and including PO8. The amount of cases represents a modest increase compared to the records of the previous year, where infection was detected on five sites based on histological investigation, combined with bacteriology and/or immunohistochemical analysis.

The Annual Survey

In the annual survey for fish health personnel and inspectors in the Norwegian Food Safety Authority mycobacteriosis is not rated among the greatest problems with regards to mortality, reduced welfare and reduced growth in atlantic salmon in hatcheries and ongrowing facilities at sea. The disease is, however, considered to be an increasing problem in salmon in ongrowing facilities by 10 out of 52 respondents (Appendix B1).

Evaluation of the mycobacteriosis situation

Mycobacteriosis in fish is not a notifiable disease, and there is no official record of the total amount of disease outbreaks in atlantic salmon in Norway. On account of this it is the amount of cases registered at the Norwegian Veterinary Institute which forms the basis for the following paragraph.

The disease was detected on three sites in 2018, seven in 2019, and five in both 2020 and 2021. This includes both hatcheries and ongrowing facilities, with more recorded cases in the latter. *Mycobacterium salmoniphilum* was identified on two of the sites where mycobacteriosis was detected in 2018, one site in 2019, three sites in 2020, two sites in 2021 and three sites in 2022 (the isolates from the two remaining sites were not sequenced). There is some variation in the prevalence over these years, making it difficult to conclude on a development over time based solely on this. However, the greatest amount of detected cases was in 2022.

Adding to this is the experiences from private laboratories. Reed et al. (Norsk veterinærtidsskrift, utg. 6 2022) reported a distinct increase in the number of cases in one laboratory from 2020 to 2021; from four sites with detected *Mycobacterium* sp. through bacterial cultivation and/or immunohistochemical analysis in 2020 to 13 (including one site with wrasse) in 2021. In 2022 the same laboratory had two confirmed cases (immunohistochemistry) with mycobacteriosis; one hatchery and one ongrowing facility. Typical histopathological changes with acid-fast, rod-shaped bacteria were observed in an additional five cases, among these one originating from a hatchery and four from ongrowing facilities.

The collected registrations from the Norwegian Veterinary Institute and the above mentioned laboratory, seen in light of the evaluations from fish health personnel in the annual survey, suggests that attention should be payed to the development of this disease.

Most fish pathogens, including *M. salmoniphilum*, do not proliferate at 37°C. As such, there is currently no certain basis for stating that human consumption of fish infected with mycobacteria represents a health risk. Several mycobacteria, among these *M. marinum* and *M. chelonae*, which are closely related to *M. salmoniphilum*, may induce skin lesions in humans in

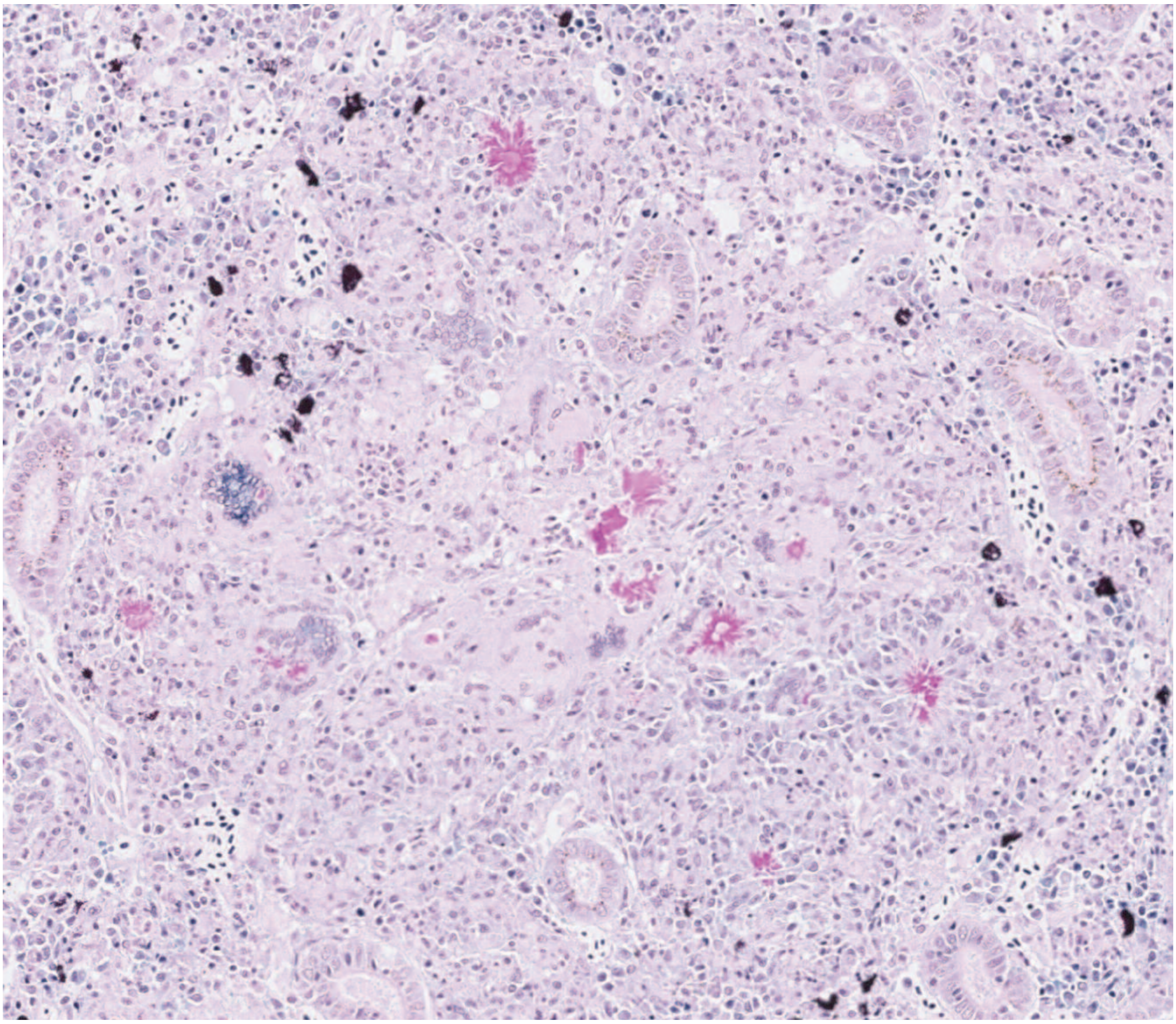


Figure 6.7.1 Kidney, Ziehl-Neelsen stain. Granulomatous inflammation with giant cells and Splendore-Hoeppli bodies. Immunohistochemical analysis for *Mycobacterium* sp. in the same individual showed postive staining of bacteria. Photo: Julie Christine Svendsen, Norwegian Veterinary Institute

the form of superficial granulomas and wounds. In immunosuppressed individuals, the lesions may spread deeper into underlying tissues. General precautions are recommended in handling infected fish, in order to prevent contaminated material from getting into contact with injured skin.

6.8 Miscellaneous bacterial infections of salmonids

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

Most bacterial infections are the result of an interaction between the bacterium, the fish and the environment. It is common to find a wide range of different bacteria from sick fish, including recognised disease-causing bacteria (pathogens) that are almost always linked to outbreaks, and more opportunistic bacteria that cause disease only in stressed and fish weakened by mechanical damage, handling or environmental conditions. In addition, it is common for bacteria from the environment around the fish to quickly infect weak or dead fish.

In diagnostic work, it can be challenging to relate detection of various types of bacteria to the observed disease. The findings are continuously assessed so that any new disease-causing variants can be rapidly identified. Culture based investigation of diseased fish is essential for uncovering new "emerging" bacterial pathogens.

The situation regarding bacterial diseases in Norwegian salmon farming has been fairly stable for many years, but some infections have again, after years of absence or low prevalence, started to become more common. The reason for the increase is unknown, but it is conceivable that the transition to physical delousing as the dominant delousing method, which entails increased stress and injury, may have contributed.

Infections with motile *Aeromonas* spp., including *A. hydrophila* and *A. sobria*, are occasionally detected in diseased farmed salmon. Such bacteria are commonly found in fresh water sources. Although these bacteria are closely related to the serious fish pathogen (and non-motile) *Aeromonas salmonicida*, and are associated with disease in some warm-water fish species, 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 be detected in sick and dying fish. As for motile Aeromonads, *Pseudomonas* spp. are common, particularly in freshwater sources. Although most detections are perceived as opportunistic infections, some cases, particularly with *Ps. fluorescence*, are linked more directly to observed mortality. *Pseudomonas fluorescens* was identified by the Veterinary Institute in ten facilities for salmon in 2022, both hatchery and ongrowing fish. The bacterium was linked to mortality in four cases.

Carnobacterium maltoaromaticum can sometimes be associated with pericarditis and peritonitis in salmon broodstock and is to some extent also isolated from hatchery and ongrowing fish. The bacterium can also be detected in rainbow trout and other salmonids, and has been isolated from e.g. lumpfish. *C. maltaromaticum* was identified by the Norwegian Veterinary Institute in four broodstock-, two ongrowing- and seven juvenile production-farms for salmon during 2022. *Carnobacterium* is a normal component of the gut flora in many fish species and the bacterium is also detected in fish without disease.

In 2021, for the first time since the 1990s, *Vagococcus salmoninarum* was detected as the dominant type of bacteria from the heart and abdominal cavity of broodstock salmon in Norway. In 2022, the bacterium was isolated from lumpfish fry with signs of sepsis. An isolate most similar to *V. salmoninarum* (MALDI-TOF and biochemical tests) was also detected in almost pure culture from serous fluid in the heart cavity of a 4kg salmon. *Vagococcus* is not considered a 'primary' pathogen.

Infection with *Vibrio anguillarum* (not serotyped) was detected in one ongrowing rainbow trout farm in 2022. *V. anguillarum* serotype O1 (see Figure 6.8.1) was detected in salmon from an ongrowing site and two hatcheries (salinity 1 and approx. 9 ‰ respectively).

Pseudomonas anguilliseptica is a widespread pathogen of lumpfish in Norway (see Chapter 11 The health situation in cleaner fish), and has been reported as pathogenic for salmon fish in the Baltic Sea. In Norway, there was a diagnosis in rainbow trout in 2019. In 2022, *Ps. anguilliseptica* infection was registered for the first time by the Veterinary Institute in an ongrowing Atlantic salmon. Sparse numbers of the bacterium were identified in a mixed flora from one of three examined salmon with signs of systemic infection and ulcers. It is not recorded whether the facility also held lumpfish.

Tenacibaculum maritimum is known to cause disease in many types of fish farmed in relatively warm seawater, including salmon farmed in the Pacific Ocean. The bacterium has occasionally been detected in the gills of farmed Norwegian salmon as one of the Tenacibaculum species that can be associated with gill necrosis. *T. maritimum* was not detected in salmon by the Veterinary Institute during 2022.

Cold-water vibriosis, caused by Aliivibrio (Vibrio) salmonicida, was not detected in salmon or other fish species during 2022.

Atypical *Aeromonas salmonicida* was detected by the Veterinary Institute in a salmon hatchery that used fresh water supplemented with seawater, in a group of 200g salmon that had been diagnosed with the same infection in 2021. Infection with atypical *A. salmonicida* was also detected in three ongrowing farms with salmon with low to moderate ulcer-related losses. In two of the cases, *Moritella viscosa* was also detected. Such infections have been uncommon in recent years since vaccination against *A. salmonicida* subsp. *salmonicida* (the furunculosis bacterium) usually provides good protection against atypical variants.

Piscirickettsiosis, caused by *Piscirickettsia salmonis*, remains a serious problem in Chilean salmon farming and is at times the cause of losses in both the Irish and Scottish farming industries. The Norwegian/European variants of the bacterium are usually associated with lower mortality. *P. salmonis* was not detected in Norwegian salmon in 2022.

Most bacterial infections are the result of interaction between the bacterium, the fish and the environment. A wide range of bacteria are being isolated from sick fish. Photo: Rudolf Svensen

6.9 Antibiotic sensitivity

By Duncan J. Colquhoun and Hanne Nilsen

The Veterinary Institute monitors antibiotic sensitivity in a large number of bacterial isolates cultured from diseased farmed fish each year. In addition, a smaller number of isolates cultured from wild fish, mainly wild salmon, are examined. The results from this surveillance continue to show a favourable situation, with a very low incidence of reduced antibiotic sensitivity in relevant disease-causing bacteria in Norwegian fish farming.

Antibiotic consumption in Norwegian fish-farming remains extremely low, but antibiotic treatment may be necessary in the event of an outbreak of bacterial disease, in order to improve fish welfare or avoid major losses early in the production cycle. In Norway, oxolinic acid and florfenicol are most commonly used. It is important that the consumption of antibiotics remains as low as possible, as antibiotic use is known to be one of the most important drivers of resistance to antibacterial agents.

In 2022, there were no signs of widespread or increasing resistance among bacteria found in sick fish in Norway. As in previous years, we have again identified reduced sensitivity to oxolinic acid in a specific strain of *Flavobacterium psychrophilum* isolated from diseased rainbow trout. Reduced sensitivity to the same antibiotic was again demonstrated in 2022 in *Aeromonas salmonicida* subsp. *salmonicida* isolated from two salmon ongrowing farms in PO6, in *Yersinia ruckeri* from two salmon hatcheries, respectively in PO7 and PO10 and in *Vibrio anguillarum* serotype O1 from a salmon hatchery in PO5.

No reduced sensitivity to antibacterial agents has been demonstrated in fish pathogenic bacteria isolated from cleaner fish in 2022.

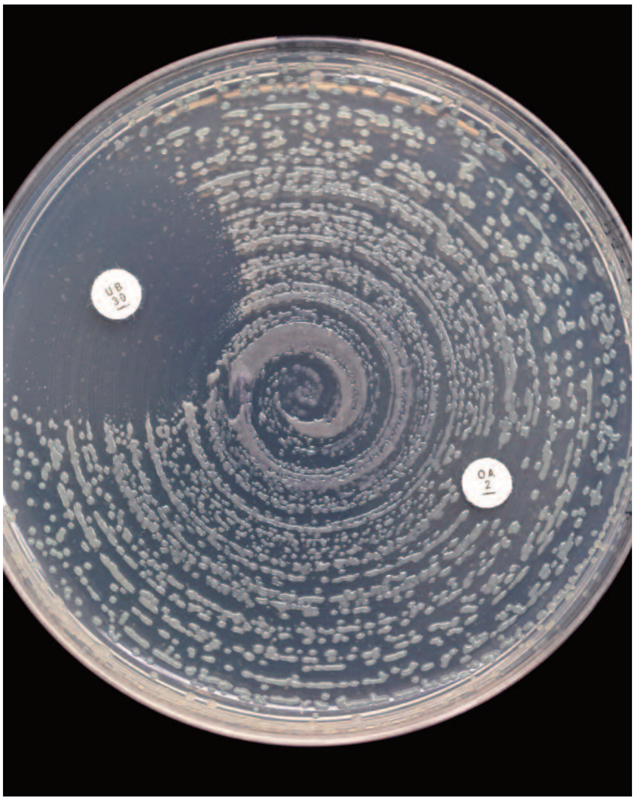


Figure 6.9.1 Bacterial colonies from fish tested for sensitivity to various antibiotics. Photo: Eivind Senneset.

7. 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 7.1.1)

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 2022

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 2022, additional requests for advice outside the diagnostic service in which saprolegnia was related to high mortality in start-feeding fry and eggs. In 2022, Saprolegnia was identified in 14 diagnostic submissions involving 13 salmon (egg, ongrowing and broodstock) and one sea trout. Saprolegnia infections in fish are mainly caused by *Saprolegnia parasitica*, but this year *Saprolegnia delica* was identified in three of the submissions. Systemic mycosis was only diagnosed in three salmon, of which one was caused by gill mycosis. *Exophiala psycrophila* was identified in lumpfish.

Data from private laboratories

Since fungal diseases are usually diagnosed and treated without laboratory diagnostics, we have not received data from other laboratories.

The Annual Survey

For salmon in hatcheries, eight of 43 respondents indicated that the disease was associated with reduced welfare, seven of 42 reported increased mortality, and three of 31 reported reduced growth. None of the respondents considered the disease to represent an increasing problem at the national level. For rainbow trout in hatcheries, one respondent reported that saprolegniosis was the cause of mortality. Furthermore, neither fungal infections nor saprolegniosis was reported as a problem for rainbow trout.

For lumpfish in sea water sites, only one respondent considered fungal infection to be an increasing problem, while the vast majority were unsure whether they have fungal infections on the fish. Fungal infections were not considered a problem to lumpfish in the hatchery phase. For wrasse in sea water sites, fungal infection as a cause of reduced welfare was reported only once, while most respondents reported that they do not know whether they have a problem with fungal infections in the wrasse.

Evaluation of the saprolegniosis situation

The Norwegian Veterinary Institute receives regular enquiries about problems with Saprolegnia. Based on the number of submissions and the responses in the survey, fungi and oomycetes appear to be effectively controlled by preventive measures.

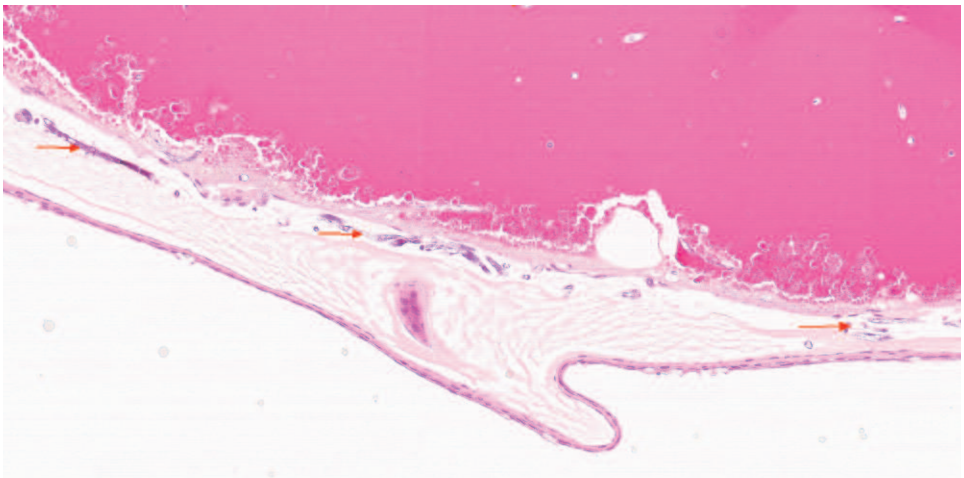


Figure 7.1.1 Saprolegnia hyphae (arrows) in fry yolk sac. Photo: Even Thoen, Patogen

8. Parasitic diseases of farmed salmonids

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. In 2022, lice levels were similar to those of the past five years, albeit with slightly fewer motile lice per fish in 2022. However, the production of salmon lice larvae during the outward migration period for wild salmon was higher than in previous years in most production areas, with some variation across different production areas. Similar to 2021, the seasonal increase in salmon lice levels started in early spring.

The resistance to pharmaceutical treatments in salmon louse remained widespread along the coast in 2022, and non-medicinal treatments or measures dominate delousing strategies. There was an 11 percent increase in non-medicinal treatments in 2022 compared to 2021, and thermal treatment is still the most widespread delousing method in the industry. After a decline in recent years, there was a small increase (3 percent) in the use of medicinal treatments for salmon lice.

In the annual survey, respondents still emphasize the significance of increased mortality after delousing as an important contributing factor to the total mortality in the on growing phase. There are also strong indications that physical injuries resulting from the different delousing procedures are associated with reduced fish welfare.

Infections with *Caligus elongatus* continued to be a problem in 2022. This parasite has been a challenge in some areas, especially in the north. There have been cases where the levels of infection with *C. elongatus* alone have been so high that treatments were necessary, while in other casestreatment against both lice species (salmon louse and *C. elongatus*) carried out at the same time. The annual survey shows that *C.elongatus* is regarded a more severe problem in 2022 than in previous years.

For several years, the parasite *Parvicapsula pseudobranchicola* has posed significant challenges in farming facilities in the two northernmost counties. In 2022, as well as in previous years, this parasite represented a major challenge in terms of mortality, growth and welfare, particularly in Troms and Finnmark. Furthermore, the parasite was detected in production areas south of Troms and Finnmark in 2022, serving as a reminder that the parasite has the capacity to evoke problems also outside these northernmost counties.

The causal agent of amoebic gill disease (AGD), the amoeba *Paramoeba perurans*, 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 2022, as was the disease. In cases of complex gill disease in salmon in the ongrowing phase, the amoeba can be present alongside other bacterial agents or parasites such as the microsporidian *Desmozoon lepeophtherii*.

Other parasites are also commonly found in farmed salmon. Since 2010, there has been an increased prevalence of infection with the tapeworm *Eubothrium crassum*. These infections are most in salmon in the sea in the southwest, western and central parts of Norway. Single-celled parasites (protozoans) such as *Ichthyobodo* necator (freshwater), *I. salmonis* (euryhaline, both freshwater and seawater) and *Trichodina* spp. commonly occur in Norwegian fish farming. Most parasite infections are detected by the fish health services. Respondents of the annual survey consider problems with these parasites to be relatively low for the country taken as a whole, but make comments of increased numbers of tapeworm infections.

The X-cell parasite, which was detected in both salmon and rainbow trout in 2021, was not detected in these fish hosts in 2022. There is one suspected detection in farmed cod, see chapter 12 for further description of this.

In 2022, the parasitic flagellate *Spironucleus salmonicida* appeared as a challenge in on growing farms in the Finnmark region, causing systemic spironucleosis in several fish farm. Sporadic disease outbreaks have occurred since the disease was first detected in 1989. The situation in 2022 stands out as it is on a scale not previously experienced. Systemic spironucleosis is a serious diagnosis with major consequences for fish health and welfare, as well resulting in economical loss.

Non-medicinal treatments or measures dominate the delousing strategies. Photo: Lisa Furnesvik, Stim AS

8.1 Salmon louse - *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 of salmonid fish in marine environments in the northern hemisphere (Figure 8.1.1). The life cycle comprises eight developmental stages separated by exoskeleton moults. The parasite reproduces sexually. Adult females can produce up to 11 pairs of egg-strings, each with several hundred eggs. During the first three planktonic stages, which may last several weeks at low temperatures, the larvae may travel many kilometres. The last five stages are all parasitic on anadromous salmonid fish in the sea.

Salmon lice feed on the skin, mucus and blood of the fish. If the burden of lice in the three last developmental stages is high, this may result in injury and anaemia in the fish. Lesions may then provide a point of entry for secondary infections and may result in osmoregulatory problems for the fish. High louse burdens may be fatal.

Louse larvae may transmit from farmed fish to wild fish. Due to the louse's infection potential and the number of available hosts, together with the potential for serious injury in both farmed and wild fish, the salmon louse represents one of the most serious problems in Norwegian aquaculture today.

Disease control

The maximum permitted louse burden is defined in legislation, with different maximum thresholds of infection defined for spring and the remainder of the year. The threshold is lower in the spring due to outward migration of wild salmon smolts. Louse numbers are monitored and reported weekly from all farms holding salmon or rainbow trout.

The main control measures have traditionally been medicinal, but increasing levels of resistance have led to a situation in which alternative treatment methods now dominate. Farmers commonly now use a combination of preventative measures including continual delousing (mainly cleaner fish) and both non-medicinal and medicinal methods.

The increased frequency of treatment and increased use of non-medicinal methodologies has led to a considerable increase in production costs in farming of salmonids in open cages. The high frequency of treatment also results in a welfare cost to the fish due to the increased risk of injury and mortality related to every treatment.

For more information on salmon lice, see the fact sheet (in Norwegian):
https://www.vetinst.no/sykdom-og-agens/lakselus

Figure 8.1.1. Adult salmon louse, female. Photo: Akerblå.

The Health Situation in 2022

Official data

All farmers are required by law to count and report lice numbers weekly. The average number of lice reported weekly for the country as a whole reveals a cyclical variation with the lowest lice counts in spring and the highest during the autumn (Figure 8.1.2). The highest numbers of adult female lice in 2022 were recorded in September (week 38) and the highest numbers of other mobile stages (pre-adults and adult males) in October (week 43). The lowest number of adult female lice per fish was seen in May (week 21), while the lowest number of other mobile lice per fish was seen in April (week 17). The louse level as a whole in 2022 was approximately the same as in 2021 and for the five-year period 2016-2020, but with somewhat fewer mobile lice (an average of 0.61 mobile lice per fish in 2022 compared to 0.59 in 2021 and 0.67 in the period 2016-2020).

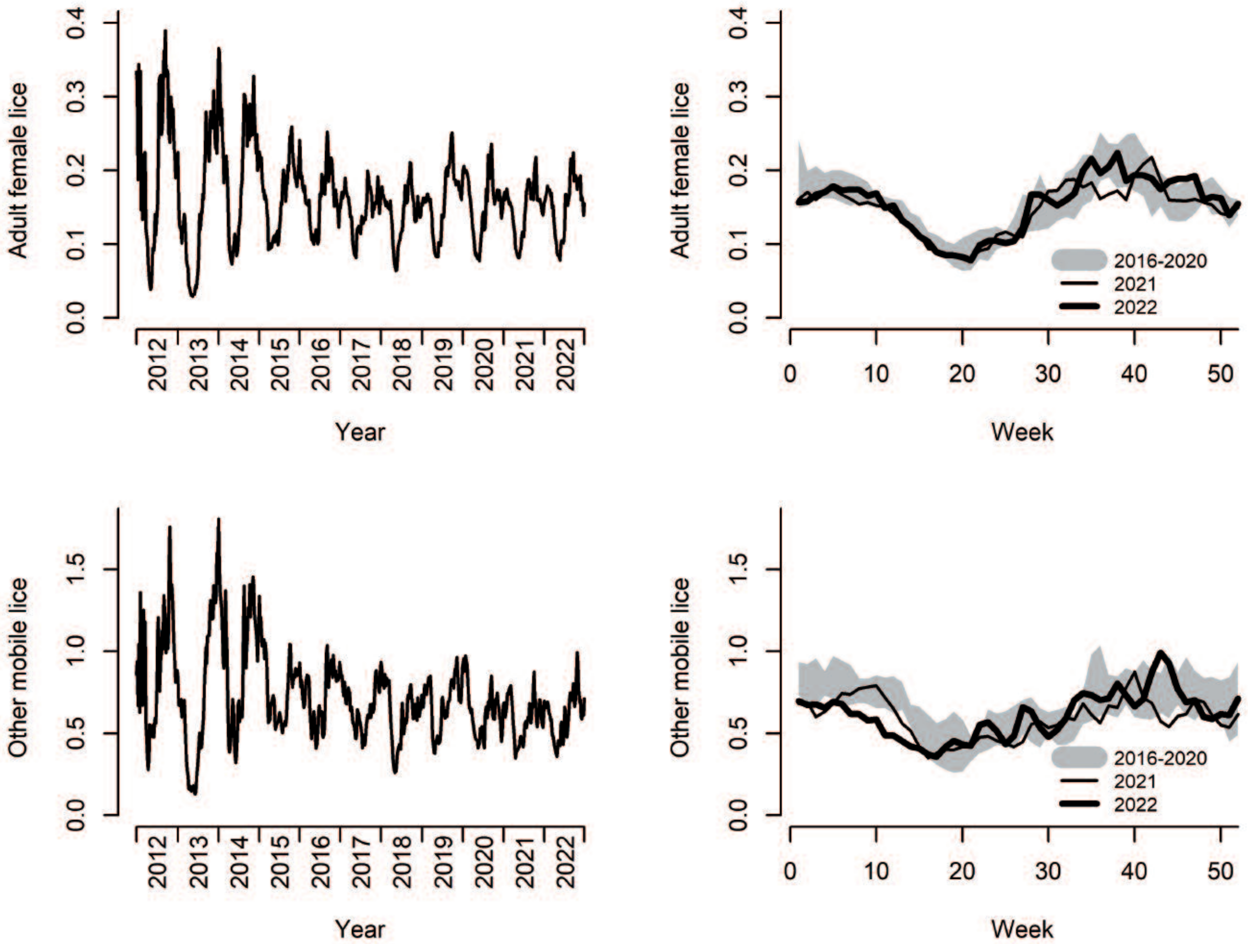


Figure 8.1.2. Average weekly reported salmon numbers from all marine farms holding salmon or rainbow trout, in the whole country for the period January 2012 to December 2022 (reported to the Norwegian Food Safety Authority as of 16.01.23). Upper panels refer to adult female lice per fish and lower panels to other motile stages of lice (pre-adult lice and adult male lice) per fish. The panels on the right show the seasonal development for each of the last two years (lines) and the range of variation in the previous five years (in grey).

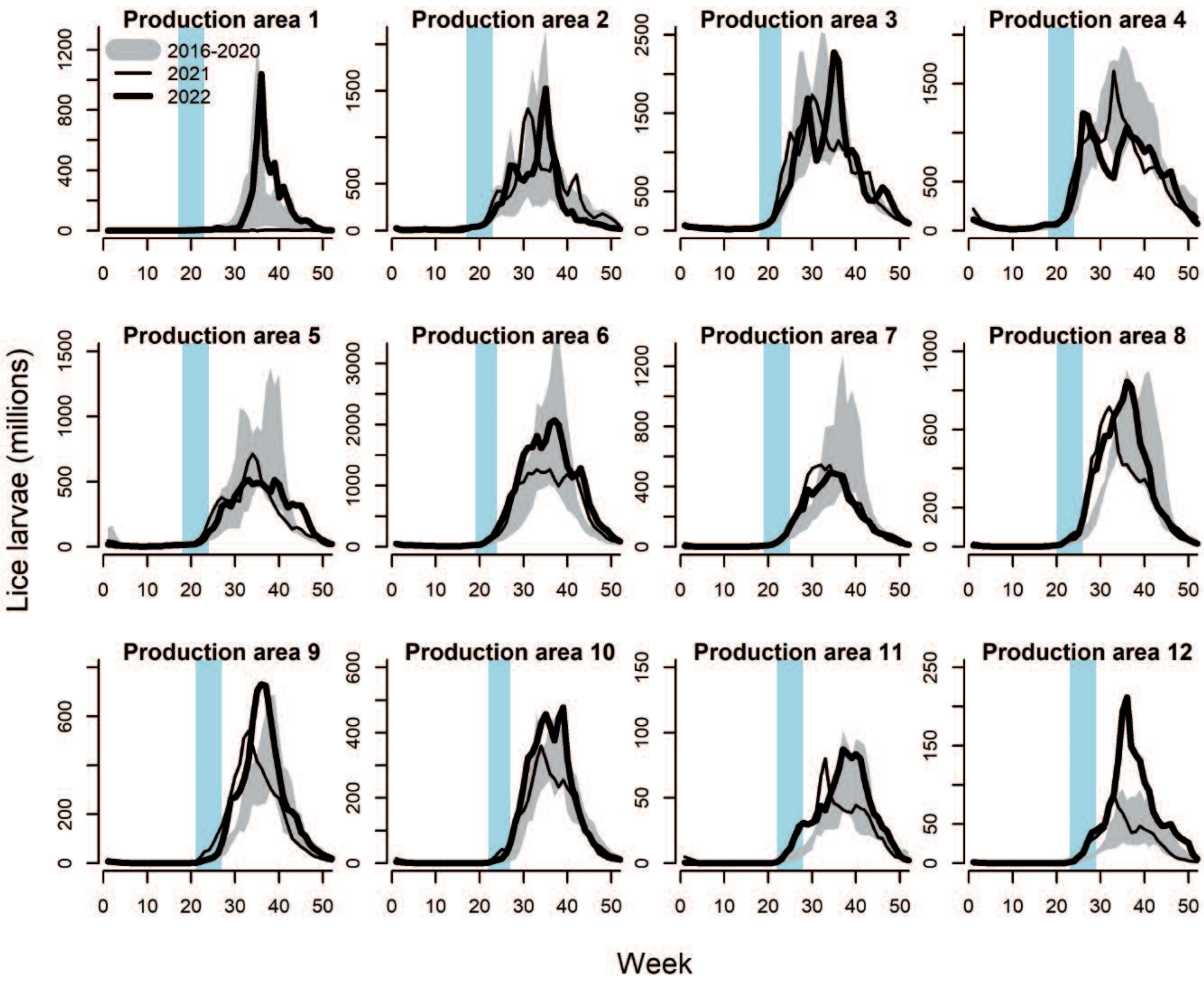


Figure 8.1.3. Calculated total production of salmon louse larvae (in millions) per week within each production area (PO). The lines show the seasonal variation for each of the last two years. The grey fields show the range in variation over the previous five years. Note that the y-axis scale is different for different production areas. PO13 is omitted. This area had negligible larval production throughout the period (with the highest larval production estimated at 10.1 million larvae in week 31 in 2016). The blue fields show the typical migration period for wild salmon smolts in each area.

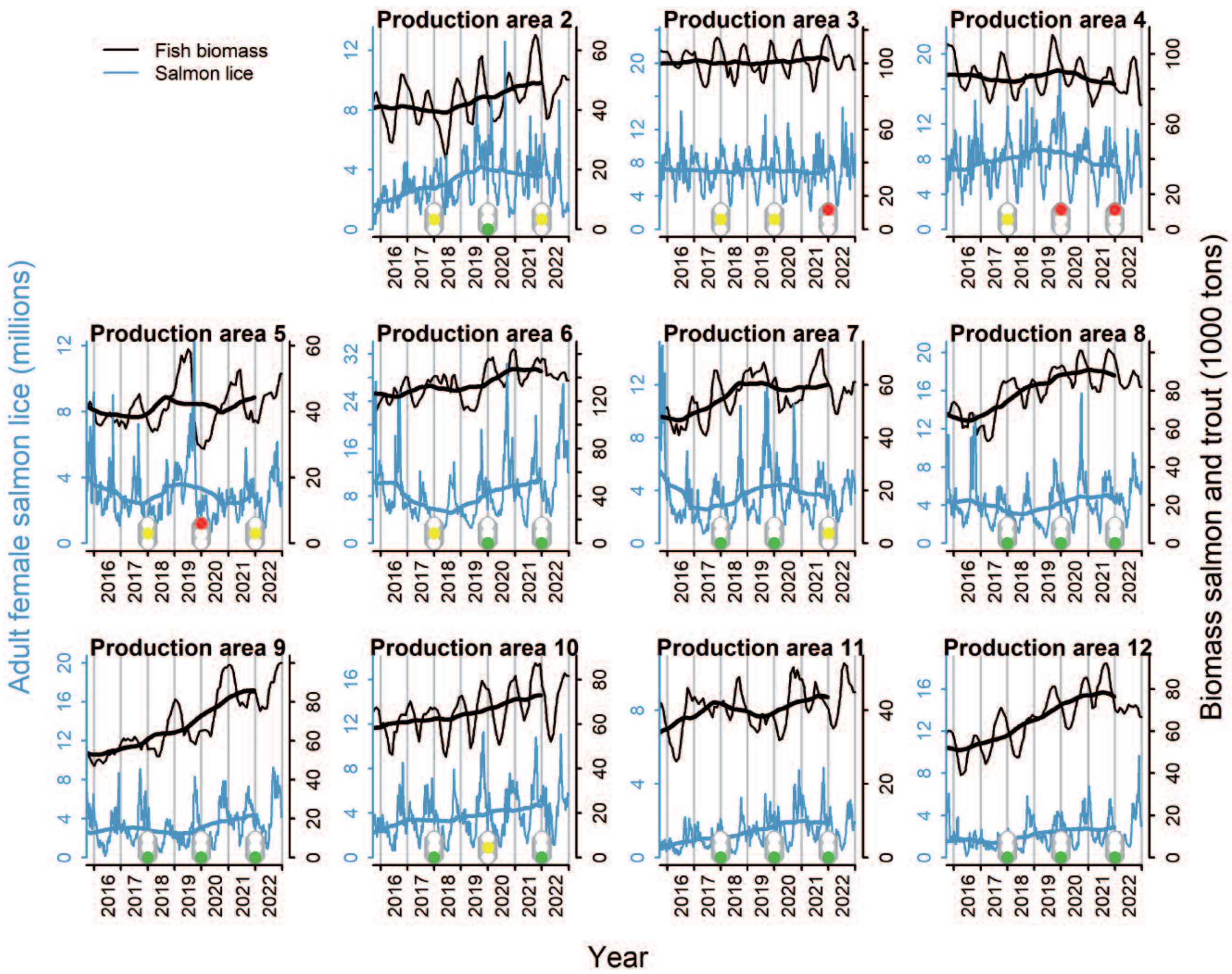


Figure 8.1.4. Time trends in salmon lice and farmed fish in each production area (PO) from 2016 to 2022. The blue lines show the estimated total number of adult female lice on farmed fish, based on weekly reporting to the Norwegian Food Safety Authority. The black lines show the biomass of salmon and rainbow trout in marine farms, based on monthly reporting to the Directorate of Fisheries. The thick lines show running two-year averages, so that each point on the line is the average for a period from one year before to one year after each timepoint, while the thin lines also show the short-term variation. Note that the y-axis scale is different for different production areas. 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 PO3 and PO4 in the first period are shown as yellow, as the red light did not result in a reduction in permitted production capacity. PO1 and PO13 are not shown because there were few farming facilities in operation.

