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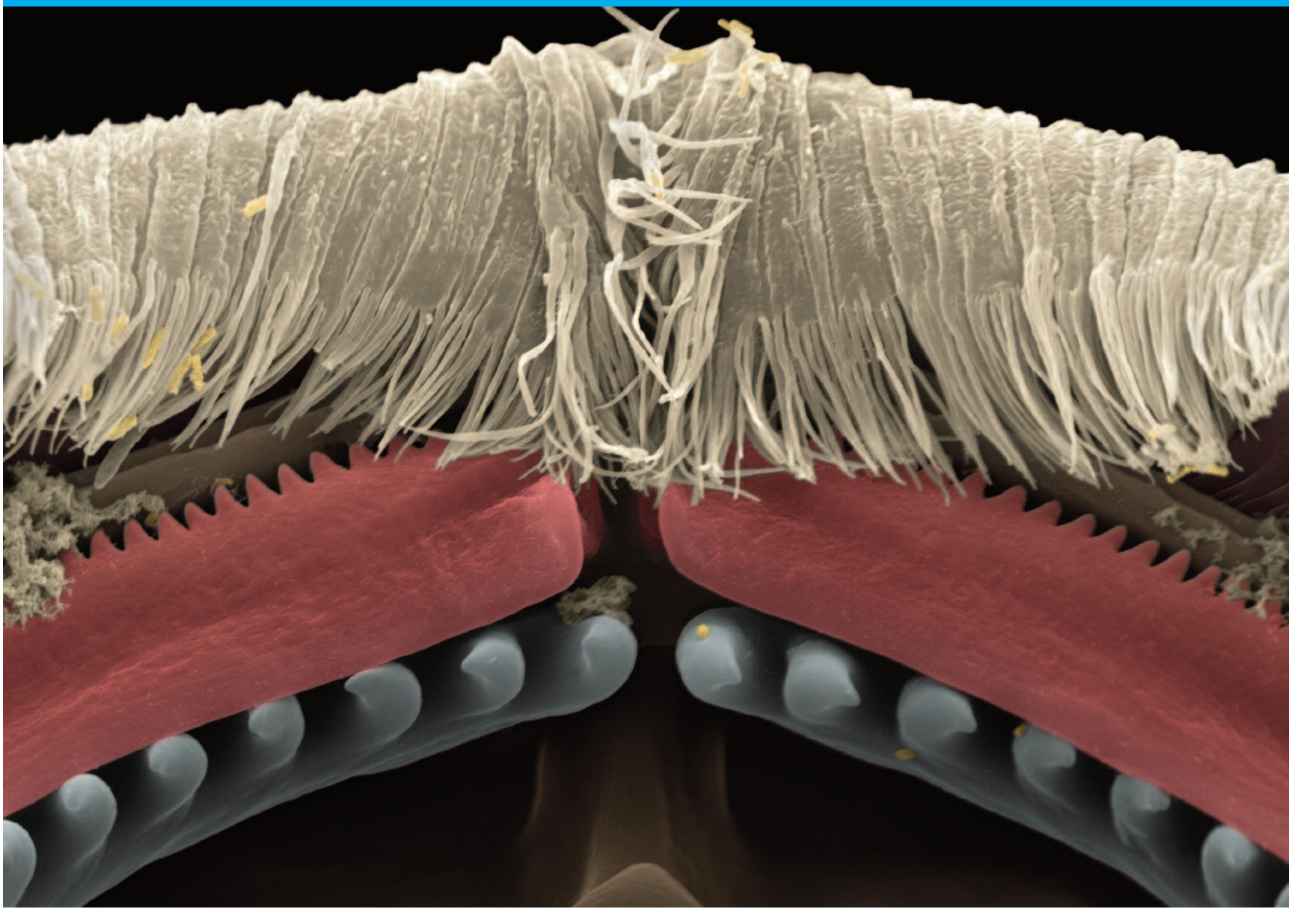
Norwegian Fish Health Report 2021



Mouth of salmon louse, enlarged 6000 times. Image taken with scanning electron microscope and then coloured.
Photo: Jannicke Wiik-Nielsen

Norwegian Fish Health Report 2021

Norwegian Veterinary Institute Report, series # 2a/2022

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

Authorship

Authors are credited for each chapter. With the exception of chapter 8.5 Water Quality, written by employees of the Norwegian Institute for Water Research (NIVA), all authors are employees