The average number of adult female lice was 0.15 in 2022, which was a similar level as in 2021 and for the period 2016-2020). To analyse the louse situation at a level deeper than average numbers of lice, we have modelled the production of louse larvae. Calculation of larval production is based on the reported number of lice, sea temperature and numbers of fish in each farm, together with knowledge of louse reproduction, developmental time and survival rates for each developmental stage.

Production of louse larvae was calculated for each of the 13 production areas (POs) for salmonid farming around the coast (See Chapter 1 Statistical Basis for the report, Figure 1.1). Each area is considered separately in the so-called Traffic Light System which is legislated under FOR-2017-01-16-61. For a discussion of the Traffic Light System and status in 2022, see Chapter 10.4 Salmon lice and sustainability.

The highest larval production in 2022 occurred in PO2, PO4 and PO6 (Figure 8.1.3). PO1, PO3, PO6 and PO8-PO12 experienced increases in larval production from 2021 to 2022. In PO2, PO4, and PO7, there was a reduction in production of salmon lice larvae, while there were only small changes in PO5 and PO13. Regarding larval production during the period of outward migration of wild salmon (Kristoffersen m.fl. 2018, Epidemics 23: 19-33), an increase was registered in these weeks in the period 2021 to 2022 in PO6 and PO12. In PO2-PO5 and PO8-PO10 larval production was reduced in these weeks, while only small changes were registered in PO1, PO7, PO11 and PO13. Larval production during the outward migration period was also high compared to the five years prior to 2021 in PO6-PO8 and PO11-PO12 and within normal variation in the remaining PO areas. The high larval production during the migration period in 2021 and 2022 was due to the fact that the seasonal increase in larval production in the summer occurred earlier than has been usual in recent years.

The long term trends in the total number of adult female lice in each production area are driven to a large degree by the number of farmed fish (Figure 8.1.4). Changes in the number of female lice influence in turn production of louse larvae, although temperature and salinity also affect larval production. In PO2, while there has been an increase in the biomass of farmed fish since 2019, the number of salmon lice has remained relatively stable. This means that there are now fewer lice per kilo farmed fish in this area. The permitted production capacity is regulated via the Traffic Light System. As can be seen in Figure 8.1.4, changes in actual production do not always follow changes in the permitted production. One cause of such discrepancy is that permitted production capacity is utilised to a variable degree at different times. Another reason is that farms may be offered 'exceptional' capacity increases if they can document particularly low louse numbers and a maximum of one medicinal delousing during the last production cycle, even if the farm is located in a red or yellow production area (§ 12 production legislation). The general overall situation is that the biomass of salmon and number of salmon lice within green areas has increased, remained stable in yellow areas and declined in red areas. It is still too early to see any effect of the last traffic light regulation that was **published** in June 2022.

If we divide the number of larvae produced by the number of fish held in each farm, large variations in the number of larvae produced per fish are identified (Figure 8.1.5). The median value of the average production of lice larvae per fish per week was highest in PO3 and PO4, and then decreased the further south or north the production area was located. This shows that the effect of any increased or reduced production of salmon and rainbow trout on how many lice larvae are produced will depend on where in the country the change in production occurs.

The number of louse treatments in 2022 is summarised in Tables 8.1.1. (medicinal) and 8.1.2. (non-medicinal).

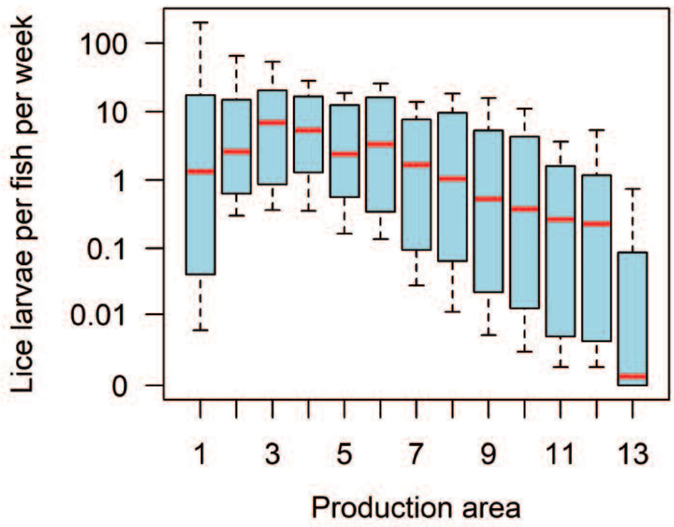


Figure 8.1.5. Calculated average production of lice larvae per fish per week within each production area (PO1-PO13) in 2022. The red lines are median values, while 50% of the values are within the blue boxes.

Counting of medicinal treatments is based on the number of registered prescriptions for salmon lice agents in the Veterinary Medicines Register (VetReg), while non-medicinal treatments are summed up as the number of weeks when the sites have registered such treatments in their weekly lice data reporting to the Norwegian Food Safety Authority. Non-medicinal treatments are sub-divided into the categories thermal (delousing with heated water), mechanical (delousing using water pressure and/or brushes), freshwater or 'other'. Both medicinal treatment and non-medicinal treatment may have been performed in only some cages or on the entire farm.

Table 8.1.1 shows a sharp reduction in the number of medicinal prescriptions for delousing agents from 2014 to 2018, which has now levelled off. Prescriptions for delousing agents increased by 5 percent in 2022 compared to 2021, and 8 percent more compared to 2020, but 1 percent fewer than in 2019. At the active substance level, the figures show that the increase in azamethiphos prescriptions, observed since 2019,

Table 8.1.1 Number of prescriptions of a given category for active substance for lice treatment in 2011 - 2022. Pyrethroids are prescriptions for the active substances deltamethrin and cypermethrin, while flubenzurons are prescriptions for the active substances teflubenzuron and diflubenzuron. The number of requisitions is taken from the Veterinary Drug Registry (VetReg) 13.01.23

Active substance	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Azametiphos	418	695	483	752	621	262	59	39	82	119	144	212
Pyrethroids	460	1163	1130	1049	664	280	82	56	73	51	42	25
Emamectin benzoate	294	169	163	481	523	612	351	371	451	415	437	371
Flubenzurones	24	133	171	195	202	173	81	40	61	51	22	22
Hydrogen perokside	179	110	255	1021	1284	629	214	96	82	47	45	35
Imidakloprid	0	0	0	0	0	0	0	0	0	0	29	73
Total	**1375**	**2270**	**2202**	**3498**	**3294**	**1956**	**787**	**602**	**749**	**683**	**719**	**738**

continued in 2022. The decline in hydrogen peroxide prescriptions, observed since 2016, also continued in 2022. Prescriptions of pyrethroids and ememectin benzoate decreased from 2021 to 2022, while prescription of flubenzorones remained low. Emamectin benzoate was the most prescribed active substance in 2022 (50 percent of prescriptions). The frequent use of emamectin benzoate continues, as it is considered to limit settlement of louse larvae on treated fish, in addition to its direct anti-louse effect. In the summer of 2021, for the first time in many years, a drug with a new active substance against lice (imidacloprid) was registered. This drug was prescribed 29 times in 2021 and 73 times in 2022. The table does not state whether hydrogen peroxide has been prescribed against salmon lice or against AGD, or whether a medicine has been prescribed against salmon lice or the sea-louse *Caligus elongatus*.

It is considered highly likely that the significant reduction in number of prescriptions and 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 was published in March 2023 https://www.vetinst.no/overvaking/lakselus-resistens.

Table 8.1.2 Number of non-medicinal treatments reported1. The treatments are weeks in which sites have reported that they have carried out non-medicinal treatment against lice to the Food Safety Authority as of 16.01.23. 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
Thermal	0	0	3	36	685	1245	1327	1447	1723	1456	1357
Mechanical	4	2	37	34	311	236	423	674	823	862	1074
Freshwater	0	1	1	28	73	75	84	148	220	286	225
Thermal and mechanical	0	0	0	0	12	42	35	56	59	30	47
Thermal and freshwater	0	0	0	0	16	21	17	27	20	63	141
Mechanical and freshwater	0	0	0	0	7	1	7	7	24	56	153
Thermal and mechanical and freshwater	0	0	0	0	0	0	1	0	1	5	9
Other	132	107	136	103	75	52	69	87	92	72	139
Total	**136**	**110**	**177**	**201**	**1179**	**1672**	**1963**	**2446**	**2962**	**2830**	**3145**

[1]The difference in figures from the Fish Health Report for 2021 is due to updated routines for identifying erroneous reports, updated routines for identifying type of processing based on text descriptions in reporting forms and late incoming forms.

The number of reported non-medicinal delousing treatments increased by 11 percent from 2021 to 2022. Thus, the increase in number of non-medicinal delousing treatments continued as it has done since 2013, with the exception of a reduction of 4 percent between 2020 and 2021. There were no changes registered in the number of thermal delousing treatments (including weeks where several different non-medicinal treatments were used). The number of mechanical delousing treatments did, however, increase by 35 percent and freshwater treatments by 29 percent. Thermal treatment remained the most popular non-medicinal delousing methodology in 2022 (49 percent of reported non-medicinal delousing, including weeks in which several non-medicinal delousing technologies were used). In comparison, mechanical delousing was reported in 41 percent of treatment weeks and freshwater in 17 percent.

In around 11 percent of the weeks reported for non-medicinal delousing, several different technologies were reported from the same farm (but not necessarily used in the same cage). This is a doubling from 2021. The most commonly reported combinations were freshwater treatment combined with either mechanical or thermal delousing. In addition to medicinal and non-medicinal treatments, various prophylactic methods and methods for continual delousing are used, including louse skirts and cleaner fish.

The Annual Survey

Fish health personnel and Food Safety Authority inspectors were asked for their views on salmon lice in general and on injuries associated with delousing practices in particular. From a list of 33 health- and welfare problems in ongrowing salmon, respondents were asked to cross off the five most relevant problems associated with mortality, reduced welfare, reduced growth or as an increasing problem during 2022. Of 63 respondents who responded regarding mortality, eleven (17 percent) chose the salmon louse as one of the five most important factors, while 46 (73 percent) chose delousing associated injuries, which resulted in tenth and first place on the list of causes of mortality. When queried about the causes of reduced welfare in ongrowing salmon, 26 of 63 respondents (41 percent) crossed off for the salmon louse as one of the most important five factors while 47 (75 percent) crossed of delousing associated injuries, which resulted in fifth and first place respectively for the cause of reduced welfare. Of the 52 respondents who replied regarding the five most important increasing problems for ongrowing salmon in 2022, 19 (37 percent) crossed off for the salmon louse, resulting in seventh place of the increasing problems. Delousing associated injury was chosen by 15 respondents (29 percent), resulting in fourth place.

There were many fewer respondents who answered the same questions for rainbow trout, but the overall picture was similar to that for salmon. Mechanical injuries associated with delousing were considered the most important cause of mortality in rainbow trout, while salmon louse grazing injuries were rarely mentioned. Mechanical delousing injuries were also considered the most important cause of reduced welfare, while the salmon louse scored third place in this regard. One respondent considered mechanical injuries associated with delousing as an increasing problem for rainbow trout, while none considered the salmon louse problem to be increasing in rainbow trout farming.

The responses to the survey also show that salmon lice, and especially treatments against salmon lice, can be a problem in salmon broodstock facilities. Mechanical damage as a result of delousing is ranked as the second most important cause of mortality, and the most important cause of reduced welfare in broodstock farms. Two out of six respondents believe such injuries are an increasing problem. Salmon lice were also reported as an important cause of mortality (one of twelve respondents), reduced welfare (one of twelve respondents), while two out of six considered this to be an increasing problem. We received only a single response regarding broodstock rainbow trout, and that respondent considered mechanical damage related to delousing as an important cause of both reduced welfare and death.

Table 8.1.3: Summary of the survey, questions related to mortality associated with delousing. A score of 1 means that mortality was never or very rarely observed, while a score of 5 means that it was seen in almost every delousing. The value given is the average of all replies to each question, and n is the number of respondents who have answered. Increased acute mortality corresponds to over 0.2 % mortality in the first three days after delousing. Increased mortality in the first two weeks after delousing is considered delayed mortality.

Mortality category	Thermal	Flushing/brushing	Freshwater
Increased acute mortality	3,5 (n=58)	3,2 (n=56)	2,4 (n=41)
Increased delayed mortality	2,7 (n=57)	2,5 (n=56)	1,9 (n=41)

One respondent reported in free text that risk assessment of salmon lice infestation within the industry is not adequate, as it does not report the highest level of lice numbers, but is based on well boat counts (following treatment). The feedback on both effectiveness and welfare in relation to non-medicinal delousing varies, and one respondent considers that sedation during thermal treatment improves treatment effect and welfare.

Questions related to mortality and delousing are summarized in Table 8.1.3. We can see from the table that increased acute mortality (more than 0.2 percent mortality in the first three days after delousing) was seen most frequently following thermal delousing, second most frequently with mechanical delousing and least frequently with freshwater delousing, of the non-medicinal methods. A similar situation was also reported for the period 2017-2021. Increased delayed mortality (i.e. mortality in the first two weeks after delousing) was seen most frequently with thermal delousing, second most frequently with mechanical delousing and least frequently with freshwater delousing. More details regarding welfare associated with non-medicinal delousing are discussed in Chapter 4 Fish welfare.

Evaluation of the salmon lice situation

The average number of adult female lice per farmed fish for the country as a whole in 2022 falls well within the variation we have observed since 2016. Broadly speaking, the pattern is that the total number of salmon lice in each production area has followed the trends in the biomass of farmed fish, and increased in production areas which have been "green" in the Traffic Light System; levelled off in "yellow" areas and decreased in "red" areas. The production of salmon lice larvae during the wild salmon migration period, which in addition to the number of lice per farmed fish depends on the sea temperature and the number of farmed fish, was approximately the same as in 2021. As in 2021, the seasonal increase came relatively early in the spring. The lice numbers in the migration period were thus slightly above previous years' variation for many of the production areas, and this tendency was particularly evident in PO11 and PO12. The production of louse larvae was highest in PO2-PO4 and PO6.

The use of non-medicinal lice treatments has increased compared to 2021 (total increase of 11 per cent), and the use of medicinal treatments has also increased somewhat (total increase of 3 percent). The increase in non-medicinal delousing was mainly due to an increase in the number of weeks of mechanical delousing and use of freshwater in combination with either mechanical or thermal delousing. There was no reduction in thermal treatments when including weeks when the method was used in combination with other methods. Thermal treatment remained the most commonly used non-medicinal louse treatment. In 2022, there was a particular increase in weeks in which the use of several different non-medicinal methods were reported from the same locality; from 5.4 percent of the weeks in 2021 to 11 percent of the weeks in 2022. This is a development that should be followed up, particularly in relation to possible development of resistance and consequences for fish welfare. The use of azamethiphos has also increased for the fourth year in a row, and in 2022 there was moderate use of the new drug with the active ingredient imidacloprid, which was registered for use against salmon lice in 2021.

Since 2017, delousing methodologies have mainly been non-medicinal. In 2022, non-medicinal treatments were reported over four times as often as medicinal. The respondents reported in the survey that thermal and mechanical treatments in particular often resulted in increased mortality in the period following treatment. This probably represents a considerable contribution to the total mortality of salmon and rainbow trout in the sea, as 2,781 weeks of treatment with these methods were reported in 2022. In addition, delousing injuries were considered by the respondents as one of the most important causes of reduced welfare in both salmon and rainbow trout in this year's survey. The welfare challenges linked to this increase are discussed further in Chapter 4 Fish welfare.

8.2 *Caligus elongatus*

By Geir Bornø, Øivind Øines and Haakon Hansen

The disease

Caligus elongatus is a parasitic crustacean in the same family (Caligidae) as salmon louse *Lepeophtheirus salmonis*. Like its relative, it lives on the skin of fish in saltwater, but it is less host specific than salmon louse, which is found only on salmonids. To date, *C. elongatus* have been found on about 80 species of marine fish, including salmonids, cod, saithe, pollock, herring, flounder, gobies and lumpfish. Lumpfish have been identified as one of the main hosts of this parasite and a single fish have been shown to carry several hundred parasites. *Caligus elongatus* is thus not only a parasite on the salmon, but also on the cleaner fish that is used to reduce the number of salmon lice on farmed fish.

Caligus elongatus, like salmon lice, have a life cycle consisting of two plantonic stages and one free-swimming infective copepodid stage, followed by 4 attached chalimus stages, anchored to the surface of the host fish, until finally reaching the adult stage. The adult stages are more mobile than other parasitic copepods, including the salmon lice, and the parasite is very capable of shifting between hosts. Therefore, wild fish can easily infect salmon and vice versa under farming conditions. Rapid increase of adult lice on farmed fish without an increase of juvenile lifestages in the cage over time, may suggest that fish in the farm were infected by *C. elongatus* from fish outside the cages.

Caligus elongatus can cause damage to the skin of affected fish, which may in turn lead to secondary bacterial infections. This parasite generally cause less damage than *L. salmonis*.

Caligus elongatus is easily distinguished morphologically from salmon lice by having so called lunules on the underside at the very front of the cephalothorax (head part) (Figure 8.2.1). In lice counts, *C. elongatus* can be distinguished from salmon lice partly because they are more translucent, less colourful, are smaller and often more mobile than salmon lice. However, it requires experience to differentiate between the two species. The mobility of *Caligus elongatus* can also cause them to detach from the host defect before being counted. In addition, *C. elongatus* is more sensitive to changes in salinity and readily leave the fish in low-salinity water.

Disease control

It has been reported, that infections with *Caligus elongatus* has in some cases been so severe that treatments were necessary. One often treats against *Caligus elongatus* when treating against salmon lice and it is reported that all applied drugs have a good effect against the parasite.

The Health Situation in 2022

The Annual Survey

In 2022, infections with *C. elongatus* is ranked as a more severe problem than earlier. Problems associated with this parasite are ranked among the ten most serious problems for farmed salmonids in the sea (Appendix B1). Several (15 out of 63 respondents) consider the parasite to be associated with reduced welfare in food fish production of salmon. Some consider that the parasite contribute to mortality (4 out of 63 respondents). A slightly higher number of respondents have indicated that *C. elongatus* contributes to reduced growth (9 of 57 respondents) and that these infections represent an

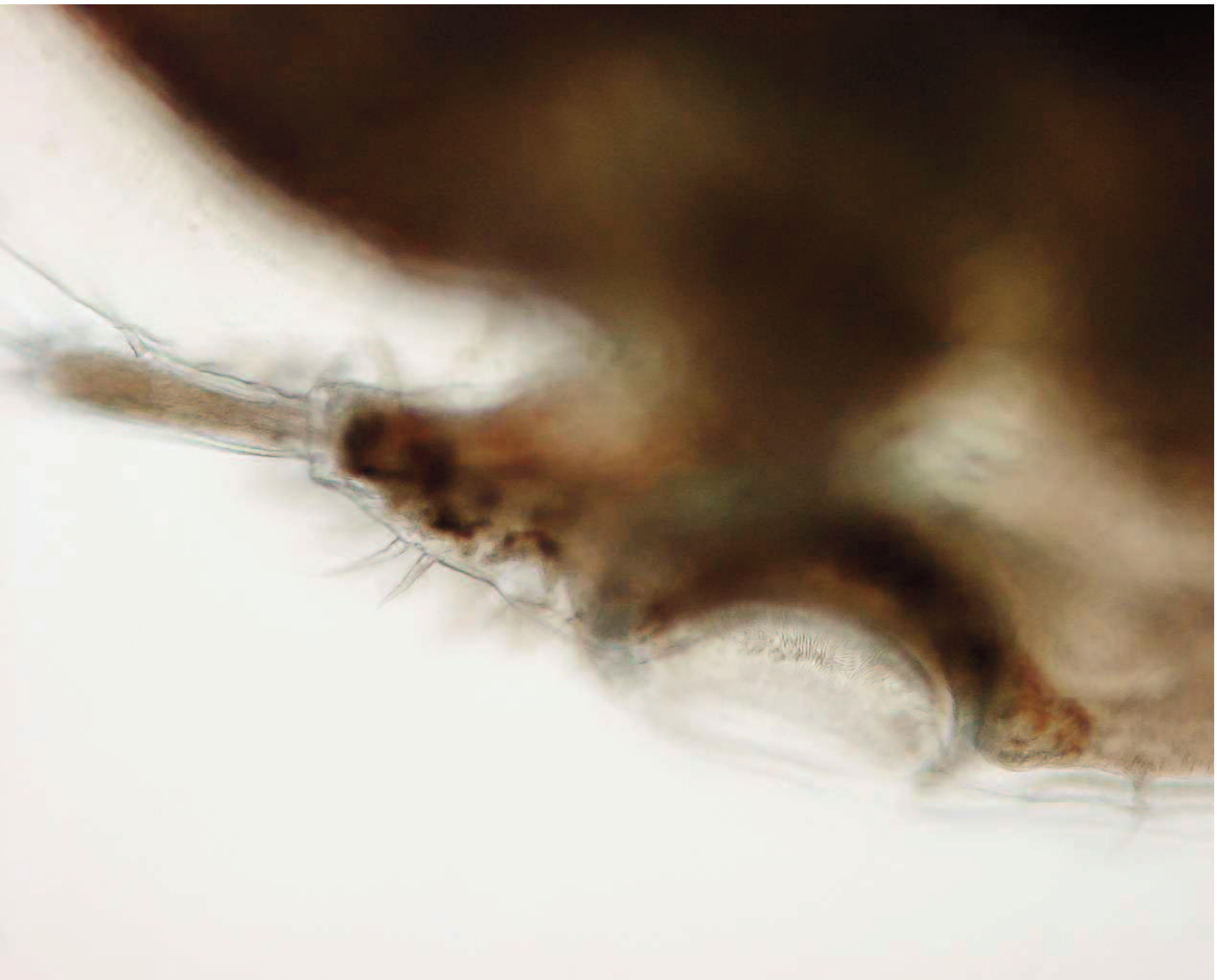


Figure 8.2.1 *Caligus elongatus*, close-up of lunules. Lunules are small, paired cup-like suckers used for attachment. These structures are present in *C. elongatus* and other species in this genus, but are absent in *Lepeophtheirus*. Thus, presence or absence of lunules can be used to distinguish between adult lice from these two genera. Photo: Øivind Øines, Norwegian Veterinary Institute

increasing problem (10 of 52 respondents). There were few respondents from salmon brood stock facilities, but those who responded indicated that infection with *C. elongatus* can contribute to reduced welfare of the fish. *Caligus elongatus* was not registered as a problem for rainbow trout in neither food nor brood-stock facilities.

Evaluation of the *Caligus elongatus* situation

Based on reports from the field, infections with *C. elongatus* do appear to have increased slightly in numbers in 2022.

8.3 Parvicapsulosis and *Parvicapsula pseudobranchicola*

By Haakon Hansen og Geir Bornø

The Disease

Parvicapsulosis is caused by *Parvicapsula pseudobranchicola*, and this disease has been known from Norwegian farmed salmon since 2002, particularly in Troms and Finnmark. *Parvicapsula pseudobranchicola* is an eukaryotic parasite, belonging to the class Myxosporea, which has a complex life cycle with a polychaete worm as its main host and fish as the intermediate host. Although *P. pseudobranchicola* primarily affects fish in farming facilities in the northern regions, it is also found in wild salmonids, such as Atlantic salmon, sea trout, and sea running Arctic char, along the entire Norwegian coast.

The pseudobranch, an organ involved in blood and oxygen supply to the eye, is the target organ for this parasite. Infections can lead to reduced vision or even blindness in fish, and high mortality rates have been reported from ongrowing facilities due to outbreaks of *Parvicapsulosis*.

For more information about Parvicapsulosis, see the fact sheet (in Norwegian): **https://www.vetinst.no/sykdom-ogagens/parvicapsulose**

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

When the figures from the Norwegian Veterinary Institute and the private laboratories are compiled, parvicapsulosis was detected at 25 unique salmon farming sites. Of these, 15 were located in PO12 and PO13, while the remaining detections were done in PO6 (one), PO7 (one), PO9 (four), PO10 (one), and PO11 (three). PCR detections for *P. pseudobranchicola* were confirmed from 19 sites. Most of the detections were made in PO7-PO9, but there was also one detection of the parasite in PO1.

The Annual Survey

Parvicapsulosis has for many years been a recurring problem in salmonids farms in the northernmost regions, and the survey for 2022 also demonstrates this (see Figure 3.2.1 C in Chapter 3 Fish Welfare). Many respondents have reported that parvicapsulosis reduces welfare and that infections with this parasite still represents a major challenge both in terms of mortality and growth. Parvicapsulosis is not considered to be an increasing problem in ongrowing facilities, based on the responses from the survey.

Evaluation of the parvicapsulosis situation

Parvicapsulosis has for long been an important disease in salmon farming and this picture has not changed. Although the parasitic agent is widespread in wild salmonids along the entire coast, it is especially in the northern parts of the country, and especially Troms and

Finnmark, where there are outbreaks of the parvicapsulosis in the farms. However, for 2022 there are a few reports of problems related to this parasite also in PO6-PO7 and PO9-PO13, a reminder that the parasite is able cause problems also outside Troms and Finnmark counties. PCR positive results for P. pseudobranchicola was registered as far south as PO1, but without clinical signs. Based on what is known about the prevalence of the parasite in farms, it is likely that the figures for the number of detections underestimate the real prevalence of infected fish and locations. There are still no treatments available and further research on this parasite and the disease it causes is made difficult as the final host for the parasite remains unknown. Parvicapsulosis generally results in increased mortality, reduced welfare, and reduced growth.

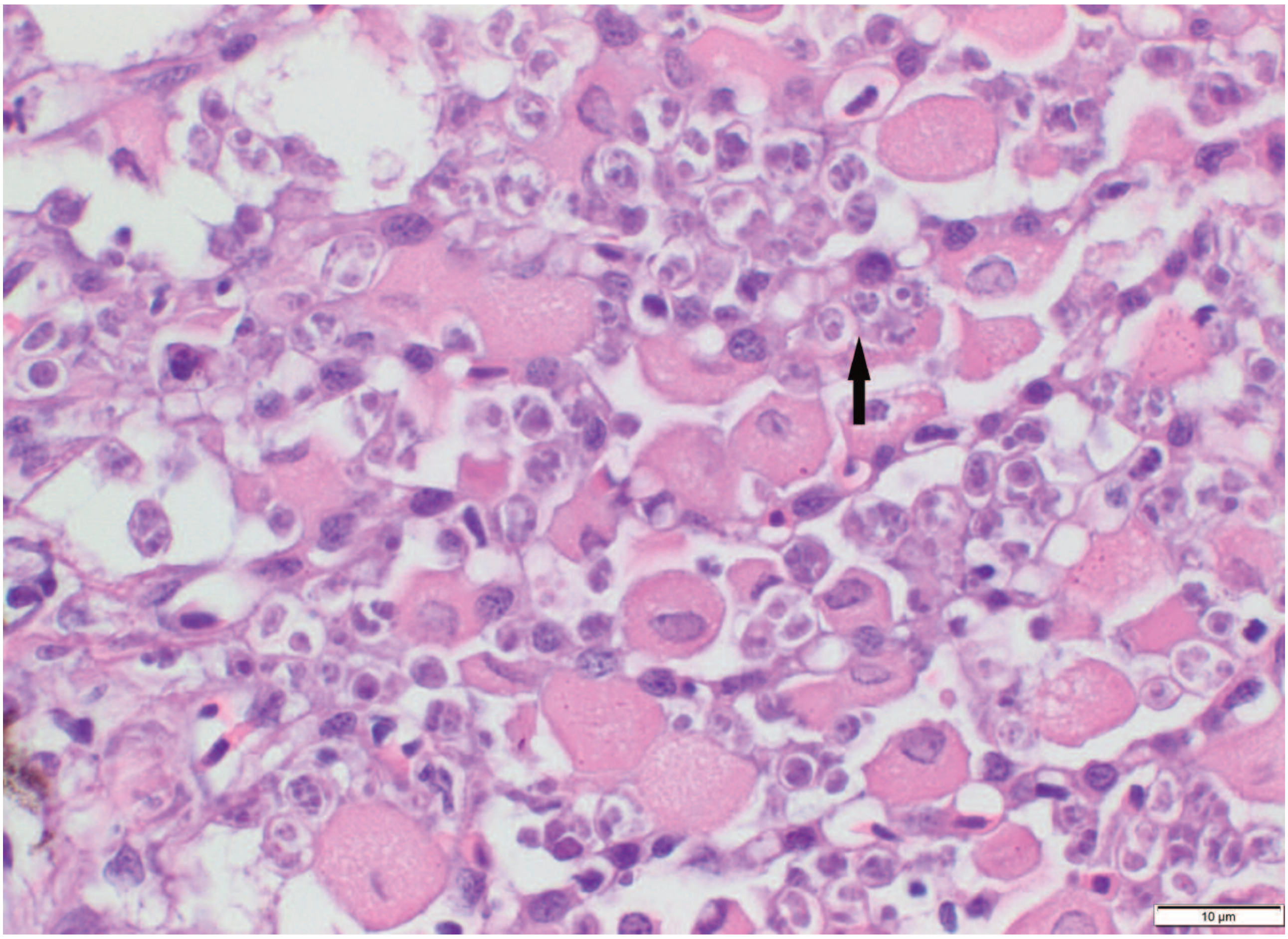


Figure 8.3.1 *Parvicapsula pseudobranchicola* parasites in salmon pseudobranch (arrow). Photo: Toni Erkinharju, Norwegian Veterinary Institute

8.4 Amoebic gill disease (AGD) and *Paramoeba perurans*

By Geir Bornø og Haakon Hansen

The Disease

The disease Amoebic gill disease (AGD) is caused by the amoeba *Paramoeba perurans* (synonymous *Neoparamoeba perurans*). AGD is not a notifiable disease.

Since the mid 1980s, this disease has caused large losses in 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 identified further and further north. In 2011 and 2012, AGD was one of the most significant causes of loss to the Irish and Scottish salmon farming industries. In 2013, *P. perurans* was identified in several farms in the Faroe Isles and the disease has since become a serious problem in Norwegian salmon farming.

Paramoeba perurans and AGD was first identified in Norwegian aquaculture in 2006, but were not identified in the subsequent years. Since 2012, however, the amoeba has been common in Norwegian fish farms and has been causing considerable losses. Genetic analyses reveal differences between the amoeba involved in the 2006 outbreaks and the later outbreaks and the origins of the amoeba involved in the Norwegian outbreaks are not known. *P. perurans* occurs in farmed fish in saltwater, primarily in Atlantic salmon, but has also been detected on other farmed species such as rainbow trout, turbot, lumpfish and various wrasse. The parasite has also caused disease in several of these species.

The two most important risk factors for an outbreak of AGD are considered to be high salinity and relatively high seawater temperatures. Pathological findings are limited to gills, where white, mucus spots can be seen with the naked eye (Figure 8.4.1). Amoebas can be detected in fresh smears from the gills that are examined under a microscope (Figure 8.4.2) or using PCR. The confirmation of AGD is made by histological examination.

Disease control

AGD is treated with hydrogen peroxide (H_2O_2) or fresh water. Neither method appears to be 100% effective and treatments must be repeated several times within the same production cycle. Treatment with freshwater seems to be more gentle to the fish and appears to be more effective than H_2O_2.

Treatment of AGD has the best effect when performed in the early stages of disease development. This reduces the probability of treatment relapse and the time it takes to develop

Figure 8.4.1 Amoebic gill disease (AGD) in salmon. The white spots on the gill is caused by the amoeba *Paramoeba perurans*. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

AGD again. It is therefore important to monitor the prevalence of amoeba in farmed fish to identify the disease at an early stage. This is done by PCR screening and macroscopic examination of the gills.

A scoring system for classifying the macroscopically visible changes associated with AGD has been developed. This scoring system is an important tool for the Fish Health Services. After repeated treatments, scoring of gills can be difficult and requires considerable experience. Since a number of other factors and/or pathogenic /agents may cause similar changes to the gills, it is important to confirm the AGD diagnosis by histological investigation.

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

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

AGD is not a notifiable disease, and the diagnosis is often made by the fish health services. It is therefore not possible to provide a complete annual overview of the number of sites with AGD diagnosis. Suspicion of AGD normally arises following visual macroscopic examination. PCR and histology are used to confirm the suspicion. Compiled data from the private laboratories and the Norwegian Veterinary Institute show findings of disease caused by AGD at 78 sites, salmon (76) and rainbow trout (2). The most reported detections are from PO6 and, with 36 sites, but detection of disease has been made from PO1 to PO6 in 2022 (Figure 8.4.3). PCR examinations show the findings of the parasite (*P.perurans*) at 62 different sites. No detections have been made of AGD north of Nordland at this time.

The Annual Survey

Feedback from the survey shows that AGD is considered an important contributor in terms of reduced growth and reduced welfare at fish farms in the sea with salmon, while the disease is ranked somewhat lower in terms of cause of mortality. It is also reported in 2022 that the condition is considered an increasing problem. In rainbow trout farms, AGD is still ranked as one of the five most important rising problems. Few cite AGD as an important issue related to mortality. Reduced welfare is weighted to a sparse degree, while reduced growth seems to be a bigger problem also on rainbow trout. In broodstock farms with salmon, AGD is not considered to be a problem by any respondents. In broodstock farms with rainbow trout, AGD is scored as a very small problem in 2022. See Appendix B1-B2 and C1-C2 for details from the 2022 survey.

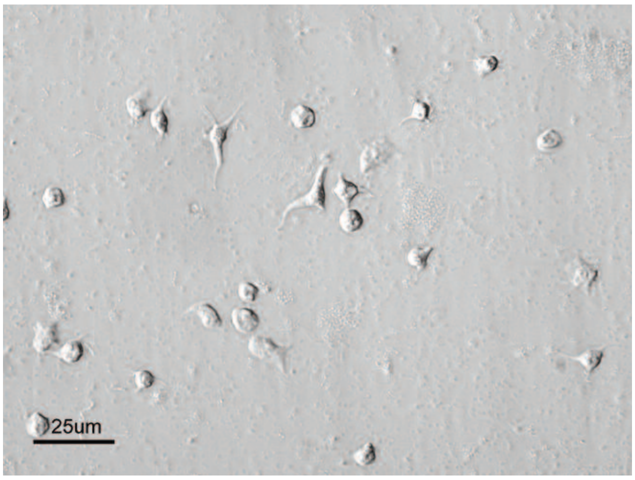


Figure 8.4.2 *Paramoeba perurans* monoculture (fase contrast microscopy). Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

Evaluation of the AGD situation

AGD is well-established and continues to be a serious fish disease in Norway. The parasite is widely detected in the southern regions of the country. The number of outbreaks and the degree of severity varies from year to year and this appears to be related to climatic conditions. Farmers and the fish health services continually gain more experience in management of AGD, both in terms of the necessity for and timing of treatment. This, together with frequent screening, has contributed to better control of the disease. In some areas, increased experience has led to fewer treatments, as those responsible for treatment understand that the disease will, dependent on environmental conditions, phase out naturally later in the yea

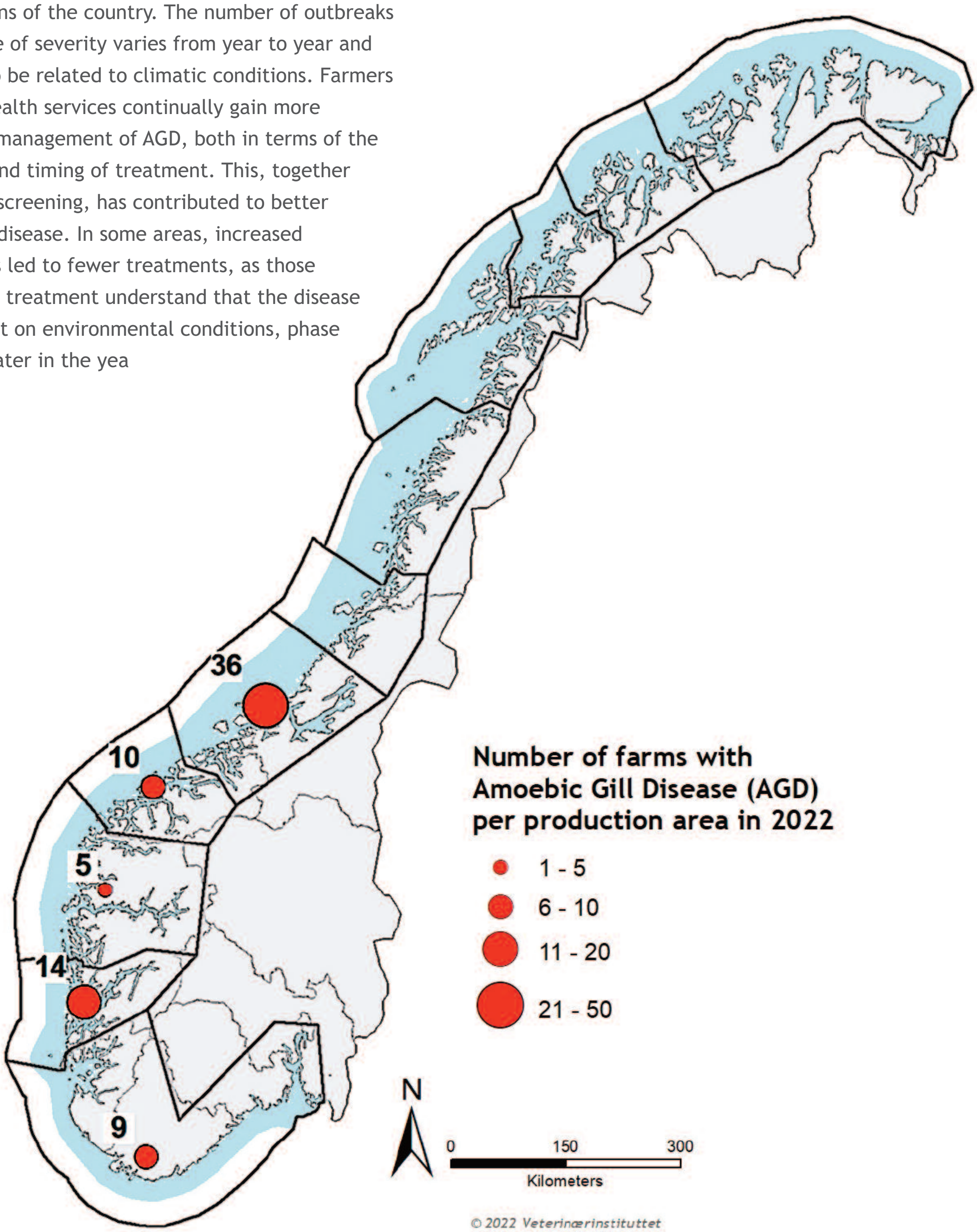


Figure 8.4.3 Distribution of AGD diagnoses by production area (PO) based on compiled data from the Norwegian Veterinary Institute and private laboratories.

8.5 Tapeworms – *Eubothrium* sp.

By Haakon Hansen and Geir Bornø

The Disease

Tapeworms (Cestoda) belong to the flatworms (Platyhelminthes), parasites that as adults are found in the intestines of animals. Tapeworms have complex life cycles involving several host species. Fish can act as both intermediate and final hosts for different species of tapeworms. Recent genetic analyses show that tapeworms in the genus *Eubothrium* infecting both salmon and brown trout and in both freshwater and saltwater, belong to the same species, namely *Eubothrium crassum*. However, the analyses also indicates that the species can be divided into two genetic groups, one associated with freshwater and one with the marine environment. This parasite has copepods as the first intermediate host and the fish becomes infected with tapeworms by ingesting copepods containing infective stages.

Tapeworms attach with the head (scolex) in the pyloric caeca of the fish. The sexually mature parasite produces large numbers of eggs that enter the water with faeces and can there infect new copepods. If a fish is left untreated, the worm will eventually become large and can grow to be more than one meter long.

Tapeworm infestations can lead to increased feed consumption and reduce fish growth. Tapeworms in the genus *Eubothrium* are found in wild salmonids throughout the country, but in farmed fish, it is not common north of Trøndelag

Disease control

Infections with *E. crassum* are treated with Praziquantel, but there have been reports of lack of effect and the use of Praziquantel has been limited in the recent years.

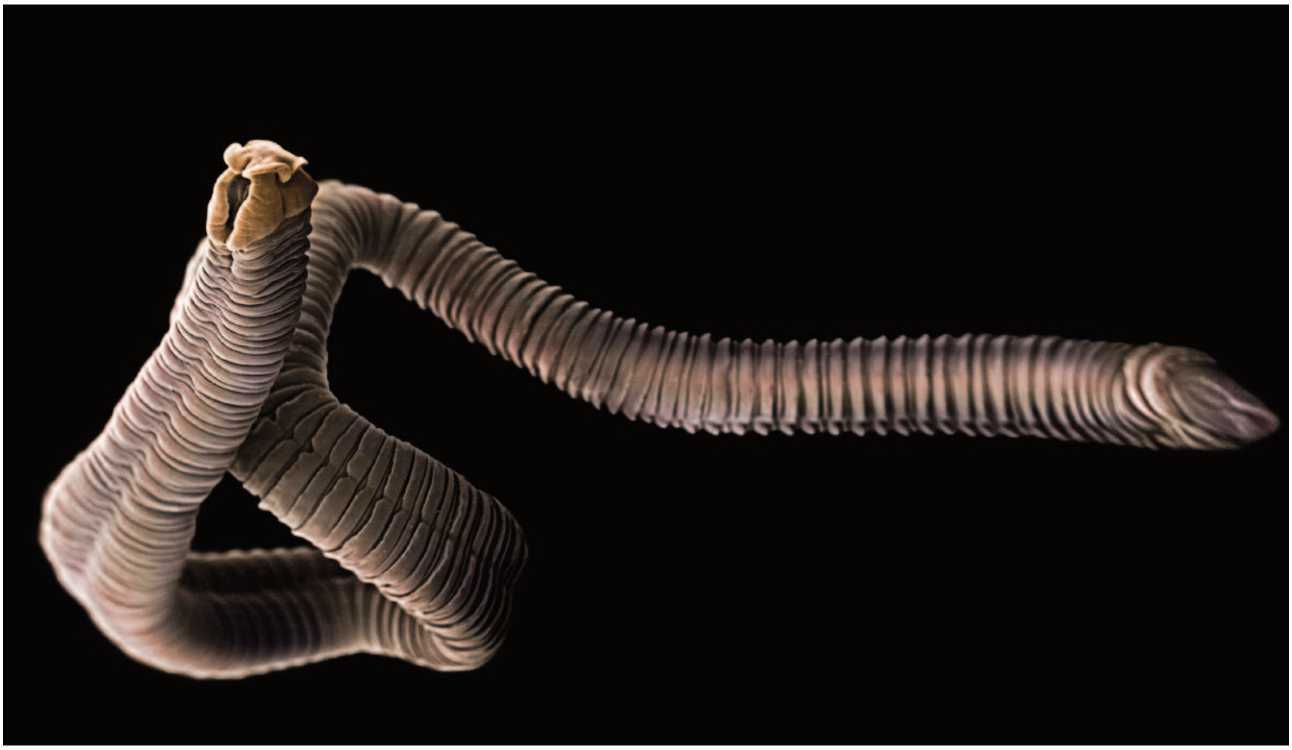


Figure 8.5.1 Tapeworm (*Eubothrium crassum*), magnified 50 times. Image taken with scanning electron microscope and colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

The Health Situation in 2022

Data from the Norwegian Veterinary Institute

In 2022, the Norwegian Veterinary Institute detected tapeworms in 20 Atlantic salmon farms. This is approximately the same number of farms as for the previous years. The majority of the facilities with tapeworm detection were located in the southwest and central parts of the country (PO2-PO6).

The Annual Survey

Most of the respondents who consider tapeworm a problem in ongrowing facilities, consider the infections to be lead to reduced growth. Some also indicate that tapeworms can lead to reduced fish welfare in salmon, but infections with *E. crassum* tapeworms are not considered to contribute considerably to mortality. For salmon broodstock facilities, no respondents has indicated that tapeworms are considered an important cause of neither mortality, growth nor welfare. For both ongrowing farms and broodstock facilities for rainbow trout, tapeworms are considered by some to contribute to reduced growth and welfare.

Evaluation of the tapeworm situation

Every year there are reports of high incidences of tapeworms in the intestines of salmon in the sea. Infections with tapeworms are reported to be most common in Western Norway and in Central Norway. Most diagnoses are made by the fish health services. In general, the parasites are not determined to species, but most or all of the detections are likely to be *E. crassum*. The aquaculture industry indicate that infections with tapeworms is a persistent problem and in some areas, it is considered an increasing problem.

Fish-eating birds can transport parasites over large areas via excrement. Photo: Eivind Senneset

8.6 The X-cell parasite *Salmoxcellia vastator*

By Anne Berit Olsen og Haakon Hansen

The Disease

The parasite *Salmoxcellia vastator* was described in 2021 from salmon and rainbow trout in Norway. The Norwegian Veterinary Institute has sporadically detected the parasite in salmon and rainbow trout in the sea phase in cases with characteristic lesions.

The parasite belongs to a group called X-cell parasites. These are single-celled organisms within the series Alveolata, which are related to the mussel parasites *Perkinsus*. Different species of X-cell parasites are found in a variety of fish species belonging to several different orders; flounder (Pleuronectiformes), turbot (Perciformes), cod fish (Gadiformes), catfish (Siluriformes) and salmonids (Salmoniformes). Little is known about the biology of the parasites, but it is suggested that the life cycle may involve an intermediate host.

Infections with these parasites most often give only external findings, such as creamy white outgrowths on the skin, on fins, in the head, in pseudobranchia and on gill filaments. However, the infection may also be present as a systemic infection without the formation of visible external lesions. This has been observed both in Norwegian salmon and rainbow trout, and in coho salmon (*Oncorhynchus kisutch*).

In salmon and rainbow trout in Norway the disease appears to develop over time. Fish with infections do not need to show clinical signs of disease, but can be clearly recognised in case of severe degree of infection. Typical post-mortem findings are bright spots and nodules on and in internal organs as well as in musculature (Figure 8.6.1). Degeneration and inflammation occur in the tissues, and by histopathological examination the disease is characterised by characteristic X-cells in the lesions (Figure 8.6.2).

The Norwegian Veterinary Institute has detected the parasite over a large area along the coast of Western and Central Norway, but only a few cases have been recorded per year. It is especially in autumn and early winter that cases have been observed. The disease might be most common in adult fish, but has affected fish throughout the sea phase. Mortality has been mostly low, while individual fish have had extensive disease changes. However, accumulated mortality of 5-10 percent has been reported.

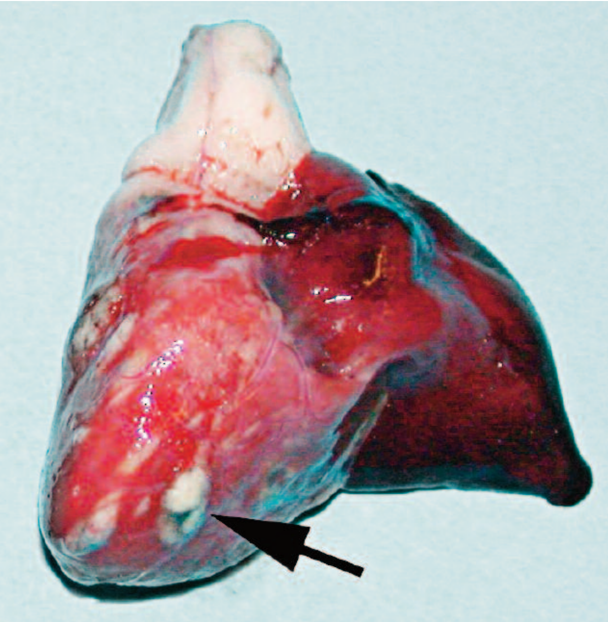


Figure 8.6.1 Rainbow trout heart with white irregular nodes and spots caused by infection with the X-cell parasite *Salmoxcellia vastator*. Photo: Anne Berit Olsen, Norwegian Veterinary Institute

In cod in farming, infections with X-cell parasites have led to serious pathology and mortality. This, together with the fact that the infections can make the fish meat unsuitable for human consumption, shows that it is important to pay attention to this disease, as it may become a problem for the aquaculture industry in the future.

Disease control

There is currently no treatment for the X-cell parasite. The visible signs of the disease can be confused with other diseases such as bacterial kidney disease (BKD). Therefore, samples should always be taken for laboratory examination.

The Health Situation in 2022

There were no reports of detections or problems of significance for salmon and rainbow trout with this parasitic disease in 2022. However, a case of possible infection with X-cell parasites in farmed cod is discussed in Chapter 12 Diseases of marine species in aquaculture.

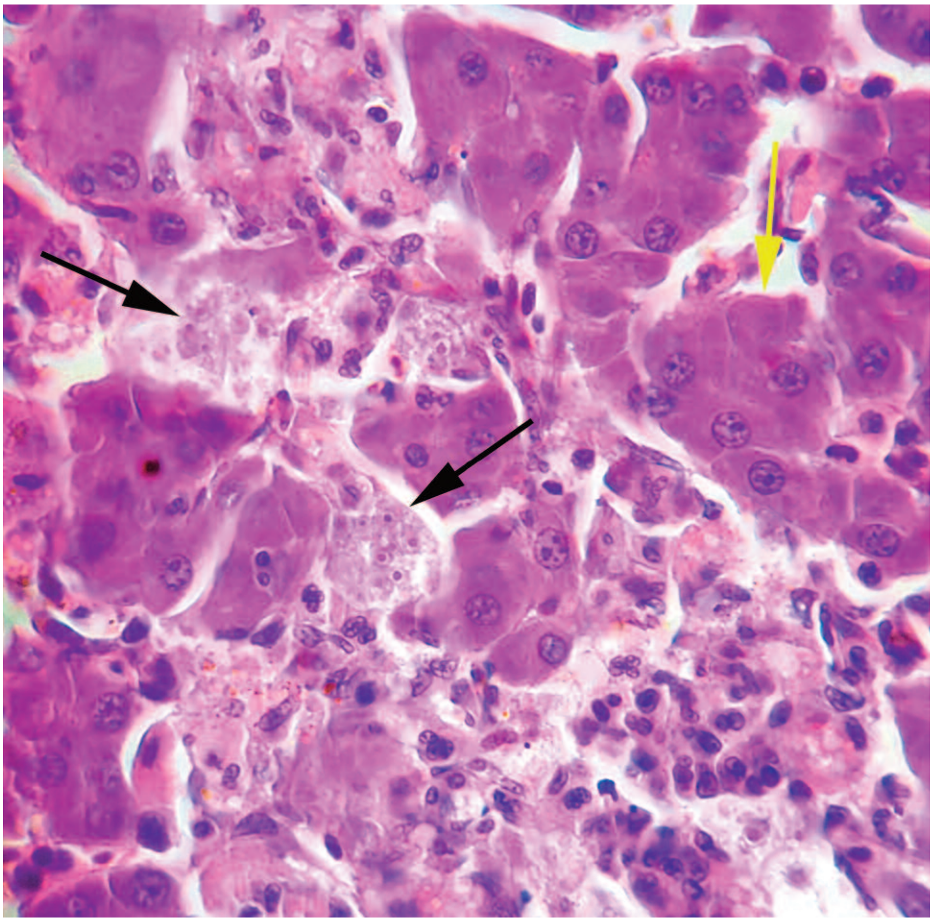


Figure 8.6.2 Tissue section of salmon liver infected with X-cell parasites (black arrows). The parasites contain several nucleus-like structures. Normal liver cells (yellow arrow) (H&E staining). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

8.7. Systemic spironucleosis and the parasite *Spironucleus salmonicida*

By Haakon Hansen, Erik Sterud, Toni Erkinharju og Geir Bornø

The Disease

In 2022, several farming facilities in Finnmark reported outbreaks of disease and mortality in farmed Atlantic salmon in the sea. The disease was found to be systemic spironucleosis, a rare disease caused by the parasite *Spironucleus salmonicida*. Parasites in the genus *Spironucleus* belong to the diplomonad flagellates, a group also containing parasites in the genus Giardia that can infect and cause infections in the intestine of humans. *Spironucleus* spp. are found in wild fishes, birds and reptiles. Several other *Spironucleus* species have been detected in fishes in Norway, including *S. torosus* in cod, *Gadus morhua*. In the fish they are found in the gall bladder and intestine, and generally appear to be harmless.

The outbreaks in 2022 were, however, not the first outbreaks of spironucleosis in the area. Systemic spironucleosis was initially observed in four Atlantic salmon farms in Finnmark county between 1989-1991. All these farms had received smolt from the same hatchery, leading to suspicion that the hatchery was the source of the infection. Around the same time, a similar case was reported from farmed king salmon in Canada. However, there were no further reports of the disease for the next ten years until 2001, when another outbreak occurred in farmed salmon, again in Finnmark. Just over a year later, the disease was also detected in farmed Arctic char, *Salvelinus alpinus*, in Vesterålen, although this case appeared to be isolated from the other outbreaks.

During the period between the first detection of the disease in farmed salmon in Finnmark and the outbreaks in salmon and Arctic char ten years later, another species of *Spironucleus* was described from wild grayling, *Thymallus thymallus*, in southern Norway, and from wild anadromous Arctic char in Finnmark. Initially, it was believed that this species, which was described as *Spironucleus barkhanus*, was the same species that caused systemic spironucleosis in Finnmark. However, subsequent research revealed that the parasite from grayling was genetically distinct from the species causing systemic spironucleosis in farmed salmon in the sea, and the latter was subsequently re-described as *S. salmonicida*. Further investigation of fishes from the water source of the hatchery revealed the presence of both *S. barkhanus* and *S. salmonicida*, as well as another species, *S. salmonis*, which was found in wild trout, *Salmo trutta*, and Arctic char. Neither *S. salmonicida* nor the other two species, were detected in salmon from the hatchery examined at the same time. However, in 2022, fish from the hatchery tested positive for *S. salmonicida*, indicating that the hatchery remains the most likely source of all reported cases of systemic spironucleosis in salmon in Finnmark to date.

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 8.7.1a). The factors triggering *S. salmonicida* to spread from the gut to other tissues are unknown. Microscopic examination of the contents of the abscesses, typically reveal a large number of highly mobile flagellates of approximately 10 µm in size. The 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 what has been observed in 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 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.

During the outbreak in Finnmark in 2022, the parasite was also detected in lumpsucker, *Cyclopterus lumpus*. This is surprising and demonstrated that the parasite can be transmitted in the marine phase from salmon to lumpsucker. Possible routes of infection could be that the lumpsucker is exposed to the parasite in seawater by ingesting infective stages of the parasite via salmon faeces, by nibbling on parasite-containing abscesses on the salmon, or by eating salmon lice or *Caligus elongatus* containing the parasite (Chapter 11 The health situation in cleaner fish).

Spironucleus parasites are quite easy to recognize by light microscopy (Figure 8.7.1 b and c), but DNA analyses are required for a definitive species identification. Both conventional PCR and qPCR methodologies are useful for identification and it is recommended to examine several tissues, including gut, to increase the probability of detecting the parasite.

The Health Situation in 2022

Data from the Norwegian Veterinary Institute

In 2022, the Veterinary Institute detected *S. salmonicida* by PCR and DNA sequencing in salmon from two grow out farms in Troms and Finnmark. In these localities, individual fish exhibited clinical and pathological characteristics consistent with systemic disease. In addition, *S. salmonicida* was also detected in cohabited lumpsucker cleaner fish, at one of the locations (Chapter 11 The health situation in cleaner fish).

Other sources report that the parasite and/or the disease has been detected at a further five grow out farms in Troms and Finnmark.

The Annual Survey

In 2022, Spironucleosis was added to the list of current diseases and conditions included in the survey for the first time. Nationally, only two respondents identified the disease as a significant contribution to mortality, reduced growth, reduced welfare and as a growing concern in farming of Atlantic salmon (Appendix B1). This supports the fact that the disease seems to be limited to specific geographical areas at present.

Evaluation of the systemic spironucleosis situation

Systemic spironucleosis is a diagnosis with severe implications for fish health and fish welfare. Although outbreaks of the disease have been rare thus far, it is

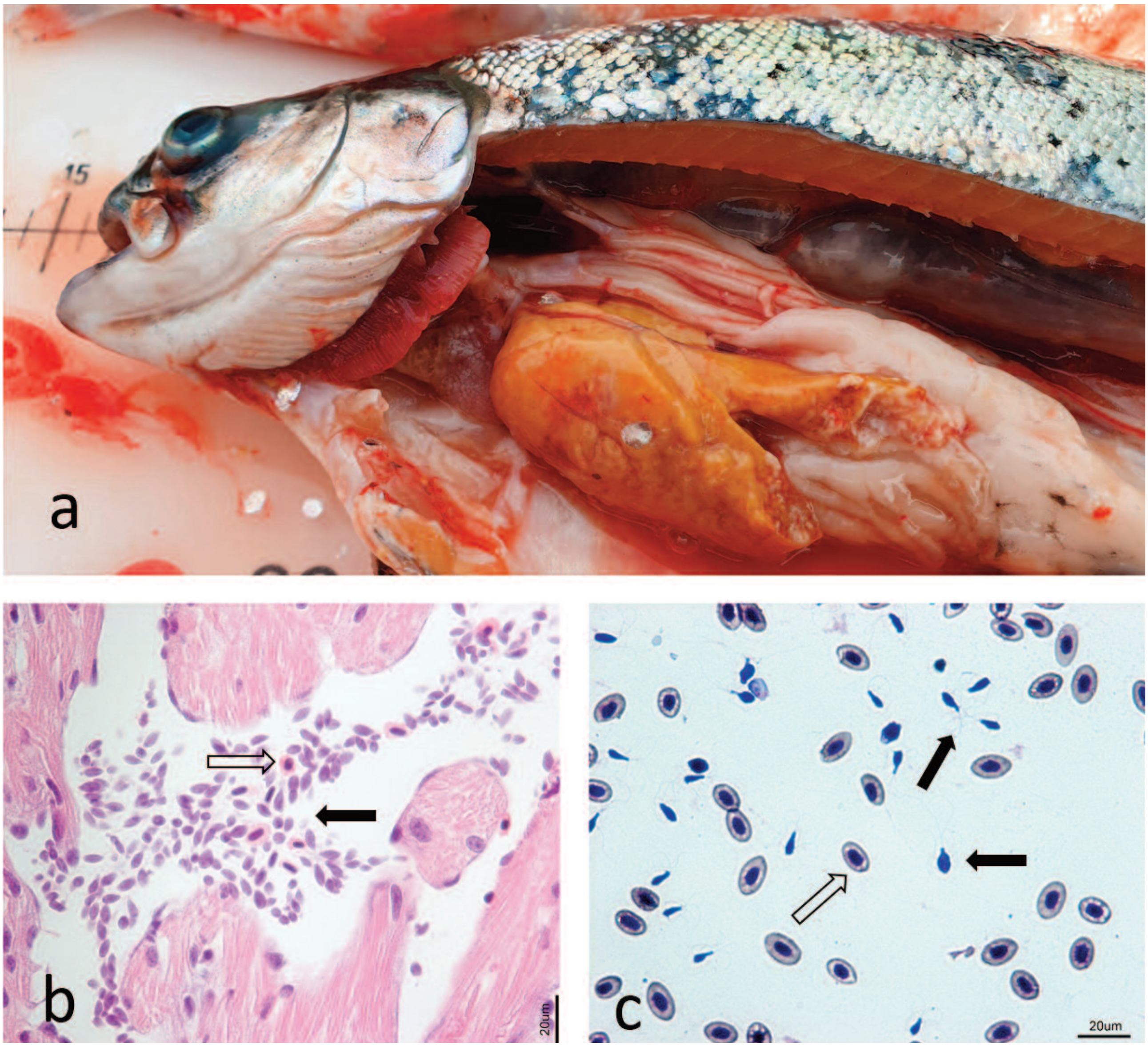


Figure 8.7.1 Spironucleosis. (a) Atlantic salmon with granulomas in the heart, abscesses in the liver and bloody fluid in the abdominal cavity. (b) Tissue section of heart from Atlantic salmon infected with the parasite *Spironucleus salmonicida* (HE stained). (c) Blood smear of *S. salmonicida* (Giemsa stained). *S. salmonicida* (black arrow), red blood cells (unfilled arrow). Photo: Sofus L Olsen, Norwegian Food Safety Authority (a), Erik Sterud (b, c)

likely that the distribution of *S. salmonicida* is wider than currently understood. While the disease has primarily been observed in fish in the sea, there is a possibility that it may also occur in hatcheries, especially considering the current practice of prolonged residence 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, which involves seasonally independent smoltification and release into the sea, often entails intensified production practices that may render fish more susceptible to *Spironucleus* infection. Furthermore, there is limited knowledge about the survival and establishment of infectious organisms in the biofilters and bioreactors of Recirculating Aquaculture Systems (RAS), as well as the potential formation of cysts by *Spironucleus salmonicida* and its ability to survive in the environment. All these factors contributes to the uncertainty surrounding this disease.

9 Other health problems in farmed salmonids

By Geir Bornø and Ingunn Sommerset

In this chapter, non-infectious diseases and health problems related to suboptimal environmental conditions, production strategies or unknown/complex causes is described. The chapter includes health problems such as complex gill disease, poor smolt quality, and runt syndrome, nephrocalcinosis, haemorrhagic smolt syndrome, water quality, vaccine side effects and problems related to algae blooms.

The Norwegian Veterinary Institute has seen an increase in the number of cases with gill problems in recent years, often with a complex/multifactorial picture. The increase is supported by results from the 2022 survey in which complex gill disease is ranked on top as an increasing health problem for salmon in the seawater production phase. Complex/multifactorial gill disease is also considered one of the main causes of reduced welfare, reduced growth and mortality and in the seawater ongrowing phase.

Smoltification problems and development of runts continues to be an important problem, and is ranked as an important reason for poor welfare and growth of salmon in hatcheries. Runt syndrome was in 2022 ranged among the 10 most important causes of reduced welfare and growth of salmon in the ongrowing seawater phase. In hatcheries for rainbow trouth, runt syndrome ranked as the highest causes of reduced welfare, growth and mortality. Causes of suboptimal smoltification and runt development are often complex and difficult to define.

Nephrocalcinosis and HSS are in 2022 ranged as the most important health challenges in salmon hatcheries. The cause of HSS remains unknown but it has been associated with osmoregulatory problems of salmon in fresh water facilities and were in 2022 ranged as the most important problem related to mortality in the hatchery fase of production. Nephrocalcinosis (kidney calcification, kidney stones) is well known in farmed fish and is perceived as a production disorder. The disease is ranged as the main cause of reduced growth and welfare in both salmon and rainbow trout hatcheries and is also reported to be an increasing problem in 2022. Good health and welfare for both salmon and rainbow trout in hatcheries is essential for the fish's survival and health in the marine phase.

Good water quality is essential for good fish health and welfare. While in the past, there were several episodes of mortality linked to hydrogen sulphide in hatcheries based on RAS-technology, fewer episodes are reported in last three years. New in this year's report is that water quality for the fish during various well boat operations is included. The survey shows that most transports in well boats go smoothly, but there are reports of problems related to various chemical water parameters and some problems with algae. When treating lice and AGD with fresh water, chemical residues (disinfection/detergent) and sub-optimal oxygen conditions are reported as the most common water quality cause of reduced welfare. Many respondents answer "don't know" to questions related to water quality parameters during such wellboat operations.

As a result of injection with oil-based vaccines, the Norwegian Veterinary Institute records in some cases tissue damage in the submitted material. In the survey, a small number of respondents consider vaccine side effects to be a major problem, but some indicate that it is a welfare problem e.g. causing reduced appetite and somewhat increased mortality in the hatchery phase. With regards to vaccine efficacy, several of the respondents are reporting low to moderate protection against classical winter wound disease.

Health issues caused by algae and jellyfish is still a challenge at individual plants, but there are no major regional problems with toxic algae blooms as in 2019. For 2022, however, jellyfish are ranked higher as a health problem in the survey than previously, and this year's chapter contains a more detailed description of damages that can occur when salmon are exposed to jellyfish.

Good water quality is essential for good fish health. Photo: Rudolf Svensen

9.1 Gill health in farmed salmonids

By Anne Berit Olsen, Mona Gjessing, Arve Nilsen and Ole Bendik Dale

Gills and gill problems

Gill anatomy and function

The gills are an organ system with many important functions. In addition to gas exchange and excretion of nitrogenous waste products, they represent a barrier and perform a critical role in osmoregulation, acid base balance and hormone turnover.

The gills have approximately the same surface area as that of the skin and are of great importance for the physiological status and health of the fish. The gills are also an important part of the immune defences; in addition to the diffuse presence of immune cells and immune components in mucus cells, the gills possess collections of specialised lymphoid tissues. These aggregates start at the bases of filaments and spread outwards over the filament and are considered an independent immune organ. With only a single cell layer separating the environment and the circulating blood supply, the gills, as with the skin and intestine, have an extremely important barrier function and act as the first line of defence. This proximity to the environment does, however, expose the gills to a significant risk of injury. There remain major knowledge gaps regarding the effect of gill injury on the physiology of the fish.

Gill disease

Gill disease may affect farmed salmon and rainbow trout throughout the whole life cycle from yolk sac larvae to brood fish and represents a significant welfare challenge. Gill injuries may result from poor production routines, poor water quality, algae, jellyfish or disease causing agents such as viruses, bacteria, fungus or parasites. When the barrier of the gill is damaged, susceptibility to infection increases.

As the environment and the physiological status of the fish are very different in freshwater and seawater, there are a number of differences between gill problems associated with the hatchery and seawater phases of culture. During the freshwater phase, changes in water quality and poor feeding routines often increase the risk of gill disease. When water treatment systems do not function optimally, there may occur significant seasonal variation in concentration of e.g. metals. Deposition of iron and toxic aluminium compounds on the gills may lead to high, acute mortality.

Bacterial gill disease and infection with the oomycete *Saprolegnia* in salmon in freshwater are often considered secondary infections, possibly following periods of low pH and metal precipitation or infection with unicellular parasites such as *Ichthyobodo necator* (Costia) or salmon pox virus (see Chapter 5.8 Salmon Gill Pox Virus).

In recirculation based farms (RAS) the interplay between technology, water chemistry and biology is particularly demanding and the gills of fish are particularly exposed to suboptimal conditions related to e.g. water quality, the microbial community and increases in particular matter and metals that may occur. There are also indications that infectious agents may accumulate in closed systems. For more information on water quality in land- and sea-based farms, see Chapter 9.5 Water quality.

In seawater farms, precipitation of aluminium compounds on the gills may occur during freshwater treatment of salmonids against amoebic gill disease (AGD) and salmon lice and during spring flooding when a freshwater layer may form in some fjord systems.

In the spring and summer months there is generally a considerable bloom of algae and jellyfish in the sea and several species may irritate or damage the gills, see Chapter 9.7 Algae, jellyfish and fish health. Fouling organisms growing on the nets within a sea farm may have a similar effect when released during net cleaning operations. Hydroids are a type of stinging organism closely related to jellyfish and often dominate the population of fouling organisms on fish farm cages (Figure 9.1.1). When nets are cleaned in the water, the hydroids are crushed, the stinging cells become spread in the water and may result in irritation and gill injury. Secondary bacterial infections caused by environmental bacteria such as *Tenacibaculum* spp. commonly follow such events. Bacteria that cause systemic infection and necrosis e.g. *Pasteurella*, can also result in gill damage.

Recent research has shown that thermal and mechanical delousing can have a negative effect on gill health, and lead to an increase in the prevalence of the bacterium *Ca*. Branchiomonas cysticola, which is commonly associated with epitheliocystis. Another study indicates that *Ca*. B. cysticola is a significant cause of gill disease in sea-farmed salmon that may well be under diagnosed. Both *Ca*. B. cysticola and the microsporidian *Desmozoon lepeophtherii* may be identified in the absence of obvious gill disease. We lack knowledge of the infection dynamics and pathogenesis for these uncultivable microorganisms. Lack of culture systems limits our ability to study the contribution of individual agents and combinations of agents and external influencing factors in development of gill disease. For more details on the individual organisms, see Chapter 8.4 Amoebic gill disease (AGD) and *Paramoeba perurans* and Chapter 5.8 Salmon Gill Pox Virus.

Environmental threats such as plastic pollution, increasing temperatures and acidification of the ocean related to climate change may have an effect on gill function. Changes in water parameters will also influence the pathogenic microbial communities.

We do not know how extensive gill pathologies must be before they affect the health of the fish, but gill pathologies in clinically sick fish are commonly extensive and chronic. As gill problems may result from different causes, experienced at different times, identification of the causal factors may be difficult, which makes it difficult to advise how the problem may be reduced. Regular monitoring of gill health throughout the life cycle of the fish is therefore very important in all types of farming systems.

New tools

While a unified nomenclature for characterisation of gill disease remains lacking, where several types of pathologies or several infectious agent are involved, the terms ‘complex gill disease’ or ‘complex gill disorder (CGD)’ are commonly used. A number of tools have now been developed for elucidation of the roles of various organisms involved in gill disease.

To increase our understanding of gill diseases, the Norwegian Veterinary Institute has developed a multiplex PCR (gill package) that can detect four organisms associated with gill disease in the sea: *Paramoeba perurans*, *Desmozoon lepeophtherii*, *Ca*. Branchiomonas cysticola and Salmon gill poxvirus.

The results of PCR investigations, together with histopathological analyses can form a good basis for identification of the presence of agents and type and extent of damage. Recent histopathology based studies have increased our insight into the developmental dynamics of gill injuries. Use of special stains, immunohistochemical methods and *in situ* hybridisation (ISH) (RNAscope®), allows visualisation of the microorganisms within the tissues (Figure 9.1.2). This provides valuable information on the causes and effects on the gill tissues.

Prevention and treatment

The same fundamental requirements regarding biosecurity apply to gill diseases as they do to other infectious diseases. There should be a strict requirement for health documentation of fish taken into the farm and there must be focus on optimal water quality and water chemistry and development of a favourable microflora. Disinfection of the biofilter should be considered following recurring gill disease. For measures to be taken on outbreak of and water chemistry see Chapter 5.8 Salmon Gill Pox Virus. As some farms experience recurring gill problems it may be advisable to consider the farm location and whether the location represents a risk of transmission to other farms. It is important that routines for washing nets and semi-enclosed farms are performed in a way that shields the fish as far as possible from particles and injurious fouling organisms. Treatment of the amoeba *Paramoeba perurans* is discussed in Chapter 8.4 Amoebic gill disease (AGD) and *Paramoeba perurans*.

The Health Situation in 2022

Gill diseases are non-notifiable and are not reported to the Norwegian Food Safety Authority. The true prevalence cannot therefore be estimated with any degree of certainty.

Submissions to the Norwegian Veterinary Institute from juvenile salmon with gill pathologies as the main or additional diagnosis were received throughout the whole year. Some farms appeared to suffer problems over several months. The dominating findings, as in previous years, were thickened and to a variable degree fused lamellae, without identification of an obvious cause. There are reasons to believe that water quality may be an important parameter in many such cases. As in recent years, only a few cases have been associated with bacterial, fungus or parasitic infections. There have been few submissions involving gill problems in juvenile rainbow trout.

In 2022, submissions to the Norwegian Veterinary Institute involving sea-farmed salmon with main or additional diagnoses of gill disease were distributed evenly throughout the year, although few submissions were received in May and September. Gill problems seem to be persistent in some farms. In many instances there were are indications of complex aetiology. Consistent

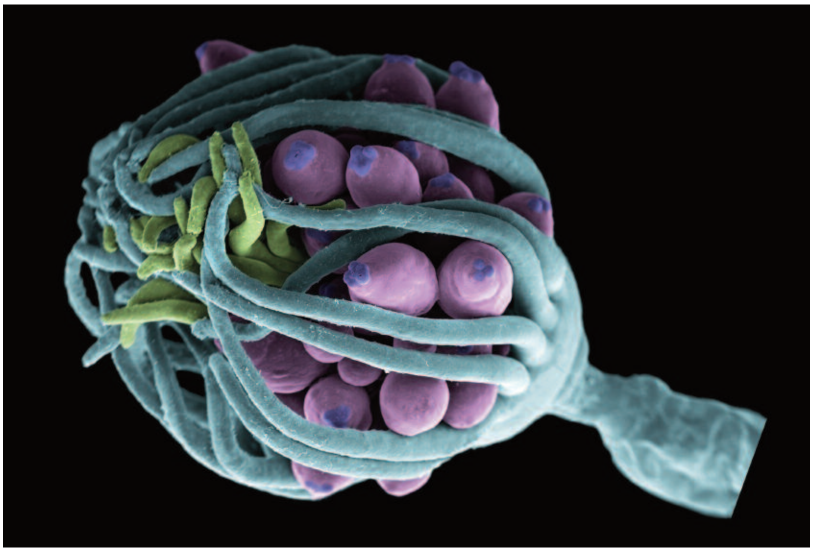


Figure 9.1.1 The hydroid *Ectopleura larynx* settles and grows on fish farm nets. The hydroid is magnified 100x and colour enhanced. Photo: Jannicke Wiik-Nilsen, Norwegian Veterinary Institute

with the overall picture, also cases involving epitheliocystis identified by histopathology, 38 percent of the submissions received in 2022, were spread throughout the year. In Norway, epitheliocystis in the gills is most commonly associated with the bacterium *Ca*. Branchiomonas cysticola, but it has also been shown that this bacterium may be associated with gill injuries in the absence of obvious epitheliocysts and is therefore probably under diagnosed.

There were also some cases of Costia (*Ichthyobodo* sp.) in gills in 2022, most commonly in cases of complex gill disease, and these were, for the most part, identified between January – June. Cases involving bleeding from the gills were received throughout the year, with a majority between July and December. Gill bleeding without known cause has been registered for many years. Only a few cases involving gill disease in sea-farmed rainbow trout were received at the NVI.

The Annual Survey

For juvenile salmon some respondents did consider gill problems as a cause of mortality, reduced growth and welfare and as an increasing problem (Appendix A1). This placed gill disease in 13th place of 26 current disease problems. None of the few respondents working with rainbow trout in the freshwater phase considered gill disease to be problematical.

In ongrowing salmon, gill disease is considered one of the most important causes of reduced growth and is considered the most important cause of reduced welfare and increased mortality (Appendix B1). Gill disease scores highest amongst all diseases as an increasing problem and lands collectively in first place as the greatest health challenge in farming of salmon in the sea. Few of the few respondents with experience in rainbow trout consider gill disease an increasing problem in sea farming of this species (Appendix B2). Gill disease scores relatively highly concerning mortality and reduced welfare in salmon broodstock (Appendix C1).

Evaluation of the gill health situation in salmon farming

The annual survey shows that gill disease is an important and increasing problem in sea farming of salmon, both as a cause of poor fish welfare and in terms of economic loss. In previous years gill problems during the sea phase were associated with the summer an autumn, but appear now to increasingly be a year round problem. New knowledge, new diagnostic tools and better surveillance have become available in recent years, but there is still a need for greater efforts and open information exchange from all actors to gain better control of gill disease.

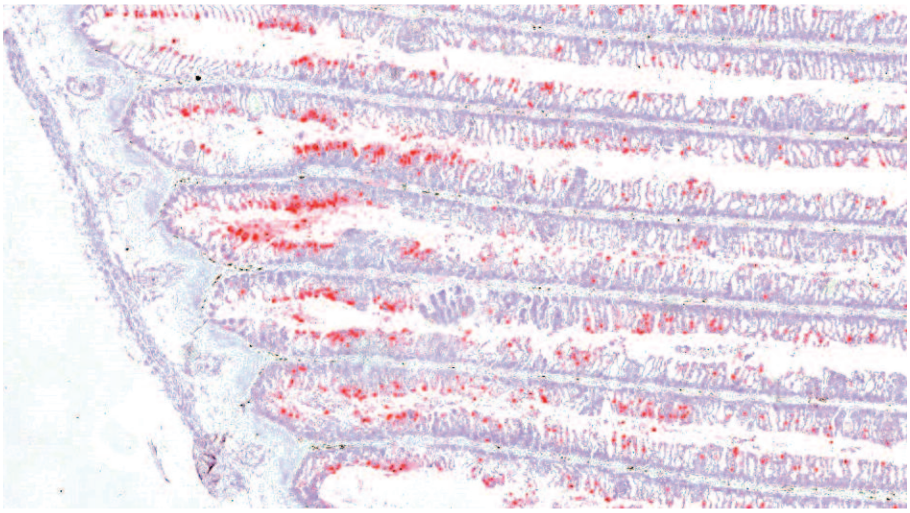


Figure 9.1.2 Gill tissues infected with the bacterium *Ca*. Branchiomonas cysticola, visible as red aggregates (*in situ* hybridisation- RNAscope®). Photo: Mona Gjessing and Anne Berit Olsen, Norwegian Veterinary Institute

9.2 Smolt quality and runt syndrome

By Synne Grønbech and Julie Christine Svendsen

Poor smolt quality may increase the risk of unsatisfactory development, growth and health of sea-transferred salmonids. Osmoregulatory problems related to poor smoltification lead to increased stress, and an increased risk of health problems and mortality in the first period after sea transfer.

Challenges in the hatchery related to smoltification include poor water quality, high biomass density, irregular light regime, early sexual maturation, development of pseudo smolts, uneven smoltification, de-smoltification etc. Diseases, triggered by both infectious and environmental factors, will disturb the smoltification process. Haemorrhagic smolt syndrome (HSS), skin ulcers, salmon pox and nephrocalcinosis are examples of conditions, which will all affect smolt quality negatively. The production of good quality smolts relies on good control of smoltification. A precise evalutation of smoltification status, in combination with sampling from fish representative of the population as a whole is important to ensure this.

“Runt syndrome” is a term used to describe a condition in which the fish become emaciated and cease to grow normally. The term is mainly used for fish post sea transfer, but runts are also seen in hatchery facilities. Typical histological findings in these individuals include decreased amounts or complete absence of fat tissue around the inner organs (perivisceral fatty tissue), and an increased amount of melanomacrophages in the kidney. Runts are assumed to incur parasites and disease to a greater extent than healthy fish. Tapeworm infections are an example of a normal finding in runted fish. Once they become carriers of disease, runts can thus increase the risk of further transmission of agents and contribute to outbreaks of disease.

The causes of runt development remain unknown and several possible factors may be involved. Stress and stress related situations probably contribute to runt development. Problems associated with smoltification and poor smolt quality can also increase the risk of runt syndrome. During the sea phase, it has been observed that fish having survived IPN, PD and/or parvicapsulosis may be extremely emaciated. Therefore, optimal smoltification, seatransfer at the right time, close monitoring during the first period of the sea phase and optimisation of feeding strategy are important factors for further normal development, growth and health of salmonids.

Despite reduced fitness, runted fish may survive for extended periods and thus they represent a welfare problem. In many instances it may be difficult to capture runted fish, but their removal from the population is necessary both in terms of the welfare of affected fish and as a preventative measure to reduce the risk of disease transmission.

The Health Situation in 2022

Data from the Norwegian Veterinary Institute

There is a lack of systematic registration of the prevalence of smoltification related problems, smolt quality and runted fish. This makes compiling reliable statistics difficult. However, we have attempted to provide an oversight of the situation based on information received by the NVI from fish health personnel.

In 2022, the NVI diagnosed emaciation at eight salmon sites, which was about the same as in 2021 and 2020. These included six sea water sites and one hatchery. There were 35 cases this year where

increased mortality was reported after the transfer of salmonids. This is the same number as for 2021. In the majority of these cases there are reports of wounds, in some cases along with signs indicating septicaemia.

Several submitters also describe findings associated with heart disease. In some cases the disease history includes confirmed or suspected HSMB prior to sea transfer, and some submitters describe autopsy findings giving suspicion of CMS. In a couple of cases there was suspicion of yersiniosis.

The Annual Survey

Runt development is not considered among the top causes of mortality in salmon in the ongrowing phase, but it is ranked at a shared sixth place as cause of reduced growth and at a ninth place as a cause of reduced welfare. Smoltification problems are considered to have greater impact on mortality, but besides this it is a relatively less important problem for the other categories. See Appendix B1 and B2 for ranking of salmon health problems in the ongrowing phase.

Problems with emaciation/runt development or smoltification is given greater significance in salmon in the hatchery phase, and both are on the top ten list for mortality, reduced growth and reduced welfare. Emaciation is ranked at the top for reduced growth, and is also considered an important cause of mortality (shared third place, see Table 9.2.1). For smoltification problems the results are similar as in 2021, with this being considered the (shared) fifth most important cause of mortality.

There are significantly fewer respondents who answered the question of which health problems they consider most important for rainbow trout in hatcheries. As a result, this data compilation may have a greater degree of uncertainty. The data do show that runt development is considered important (Table 9.2.2) while there are no answers as to problems with smoltification.

The causes of runt development and the background for smoltification problems are often complex, making it challenging to point to specific reasons for individual sites. In general though, the overall health condition of the fish as well as the water quality will both probably be of great consequence. For more details considering the ranking of problem in salmonids in the hatchery phase, see Appendix A1 and A2.

Like previous years, respondents of the survey have described issues related to smolt quality and runt syndrome in free text fields:

There are comments on smoltification problems in the hatchery phase, where fish are smoltified around the time of vaccination and then desmoltify before sea transfer, as well as a generally high mortality after sea transfer. Furthermore, some respondents describe challenges with smoltification (pseudosmolt) in a premature phase, without any controlled signals to induce smoltification. This is further described to lead to challenges with mortality when the fish do not receive sea water (in a desmolt-phase) and also in the control of production as larger groups of smolt must be «rescued» until planned sea transfer. This happens either through using large amounts of seawater (the fish may need to move tanks in order to achieve this) or through using special feeds, etc. Groups vaccinated in the fall, which remain in fresh water throughout the winter prior to sea transfer in the spring, may experience high mortality and development of extensive organ injuries (typically mineralisation) due to osmotic imbalance. On a positive note, it is commented that increased use of special feeds

Table 9.2.1: The evaluations of the respondents with respects to the five most important problems in hatchery fish (salmon). The respondents evaluated whether the problems cause increased mortality, reduced growth, reduced welfare and whether the problem is increasing.

Ranking	Mortality	Reduced growth	Reduced welfare	Increasing problem
1	Hemorrhagic smolt syndrome (HSS)	**Loser fish**	Fin erosion	Nephrocalcinosis
2	Nephrocalcinosis	Nephrocalcinosis	Nephrocalcinosis	Inf. with non-virulent ISAV
3	**Loser fish**	Deformities	Short operculum	IPN
4	Poor water quality	Short operculum	HSS	Yersiniosis
5	Yersiniosis	Poor water quality	Deformities	*Pseudomonas* sp. infection

in addition to light control seems to have provided better control of smoltification for some producers.

Problems with gill health especially in RAS facilities is mentioned by several respondents, with noticeable effects also post sea transfer. An increased incidence of shortening of the operculum and poor skin health is noted. Similar problems are mentioned for flow-through facilities with low water capacity. There are reports of changes in the skeletal muscle in fish in RAS facilities, with one respondent describing degeneration/necrosis of this tissue and another describing changes resembling dystrophic calcification. Production related diseases such as aplasia of the septum transversum (AST) and deformed hearts are mentioned both in RAS – as well as flow-through facilities.

Respondents of the survey have also commented on areas where fish health and welfare may be improved in the free text fields. Among these are intensive management where there should be increased control with water quality and possibly reductions in fish density. Absolute sectioning in hatcheries and periodical fallowing of biofilters on RAS facilities is also suggested. Reducing the temperature and speed of production in hatcheries in order to have more robust fish in the ongrowing phase are also mentioned as measures. It is further mentioned that a focus on size over robustness of the smolts leads to a reduction of the smolt quality. An increased prevalence of nephrocalcinosis is reported by several responders, where one respondent mentions this particularly when mixing in seawater. Some people would like more research and improved protocols regarding smoltification in order to avoid problems with osmoregulation and nephrocalcinosis.

Evaluation of the smolt quality and runt syndrome situation

There is increased use of large smolts and postsmolts, as a part of the strategy to limit infection with salmon louse, along with other viral and bacterial diseases. Several RAS facilities are built in order to produce fish up to 1 kg. High biomass may lead to challenges with water quality and synchronisation of fish groups during smoltification. How well the large smolts and postsmolts fare after sea transfer varies, which highlights the need for more knowledge regarding this production method. Applying water with low salinity throughout the hatchery phase, and desmoltification, is mentioned as problematic in the smolt production. Fluctuations in water temperature in flow-through facilities remains challenging for smoltification, especially in the production of spring smolt.

Based on the survey results, inadequate smoltification and the development of runt syndrome are important problems along the Norwegian coast. Causes of suboptimal smoltification and runt development are often complex. There is an increasing diversity in the ways in which to produce fish in the hatchery phase, and this field is somewhat difficult to have a complete overview of both with regards to new production technology as well as protocols for smoltification. What is clear is that a continuous focus must be placed on production planning and optimising conditions, especially during the hatchery phase, in order for the smolt to have the best possible starting point for good welfare and health for a continued life in the sea.

Table 9.2.2: The evaluations of the respondents with respects to the five most important problems in hatcheries rearing rainbow trout. The respondents evaluated whether the problems cause increased mortality, reduced growth, reduced welfare and whether the problem is increasing.

Ranking	Mortality	Reduced growth	Reduced welfare	Increasing problem
1	IPN	**Loser fish**	**Loser fish**	Deformities
2	**Loser fish**	Nephrocalcinosis	Nephrocalcinosis	Nephrocalcinosis
3	Deformities	HSMI	Short operculum	IPN
4	Nephrocalcinosis	IPN	Fin erosion	(0)
5	HSMI	Deformities	Poor water quality	(0)

(0) too few answers

9.3 Nephrocalcinosis

By Anne Berit Olsen and Arve Nilsen

The Disease

Nephrocalcinosis (kidney calcification, kidney stones) is a production related disease that was previously most commonly associated with intensively farmed rainbow trout, but in more recent times has also been associated with farmed salmon. The condition is also recognised in several other species of intensively farmed fish. Mortality associated with nephrocalcinosis is generally low, but may be increased during e.g. handling and sea-transfer. Calcium deposits in the kidney are a result of abnormal physiological conditions within the fish, and affected fish commonly display poor growth.

Nephrocalcinosis is an important welfare indicator in farmed fish as the condition may indicate suboptimal water quality related to the balance between water volume/use and biomass of fish. Diagnosis of nephrocalcinosis is almost certainly an indicator of several reduced welfare parameters.

Early changes in the kidney are macroscopically invisible, but may be revealed by histopathological (microscope) investigations as deposits of calcium containing material in the excretion system of the kidney where urine production occurs (Figure 9.3.1) The deposits may block the excretion system, resulting in expansion of the tubules. Cells covering the inner surfaces of these tubules (epithelial cells) are often destroyed. The blood forming tissues surrounding these tubules will subsequently become fibrous. In serious cases deposits may burst the tubule system and lead to inflammatory reactions in surrounding tissues.

On deposition within the collection ducts of the kidney, long, white, ‘stripes’ (Figure 9.3.2) may be observed. The kidney may become enlarged and nodular. The changes may be extensive and the function of the kidney drastically reduced. There are indications that fish with extensive nephrocalcinosis display severely reduced metabolic activity and energy production in the kidney.

Development of kidney stones may have various or complex causes. In mammals the composition of the deposits can indicate the cause. In salmon, while the composition may vary, the majority of the deposits appear to be calcium phosphate. Magnesium is also a common constituent. Although some studies indicate that an abnormal mineral balance in feed may result in nephrocalcinosis, the most normal cause in intensive fish farming is considered to be persistently high CO_2 levels in the water. This is common in modern intensive, water-saving modes of operation. Not all studies have confirmed the relationship between high CO_2 and nephrocalcinosis, and it is speculated that changes in other water quality parameters may also contribute. The mechanisms are not completely understood, but high CO_2 level in the water change the composition of blood plasma, which then pose metabolic challenges to the fish. The highest recommended CO_2 levels in juvenile production farms is 15 mg/L, but recent research has shown that injurious effects of CO_2 may occur at lower levels, perhaps particularly where seawater is also used. Several research projects are currently studying the risk factors for development of kidney stones.

Nephrocalcinosis is commonly identified in association with haemorrhagic smolt syndrome (HSS, Chapter 9.6 Hemorrhagic smolt syndrome (HSS) / Hemorrhagic diatesis (HD)). Typical findings with HSS include bleeding to the kidney tubules, such that the fish produces bloody urine. Recent research suggests that HSS does not promote nephrocalcinosis but that both conditions can be promoted by similar farming conditions.

Most cases of nephrocalcinosis are identified in populations of presmolts, smolts and postsmolts. An increased incidence is reported in association with increased levels of seawater use during the postsmolt phase. The condition may be observed in rainbow trout during the whole sea phase. Mild and moderate kidney damage will often heal without treatment. Extensive damage will not heal and results in increased mortality.

Kidney lesions caused by nephrocalcinosis cannot always be easily differentiated with those caused by the notifiable bacterial kidney disease (BKD), and must be investigated in the laboratory.

Disease control

Nephrocalcinosis is considered an environmentally dependent disease. Ensuring good intake water quality, satisfactory monitoring and optimisation of level and stability of water quality in tanks and cages, including CO_2 and pH, and sufficient through-flow (specifically water consumption) will reduce the the risk of development of nephrocalcinosis. Systematic surveillance of water parameters and metabolic waste products such as CO_2 are important. There may be reason to limit use of seawater, both early in the hatchery phase and during smoltification and transition to the postsmolt phase.

Nephrocalcinosis has in some cases been associated with an unbalanced feed. Use of feed designed to cater for the fishes particular requirements related to the various developmental stages and environmental conditions may, therefore, be important for prevention of the disease.

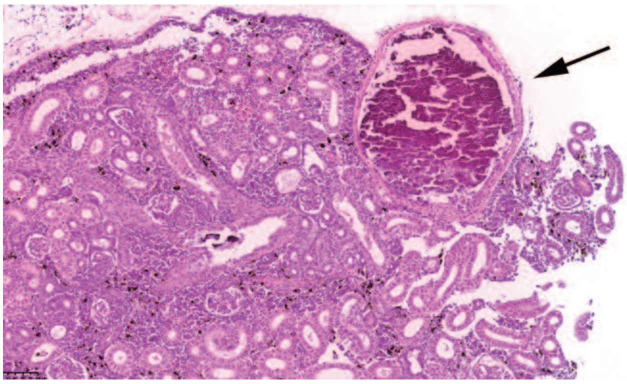


Figure 9.3.1 Nephrocalcinosis. Tissue section of distended excretory duct with calciferous material (arrow) (H&E staining). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

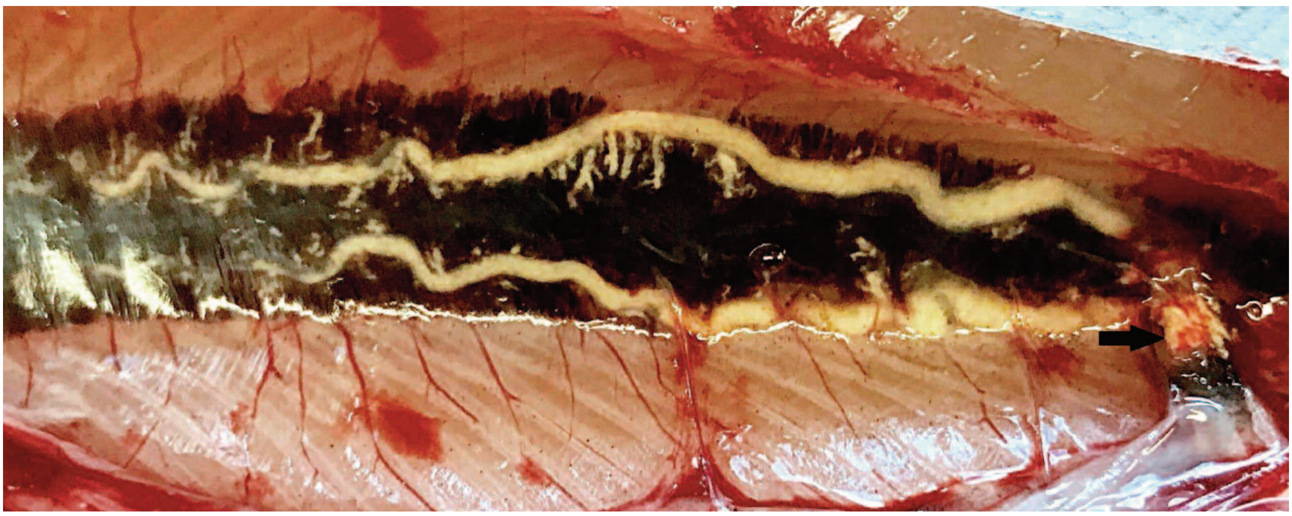


Figure 9.3.2 Severe nephrocalcinosis. The excretory duct and urinary bladder (arrow) are filled with yellowish-white calciferous material. Photo: Stim

The Health Situation in 2022

The number of farms affected in 2022 is uncertain, and the number of registered laboratory diagnoses is certainly an underestimate. Diagnoses are commonly made in the field, based on typical changes in the kidney, and some cases remain undiscovered as the deposits may not be macroscopically visible. Histopathologically diagnosed cases are commonly incidental to other diagnoses.

In submissions sent to the Norwegian Veterinary Institute, nephrocalcinosis was diagnosed in fish between 2-400g, with 50 percent of cases identified in large smolts ≥ 100g. Of sea-transferred fish the disease was diagnosed in fish up to 6kg in weight, with a considerable proportion of these large fish weighing 2.5 kg or more.

The Annual Survey

For hatchery salmon, nephrocalcinosis was considered the second most important cause of mortality, reduced growth and reduced welfare and as the problem most increased during the year (Appendix A1). Overall, and as in the two previous years, nephrocalcinosis tops the list of the most important health challenges for salmon in the juvenile phase of culture in 2022. There were fewer responses to the survey for juvenile rainbow trout, but as in the previous years survey, nephrocalcinosis was again considered the second most important increasing problem after deformities (Appendix A2).

Nephrocalcinosis is still considered to be of limited significance for mortality, reduced growth and reduced welfare for sea-farmed salmon (Appendix B1). For sea-farmed rainbow trout (few respondents), nephrocalcinosis achieved the second highest score for reduced growth, but lower score for the remaining questions (Appendix B2). Of the health challenges considered important for sea-farmed rainbow trout at a national level, nephrocalcinosis was placed fourth in 2022, two places down from 2021.

Evaluation of the nephrocalcinosis situation

Results of the annual survey reveal that nephrocalcinosis remains a frequent and important health and welfare diagnosis for both hatchery salmon and rainbow trout, and thereafter survival and health in the sea-phase. Norwegian Veterinary Institute statistics reveal a significant number of diagnoses in large smolts between 100-500g both before and after sea-transfer. In other words, this suggests a less than optimal start to the sea-phase of culture during which the fish must adapt to important physiological and environmental changes.

RAS-farms have been considered as representing a significant risk for development of nephrocalcinosis, which may be directly related to water quality. There is a need for more systematic water quality surveillance to allow comparison of RAS-farms with through-flow farms.

In ongrowing farms, nephrocalcinosis is commonly identified during the first months post sea-transfer, and originates almost certainly from the hatchery phase. High mortality associated with nephrocalcinosis has been registered in a few ongrowing farms shortly after sea-transfer, but the presence of the disease has also been registered in some farms several months after sea-transfer. Moderate tissue damage may heal relatively rapidly after sea-transfer, with more serious lesions taking longer to heal. It is not unlikely that the increased prevalence identified in larger fish amongst the material submitted to the Norwegian Veterinary Institute is related to conditions prior to or surrounding sea-transfer. However, this should be examined closer.

9.4 Hemorrhagic smolt syndrome (HSS) / Hemorrhagic diathesis (HD)

By Geir Bornø, Anne Berit Olsen and Toni Erkinharju

The Disease

Hemorrhagic smolt syndrome (HSS), also called hemorrhagic diathesis (HD), is a condition that often occurs in the late hatchery phase and early after exposure of Atlantic salmon smolts to the sea. The fish often develop a bleeding pattern in the musculature, peritoneum and internal organs. Haemorrhage in skeletal muscle, perivisceral fat, kidney and heart are particularly typical (Figure 9.4.1).

The cause of this disease is not known, and no infectious agent has so far been detected. It is believed that the condition is caused by osmoregulatory problems linked to the process around smoltification, but there is little literature in the field. HSS does not usually lead to a particularly high mortality rate, but several thousand individuals with this condition and a relatively high, acute mortality rate have been reported in some cases. Normally, the condition improves a few weeks after transfer to seawater.

Disease control

There are no control measures available, but the condition may be slowed in some cases by transfer of the affected group of fish to sea. It is very important to consider more serious, infectious diseases such as viral haemorrhagic septicemia (VHS) as a possible differential diagnosis, as this disease also produces a similar clinical picture. If HSS is suspected, samples for histopathological examination and PCR detection of VHS virus should therefore be secured.

Salmon smolt with hemorrhagic smolt syndrome (HSS). Photo: Anne Berit Olsen, Norwegian Veterinary Institute

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

In the NVI material from 2022, hemorrhagic smolt syndrome was diagnosed in salmon from four hatcheries. In addition, HSS was suspected in some farms. This is a decrease from 2021, when HSS was diagnosed at ten locations, but this may be because more samples have been analyzed by private laboratories. The disease is not listed, and samples are not always sent for laboratory examination.

The Annual Survey

In the survey among fish health personnel and inspectors at the Norwegian Food Safety Authority, HSS is cited second among the most important health challenges for salmon in the hatchery phase. The disease is ranked as the most important cause of mortality by 64 percent of the respondents (27 out of 42). For 49 percent of the respondents, HSS is considered to be an important cause of reduced welfare. A lower proportion indicated HSS as an important cause of reduced growth or as an increasing problem (14 and 16 percent, respectively) in salmon in the hatchery phase. HSS is considered a minor problem in juvenile rainbow trout (Appendix A2).

Evaluation of the HSS situation

In all three annual surveys since 2020, HSS has been indicated as among the most frequent causes of mortality in hatchery salmon. HSS is a condition recognised for many years, but still there is very little knowledge of causal relationships.

9.5 Water quality

By Kamilla Furseth, Ole-Kristian Hess-Erga, Endre Steigum & Åse Åtland
Norwegian Institute for Water Research (NIVA), Aquaculture section

Whether water quality is satisfactory regarding good fish welfare is dependent on a number of factors and the complex interplay between these factors. Some parameters may be synergistic, while others may protect against the toxic nature of other compounds. This situation becomes even more complex when technological innovations and changes to the farms structure are introduced. Land-based aquaculture is increasingly dominated by recirculation based systems (RAS-farms), which require significant treatment of the re-used water. An already complex water-chemistry is made even more complex by addition of chemicals. This is the fifth year in which water quality has been included as a theme in the Fish Health Report and many of the challenges presented previously by NIVA continue to be relevant. This year we consider the trends in land- and sea-based farms, but also specific areas related to well-boat operations. The text is based on NIVA registrations and responses to this year's questionnaire.

Land-based farms

NIVA has registered a number of acute and serious events related to water quality during 2022 in land-based fish farms, of which the most serious occurred in RAS. RAS are rapidly becoming more complex with increasingly advanced water treatment and a high degree of recirculation. There are an increasing number of factors that may negatively affect fish welfare, despite the intention being the opposite. It is important that cause and effect is established in every case. One example involving wrong dosage of a cleaning chemical led to a fish mortality. Other examples include sub-optimal farm design or poor routines that have led to introduction of chemicals or stagnant water with subsequent H^2S toxicity.

Hydrogen sulphide

Hydrogen sulphide (H2S) has again been a theme of relevance in 2022. Replies to the annual questionnaire confirmed this (Figure 9.5.1). The proportion of respondents who considered that H2S has negatively affected fish welfare in RAS, increased from 11 percent in 2021 to 19 percent in 2022. There was no equivalent increase registered for flow-through farms. Analysis of samples submitted to NIVA often showed low levels of H2S, which although not directly related to acute mortality, are considered suboptimal for the fish.

Data from the NRC- project «H^2Salar», led by NOFIMA, indicate that long term exposure to H^2S can lead to increased mortality of salmon post-smolts, even at values as low as 5 µg/l. Newer sensors with low detection limits for H^2S (Aquasense) are now installed in several smolt producing farms and surveillance performed under the aforementioned project revealed that normally functioning RAS-farms, without apparent H^2S problems have background levels of H^2S below 1 µg/L.

Aluminium and metals

Metal problems related to intake water and accumulation of metals, both on the gills and in recirculated water, remain fairly frequent in freshwater farms, but appear, in terms of responses to the annual questionnaire and in submissions to NIVA, to be less of a problem than previously both in RAS and flow-through farms. Samples received by NIVA are generally submitted for assessment of water treatment or following a flooding event, rather than on suspicion of metal poisoning and associated mortality. We have identified cases in which copper in particular has accumulated in RAS with high degree of recirculation. The more acute toxic events were to a significant degree related to well-boat treatments, which are discussed in the next section.

Low and variable calcium levels

Low water calcium levels continued to be a problem in land-based aquaculture in 2022. This occurs most commonly in ion-poor and acidic intake water with a low buffering capacity, but may also be observed in production water. Differences in calcium concentration between departments has in one case led to ion regulation problems in fish moved from one department to another with higher concentrations of calcium in the water. The concentrations were not considered high in themselves, but the difference between departments was so high that blood plasma analyses indicated that the fish died of osmotic stress. Farms that use different degrees of buffering between departments should try to avoid exposure of fish to large differences in ionic concentration, particularly in relation to calcium. Research has shown that calcium has a protective effect regarding metal toxicity in fish. To counteract aluminium toxicity in freshwater, Ca-levels greater than 2-2.5 mg/L are recommended, but there are no clear recommendations for other metals in the typically ion-poor water qualities used as intake water in Norway.

The main causes of reduced fish welfare in RAS and flow-through farms

It is clear from this year's questionnaire that high turbidity, CO_2- challenges and gas supersaturation were considered the most negative causes of poor fish welfare in RAS farms in 2022. The results indicate an increase from 23 percent in 2021 to 56 percent in 2022 for turbidity, from 41 percent to 44 percent for CO_2 and from 13 percent to 44 percent for gas supersaturation.

In addition, nitrogenous compounds (from 8 percent to 31 percent) and H_2S were also considered negative factors. For H_2S, responses for 2022 indicate an increase, in contrast to the decreasing trend recorded over the last few years. This may either indicate a generally increased level of knowledge of the problem and a consequent increase in the number of analyses performed, or that it is an increasing problem.

There appears to be a greater focus on level of particulate matter (particles) in production water and NIVA has received an increasing number of enquiries related to this subject. There is a demand for general advice and quantification of particles in the water, most commonly PSD-analyses (Particle Size Distribution), but also evaluation of treatments aimed at particle removal. Another knowledge gap relates to how particle-associated bacteria influence production and welfare and how pathogenic microorganisms can establish and survive in such complex systems. We hope that a current

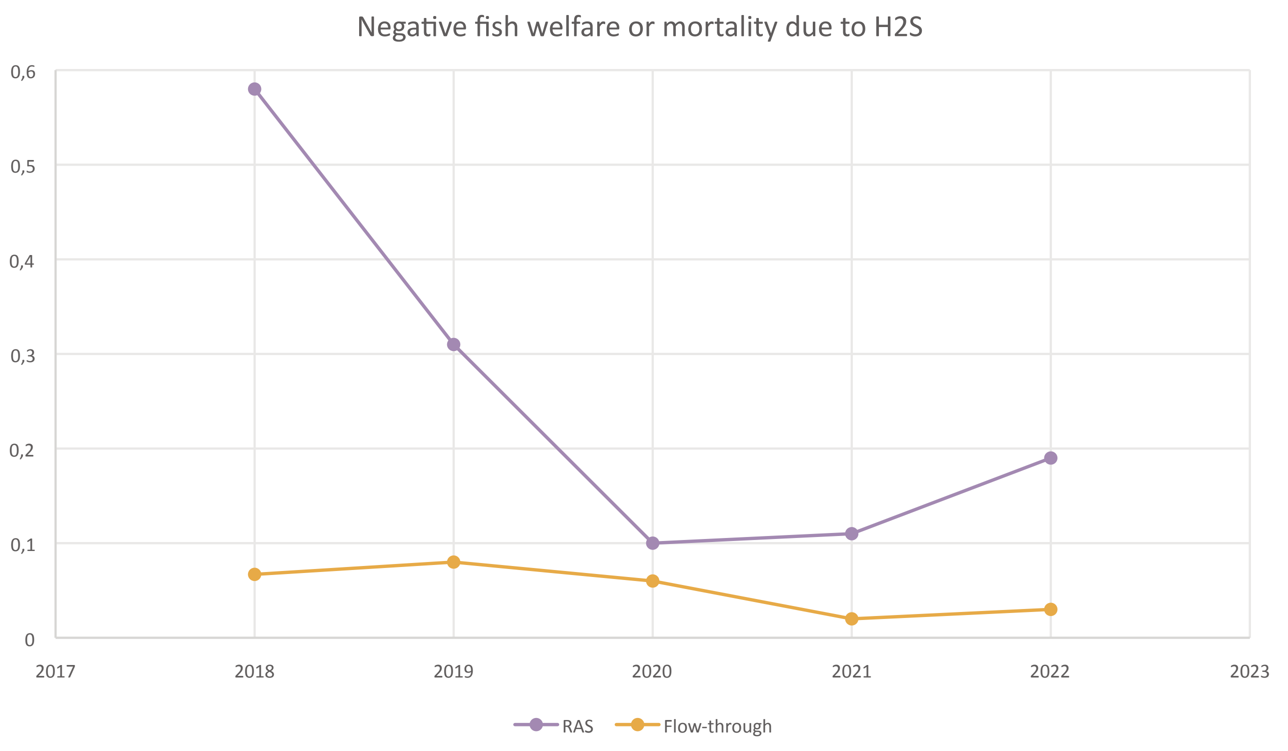


Figure 9.5.1 Results from the annual survey related to H_2S having negatively affected fish welfare in recirculation (RAS)- and through-flow- farms.

research problem 'Biosecurity in RAS' led by NIVA will provide insights into these areas.

In flow- through farms, responses to the questionnaire indicate a continued reduction in problems related to poor fish welfare. The proportion of responses related to CO_2 levels fell from 48 percent in 2021 to 32 percent in 2022 while oxygen fell slightly from 26 percent in 2021 to 23 percent in 2022. Responses for gas supersaturation increased form 7 percent in 2021 to 22 percent in 2022.

The industry works constantly towards increased production of fish, but increased production requires increased quantities of water, via either increases in raw water volume or an increased degree of recirculation. This year's questionnaire again indicates that the main factors contributing to reduced fish welfare are related to increased intensity in juvenile production farms, particularly in relation to correct dimensioning, water consumption and water treatment.

Well-boat operations

Water quality during various well-boat operations was considered for the first time in this year's questionnaire, and covered transport of smolts and harvest ready fish, AGD treatments and delousing. The number of respondents replying to this part of the survey was high, indicating significant interest in this theme. This is consistent with the number of enquiries received by NIVA on these matters. The aquaculture industry is repeatedly reminded of the biological risks associated with transport and treatment of live fish in well-boats. Biological risk is here defined as all factors e.g. procedures, technologies and environmental conditions that have an inherent risk of negatively affecting fish welfare. Fish are exposed to a variable degree of handling stress before loading and during transport. This will vary dependent on the loading-, treatment- and transport methods used. Such negative effects may be directly related to several cases of mortality during non-medicinal delousing (thermal, mechanical and freshwater) and during closed transport. There has been a general increase in non-medicinal delousing operations over the last 10 years. The consequences of this result in this type of delousing being considered, as described in the Fish Health Report 2021, as the most important welfare challenge in salmon farming and the second most important cause of mortality in sea-farmed salmon.

The aquaculture industry and FHF have expressed a need for more knowledge relating to well-boat operation, in particular regarding the effect of pressure changes during loading and unloading the fish, but also concerning accumulation of metabolites during transport. NIVA have been involved in investigation of several mortality related incidences associated with well-boat operations, particularly freshwater-based treatments. The investigations suggest that washing- and disinfectant- substances may not have been completely removed and that increased concentrations of certain metals may be involved. Another aspect we will highlight is the lack of water sampling and uncertainty associated with sensor data collected by well-boats. The ability to identify causes of mortality increases considerably if sensors are subject to good maintenance- and calibration- routines and if water samples are available from before, during and after the event.

Smolt and harvest transport

Transport of fish is considered less risky than well-boat treatment, as is apparent from the annual survey where most respondents replied 'no' or 'don't know' regarding the parameters that can affect fish welfare negatively. Regarding smolt transport, 5 percent replied that CO_2 and O_2 influence fish welfare, 7 percent answered nitrogen compounds, 3 percent H_2S and gas supersaturation while 2 percent replied temperature, algae/jellyfish and metals. For harvest transport the replies differed; 10 percent answered CO_2, 8 percent O_2, 6 percent algae/jellyfish, 4 percent turbidity and 2 percent gas supersaturation (Figure 9.5.2).

Most transport events are problem free, but NIVA received some enquiries related to mortality events. Most appear related to poor water quality, either chemical of physical factors in water taken aboard, changed during transport or in the receiving water. The requirement for closed valves during longer transports will generally also have consequences for water quality. In cases investigated by NIVA, we often find that water samples have not been satisfactorily taken during transport. It is thus difficult to identify the underlying cause of the reduced welfare.

In the survey, several respondents commented that closed transport of harvest fish is problematic, while changes in water chemistry including nitrogenous compounds and temperature differences between tank to boat or between boat and cage are considered important for transport of smolts.

Treatment of salmon lice and AGD with freshwater

Treatment of fish in well-boats is considered by many as the most risk-associated operation during the production cycle of fish. There are many parameters which must be satisfactory, not just in relation to biological risk, but also technical challenges on the boat and the life history of the fish. Increased production, larger farms and increased demands on efficiency result in development of larger boats capable of treating larger numbers of fish with a larger biomass and at higher densities. In general, we lack knowledge of the effect of these factors on the fish. Such operations require considerable knowledge of water chemistry, fish welfare, stress and handling. These are themes we will highlight in the newly started FHF

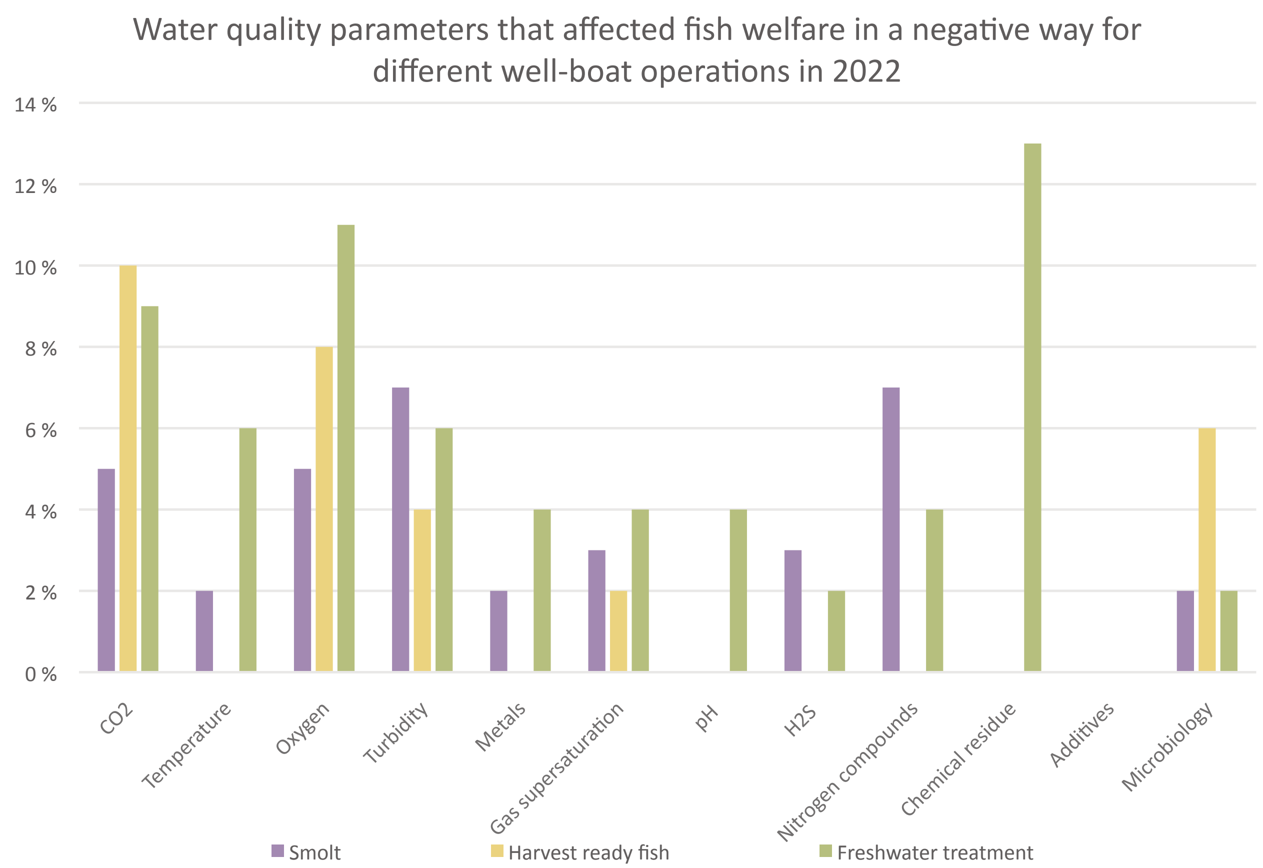


Figure 9.5.2 Proportion of respondents to the annual survey who replied ‘yes’ regarding the various water quality parameters related to different well-boat operations; smolt transport, harvesting and freshwater treatment.

projects BRØK and NYBRØK, which also include several industry partners.

In the survey, many respondents replied 'no' or 'don't know' when asked which water quality parameters influenced fish welfare negatively during delousing or AGD treatment. Of those who replied 'yes', 13 percent wrote cleaning fluid/disinfectant contamination, 11 percent oxygen, 9 percent CO_2, 6 percent turbidity and temperature, 4 percent pH, metals, nitrogenous compounds and gas supersaturation, while 2 percent replied H_2S and algae (Figure 9.5.2). There are many external factors which may lead to deviation during delousing or AGD treatment, so the 'no' replies to the water quality question may be explained in this way. The number of 'don't know' replies is somewhat disturbing, but is also consistent with the investigations where NIVA has been involved. Although on occasion a clear reason for the incident may be established, most investigations do not identify a single cause. The underlying cause may be complex due to several suboptimal parameters including fish health status. Lack of suitable water sampling is a common contributing factor to lack of a diagnosis.

Conclusion

Most juvenile production farms are well aware of the various threats to water quality and are in control of the situation. Many have water sample archives, emergency kits and there is a continual demand for instruction and knowledge building related to water chemistry and monitoring equipment. Most farms are in frequent contact with fish health services regarding matters related to water quality and changes in water quality that may negatively affect the fish.

We do not have the same impression regarding the sea-phase of aquaculture. The same precautionary principle observed during the freshwater stage does not appear to be considered important at sea. There are an increasing number of submissions related to mortality during or following handling, e.g. well-boat operations or net-washing. It is normally not possible to identify any water-chemistry based cause, due to the lack of water sampling or that sampling is performed too late.

Well-boat moving fish to waiting cages. Photo: Geir Bornø, Veterinærinstituttet

9.6 Vaccine efficacy and side effects

By Kristoffer Vale Nielsen, Sonal Jayesh Patel og Ingunn Sommerset

Vaccination is an important preventive health measure in fish farming. Due to vaccination of salmonids against important bacterial diseases, such as cold-water vibriosis and furunculosis, outbreaks caused by these bacteria now occurr very rarely. Thus, vaccination has contributed to reduced losses, a significant reduction in the antibiotic consumption and improved fish welfare. Vaccination of fish is currently regulated by the Food Act (§ 19), the Aquaculture Operations Regulations (Akvakulturforskriften §§ 11 and 28) and the Animal Disease Control Regulations §§ 5-9. The regulation describes the general terms regarding the duty to implement relevant disease preventive measures, including vaccination.

Fish may be vaccinated by dip, bath, orally via feed and by injection. In Norway, intraperitoneal (i.p.) injection with multivalent oil-based vaccines is the most common form of vaccination for salmonids. Additional vaccination with single-component, utilising either oil adjuvant for i.p. deposition (eg inactivated PD and yersiniosis vaccines) or non-adjuvanted vaccine given intramuscularly, (eg DNA vaccine against PD) is common practice.

For salmonids, there are good and effective vaccines against many diseases, but for farmed species, such as halibut, lumpsucker and ballan wrasse that are produced in smaller quanta, there is still a need of research and development beforeeffective vaccines are available. All products used to treat and prevent disease in fish are considered medicines and must be approved by the Norwegian Medicines Agency. The documentation requirements for obtaining marketing authorization for a fish vaccine is similar to that for other animals, and is quite extensive. An alternative is autogenous vaccine which is often used when new infectious agents or variants of known infectious agents cause problems at specific farms or in a limited geographical area and commercial vaccines are not available, or provide sufficient protection to known agents. Autogenous vaccines are based on an infectious agent isolated from one or more fish, which belong to the same "epidemiological unit". In each case, application for approval to use autogenous vaccine must be sent to the Norwegian Medicines Agency before use. Criteria of approved manufacturer/producer of vaccine needs to be met before such approval is granted.

Figure 9.6.1 Minor adhesions and melanin deposition around the injection site. Photo: Kristoffer Vale Nielsen, Norwegian Veterinary Institute.

Farmed salmon in Norway are often vaccinated before transfer from fresh water to sea water, and usually against furunculosis, vibriosis, cold water vibriosis, winter ulcer (*M. viscosa*) and IPN. Vaccination against PD has been common in Western Norway (endemic area for SAV3) and to varying degrees in Trøndelag (endemic area for SAV2). In Trøndelag and parts of Vestlandet, it is also common to vaccinate against yersiniosis. Vaccination against ISA in Norway was limited until 2020, but increased use has been reported in both 2021 and 2022. Regarding the use of autogenous vaccines, the statistics regarding number of products and volumes are not available.

The main principle of vaccines is that the antigen(s) incorporated in the vaccine stimulates the fish's specific (adaptive) immune system, so that the fish responds faster and stronger if it is exposed to the same antigen representing a specific infectious agent at a later time-point. Vaccines can also stimulate the innate immune system, and thus fish, often for a limited period of time after vaccination, may be protected against other non-specific infectious agents. Most vaccines protect against the development of disease, and not necessarily against infection, and thus amongst vaccinated individuals there may be infected, apparently healthy individuals. The time it takes from vaccination until the fish has built up a sufficient immune response, is known as "onset of immunity", which is often stated in day-degrees. The vaccine manufacturers often state a lower and an upper temperature at which the effect and side-effects of the vaccines are documented, and recommend immunisation temperature within this range. In particular, vaccination at low temperatures may lead to late development of immunity, or that immunity is not achieved. The duration for which vaccine offers protection, so-called "duration of immunity", is also an important factor and for most diseases it is desirable that the farmed fish is protected throughout the production cycle until fish is slaughtered. The classic inactivated vaccines are often water-in-oil emulsions, where the oil acts as an adjuvant and the formulation provides a depot effect so that the immune system is stimulated over time.

Side effects commonly observed in salmon post i.p. vaccination with oil-adjuvanted vaccines are 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 9.6.1). Spinal

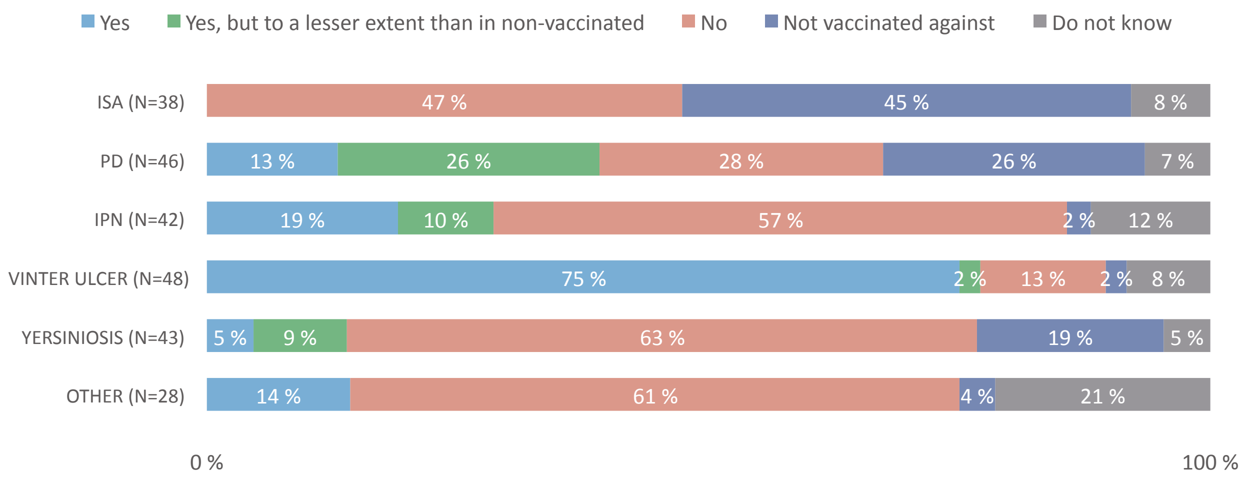


Figure 9.6.2. Summarized answers to the question: "Have you experienced clinical outbreaks of the following disorders despite the fish being vaccinated against these diseases?". N = number of respondents who answered the question for each of the diseases ISA, PD, IPN, Winterulcer (*M. viscosa*), Yersiniosis (*Y. ruckeri*) and "Other".

deformities have also been reported, with a particular "cross-stitch vertebrae" being associated with some oil-adjuvanted PD vaccines. The degree of side effects will vary with the type of vaccine and conditions surrounding the vaccination such as e.g. fish size, degree of misplaced vaccination, injection pressure, water temperature, hygiene etc. and are assumed to be painful for the fish. Taking into account the extent of vaccination, and thus the extent of reduced welfare as a result of vaccine side effects, continuos efforts to reduce side effects is important.

The Annual Survey

In this year's survey, Fish health personnel and the Norwegian Food Safety Authority were asked about both the effect and side effects of current vaccines used for salmonids. Fifty-three out of seventy-five respondents (70.7 per cent) replied that they had experience with vaccination of salmonids, side effects of vaccination and/or degree of protection after vaccination. The results of the survey give an impression of the perceptions of a selection of professionals in the industry, and must therefore also be interpreted accordingly and with caution.

The first question was: "Have you experienced clinical outbreaks of the following disorders despite the fish being vaccinated against these diseases?". Specific questions were asked about the diseases ISA, PD, IPN, Winterulcer, Yersiniosis and "others". There were five answer options for each disease: 1) "Yes", 2) "Yes, but to a lesser extent than in unvaccinated groups", 3) "No", 4) "Not vaccinated against" and 5) "Don't know". Of the 38 respondents who answered the question about ISA, 17 and 3 answered respectively that they had not vaccinated against, or did not know (altogether 53 per cent), while 18 respondents (47 per cent) answered "No" to whether they had experienced an outbreak of ISA despite vaccination (Figure 9.6.2). According to the Veterinary Institutes knowledge, at least one outbreak of ISA-vaccinated fish has been registered in 2022 (see Chapter 5.2 Infectious salmon anemia (ISA)), which shows that the survey does not provide a complete overview. In the case of PD-vaccinated fish, several respondents had experienced outbreaks (18 out of 46 responses), but here 12 out of 18 reported that outbreaks had less impact than in unvaccinated fish. IPN vaccination also does not seem to provide full protection against outbreaks. Twelve out of 42 had experienced outbreaks of IPN in vaccinated fish, of which four indicated that outbreaks were milder than in unvaccinated fish. Outbreaks of winter ulcers occur relatively often despite vaccination, 37 out of 48 respondents (77 per cent) have experienced this, and of these, only one reports a smaller extent as a result of vaccination. Yersiniosis vaccination apparently often provides relatively good protection against outbreaks. Six out of 43 nevertheless state that they have experienced outbreaks of yersiniosis despite vaccination, of which four stated that outbreaks had been smaller than in unvaccinated fish.

Upon request for descriptive response regarding vaccine efficacy, 27 responded. Amongst these, 16 mentioned winter ulcers, seven IPN, six PD, two Pasteurella vaccine, two yersiniosis, one ISA, one vibriosis (rainbow trout) and one atypical furunculosis (lumpsucker). Regarding winter ulcers, several replied that lack of efficacy may be due to outbreaks caused by a different variant of *Moritella viscosa* than the component in the vaccine . In 2022, several salmon producers adopted a new monovalent vaccine against so-called "variant *M. viscosa*", which is being tested in field trials. Some respondents believe they observed an improved vaccine effect against winter ulcers, but this will probably be better documented next year. Application for marketing authorization has been sent for this vaccine and it is currently being sold under exemption from approval.

In connection with vaccination in the hatchery phase, various acute side effects often occur in all or parts of the fish group. These side effects may be an attribute to the process and conditions of vaccination and/or due to side effect of the vaccine itself. Acute side effects of vaccination can be seen in the form of reduced appetite or increased mortality for a shorter period. Adverse events related to the vaccination may also occur which may affect the vaccine efficacy or side effects. A vaccine leak e.g. through the injection channel might result in the fish being exposed to a lower dose than planned. Incorrect injection or incorrect vaccine delivery could result in stronger side effects or a reduced effect, while contamination of vaccination equipment may lead to infection and mortality in fish shortly after vaccination. According to Table 4.4.1 (Chapter 4 Fish welfare), in 2022 there were 19 reports to the Norwegian Food Safety Authority regarding welfare incidents related to vaccination. This is an increase in the number of reports from both 2020 and 2021.

We asked "How often do you experience the following acute side effects of the vaccine and vaccination process in hatcheries". The responses were given on a scale from 1 to 5, where 1 corresponds to "very rarely/never" and 5 corresponds to "very often". The results (Figure 9.6.3) show that several respondents believe that acute side effects and unwanted events occur "very rarely/never" or "rarely". Nevertheless, there are also a number of replies in the categories from "Occasionally" to "Very often", especially regarding increased mortality and reduced appetite. The spread in the responses reflects that there is room for improvement in the routines around vaccination at few of the facilities. The follow-up question "Do you have any other/in-depth comments regarding acute side effects of the vaccine and the vaccination process (e.g. vaccine leakage, sea-transfer before the recommended number of days for immunity)?" was answered by eight respondents. Themes that were highlighted were: 1) "sea-transfer before the recommended number of day-degrees", where several mentioned that this is a known problem, but one respondent believed that there had been increased focus and improvement in recent years. 2) "vaccination technology/handling" where two respondents specifically mentioned that there is a need for "best practice" in lumpsucker vaccination.

We also asked "How often do you experience the following long-term side effects of vaccines in fish farms/on the slaughter line", where the sub-questions dealt with spinal deformities, reduced growth, melanin in fillets and degree of adhesions (Speilberg score). The responses were given on a scale from 1 to 5, where 1

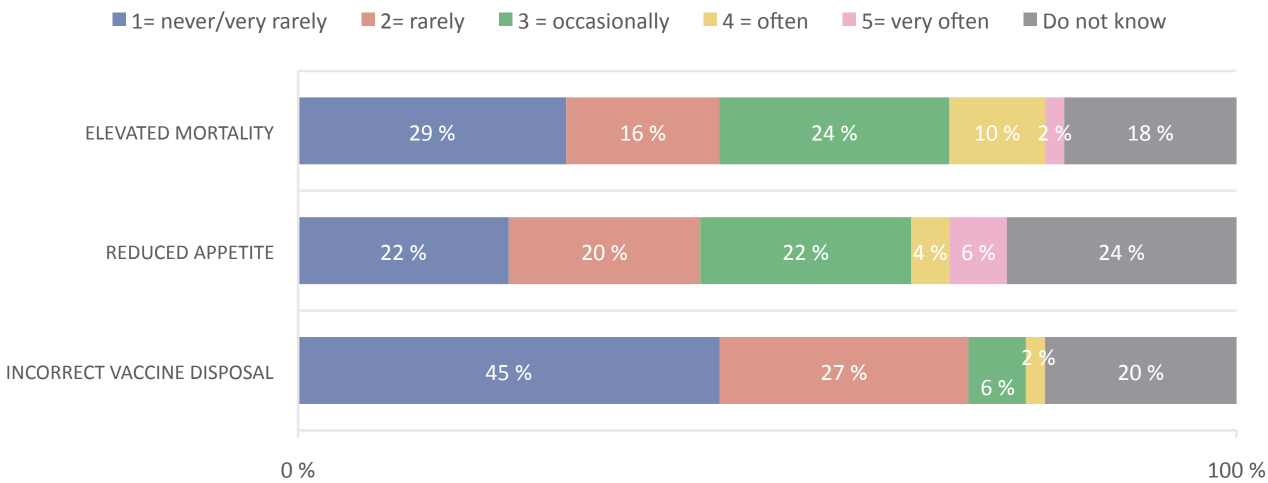


Figure 9.6.3 Summarized answers to the question: "How often do you experience the following acute side effects of vaccine and vaccination process in hatcheries?", with the side effects "Increased mortality after vaccination (N=49), "Reduced appetite beyond 7 days' duration" (N=49) and " Incorrect vaccine disposal in more than 5 percent of the vaccinated fish" (N=49). The answers are given on a scale from 1 = never/very rarely to 5 = very often, as well as the answer option "don't know". The columns for each acute side effect indicate in percent the number who have given the different answer options.

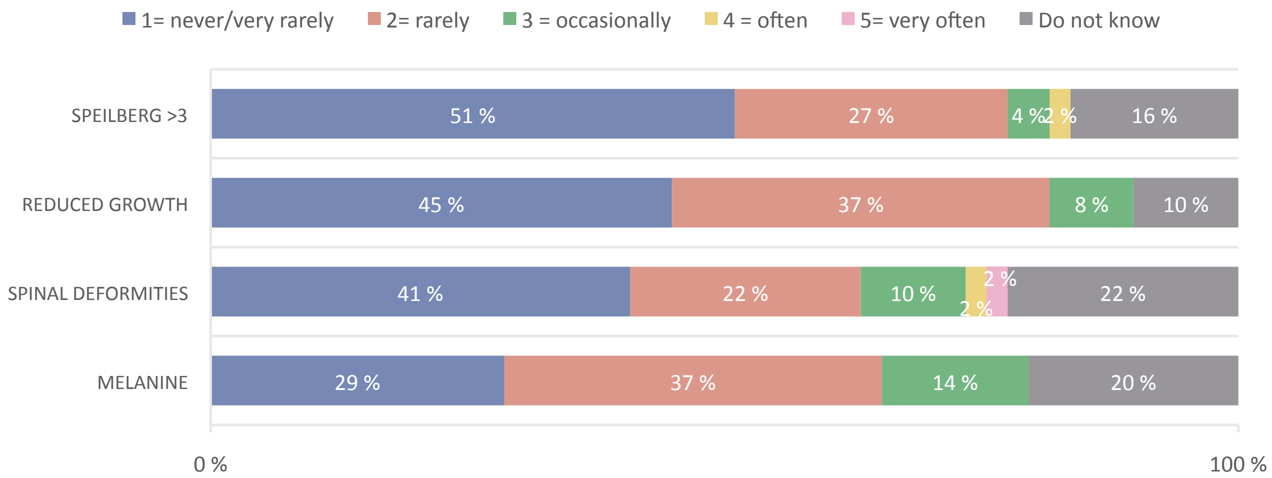


Figure 9.6.4 Summarized answers to the question: "How often do you experience the following long-term side effects of vaccines in grow-out fish farms/on the slaughter line?": "Speilberg score grade 3 or above, in more than 10% of examined fish" (Speilberg > 3, N = 49), "Suspicion about reduced growth in the fish group due to vaccine side effects" (Reduced growth, N = 49), "Suspicion of vaccine-induced spinal deformities in more than 5% of the fish" (Spinal deformities, N = 49) and "Suspicion of vaccine-induced melanin spots in muscles" (Melanin, N = 49).The answers were given on a scale from 1 = very rarely/never to 5 = very often, as well as the answer option "don't know". The columns for each long-term side effect indicate the percentage of the respondents who gave the various answer options.

corresponds to "very rarely/never" and 5 corresponds to "very often". The results (Figure 9.6.4) show that most respondents believe that long-term side effects above a certain extent occur relatively rarely. At the same time, the spread in the responses and the seriousness of the side effects reflect that there is still room for improvement.

The follow-up question "Do you have any other/in-depth comments regarding the long-term side effects of the vaccine?" was only answered by five respondents. This strengthens the impression that long-term side effects of vaccines are not considered to be a major problem.

In the overall questions regarding welfare in the survey, where a wide range of disease and welfare problems are compared, vaccine damage does not feature highly on the list of the most prominent welfare problems in salmon and rainbow trout farming. Nevertheless, there are some respondents who tick welfare problems related to vaccination as one of their "top five" in salmon farming, both at hatcheries and at grow-out facilities (see Table 9.6.1). On the other hand, none of the respondents believed that vaccine side effects are a major problem in rainbow trout farming. None, or very few, believed that vaccine side effects are a growing problem in salmon and rainbow trout farming.

Tabell 9.6.1. Number of respondents out of the number of responses (N), within different categories of salmon farming, who indicate that vaccine damage is among the 5 most important problems in terms of mortality, growth, welfare or as an increasing problem.

	Mortality	Reduced growth	Redused welfare	Increasing problem
Hatchery salmon	2 of 42	5 of 31	5 of 43	1 of 27
Hatchery rainbow trout	0 of 6	0 of 4	0 of 6	0 of 4
Grow-out salmon	0 of 63	1 of 57	1 of 63	1 of 52
Grow-out rainbow trout	0 of 5	0 of 5	0 of 6	0 of 3

9.7 Algae, jellyfish and fish health

By Alf Seljenes Dalum, Stefanie Wüstner, Martin Huun-Røed, Even Thoen (Patogen), Trine Dale (NIVA) and Geir Bornø

Algae and jellyfish

There are many thousands of species of algae. Of these, around 300 are known to cause algal blooms, while only 80 or so have the ability to produce potent toxins, and even fewer are recognised as injurious for fish. Of the jellyfish capable of damaging fish, four groups are particularly dominating i.e. the Sycphozoa, Hydrozoa, Siphonophora and the Ctenophora. The injuries inflicted by jellyfish on farmed fish may be indirect (e.g. blocking of nets leading to low oxygen levels) or direct (e.g. blockage of mouth and operculae, or the toxic effect of stinging nematocysts (not Ctenophora which lack nematocysts)). The effect of toxic algae, eaten by jellyfish, which in turn have been eaten by fish, has also been discussed as a possible mechanism.

The Health Situation in 2022

The annual survey

Based on responses from fish health personnel and Food Safety Authority inspectors to the annual questionnaire, algae do not appear to have been a serious cause for concern in 2022. However, losses of 20 percent over the course of a few days were reported from individual farms, illustrating that the consequences can be serious in some cases.

Eight of 52 respondents considered jellyfish to represent one of the most important increasing problems in 2022. Algae and jellyfish were also considered challenging in relation to welfare and reduced growth. Fish health personnel also consider current surveillance for algae, jellyfish and other zooplankton inadequate.

The jellyfish situation

Throughout the autumn and winter of 2022, fish health personnel have reported significant numbers of jellyfish during routine farm visits, particularly the increased prevalence of the string jellyfish Apolemia uvaria, a member of the Siphonophora. The geographical extent of the area affected has not been systematically mapped, but reports have been received from large areas of the coastline. Previous investigations have identified string jellyfish as far north as Finnmark.

10. The health situation of wild fish

By Åse Helen Garseth, Toni Erkinharju, Haakon Hansen, Øystein Nordeide Kielland, Raoul Valentin Kuiper, Hege Løkslett and Julie Svendsen

In 2022, 43 years after the introduction of *Gyrodactylus salaris*, the Skiboth infection area was declared free from the parasite. The control strategy has been a success and has significantly decreased the risk of further damage to wild salmon on a national level.

At the same time as one disease-causing organism is defeated, other disease challenges gain increasing scope and importance. In several watercourses, the oomycete *Saprolegnia parasitica* had a strong impact on the spawning populations in the autumn of 2022. Salmon, sea trout and freshwater resident brown trout were affected.

Vibriosis, caused by *Vibrio anguillarum* is a well-known disease in wild marine fish at high seawater temperatures, typically late in the summer. In September 2022, a rare case of mortality due to this infection was recorded in two rivers in the inner Oslofjord. Seawater temperatures were high, and water flow in the rivers was low. Atlantic salmon at high densities were observed milling in the estuary. Vibriosis is a disease to be reckoned with in the ongoing climatic changes.

Investigation of disease outbreaks in wild salmonids is also reminding us that *Ichthyophthirius multifiliis*, "Ich" is a parasite to be reckoned with as water temperatures increase. We need more information about the occurrence and local impact of this very pathogenic parasite.

In 2022, a new parasite discovery was made in pink salmon that had been kept in a freezer since 2021. The pink salmon was found moribund prior to spawning in 2021 and histological investigation revealed infection with *Ichtyophonus* sp.

Escape of farmed fish that carry diseases was highlighted when 35 000 salmon from a sea site diagnosed with pancreas disease (PD) escaped. With a high number of escaped fish in the rivers, both the genetic integrity and the health of wild salmon are threatened.

Infestation of salmon lice that spill over from aquaculture is a significant threat to wild salmon, sea trout and char. The aim of the Traffic light system is to ensure susctainable growth of the aquaculture industry. However, exemptions in the provisions provide loopholes that ensure growth regardless of the colour of the traffic lights. Thus, the principle of sustainability is set aside at the expense of the welfare and productivity of both wild and farmed salmonids.

The Norwegian Veterinary Institute handles the public's responsibility for clarifying infectious diseases also in wild fish in the sea. In 2022, mass mortalities in horse mackerel and silvery lightfish were recorded, but infections that could explain the mortality was not detected. Mycobacteriosis was detected in one wild cod. In connection with an outbreak of classic vibriosis in wild salmon in the Lysakerelva, mortality was also recorded in the European flounder in the same area. Vibrio anguillarum, which causes vibriosis, was not detected, but the European flounders were emaciated and had adenomas and cellular changes in the digestive gland. These are indicators of organic pollution.

10.1 Notification system for diseases in wild fish

According to the Norwegian Food Act and the Animal Health Regulations, everyone are obligated to notify the Food Safety Authority when there are reasons to suspect infectious animal disease with societal consequences. The fact that the duty to notify also includes wild fish is unknown to many. In 2020, the Norwegian Veterinary Institute (NVI) launched a national notification system for disease in wild fish in cooperation with the Norwegian Food Safety Authority (NFSA). The system is a part of the health surveillance of wild fish, and the main purpose is to detect serious incidents which are relevant for the fish health in Norway. In addition to providing valuable information about the general health situation for wild fish, the system identifies health challenges which should be monitored more actively. The notification system applies for fish both in freshwater and in the marine encironment. Notified cases are assessed by pathologists, and everybody who reports a case will receive an answer from the NVI.

The system for notifications may also be used for other purposes than infectious disease. The more the system is applied, the more information we gather regarding the health of wild fish, and as a result our knowledge on this topic is strengthened. If in doubt, it is better to notify about a disease rather than not.

There were 39 reported cases in 2022, which is at about the same level as in 2020. There was a significantly higher amount of cases in 2021. Several of the cases were reported to the NVI through other channels than the online message portal, many of these from the county governor. The reports encompassed disease in salmon, trout, arctic char, pike, cod, perch, european flounder, haddock, horse mackerel and Mueller's pearlside. The reports originated from the entire country, the majority from coastal regions (Figure 10.1.1).

The main findings in 2022 includes serious saprolegniosis in several rivers, classic vibriosis in rivers in the inner parts of the Oslo fiord,

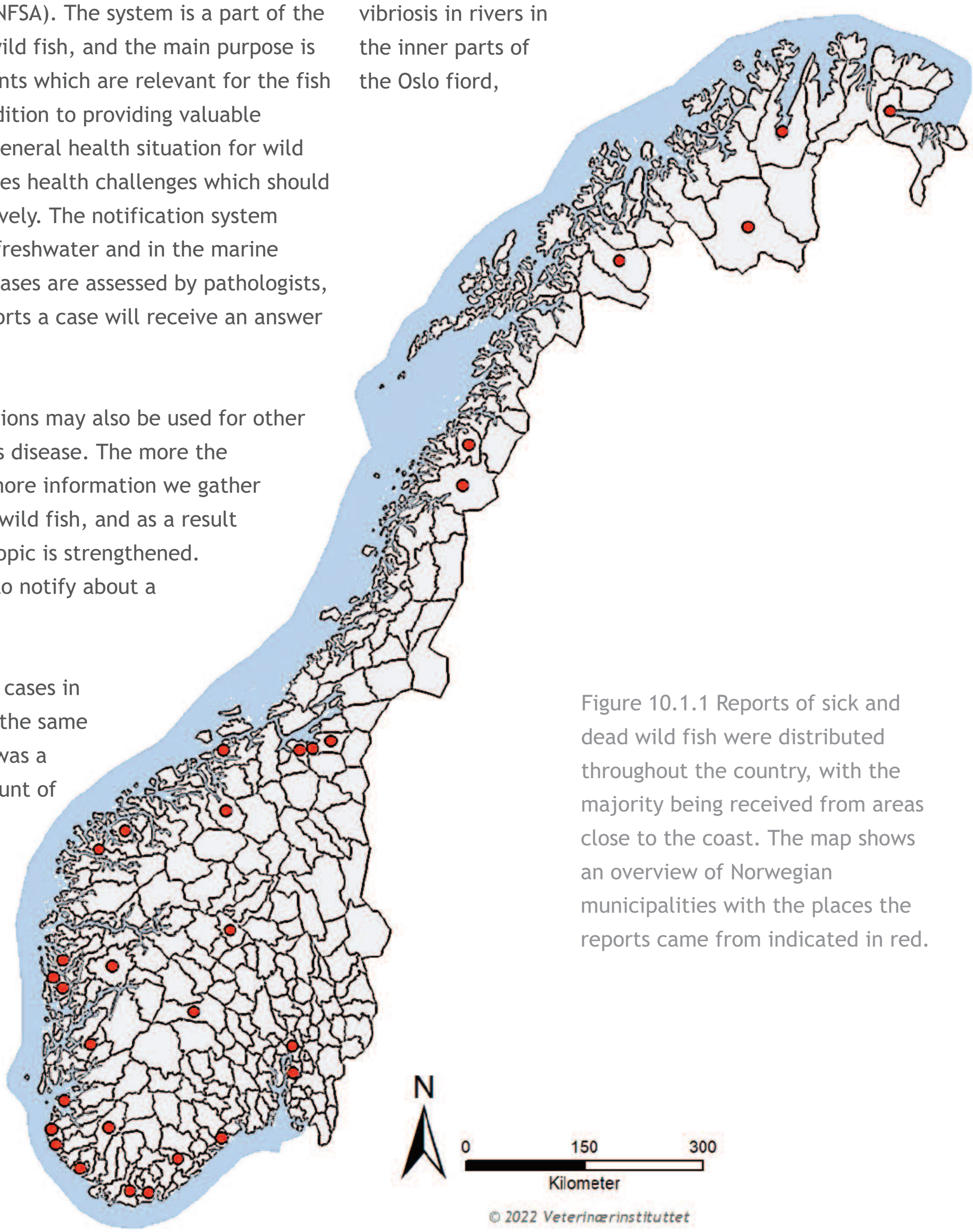


Figure 10.1.1 Reports of sick and dead wild fish were distributed throughout the country, with the majority being received from areas close to the coast. The map shows an overview of Norwegian municipalities with the places the reports came from indicated in red.

mycobacteriosis in cod, mass mortality in marine schooling fish, as well as several cases with suspicion of papillomatosis or other skin changes in salmon fish. As in previous years there are also several cases involving intestinal worms or other parasites. Here are some selected cases that were reported in the previous year. Some of these were reported through the notification system, while others were reported through other channels.

Other relevant notification systems

Some of the enquiries in the Wild fish health portal concern species identification, at times in combination with disease findings. Discoveries of alien species must be notified to the Norwegian Biodiversity Information Centre (Artsdatabanken) via the species observations database (Artsobservasjoner). Furthermore, the Institute of Marine Research has established a marine citizen science website, in Norwegian called "Dugnad for havet", where you can record your observations and help map the occurrence of different species in the ocean. Acute pollution should be notified to the fire department using the emergency hotline number 110.

Classic vibriosis in wild salmon in River Lysakerelva and River Akerselva

Classic vibriosis is a systemic infection with the bacterium *Vibrio anguillarum* (*V. anguillarum*) (Figure 10.1.2). The bacterium is commonly found in seawater and brackish water, and causes disease in several species of wild and farmed fish throughout the world. In Norway, the disease caused significant mortality in salmon farming in the 1980s and 1990s before effective vaccines were introduced. It is not uncommon to observe outbreaks of classic vibriosis in marine wild fish, and in addition, sporadic cases are seen in farming, especially in late summer at high water temperatures.

Classic vibriosis in wild Atlantic salmon is uncommon, but anecdotal descriptions do exist. In August and September 2022, the infection caused mortality in wild salmon in River Lysakerelva and River Akerselva, both draining to

Figure 10.1.2 Culture of *Vibrio anguillarum* from internal organs (kidney) is a central element in the diagnosis of vibriosis. Photo: Duncan Colquhoun, Norwegian Veterinary Institute

Figure 10.1.3 Necrotic lesions and haemorrhages in a wild salmon with vibriosis. Photo: Frode Dalen

the inner Oslofjord. The total number of dead salmon is uncertain in River Akerselva, and estimated to 60 salmon in River Lysakerelva.

Disease symptoms in infected fish are apathy and mortality in individuals with ulcers or bleeding in the skin and blood stained boils in muscles (Fig. 10.1.3). Infected fish may also have protruding eyes (exophthalmos). At autopsy, fluid can be observed in the abdominal cavity (ascites), small haemorrhages on organs and fatty tissue (petechia), and also enlarged spleen.

High water temperatures are often decisive for the development of classic vibriosis. Since *V. anguillarum* is a common bacterium in seawater and brackish water, the salmon were probably infected there. Low water levels and water flow in the affected rivers seem to have hindered or delayed the salmon run and resulted in high fish density in the estuary and thus increased probability of infection. Damage to the skin barrier, for example caused by salmon lice and predators, may also have been a contributing cause of infection.

Figure 10.1.4 Severe saprolegniois due to *Saprolegnia parasitica* in wild Atlantic salmon in River Homla, Trøndelag. Photo: Åse Helen Garseth, Norwegian Veterinary Institute

When the infection has established in members of a fish population, the bacterium multiplies in the fish with consequent increasing infection pressure and the development of disease. With climate change, rising water temperatures are expected in both sea and freshwater, as well as lower water flows in rivers. Classic vibriosis may thus become a more common diagnosis in the years to come.

Vibrio anguillarum primarily infects finfish, crustaceans and shellfish. Disease in humans with compromised immune systems has been described.

Saprolegniosis caused by *Saprolegnia parasitica*

Saprolegniosis is a disease condition caused by oomycetes in the saprolegnia family. Saprolegnia sp is not a fungi but share some similar features. Saprolegnia is found in freshwater and mainly causes disease in fish with a damaged mucus layer, damaged skin or a fish which are subjected to stress. In wild fish the disease is most commonly seen in spawners, or in fish that have been handled (catch and release) or under particularly unfavourable environmental conditions. Saprolegnia infects the skin and most commonly starts in scale-less areas including the head and fins. If the affected areas become too large, the fish can die due to failure to maintain an appropriate salt/water balance (osmotic failure). The fungus may affect the gills resulting in the fish suffocating. If mortality occurs before spawning, the spawning stock numbers can also be affected. The disease is easily diagnosed as it results in a white, cotton-wool like layer spread across the surface of the fish. However, there are different species within the Saprolegnia family, and these have different abilities to cause disease. In 2022, *Saprolegnia parasitica* caused mortality in several rivers. This species has caused between 0 and 89% mortality in infection trials.

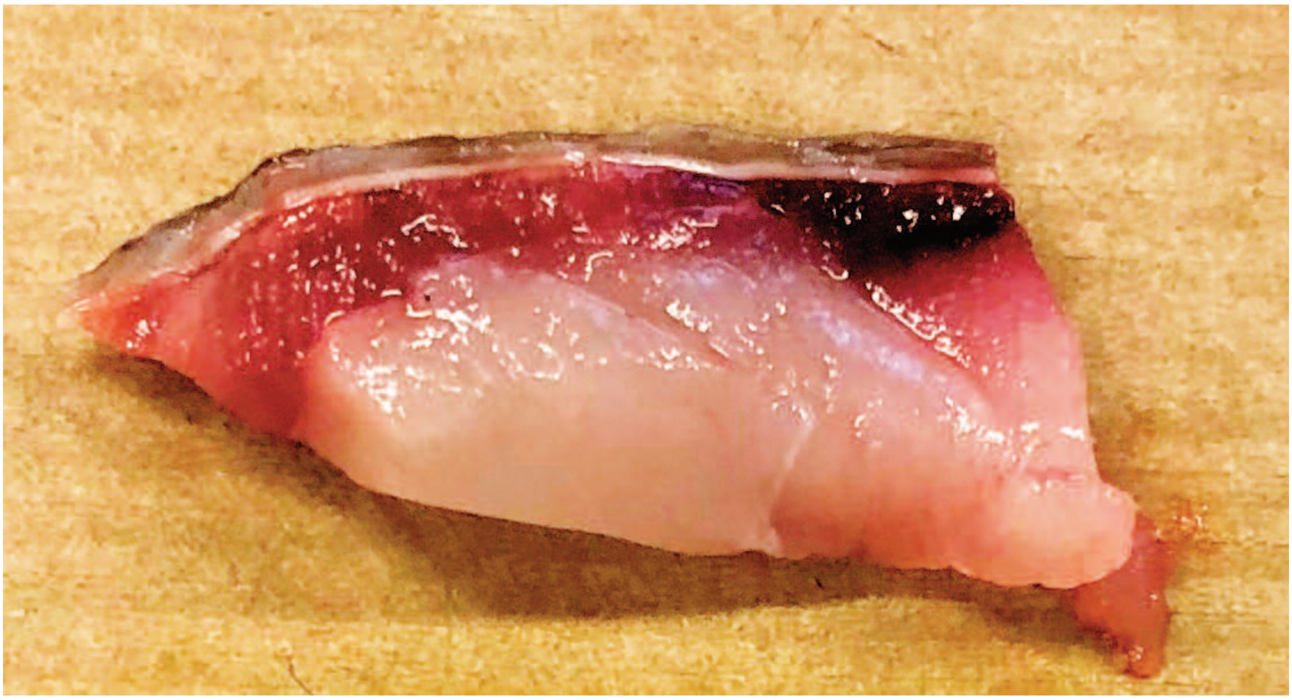


Figure 10.1.5 Section through skin and muscle. Beneath the fungal lesions, bleeding is seen in the skin, subcutaneous tissue and muscle. Photo: Åse Helen Garseth, Norwegian Veterinary Institute

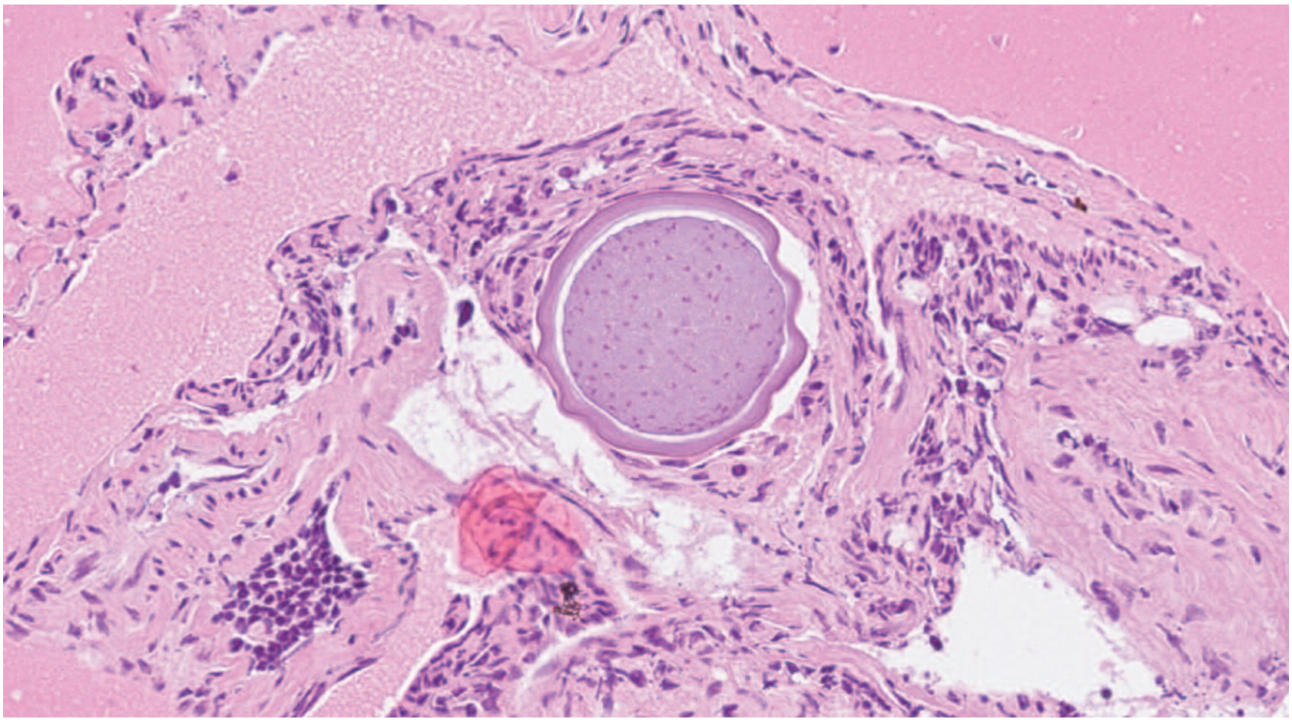


Figure 10.1.6 Histological tissue section of pyloric ceca from pink salmon showing a singular, double-walled fungal-like parasitic structure (consistent with *Ichthyophonus* sp.) within the intestinal wall. Photo: Toni Erkinharju, Norwegian Veterinary Institute

Ichthyophonosis in pink salmon (*Oncorhynchus gorbuscha*) in Troms & Finnmark

In September, NVI received two frozen pink salmon, originally found in River Lakselva, Porsanger in August of the previous year (2021). The pink salmon had shown abnormal behaviour and were passive in shallow water. The gills were pale, but otherwise the fish appeared to be in good condition. Both were female and ready to spawn with a lot of eggs in the abdominal cavity.

A routine autopsy and organ examination was carried out with tissue sampling for histological, microbiological (bacteriology and virology) and molecular biological examinations. Histopathological examination revealed several round, double-walled structures of varying sizes in several organs in one of the pink salmon (Figure 10.1.6.). Heart and skeletal muscled were particularly affected, but generally there were no or only a mild degree of local tissue response.

Based on the histpathology Ichthyophonosis was suspected. This is a systemic disease caused by *Ichthyophonus* sp., a parasite in the class Mesomycetozoea, which is a group of microorganisms between fungi and animals. PCR and DNA sequencing of parts of the ribosomal 18S gene in samples from skin, heart and gills, and comparison with DNA sequences of Ichthyophonus in GenBank confirmed the suspicion. .

There is some uncertainty with regard to both species diversity and host specificity within the *Ichthyophonus* genus. Currently only two species have been formally described, *Ichthyophonus hoferi (I. hoferi)* from rainbow trout and *I. irregularis* from yellowtail flounder *(Limanda ferruginea*). However, there are strong genetic indications that the genus includes more species than the two described so far.

I. hoferi has been detected in pink salmon captured in the Gulf of Alaska by PCR analysis. To our knowledge, this is the first reported case of Ichthyophonosis in pink salmon in the Atlantic ocean. *I. hoferi* has low host specificity and has been described from more than 100 different fish species, including several salmonids. The parasite has caused mass mortality in herring, disease outbreaks in rainbow trout and has previously also been detected in cleaner fish within aquaculture. It is recommended to include this parasite during future health monitoring of pink salmon.

Mass mortality in marine schooling fish

From time to time, mass mortality of marine schooling fish are observed. These cases always trigger speculation about possible causes, such as chasing by predators, harsh weather conditions, the fish being caught in pockets of fresh water or injured during fishing.

Since mass mortality is a strong indication of infectious diseases, the cases should always be reported and investigated by the Norwegian Veterinary. In 2022, we received reports of mortality in Atlantic horse mackerel (*Trachurus trachurus*) in Gumøy, Kragerø municipality and in silvery lightfish (*Maurolicus muelleri*) in Salhusfjorden, Bergen (Figure 10.1.7). In both cases, we received dead fish for examination. Samples were cultivated for viruses in several cell lines and for bacteria on growth media. In addition, silvery lightfish were examined for ISAV and VHSV by qPCR. The investigation did not detect infectious agents that could explain the mortality.

Mortality in European flounder (*Platichthys flesus*) in the inner Oslofjord.

During the outbreak of vibriosis in wild Atlantic salmon in River Lysaker, several dead European flounders were observed in the estuary and along the river banks. The flounders were emaciated, had empty intestinal tracts and large gall bladders, all indication that they had not taken food for a period. Parasites (*Ichthyobodo* sp. and gill maggots) were detected, but *Vibrio anguillarum*, the bacterium causing vibriosis was not found.

Flounders have a so-called digestive gland (hepatopancreas), where pancreatic tissue occur as scattered foci within the liver. Adenomas, that is benign tumours in the digestive gland, were found in one of the flounders. "Benign" in this context means that the tumours appear locally in the digestive gland, without spreading to other organs.

Figure 10.1.7 In 2022, several dead horse mackerel were observed at Gumøy, Kragerø. Photo: Ragnhild Helsing

Figure 10.1.8 Emaciated European flounder from River Lysakerelva, Photo: Raoul Valentin Kuiper, Norwegian Veterinary Institute

In addition to the adenomas, areas with cells that stain more eosinophilic (pink) than usual with routine hematoxylin-eosin staining were detected. These eosinophilic areas, called Focus of Cellular Alteration (FCA) are associated with pollution with organic chemicals. Occurrence of FCA in flounder and common dab (*Limanda limanda*) is therefore used as an indicator in monitoring of pollution.

Mycobacteriosis (fish tuberculosis) in Atlantic cod (*Gadus morrhua*)

In February 2022, a male cod with small white pearls in the abdominal cavity was captured outside Nordfjordeid. The clinical signs are comapatible with both mycobacteriosis and franciscellosis caused by *Francisella noatunensis* subsp. *noatunensis*, which is a listed disease in cod. The veterinary institute received a spleen with multiple bright nodules, as well as a head (figure 10.1.10). On histopathological examination of the spleen and peudobranch with routine HE staining and special stains, multiple granulomas (chronic inflammatory nodules) infiltrated with large amounts of gram-positive, acid-fast bacteria were detected.

These are findings that are associated with infection with *Mycobacterium* sp., and immunohistochemical

Figure 10.1.9: Hepatopacreas in European flounder. Pancreatic tissue (pancreas, marked with *.) usually occurs scattered in the liver in this species. Several smaller groups of eosinophilic (pink) cells are observed (so called focus of cellular alteration, FCA). The larger structure, that compresses surrounding tissue is an adenoma (marked with an A). HE staining, scale = 250 µm. Photo: Raoul Valentin Kuiper, Norwegian Veterinary Institute

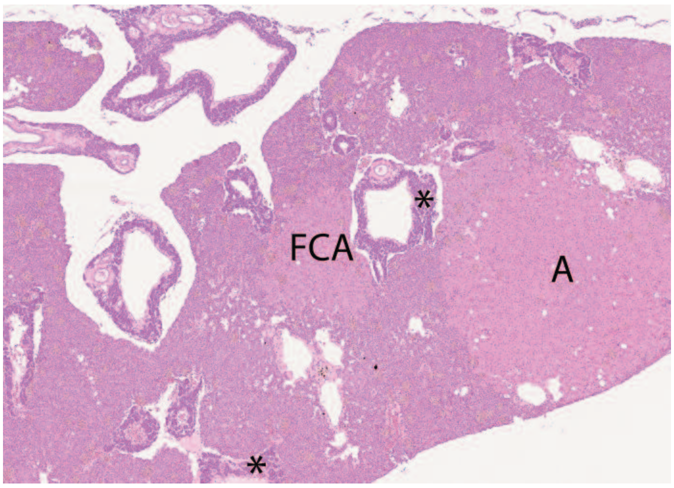


Figure 10.1.10 Spleen permeated by creamy white "nodules", approx. 1-3 mm in diameter. Photo: Anne Berit Olsen, Norwegian Veterinary Institute

examination gave positive labelling of the bacteria. When cultured from the spleen, *Mycobacterium* sp. grew, which on the basis of phenotypic and genotypic investigations was identified as most similar to *Mycobacterium salmoniphilum (M. salmoniphilum*). It was thus concluded that this was a serious case of mycobacteriosis.

Mycobacteriosis is caused by mycobacteria, and usually occurs as a chronic disease with variable mortality. The disease is known in a large number of fish species worldwide. Affected individuals may become emaciated over time and have light nodules in their internal organs. There are several species of mycobacteria, but only a few are associated with disease in fish.

Most fish pathogenic mycobacteria, including *M. salmoniphilum*, do not grow at 37 ℃, and there is currently no reliable basis for claiming that human consumption of fish with mycobacteriosis represents a health risk. Several mycobacteria, including *M. marinum* and *M. chelonae*, which are closely related to *M. salmoniphilum*, can still cause infections in the skin of humans in the form of superficial granulomas and wounds, and can spread to deeper tissues in people with compromised immune systems. In general, it is recommended to take precautions by protecting damaged skin when handling fish.

Francisella noatunensis is a bacterium that can cause similar changes in internal organs (especially the spleen) in cod. This was the background for the suspicion of franciscellosis in this case. The Veterinary Institute is the national reference laboratory for fish and crustacean diseases. In the case of findings that give grounds for suspecting a listed disease, samples must be sent to the Veterinary Institute for verification of the diagnosis.

Health monitoring for the Norwegian Food Safety Authority

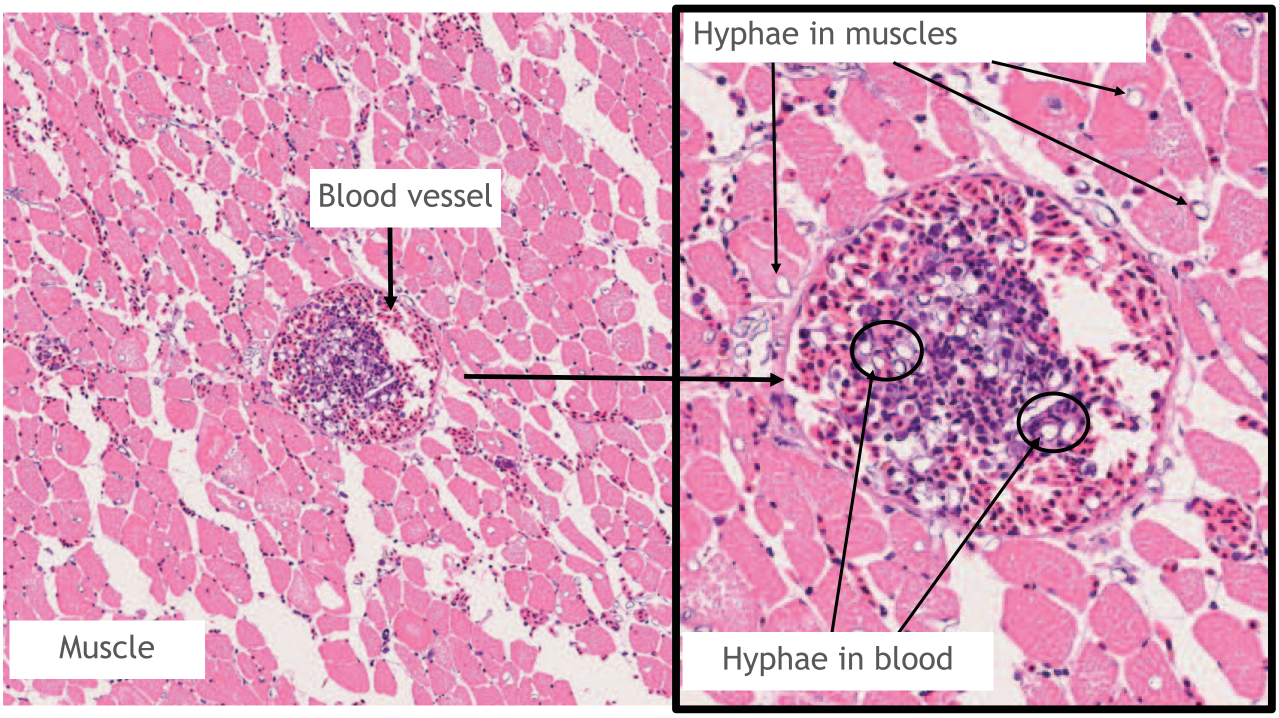
During the period 2012 to 2021, the overall purpose of the health monitoring program for wild salmonids was to investigating occurrence of pathogens in wild salmonids (salmon, trout and char). During this period, the program was carried out as a qPCR-based screening of samples from wild-caught spawners that were used as broodstock of stock enhancement hatcheries and samples from clinically healthy wild fish from other sources. This has provided valuable information on the occurrence of a number of infectious agents in wild fish.

From 2022, the monitoring program was altered to be an extended diagnostic effort in the investigation of disease in wild fish. The samples used in the programme thus originate from sample material provided by the national notification system for disease and mortality in wild fish,- the "wild fish health portal". The monitoring program consists of traditional cultivation for bacteria on growth media and cultivation for the detection of cultivable viruses on a panel of cell lines.

By examining diseased fish rather than random healthy fish, and at the same time relying on cultivation, the probability of discovering known cultivable pathogens but also hitherto undescribed infectious agents increases.

The monitoring program is therefore an important contribution to anticipatory preparedness, i.e. anticipating tomorrow's health problems in wild and farmed fish. The program also provides monitoring of, for example, infectious haematopoietic necrosis (IHN), viral haemorrhagic septicemia (VHSV), ranavirus, *Aeromonas salmonicida* subsp. *salmonicida* (classic/typical furunculosis), *Pasteurella* sp., *Yersinia ruckeri*, etc.

In 2022, no cultivable viruses were detected when examining diseased wild fish. In addition to the detection of *Vibrio anguillarum* in wild salmon and *Mycobacterium salmoniphilum* in cod described in this sub-chapter, *Yersinia ruckeri* O2 was detected in a wild salmon. *Yersinia ruckeri* O2 is not the same variant that has caused disease in Norwegian farmed salmon.



Figur 10.1.11 *Saprolegnia parasitica* invading muscles and blood vessels in a wild salmon from Mandalselva. Photo: Mona Gjessing, Norwegian Veterinary Institute

10.2 The health situation in the wild salmonid brood fish

The Norwegian gene bank program for wild Atlantic salmon was established in 1986 by the Norwegian Environment Agency as a measure to safeguard threatened salmon populations. Today the Genbank program also include anadromous trout (sea trout) and anadromous Arctic char. The Genbank program consist of cryopreserved milt at two different biorepositories and five gene bank stations where salmon populations are maintained as living fish, called live gene bank. The salmonids in the live gene banks are offspring of wild founder fish that were captured in the rivers.
The five live gene banks are Bjerka i the county of Nordland, Haukvik in Trøndelag, Hamre and Herje in Møre og Romsdal and Ims in Rogaland.

The Veterinary Institute is the national centre of expertise for the Norwegian gene bank program and coordinates activities under contract from the Norwegian Environment Agency. This includes a responsibility for fish health and biosecurity.

The aim of the gene bank's biosecurity strategy is 1) prevention of amplification and spread of infectious disease during reestablishment and restocking projects, 2) secure good fish health within the gene bank itself and thereby avoid genetic selection and/or loss of the important genetic stocks.

Health examination and risk assessment

Introduction of fish material is potentially the most important source of infection for the gene bank facilities. To reduce the risk of infection, only disinfected eggs are introduced to gene banks, and only from parent fish that 1) have been assessed as wild on the basis of scale analysis at the Veterinary Institute and gene analysis at the Norwegian Institute for Nature Management, 2) have passed the health examination.

The main aim of the health examination is to reduce the likelihood of introducing infectious with disinfected eggs. Accordingly, the emphasis is particularly on known vertically transmissible infectious agents. The gene bank also has a responsibility to reduce the likelihood of introducing infectious agents with unknown route of infection the gene bank facilities. Various measures are therefore used to accomplish this:

1. Research on vertical transmission of infection: The gene bank has its own research and development activity where vertical transmission, from parents to offspring, is investigated through testing of offspring from infected broodstock.
2. Risk-benefit assessment: In addition, a risk-benefit assessment is made in each individual case. Here, both the properties of the relevant infectious agent, occurrence in the environment, amount of infectious agent in examined material (Ct values) and how important the individual fish is to the conservation work are assessed.

The health controls in wild fish the Genbank must also follow trends in the general fish health situation in Norway. Fish diseases caused by bacteria are on the rise in the farming industry, including typical furunculosis, pasteurellosis and yersiniosis. With the ongoing climate changes, it is also expected that bacterial diseases will increase in occurrence and importance. There is a need to monitor this development. Cultivation for bacteria from wild-caught broodfish was therefore reintroduced in 2021.

The health controls of the wild founder broodstock consist of necropsy, PCR analyses and bacteriology. Histological examinations are carried out in case with abnormal autopsy findings. In addition, sample material from broodstock with abnormal autopsy findings is included in the Norwegian Food Safety Authority's health monitoring program for diseases in wild fish (Chapter 10.1 Notification system for diseases in wild fish).
After health control and stripping, fertilized eggs are kept in a quarantine facility until test results and conclusions from the health examinations are available. Organ samples on RNAlater from all wild founder fish are stored in a biobank for retrospective investigations and research.

In a limited number of watercourses, the stocks are so weakened that adult broodstock are not available. In these cases, salmon fingerlings are captured, genetically tested (wild/farmed) and then bred into broodstock (fingerling-based gene bank). When these fingerlings become broodfish and are stripped for milt and eggs, they are subject to the same health examinations as wild-caught broodstock.

Results

In 2022, 359 salmon and 270 sea trout were examined. PCR analyses of kidney tissue were carried out for *Renibacterium salmoniarium* which causes bacterial kidney disease (BKD), infectious pancreatic necrosis virus (IPNV) and piscine orthoreovirus (PRV-1 in salmon and PRV-3 in sea trout). In addition, gill tissue was analysed for infectious salmon anaemia virus (ILAV).

Bacterial investigations

In 2022, bacterial investigations comprised cultures from headkidney on blood agar, blood agar with 2% NaCl, and selective kidney disease medium (SKDM). *Renibacterium salmoninarum* (BKD), *Aeromonas salmonicida* ssp. *salmonicida* (typical furunculosis) were not detected. There was sporadic growth of mixed flora with bacteria that are found in the environment and that can cause secondary infections in weakened fish such as *Carnobacterium maltaromaticum* and *Pseudomonas* sp.

PCR-analyses

The wild founder fish are kept together in tanks prior to stripping and health examination. It is therefore possible for infectious agents to spread from one host to several hosts during the cohabitation period. Accordingly, the founder fish have a higher prevalence of infectious agents than in wild fish in waterways. However, fish from different watercourses are not kept together. These two factors must be taken into account when interpreting results.

PRV-3 was detected in 43 out of 270 sea trout in 12 out of 14 rivers examined. PRV-1 was found in 12 out of 359 (3.3 percent) salmon, but only from two out of 21 examined rivers. For both PRV-3 and PRV-1, the within-river result can be affected by operational conditions such as duration of holding time in tanks.
We nevertheless see that there are geographical differences in the occurrence of PRV-1 in 2022, which this year was detected in Helgeland and Sunnmøre, but not in the Drammen, Hardanger and Driva regions. However, PRV-3 was detected in all investigated regions. PCR assays for IPNV, R. salmoninarum and ILAV-HPR0 were negative (Table 10.2.1).

Histology

No notifiable diseases were detected.

Table 10.2.1 Results from PCR-analysis for *Renibacterium salmoninarum* (BKD), infectious pancreatic necrosis virus (IPNV), infectious salmon anaemia HPR0 (ISA-HPR0) and Piscine orthoreovirus 1 (PRV-1, salmon) and 3 (PRV-3 sea trout) performed on wild-caught broodstock destined for the gene bank for wild salmon.

Region	Salmon (No.)	Sea trout (No.)	PCR positive (No.)
Drammen (PO1)	43	102	5 PRV-3
Hardanger (PO3)	119	98	28 PRV-3
Hardanger (PO3) Parrbasert	17	0	0
Driva- and Sunnmøre (PO5 and PO6)	140	70	10 PRV-3, 8 PRV-1
Helgeland (PO8)*	40	0	4 PRV-1
Total	359	270	43 PRV-3, 12 PRV-1

*Analysed for PRV-1, BKD, IPNV and PMCV

10.3 *Gyrodactylus salaris*

The Disease

Gyrodactylus salaris (G. salaris) was introduced to Norway in the 1970s and has so far been detected in 51 Norwegian rivers. The last detection was in 2019, in the River Selvikvassdraget, Vestfold & Telemark. The parasite has caused catastrophic declines in the salmon populations of affected rivers and the aim of the authorities is to eradicate it from all infected rivers . The Veterinary Institute is the national centre of expertise regarding eradication of G. salaris and as such is responsible for all eradication operations in Norwegian rivers. All control measures are performed under contract from the Norwegian Environment Agency.

Monitoring for Gyrodactylus salaris in Norway in 2022

The Norwegian Veterinary Institute coordinated three surveillance programmes in 2022 for G. salaris, 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 the River Drammenselva upstream of the waterfall 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 3126 salmon and rainbow trout from 90 hatcheries and 2273 salmon from 72 rivers were examined in the OK-programme in 2022. *Gyrodactylus salaris* was not found. In the FM-programme, 657 salmon from four river catchments (Fusta, Nordland county and the rivers Skibotnelva, Signdalselva and Kitdalselva), and fins from 533 arctic char from three lakes in the Fusta catchment, Nordland county, were examined. *G. salaris* was not found.

Infection status and the current threat situation

The eradication measures carried out in the last decades have substantially reduced the number of infected salmon populations in Norway. At the end of 2022, only eight rivers are known to be infected by *G. salaris* (figure 10.3.1). These are the rivers Drammenselva and Lierelva in Viken county, River Sandeelva (Vesleelva) and River Selvikvassdraget in Vestfold and Telemark county, and the rivers Driva, Usma, Litledalselva and Batnfjordselva in Møre og Romsdal county.

Following eradication measures carried out in 2015 and 2016, and subsequent analyses in the FM-programme, the rivers in the Skibotn infection region, Troms & Finnmark county, were declared free from infection with *G. salaris* in 2022. The Fusta catchment in Nordland county is per 2022 the only catchment included in the FM-programme.

There were no reports of detections of *G. salaris* in areas bordering Norway in 2022.

Eradication measures in 2022

The first round of treatment in the Driva region, Møre og Romsdal county, started in 2022. This was the first attempt to eradicate G. salaris using a novel method combining the chemicals chlorine and rotenone. Chlorine was applied as a main chemical in the rivers of Litledalselva and Driva, while the rivers of Usma and Batnfjordselva, and the peripheral areas were treated exclusively with rotenone. In the Drammen infection region, preparations for future eradication measures have started.

Skibotn infection area

In the Skibotn region in Troms and Finnmark, restoration of sea trout and char stocks is ongoing and might complete in 2024. The replenishment of salmon roe from live gene bank has completed.

Driva infection area

Gyrodactylus salaris was detected in River Driva in Møre og Romsdal county for the first time in 1980 and has remained infected ever since. The infection area includes the rivers Driva, Litledalselva, Usma and Batnfjordelva and some smaller streams. Driva is a long river, 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 at Snøvasmelan, approximately 25 km from the river mouth. All salmon present upstream of the barrier at the time of construction were assumed to have migrated downstream and out of the system by the start of treatment in August 2022. The treatment, using chlorine as main chemical component in the rivers Driva and Litledalselva, was initiated in August 2022. At the same time, several rivers located further out in the fjord were treated with rotenone, including the infected rivers Usma and Batnfjordselva. The entire stretch of the main rivers, as well as smaller streams and other accessible water catchments in their vicinity were treated. A new round of treatment is planned for August 2023.

To conserve the sea trout population in the Driva watercourse, all sea trout stopped by the fish barrier are released upstream the barrier following both genetic testing and saltwater treatment. Genetic testing and saltwater treatment is done to prevent the unintentional movement of hybrids and to remove any parasites. Since 2020, also sea trout caught downstream of the barrier have been transported across the barrier. The Atlantic salmon in the watercourse are preserved in both live and “frozen” gene banks. New families were added in 2018 and 2021. The conservation work for salmon in River Batnsfjordelva has followed a similar plan. In 2020, collection of material intended for gene bank from the Driva region was extended to include sea trout from the rivers Batnfjordselva and Litledalselva, and salmon and sea trout from river Usma. The work in 2022 was carried out as in 2021. The eradication and preservation project coordination group is led by the County Governor for Møre og Romsdal county and includes representatives from the Norwegian Food Safety Authority, the Environmental Agency and the Norwegian Veterinary Institute as well as a local coordinator employed by the Municipality of Sunndal.

Drammen infection area

This region comprises the four rivers Drammenselva, Lierelva, Sandeelva and Selviksvassdraget, all of which are infected with *G. salaris*. In 2018, an expert group established by the 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. As of today, experience with using the chlorine method is lacking and its further use is dependent on the experience and knowledge that will be gained in Driva and Litledalselva during the ongoing treatments. In preparation for future treatment, hydrological and mapping surveys of River Lierelva, as well as of the downstream areas of River Drammenselva were carried out during 2022. Only supplementary mapping of Drammenselva and its tributaries remain to complete the mapping process.

Since 2016, the Norwegian Veterinary Institute has collected wild salmon from Lierelva and Drammenselva for inclusion of their offspring in the gene bank for wild salmon. The collection was extended in 2020 to include salmon and sea trout from River Sandeelva and River Selvikelva in Vestfold, and sea trout from River Lierelva in 2021. To preserve the sea trout population in Drammenselva, all sea trout reaching the fish barrier at Hellefossen waterfalls are transported upstream following genetic testing and saline water treatment. The fish ladder at Hellefossen waterfall has been closed for salmon since 2019, and the presence of salmon and *G. salaris* above Hellefossen are monitored in a separate monitoring programme. The eradication and preservation project coordination group is led by the County Governor for Oslo og Viken and includes representatives from the Food Safety Authority, the Environmental Agency and the Veterinary Institute.

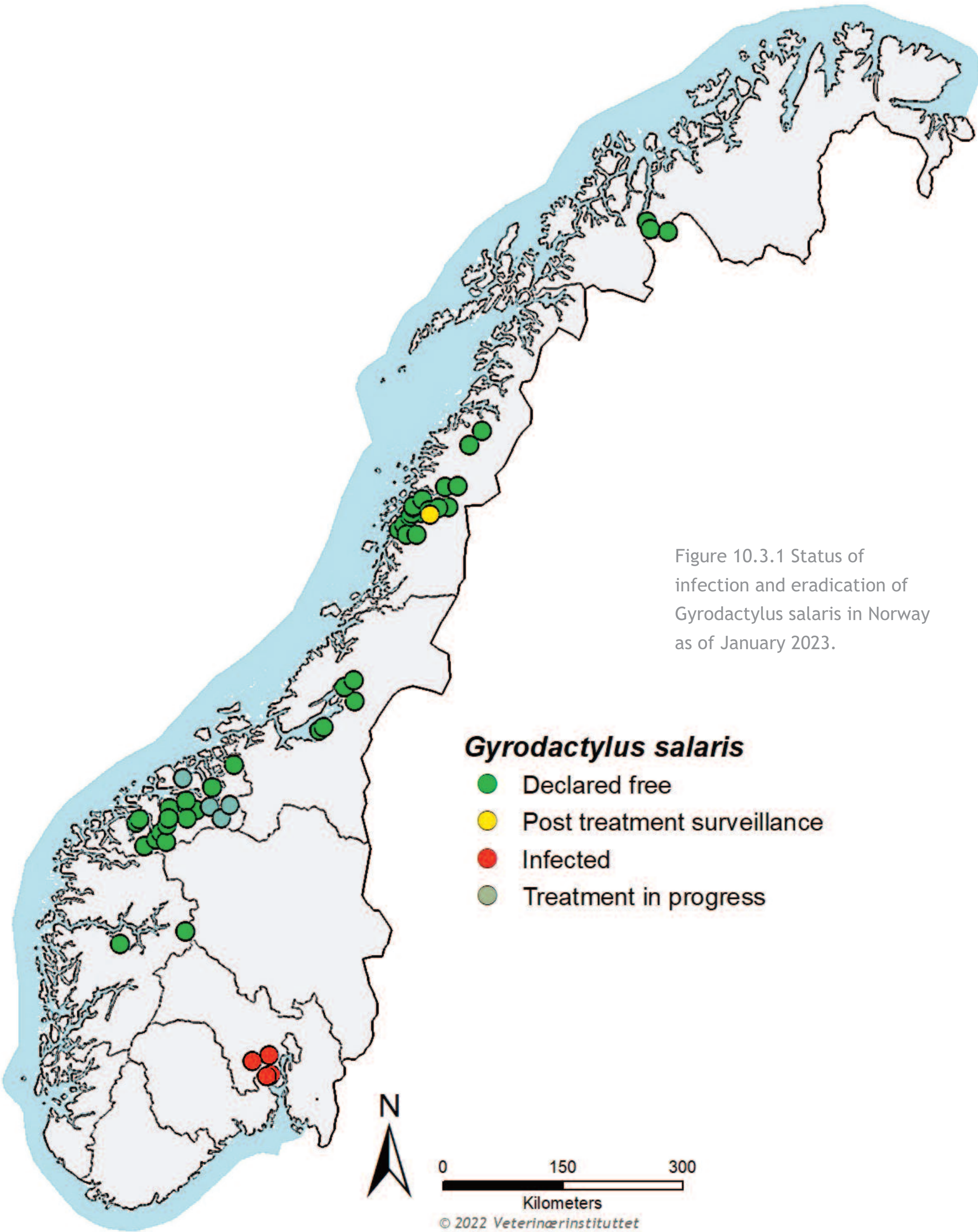


Figure 10.3.1 Status of infection and eradication of Gyrodactylus salaris in Norway as of January 2023.

10.4 Salmon lice and sustainability

The expansion of the aquaculture industry is to be done in a sustainable manner. In Norway, this is regulated through the so called «Traffic Light System». As of today, mortality attributable to
salmon lice infestation in outward migrating wild salmon smolt is the only indicator of sustainability in the system. A steering group consisting of representatives from the Norwegian Institute for Nature Research (NINA), the Institute of Marine Research (IMR) and the Norwegian Veterinary Institute (NVI) has appointed an expert group that annually reviews scientific documentation and provides an assessment of the risk of mortality in wild salmon smolts. Low risk corresponds to less than 10 percent mortality, moderate risk corresponds to 10-30 percent mortality, and high risk corresponds to over 30 percent salmon lice-induced mortality in wild salmon smolts.

The main rule of the Traffic Light System is that in production areas that receive a red light farmers are required to reduce production, in yellow areas production remain stable, while farmers in green areas can increase production.

Based on the expert group's assessments, the steering group provides advice to the Ministry of Trade, Industry and Fisheries (NFD). In the NFD's final decision on colours for a production area in the Traffic Light System, both the advice of the steering group as well as an assessment of socioeconomic consequences are taken into account. The results may thus differ from the advice given by the steering group and the expert group.

In the most recent assessment, published in November 2022, the expert group has made adjustments in the presentation of uncertainty in methods and conclusions. The new terms of uncertainty are in accordance with the Intergovernmental Panel on Climate Change (IPCC). In the report, PO3 and PO4 are in the high-risk category (red), PO2 and PO5 are in the moderate-risk category (yellow), while PO1 and the five northernmost areas are considered to have a low risk of mortality (green). Table 10.4.1 displays the conclusions of the expert group for the 13 production areas (PO) in the period 2016-2022.

The evaluations of salmon lice induced mortality for 2020 and 2021 formed the scientific foundation for the colour setting of the production areas, determined by NFD in June, 2022 (figure 10.4.1). The production areas in the north, as well as the southernmost areas, may increase their production capacity by up to six percent. The remaining production areas may carry on with the

Table 10.4.1 The expert group's evaluation in the period 2016-2022. Low risk = <10% salmon louse induced mortality in wild salmon smolts, moderate risk = 10-30% salmon louse induced mortality in wild salmon smolts and high = >30% salmon louse induced mortality in wild salmon smolts.

Production zone	2016	2017	2018	2019	2020	2021	2022
1. Svenskegrensa - Jæren	Low	Low	Low	Low	Low	Low	Low
2. Ryfylke	Mod	Low	Mod	Low	High	Low	Mod
3. Område Karmøy til Sotra	High	High	High	Mod	High	High	High
4. Nord-Hordaland til Stadt	Mod	High	Mod	High	Mod	High	High
5. Stadt til Hustadvika	Mod	Mod	Mod	High	Lav	Mod	Mod
6 Nordmøre - Sør-Trøndelag	Mod	Low	Low	Low	Low	Low	Mod
7 Nord-Trøndelag med Bindal	Mod	Low	Mod	Lav	Mod	Mod	Mod
8 Helgeland - Bodø	Low	Low	Low	Low	Low	Low	Mod
9 Vestfjorden og Vesterålen	Low	Low	Low	Low	Low	Low	Low
10 Andøya - Senja	Low	Low	Low	Mod	Low	Low	Low
11 Kvaløya - Loppa	Low	Low	Low	Low	Low	Low	Low
12 Vest-Finnmark	Low	Low	Low	Low	Low	Low	Low
13 Øst-Finnmark	Low	Low	Low	Low	Low	Low	Low

current production capacity, or reduce this with six percent.

Sea trout and arctic char

The parliamentary announcement 16 (2014-2015) «Predictable and environmentally sustainable growth in Norwegian aquaculture of salmon and trout» states that the Traffic Light System should include effects of salmon lice on sea trout and arctic char. Because of this, the expert group has also considered how the infectious pressure of salmon lice develops after what is defined as the critical period for migrating smolt. The purpose of this has been to shed light on whether the infectious pressure changes in the period in which sea trout and arctic char are in a marine habitat. The results reveal that the infectious pressure generally increases as summer unfolds in PO1-PO10, which holds particularly true for PO6. The life history and behaviour of sea trout and arctic char differ from that of the salmon, and a new evaluation of sea lice induced mortality for these two species has not been undertaken. The steering committee has recommended that criteria are made in order to include sea trout and arctic char in the Traffic Light System, as soon as possible. These should encompass indicators and limit values relevant for these species.

Extensive exemptions

In the 2022 report, the Steering group suggest changes in the decision process for allocation of so called «exemption growth». The basis for the suggestion is paragraph 12 in the Production Area Regulation, allowing fish farmers to apply for increased production or exemption from capacity reduction, regardless of the environmental status (colour) in the production area. Grant of exemption growth is based on the conditions that not more than one medical delousing treatment has been performed on a particular farm during the previous production period, and that the number of lice has been held under a 0.1 adult female lice per fish in the period of week 13-39. This means that there are no limitations on non-medicinal delousing methods. The current regulations is therefore a driver of frequent use of non-medicinal delousing methods for the purpose of avoiding production reduction or to gain production increases. This again has unfortunate implications on fish health and welfare, and it makes it harder to achieve the intentions of the Traffic Light System. This is further discussed in The Norwegian Fish Health Report 2021. The steering group suggests that paragraph 12 also sets limitations on the number of non-medicinal delousing treatments, and also that fish health and welfare are considered when reviewing applications for exemption growth (see chapter 4 Fish Welfare).

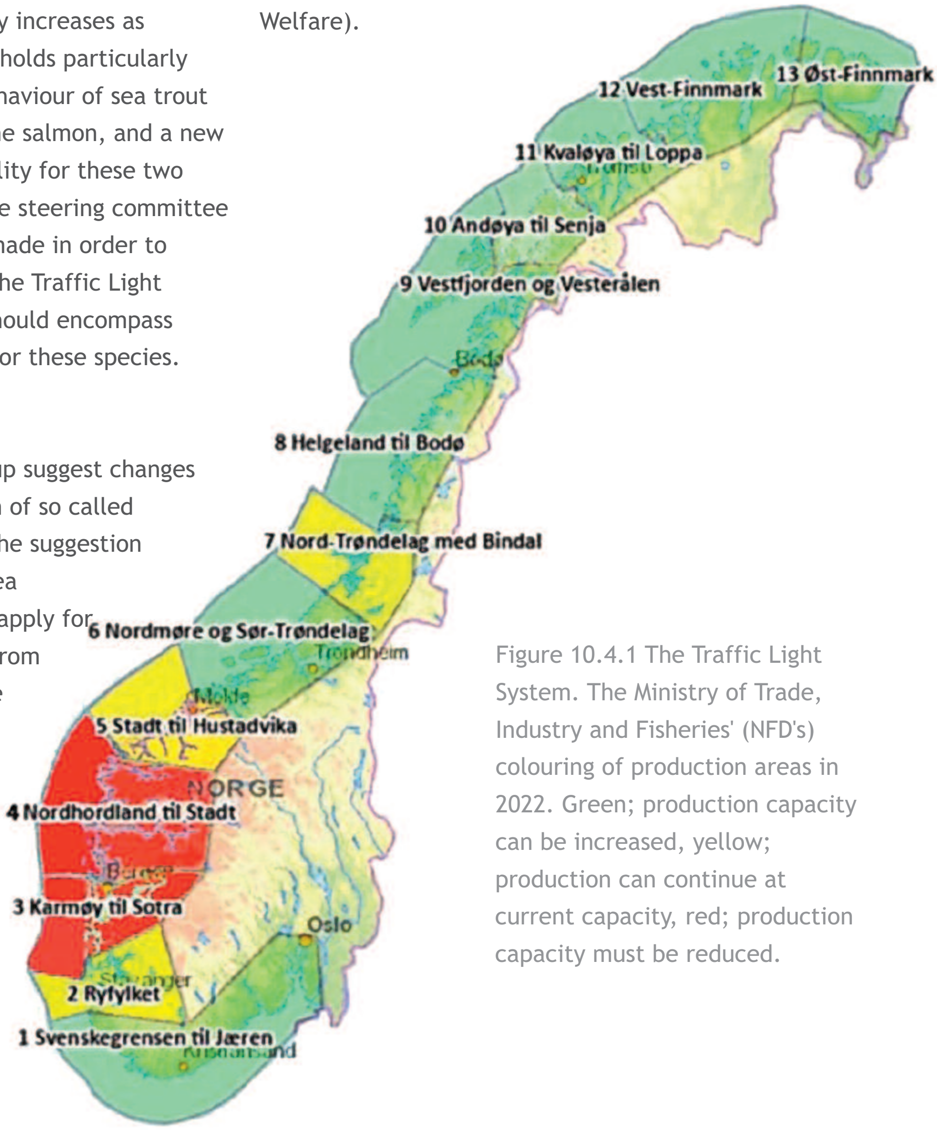


Figure 10.4.1 The Traffic Light System. The Ministry of Trade, Industry and Fisheries' (NFD's) colouring of production areas in 2022. Green; production capacity can be increased, yellow; production can continue at current capacity, red; production capacity must be reduced.

11. The health situation in cleaner fish

By Toni Erkinharju, Snorre Gulla, Julie Christine Svendsen, Synne Grønbech and Haakon Hansen

Use of cleaner fish in aquaculture

Large numbers of wild-caught and farmed cleaner fish have in recent years been used in the fight against the salmon louse. Cleaner fish is a collective term used for lumpfish and various wrasse species used for this purpose. The most commonly used wrasse species are goldsinny, corkwing, ballan and to a lesser extent rock cook.

According to the Directorate of Fisheries (biomass data as of 19.01.2023) a total of 30.3 million cleaner fish were transferred to sea in Norway in 2022. This is lower than the updated figures for 2021 (biomass data updated on 30.06.2022) with transfer of 40.6 million cleaner fish to the sea. According to the same register, 15.4 million lumpfish were transferred to sea in 2022 compared to 21.8 million lumpfish in 2021. For sea-transfer and sales figures for wrasse species, reference is made to the Directorate of Fisheries' biomass statistics and aquaculture statistics (https://www.fiskeridir.no/Akvakultur/Tall-og-analyse).

Compared to wrasse, the lumpfish are considered to be easier to farm, in addition to having a much faster production cycle. The lumpfish is also more active than wrasse at lower water temperatures. In addition, high sea temperatures have proven challenging for lumpfish health, and lumpfish are therefore more commonly used than wrasse in northern parts of the country. In previous years, it was reported that the cleaner fish producers', especially in Southern Norway, had reduced number of sea-transfers of lumpfish in summer and autumn, probably as a measure to reduce mortality rates at the farming facilities. Based on reported data sorted by month and production area (biomass register), there is reason to believe that there is a similar trend for 2022, especially in PO2-PO5.

Approximately all lumpfish utilized as cleaner fish are farmed, while a great proportion of the wrasse are wild caught. Wrasse fisheries are regulated and performed using fyke nets or fish traps during the summer. After capture, the fish are transported to salmon farms in smaller boats, wellboats or in tankers. In addition to fish captured along the Norwegian coast, wild-caught wrasse are also imported from Sweden, since the demand is greater than what can be covered with farming or capture in Norwegian waters. From a biosecurity perspective, such transport is unfortunate and involve a considerable risk of spreading infectious agents that the cleaner fish might be carrying.

The most important health and welfare challenges in the use of cleaner fish in Norway include mortality and problems which result directly or indirectly as a result of handling (e.g. during delousing), development of skin lesions and several bacterial diseases. Lumpfish in particular have proven to be susceptible to a number of different disease-causing agents. Several of these can occur at the same time, thus making it difficult to investigate the primary cause of disease and mortality among affected fish.

Diseases/agents in cleaner fish

Bacteria

Atypical *Aeromonas salmonicida, Vibrio anguillarum, Vibrio ordalii*-like bacteria, *Pasteurella* sp. (working name '*P. atlantica* genomovar *cyclopteri*'), *Pseudomonas anguilliseptica, Moritella viscosa* and *Tenacibaculosis* spp. are among the most common bacteria identified from disease outbreaks in wrasse and/or lumpfish in Norway. Several other types of bacteria are regularly isolated from sick and dying fish, but knowledge of their pathogenic significance is limited.

So-called "atypical" *Aeromonas salmonicida* cause the disease atypical furunculosis, of which there are two genetic variants of the bacterium dominating amongst Norwegian cleaner fish (A-layer types 5 and 6). A common disease scenario is chronic infection with the formation of boils, ulcers and inflammatory nodules (granulomas) in internal organs with micro-colonies of bacteria. 'Typical' *A. salmonicida*, which is the cause of classic furunculosis in salmonids, is a notifiable disease. In recent years, this bacterium has been sporadically detected in lumpfish in one area of Trøndelag, of which there are known endemic infections in wild salmonids (Chapter 6.2 Furunculosis).

Classical vibriosis caused by *Vibrio anguillarum* is an important disease of marine fish, and also occurs sporadically in cleaner fish. Clinical signs include skin lesions, fin erosion, skin haemorrhage and haemorrhages in internal organs. Vibriosis is often associated with high water temperatures, but outbreaks have been described at temperatures as low as 6 degrees Celsius in lumpfish. Among cleaner fish isolates, serotype O1 and several subtypes of O2 are most common.

Infection with *Vibrio ordalii*-like bacteria has occurred sporadically in farmed lumpfish in Norway. These infections can lead to severe haemorrhagic septicaemia and are associated with high mortality. Problems with recurring outbreaks have also been observed.

Other *Vibrio*- and *Aliivibrio* species, such as *V. splendidus, V. logei, V. wodanis* and *V. tapetis,* are often isolated from cleaner fish. They are common environmental bacteria, and their significance as pathogenic agents in cleaner fish is uncertain. It may be speculated that external factors such as transport and the stress involved in being held in a salmon cage contribute to susceptibility to bacteria that normally do not result in disease.

Pasteurella sp. causes pasteurellosis in farmed lumpfish in Norway and Scotland. A closely related bacterium also causes pasteurellosis in salmon in Norway (Chapter 6.5 Pasteurellosis). The Norwegian Veterinary Institute (NVI) has recently proposed the 'working name' of P*asteurella atlantica* genomovar *cyclopteri* for the variant causing disease in lumpfish. Clinically, the disease manifests itself as bacterial sepsis, with skin lesions in the form of white spots, tailfin erosion, ascites and haemorrhages in

Figure 11.1 Growth of *Exophiala psychrophila* fungal colonies isolated from lumpfish on Sabouraud agar media. Photo: Ellen Christensen, Norwegian Veterinary Institute

gills and at the base of the fin. Disease outbreaks can occur both in the hatchery phase and in sea cages. The mortality rate 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 a haemorrhagic septicaemia and has been detected from several sites in recent years.

Moritella viscosa is regularly isolated from cleaner fish, often in association with skin lesions and most commonly at low water temperatures. *Tenacibaculum* spp. is also isolated, often from wounded fish and from fish with tail/fin erosion, 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 widespread in the marine environment and several species have been described from cleaner fish, such as *T. maritimum, T. finnmarkense, T. dicentrarchi* and *T. soleae*. Several of these species are also isolated from salmonids with skin ulcers (Chapter 6.4 Winter ulcer).

Infections with other bacterial species have also been reported in cleaner fish. *Piscirickettsia salmonis,* which causes piscirickettsiosis in salmonids, was detected in lumpfish in Ireland in 2017. Systemic infection with *Photobacterium damselae* subsp. *damselae* was recently reported in 2019; described in wild-caught ballan wrasse near the southwest coast of England. None of these bacteria have been detected in cleaner fish in Norway.

In an experimental study from Canada, lumpfish was shown to be susceptible to infection with the bacterium *Renibacterium salmoninarum*, which is the cause of the notifiable disease bacterial kidney disease (BKD) in salmon. In the study, infected lumpfish developed a chronic infection and the bacterium could be re-isolated from organ samples for almost 100 days. So far, no natural disease outbreak with *R. salmoninarum* has been reported from any of the cleaner fish species, and the bacterium is within the literature only described as a serious pathogen for various species of salmonids.

A case of mycobacteriosis was reported from a site farming wrasse in 2021. Histopathological examination revealed acid-fast, rod-shaped bacteria, and *Mycobacterium* sp. was confirmed through cultivation and/or immunohistochemical analysis. Mycobacterial infection may lead to the development of chronic disease with granuloma formation in internal organs. The disease affects a diverse range of species, among these salmon (Chapter 6.7 Mycobacteriosis). Mycobacteriosis has not been described in lumpfish.

Fungi

Fungal disease occurs sporadically in cleaner fish and can potentially lead to health problems in affected fish. Increased mortality and generalised infection has been reported in lumpfish with yeast (Exophiala) infections, of which three species have been identified: *E. angulospora, E. psychrophila* and *E. salmonis*. Infection with *E. psychrophila* has been reported in lumpfish in Norway.

Parasites

A broad spectrum of protozoan and metazoan parasites has been identified in both wild and farmed cleaner fish. *Paramoeba perurans, Nucleospora cyclopteri, Trichodina* sp., *Ichtyobodo* sp., *Kudoa islandica, Gyrodactylus* sp., *Caligus elongatus, Eimeria* sp. and *Ichthyophonus* sp. in particular, are considered potentially serious cleaner fish pathogens in Norwegian aquaculture. Potential crossspecies transmission from cleaner fish to salmon is also a possibility for *P. perurans, C. elongatus, Ichthyophonus* sp. and *Anisakis simplex*. For *A. simplex,* it is important to note that the parasite can be transmitted to humans if the salmon have eaten infected cleaner fish. *A. simplex* has not, however, been detected in farmed salmon destined for human consumption.

The amoeba *Paramoeba perurans* (agent of amoebic gill disease, AGD) was first identified in Norwegian farmed salmon in 2006, and has since been diagnosed in both wrasse and lumpfish. As in salmon and other fish species, the parasite causes pathological changes in the gills and can become a problem in case of heavy infection. The amoeba has been detected in cleaner fish in the sea stocked with salmon and in lumpfish farmed on land in tanks.

Microsporidea are single-celled intracellular parasites. In Norway, *Nucleospora cyclopteri* has been detected in lumpfish. *N. cyclopteri* infects the cell nucleus of white blood cells, thereby destroying the leukocytes in infected lumpfish. Infected fish often develop a pale and enlarged kidney, with or without the presence of white nodules. The parasite is difficult to identify in routine histopathology and is therefore most probably underdiagnosed in samples that are only examined with histology.

Fish coccidia (*Eimeria* sp.) have been detected in the intestinal tract of both wild and farmed lumpfish, and appear to be a common occurrence, especially in wild lumpfish. Coccidian infection has also recently been reported from wild-caught wrasse. Healthwise, it can become a problem in high densities of fish, such as in farming, as the parasites spread more easily and the fish are more stressed than under natural conditions. There have been reports of cases associated with disease and mortality in lumpfish. It may also be speculated upon the extent to which coccidian infection affects the fish's appetite and louse-grazing ability.

Infection with the ectoparasite *Caligus elongatus* has been reported as a problem in lumpfish in several areas in Troms og Finnmark. In some cases, up to several hundred individuals have been observed on the same fish. The parasite causes skin injuries which may cause secondary infections by other agents. Lumpfish have been identified as the main host for one genotype of *C. elongatus*. Due to its low host specificity, this parasite can also transmit to salmon.

Several responders' in the annual survey report of a decreased use of cleaner fish, in some cases a complete cessation. Photo: Rudolf Svendsen

In 2022 outbreaks of systemic spironucleosis in salmon, caused by infection with the flagellate *Spironucleus salmonicida,* were recorded on several sea farms in northern Norway (Chapter 8.7 Systemic spironucleosis and the parasite *Spironucleus salmonicida*). On one of these sites the parasite was also detected in lumpfish. The lumpfish must have been infected in the marine environment. This may have happened through either direct or indirect horizontal transmission. Possible routes of transmission inlclude lumpfish grazing on infected salmon, possibly eating lice infected with the parasite, or through fecal contamination.

Virus

A virus belonging to the family Flaviviridae, called cyclopterus lumpus virus (CLuV) or lumpfish flavivirus, has been reported widely since 2016, with a gradual reduction in the last few years. On a national level, the virus has been one of the most significant health threats to farmed lumpfish, particularly during the hatchery phase. In the event of disease outbreaks, high mortality has been reported in facilities where the virus has been detected. The liver appears to be particularly affected during infection, causing massive necrosis of hepatocytes. In a chronic phase, changes reminiscent of cirrhosis are seen. The virus is thought to be present along the whole Norwegian coastline, but the Norwegian Veterinary Institute does not currently have the diagnostic capability for this disease. The disease was recently reported in connection with a mortality episode at an aquaculture production site in England. The site was using lumpfish imported from Norway, and the case probably represents the first known disease occurence in the country.

Other types of virus have been recently reported from lumpfish, including a new ranavirus in Ireland, Scotland, the Faroe Isles and Iceland for which the name European North Atlantic Ranavirus has been proposed. The virus is reported to be closely related to epizootic haematopoietic necrosis virus (EHNV) which is a notifiable disease. The virus has not been identified in cleaner fish in Norway.

In 2018, two new viruses were described from sick lumpfish juveniles with fluid filled intestines (diarrhoealike condition), provisionally termed Cyclopterus lumpus Totivirus (CLuTV) and Cyclopterus lumpus Coronavirus (CLuCV). The clinical significance of these infections for lumpfish in fish farms is currently unknown. At the close of 2020, a new virus was identified in association with high mortality levels in ballan wrasse. The virus has been preliminary named Ballan wrasse birnavirus (BWBV).

It has been shown experimentally that lumpfish may be infected with nodavirus and that lumpfish and wrasse may become infected with infectious pancreatic necrosis virus (IPNV). None of these viruses have been detected in Norwegian farmed cleaner fish. Nodavirus has been previously identified in Norwegian and Swedish wildcaught wrasse. Viral haemorrhagic septicaemia virus (VHSV) has been identified in wild-caught wrasse and lumpfish in Scotland and Iceland respectively, but has not been detected in these fish in Norway.

The salmon pathogenic viruses salmonid alphavirus (SAV), infectious salmon anaemia virus (ISAV), piscine myocarditis virus (PMCV) and piscine orthoreovirus (PRV) have previously (from Norway and other countries) been occasionally reported in wrasse co-inhabiting in sea cages with infected salmon. The detections were considered of low or unknown importance for the wrasse and in several occasions sample contamination could not be discounted. Recently, a unique variant of the SAV-virus was described from ballan wrasse in Ireland, termed SAV genotype 7 (SAV-7). None of these viruses have been reported in lumpfish.

Other diseases and health problems

Cataract (degradation of the lens of the eye) has previously been a frequent finding in lumpfish held in hatcheries and broodstock farms. Calcifications in the kidney (nephrocalcinosis) are detected sporadically to varying degrees in cleaner fish.

The Health Situation in 2022

Data from the Norwegian Veterinary Institute and private laboratories

Bacteria

In 2022, the NVI has detected atypical furunculosis/atypical *Aeromonas salmonicida* in lumpfish at 12 sites and in wrasse at 25 sites. This is significantly lower compared to last year for lumpfish, when the number of cases was 36. For wrasse, the number of detections is at the same level as in 2021. Corresponding numbers from 2020 was 51 lumpfish- and 29 sites with wrasse. On account of this it may appear like there has been a significant reduction in the number of detections in lumpfish over the last couple of years. However, figures from 2020 are not directly comparable with numbers from 2021 and 2022, as the detections for this year included data from both the NVI and other laboratories.

In 2022, the NVI detected infection with *A. salmonicida* subsp. *salmonicida* (furunculosis) in lumpfish from one sea farm where the same bacteria was detected in salmon (Chapter 6.2 Furunculosis).

A private laboratory detected pasteurellosis in lumpfish from one fish farm in 2022. In addition both the NVI and other laboratories detected *Pasteurella* sp. (*P. atlantica* gv. *cyclopteri*) in lumpfish on three additional sites where there were clinical signs associated with disease outbreak.

In 2022, *Pseudomonas anguilliseptica* was detected by the NVI in lumpfish on 11 fish farms, which is less than the numbers of farms for both 2021 (15) and 2020 (18). *P. anguilliseptica* was not detected in wrasse in 2022.

The NVI detected *Vibrio anguillarum* in corkwing wrasse on two farms in 2022. There were no detections in lumpfish. *Vibrio ordalii*-like bacteria were not detected in lumpfish in 2022. In general, there has been a modest amount of detections of *V. ordalii* in lumpfish over the last years.

A broad array of *Vibrio*- and *Aliivibrio*-species (V. *splendidus, A. logei, V. tapetis, A. wodanis,* and non-specified *Vibrio* sp.), as well as *Tenacibaculum* spp. and *Moritella viscosa*, were also isolated from cleaner fish in 2022, often in a mixed culture.

Wound infections involving *M. viscosa* was detected by the NVI and other laboratories in lumpfish at 19 sites and in wrasse at four sites. In addition, *M. viscosa* was detected in wrasse and lumpfish at respectively one and 13 other sites where clinical signs were associated with disease outbreaks. *Tenacibaculum* spp. was detected by the NVI and other laboratories in lumpfish at 43 sites, of which 21 were associated with wound infections. The bacteria was also detected in association with wound infection in wrasse at seven sites. Where species affiliation was determined, *T. finnmarkense* gv. *finnmarkense* was found in lumpfish at seven sites and in wrasse at one site. *T. finnmarkense* gv. *ulcerans* was detected in lumpfish at nine sites and in wrasse at four sites. *T. dicentrarchi* was detected in lumpfish at two sites and in wrasse at one site.

Fungi

In 2022, *Exophiala psychrophila* was detected in lumpfish (Figure 11.1.1) at one site in northern Norway, where the disease history indicated systemic disease at the site.

Virus

No virus was detected in diagnostic cleaner fish material submitted to the Veterinary Institute in 2022. Figures from private laboratories show a total of 12 sites with detections of cyclopterus lumpus virus (CLuV) or lumpfish flavivirus virus in 2022. The corresponding figure for last year was a total of 21 sites with detections of the virus.

Parasites

In 2022, the NVI and other laboratories detected AGD in lumpfish at eight sites and in wrasse at elleven sites. A modest amount of ciliates (probably *Trichodina* sp.) was detected in the gills of lumpfish at a couple of sites, but there was no evident correlation with significant health issues in the fish. Ciliates (probably scuticociliates) were detected in the skin of lumpfish with bacterial wound infection at one site. Coccidiosis was diagnosed in lumpfish at one site, nematodes were detected in an organ sample (peritoneum) from lumpfish at another, and a modest amount of flagellates (probably *Cryptobia* sp.) were registered in the stomach of a lumpfish at yet another site.

Infection with the flagellate *Spironucleus salmonicida* was detected for the first time in lumpfish on a sea farm in northern Norway. The parasite was also detected in salmon at the same site (Chapter 8.7 Systemic spironucleosis and the parasite *Spironucleus salmonicida*).

Nucleospora cyclopteri was not detected in lumpfish by the NVI in 2022, and has not been detected at the NVI in the last few years. As previously mentioned, it is likely that *N. cyclopteri* may be underdiagnosed, as the parasite is often difficult to detect by routine histological examination.

Other diseases and health problems

Nephrocalcinosis was diagnosed on two lumpfish sites in 2022. In addition to this calcified material was detected in the kidney and urinary bladder of ballan wrasse at two sites. There was a modest number of sites with registrations of emaciation in varying degrees in lumpfish.

The Annual Survey

Regarding whether the mortality for cleaner fish has changed, 79 percent (lumpfish) and 86 percent (wrasse) of the respondees reply that the level was stable, or that they do not know. Five percent (lumpfish) and seven percent (wrasse) report of increased mortality, while 16 percent (lumpfish) and seven percent (wrasse) believe the mortality is reduced.

For cleaner fish in the hatchery phase the situation is as in the previous year, with production related diseases such as fin erosion and suboptimal care highlighted as the greatest challenges. «Crater disease» in lumpfish and AGD in wrasse are considered to be the most important infectious diseases (Appendix D1 and E1).

Also in accordance with last year's survey results, production-related disorders are ranked highly for both cleaner fish groups (Appendix D2 and E2) after transfer to sea in salmon cages. Problems in connection with non-medicinal delousing methods are considered of particular importance in this context. Two specific infectious diseases are important, namely crater disease in lumpfish and atypical *A. salmonicida* in wrasse. For further evaluations of the annual survey with regards to cleaner fish, see Chapter 4 Fish Welfare.

Evaluation of the cleaner fish situation

As in previous years, fish health personnel reported that a lot of cleaner fish are still dying in the fish farms. Along with infectious, in particular bacterial diseases, there are reports of production related illnesses, such as mortality and reduced welfare in connection with non-medicinal delousing of salmon. Although exact mortality data are not currently available, previous reports have indicated a near total loss of cleaner fish throughout the production cycle. Feedback from the survey does not suggest a major change in this respect. Several respondees report of a decreased use of cleaner fish, in some cases a complete cessation. Both considerations of animal welfare, as well as practical factors, are mentioned as causes for this development.

Keeping multiple fish species in the same net pen may present challenges with respect to biosafety. This is especially relevant when using wild caught cleaner fish, as well as in cases where cleaner fish have been transported from other geographical regions. Transmission of infection with *Peramoeba perurans* (AGD) between cleaner fish and farmed fish has previously been proven, and it is possible that cleaner fish may function as a vector for other disease agents. Detection of *Spironucleus salmonicida* from both salmon and lumpfish on one site in 2022 indicates a possible transmission of the parasite between these two species. It is important to pay attention to infection dynamics when keeping multiple fish species on the same site, especially with regards to agents known to cause disease in salmonids with a marine reservoir.

A total of 30.3 million cleaner fish were transferred to sea in Norway in 2022. Photo: Rudolf Svendsen

12. Diseases of marine species in aquaculture

By Hanne Nilsen, Toni Erkinharju, Geir Bornø, Mona Gjessing

Marine species - aquaculture

Increased diversity of fish species in aquaculture is an ambition, and interest in the farming of marine species is increasing. Cod farming in particular has had a huge increase in production in recent years.

Knowledge of the fish's biology and favorable farming conditions are essential to achieve good welfare and health. Species such as halibut and spotted catfish require horizontal resting areas in order to thrive. Turbot thrive in warm water and are produced in land-based facilities where temperature can be regulated. The national cod breeding program which started in 2002 reports that the sixth generation grows faster than previously and is better adapted to a life in aquaculture.

Diseases of marine species in aquaculture

In Norway, nodavirus infection has caused losses in farming of marine fish species since the mid-1990s, and the infection remains a potential threat. Other relevant viruses in farming of halibut include aquatic halibut reovirus (AHRV) and infectious pancreatic necrosis virus (IPNV).

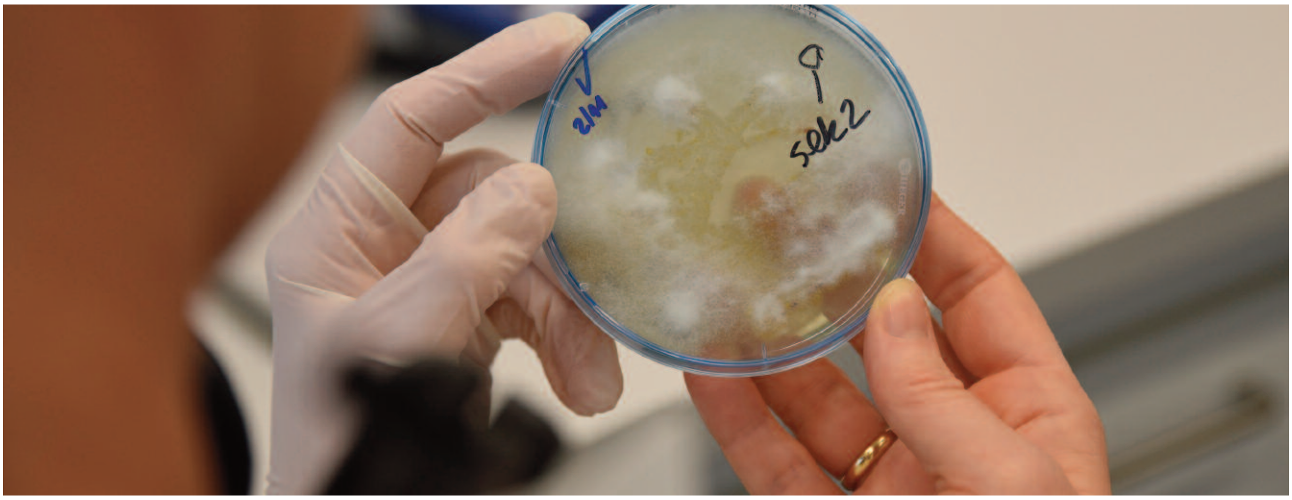
In cod, the bacterial disease francisellosis, caused by the bacterium *Francisella noatunensis* subsp. *noatunensis*, was previously an important disease and one of the reasons why profitability in cod farming declined 10-12 years ago. Infection with atypical *Aeromonas salmonicida* can lead to mortality in most farmed marine species. Infection with *Vibrio anguillarum* can also lead to disease outbreaks in cod. In connection with development of ulcers in the skin and eyes, it is common to find bacteria such as *Tenacibaculum* spp. and *Moritella viscosa*. Of the parasitic diseases, "Costia" caused by *Ichthyobodo* spp. is not an uncommon finding in the skin and gills of halibut and cod. Cod can also be infected by the sea-louse, *Caligus elongatus*, and the cod louse, *Caligus curtus*.

Disease control

Viral nervous necrosis (VNN)/Viral encephalo- and retinopathy (VER) caused by nodavirus, and francisellosis in cod, are notifiable diseases in Norway (category F). There are no commercially available vaccines against these diseases.

For more information, see the fact sheets (in Norwegian):
https://www.vetinst.no/sykdom-og-agens/francisellose

https://www.vetinst.no/tyksam-og-agens/nodavirus-hos-marin-fisk-vnn-ver



Culture from wild salmon. Photo: Mari Press, Norwegian Veterinary Institute

The Health Situation in 2022

Official data

No infections with nodavirus or francisellosis were detected in farmed fish in Norway in 2022.

Data from the Norwegian Veterinary Institute

Halibut and turbot

In 2022, a total of 13 submissions were received by the Veterinary Institute from halibut and turbot. This is a similar situation to 2021. As before, atypical *Aeromonas salmonicida* and *Vibrio anguillarum* O1 have been detected in connection with disease in halibut. In halibut, emaciation and mortality have been observed in association with *Icthyobodo* sp. "costia" infection.

Cod

In 2022, material was received from twelve sites with cod. Increased mortality in fry has been the reason for several submissions. *Moritella viscosa* infected ulcers were reported. In addition, other commonly occurring ulcer-associated bacteria such as *Aliivibrio wodanis, Tenacibaculum finnmarkense* gv *finnmarkense* and various *Vibrio* species were also detected. Fluid-filled intestinal organs, intestinal strangulation, emaciation, fin rot and parasitic infections have been seen in cod populations with persistently high mortality. At one location, X-cell parasites were detected in several organs. Fast-growing mycobacteria were detected in wild cod with granuloma in the spleen (see Chapter 10 The health situation in wild fish).

Spotted wolffish

In 2022, no submissions from wolffish were received.

The annual survey

For cod, ulcers, deformities and aggression are reported when under-fed. Spawning problems and a possible increase in parasitic diseases are also seen. In halibut, *Trichodina* spp. is a recurring problem at high fish density and high temperature. Poor sun protection may cause sunburn. Nephrocalcinosis has been reported from wolfish.

Assessment of the health situation of marine species in Norwegian aquaculture

With increasing farming of cod, it is important to be aware of possible new detections of francisellosis.

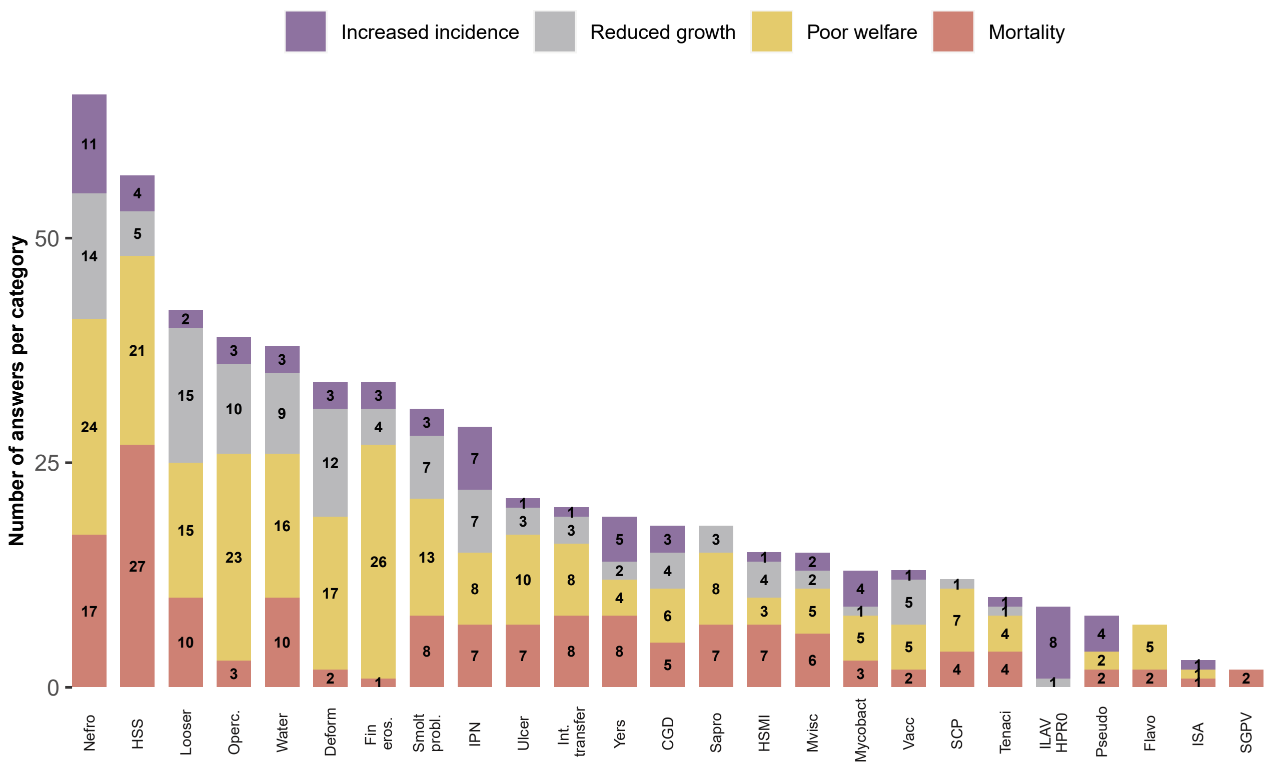
Appendix A1:

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 2022. Respondents with experience in salmon hatcheries 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=27 respondents who responded on increasing prevalence, N=31 on reduced growth, N=43 on reduced welfare and N=42 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
HSMI	=	heart and skeletal muscle inflammation
HSS	=	haemorrhagic smolt syndrome
Int transfer	=	moving fish between operational
IPN	=	infectious pancreas necrosis
ISA	=	Infectious salmon anaemia (infection with ISAV HPR-deleted)
ISAV HPR0	=	infection with non-virulent ISAV (ISAV HPR0)
Looser	=	runted fish, runt syndrome, emaciation
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Myco	=	infection with Mycobacteria
Nefro	=	nephrocalcinosis
Operc.	=	shortened gill covers
Pseudo	=	infection with *Pseudomonas* spp.
Sapro	=	infection with *Saprolegnia* spp.
SGPV	=	salmon gill pox virus (disease due to SGPV)
Smoltprob	=	smoltification problems
SPC	=	single-celled parasites on gills/skin (e.g Ichthyobodo spp., *Trichodina* spp.)
Tena	=	infection with *Tenacibaculum* spp. (non-classic winter ulcer)
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)
yers	=	infection with *Yersinia ruckeri* (yersinosis)



Appendix A2:

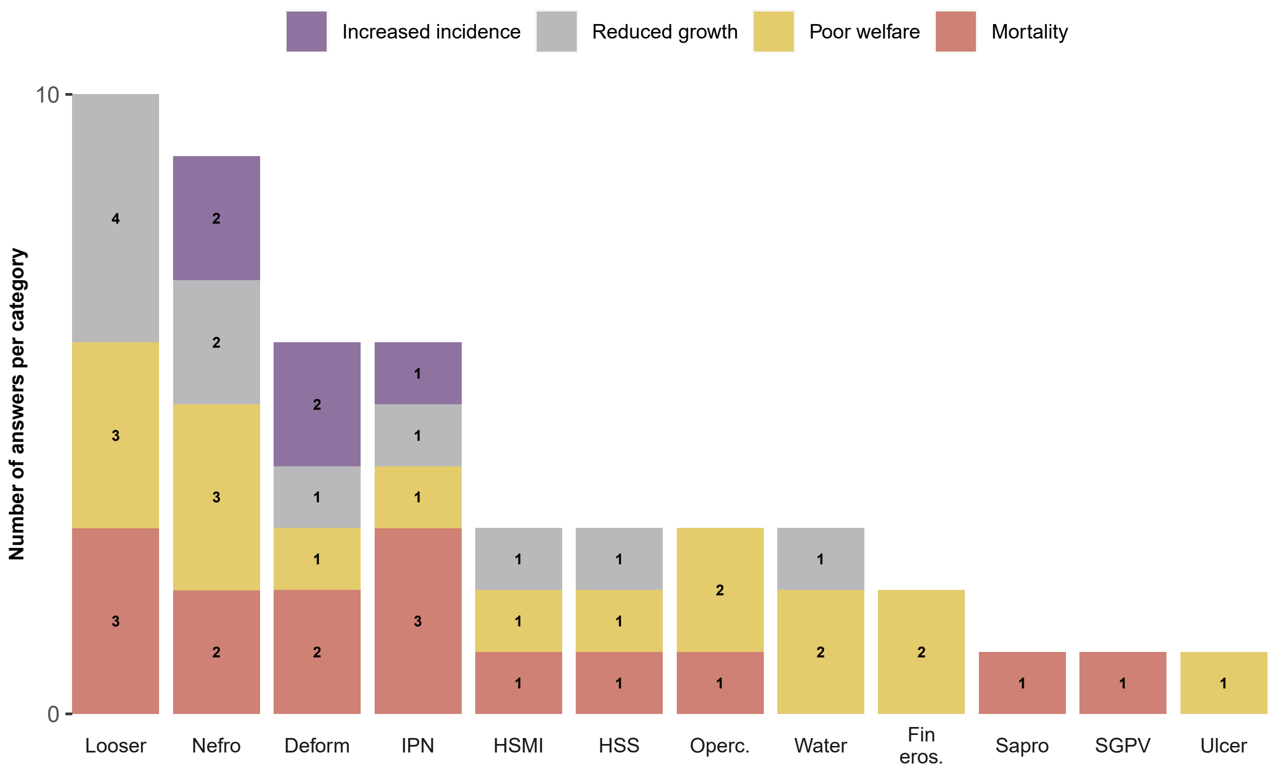
Health problems in juvenile rainbow trout production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2022. Respondents with experience in salmon hatcheries were asked to cross off the five most important of 23 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=4 on reduced growth, N=6 on reduced welfare and N=6 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	=	heart and skeletal muscle inflammation
HSS	=	haemorrhagic smolt syndrome
IPN	=	infectious pancreas necrosis
Looser	=	runted fish, runt syndrome, emaciation
Nefro	=	nephrocalcinosis
Operc	=	shortened gill covers
Sapro	=	infection with *Saprolegnia* spp.
SGPV	=	salmon gill pox virus (disease due to SGPV)
Ulcer	=	skin ulcers and underlying tissues, unspecified cause
Water	=	poor water quality departments with different water qualities (e.g. RAS to flow-through)



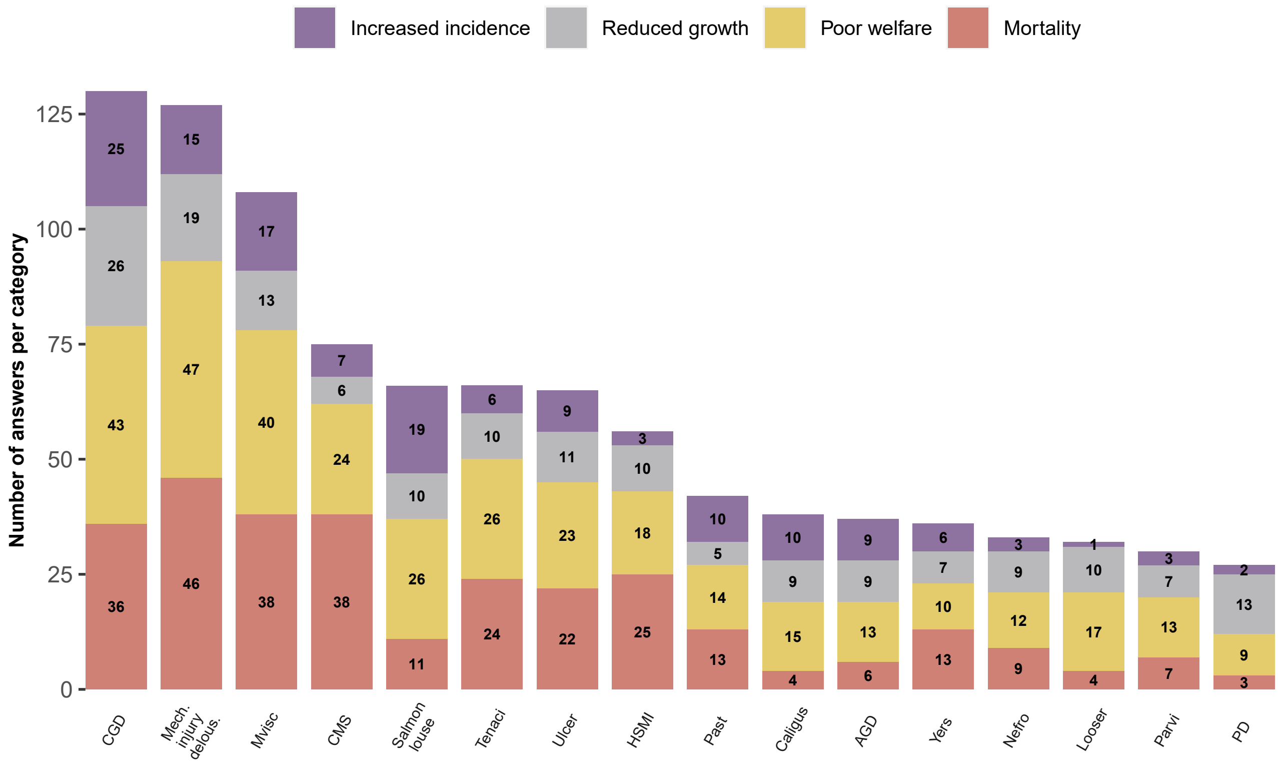
Appendix B1:

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 2022. Respondents with experience in salmon ongrowing facilities were asked to cross off the five most important of 33 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=52 respondents who responded on increasing prevalence, N=57 on reduced growth, N=63 on reduced welfare and N=63 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)
ISAV HPR0	=	infection with non-virulent ISAV (ISAV HPR0)
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)
Myco	=	infection with Mycobacteria
Nefro	=	nephrocalcinosis
Parvi	=	infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Past	=	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)
Ulcer	=	skin ulcers and underlying tissues, unspecified cause
Vacc	=	vaccine side effects
Yers	=	infection with *Yersinia ruckeri* (yersinosis)



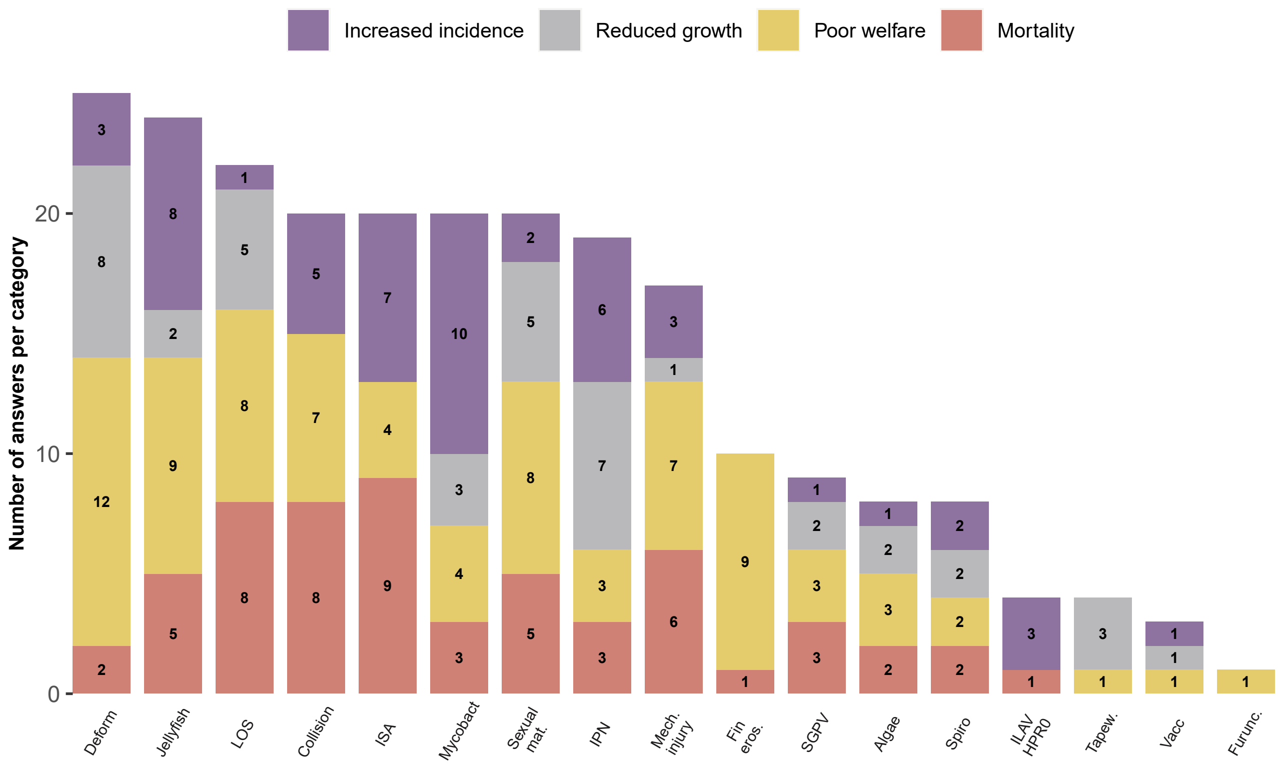


Chart part 2. Ranking of health problems 17 to 32 in salmon at ongrowing facilities.

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 2022. Respondents with experience in salmon ongrowing facilities were asked to cross off the five most important of 28 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=3 respondents who responded on increasing prevalence, N=5 on reduced growth, N=6 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):

AGD	=	amoebic gill disease
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	=	PRV3/HSMI like disease
Jellyfish	=	jellyfish
Looser	=	runted fish, runt syndrome, emaciation
LOS	=	lack of smoltification
Mech injury delouse	=	mechanical harm related to delousing
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Nefro	=	nephrocalcinosis
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)

Appendix C1:

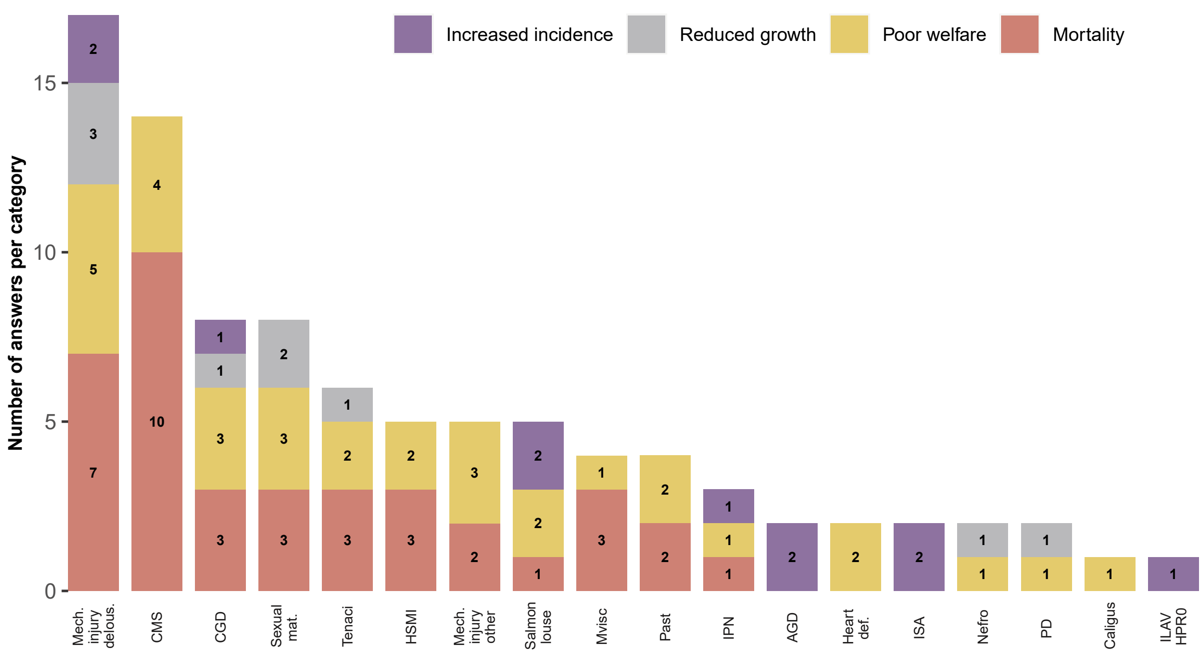
Health problems in broodstock salmon production*

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2022. Respondents with experience in broodstock salmon were asked to cross off the five most important of 27 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 respondents who responded on increasing prevalence, N=6 on reduced growth, N=12 on reduced welfare and N=12 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
Caligus	=	Caligus elongatus (grazing injuries following infestation with C. elongatus)
CGP	=	gill disease complex/multifactoral
CMS	=	cardiomyopathy syndrome
Heart deform	=	cardiac deformities
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)
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)
Nefro	=	nephrocalcinosis
Past	=	infection with Pasteurella sp. (pasteurellosis)
PD	=	Pancreas disease
Salmon louse	=	salmon lice (grazing injuries following infection with Lepeoptheirus salmonis)
Sexual mat	=	sexual maturation
Tenaci	=	infection with Tenacibaculum spp. (non-classic winter ulcer)



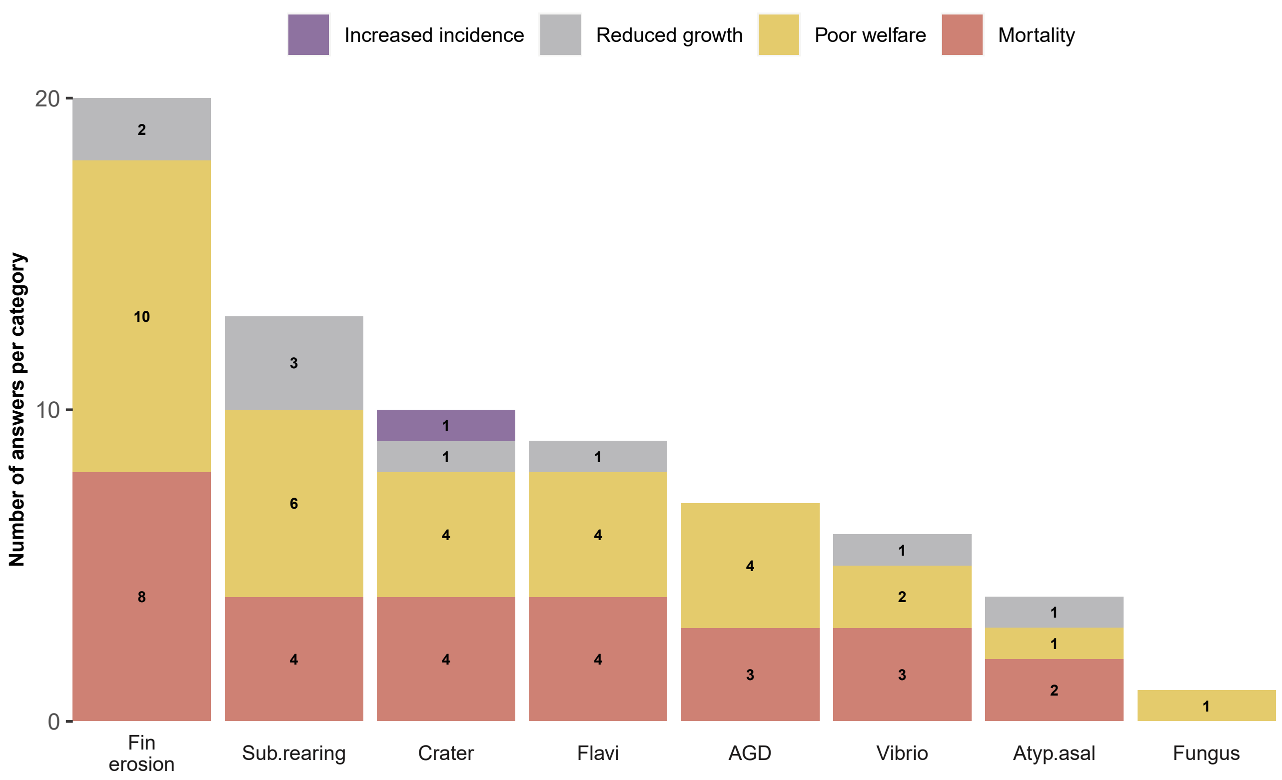
Appendix D1:

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 2022. Respondents with experience in juvenile lumpfish production 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=1 respondent who responded on increasing prevalence, N=6 on reduced growth, N=13 on reduced welfare and N=13 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*)
Crater	=	crater disease (infection with *Tenacibaculosis* spp.)
Fin eros	=	fin erosion
Flavi	=	lumpfish flavivirus
Fungus	=	fungal infection
Sub rearing	=	suboptimal care
Vibrio	=	vibriosis (Infection with *Vibrio* spp.)



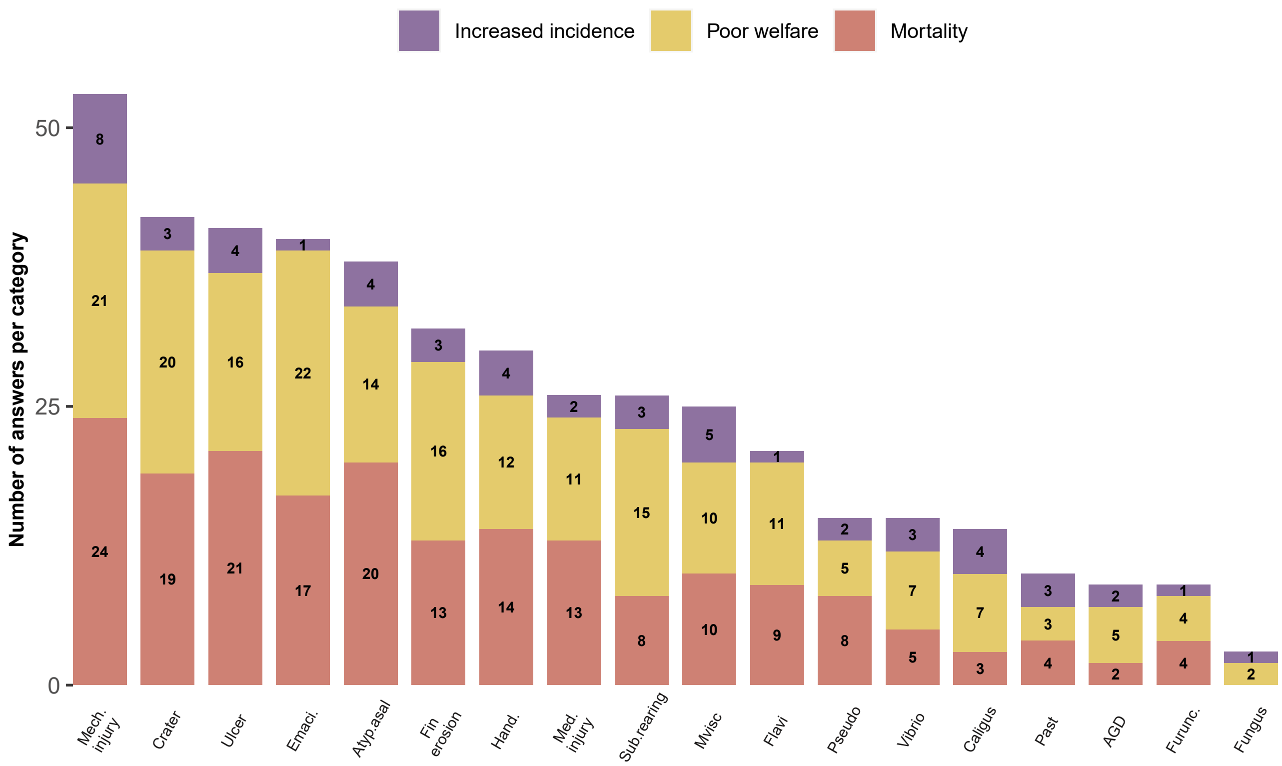
Appendix D2:

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 2022. Respondents with experience in lumpfish held in ongrowing facilities were asked to cross off the five most important of 19 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=19 respondents who responded on increasing prevalence, N=44 on reduced welfare and N=44 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*)
Caligus	=	infestation with *Caligus elongatus*
Crater	=	crater disease (infection with *Tenacibaculosis* spp.)
Emaci	=	emaciation, malnutrition
Fin eros	=	fin erosion
Flavi	=	lumpfish flavivirus
Fungus	=	fungal infection
Furunc	=	furunculosis (infection with *Aeromonas salmonicida* subsp *salmonicida*)
Hand	=	mortality rate as a consequence of handling
Mech injury delouse	=	mechanical harm related to delousing
Mech injury	=	mechanical harm not related to delousing
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Past	=	infection with *Pasteurella* sp. (pasteurellosis)
Pseudo	=	infection with *Pseudomonas anguilliseptica*
Sub rearing	=	suboptimal care
Ulcer	=	skin ulcers and underlying tissues
Vibrio	=	vibriosis (Infection with *Vibrio* spp.)



Appendix E1:

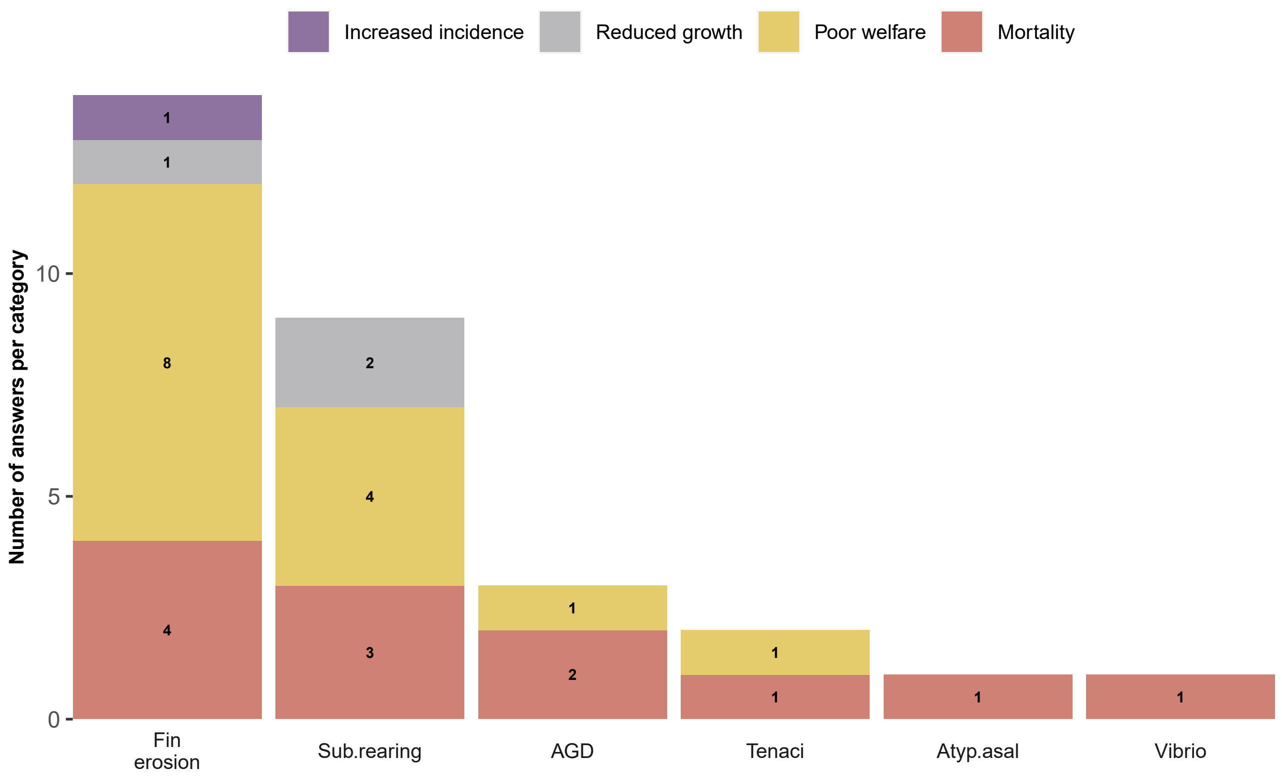
Health problems in juvenile wrasse production

Results from the annual survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report 2022. Respondents with experience in wrasse hatcheries were asked to cross off the five most important of 7 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=1 respondent who responded on increasing prevalence, N=2 on reduced growth, N=9 on reduced welfare and N=8 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
Sub rearing	=	suboptimal care
Tenaci	=	infection with *Tenacibaculum* spp.
Vibrio	=	vibriosis (Infection with *Vibrio* spp.)



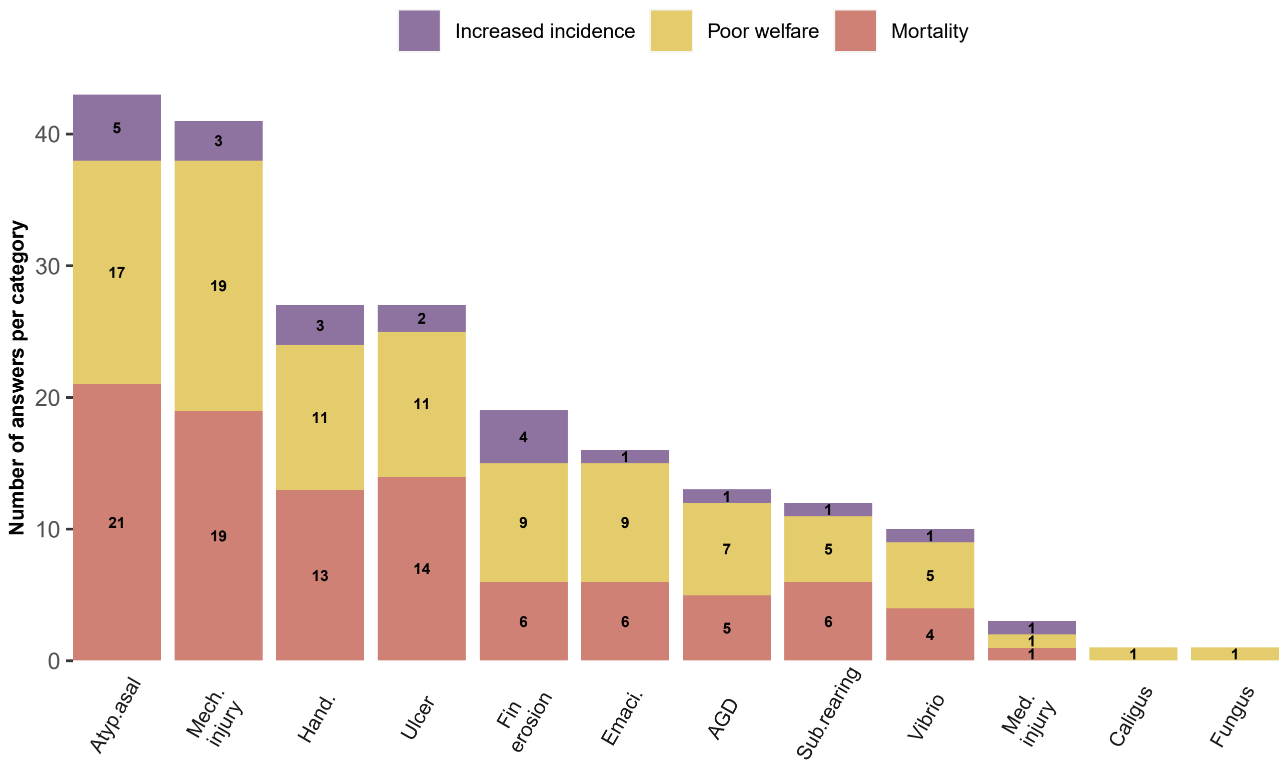
Appendix E2:

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 2022. Respondents with experience in wrasse held in ongrowing facilities were asked to cross off the five most important of 13 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=9 respondents who responded on increasing prevalence, N=28 on reduced welfare and N=29 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*)
Caligus = infestation with *Caligus elongatus*
Emaci = emaciation, malnutrition
Fin eros = fin erosion
Fungus = fungal infection
Hand = mortality rate as a consequence of handling
Mech injury delouse = mechanical harm related to delousing
Mech injury = mechanical harm not related to delousing
Sub rearing = suboptimal care
Ulcer = skin ulcers and underlying tissues
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: Eivind Senneset

Acknowledgements

The editorial committee would like to thank everyone that has contributed to the Fish Health Report 2022 and the statistical basis upon which it is based.

Many thanks to the 74 respondents to the annual survey, and with this have contributed with important information from the field. The survey is sent to employees of various fish health services, fish health personnel employed by the various farming companies and inspectors employed by the Norwegian Food Safety Authority, amongst others:

Hanna Ommedal Aa
Sebastian Siiri
Erika Kunickiene
Susanne Tofte
Kari Marie Børtveit
Eline Røislien
Berit ulvin Halvorsen
Ioan Simion
Liss Lunde
Ivar Bastian Kramer
Kari Kaasen McDougall
Koen Van Nieuwenhove
Jakob Mo
Anne Tjessem
Adina Svedberg
Helle Hagenlund
Tom Christian Tonheim
Kjetil S. Olsen
Oda Klingenberg
Anne Alina Sandvik
Mattias Bendiksen Lind
Elisabeth Ann Myklebust
Hege Skjåvik
Karl Fredrik Ottem
Hedda Skjold
Marte Andrea Fjær
Kari Lillesund
Torbjørn Lysne
Daniel Lauritzen
Anders Olsen
Liv Norderval
Barbo Klakegg

The Norwegian Veterinary Institute tanks Pharmaq Analytiq AS and PatoGen AS for their important contributions to this year's Fish Health Report in making available data lists for the detection of selected diseases and/or infectious agents (see Chapter 1 Statistical Basis for the report). Further, we would like to thank the various farming companies who have shared their health-related data and contributed to quality assurance of its use prior to publication in the Norwegian Fish Health Report.

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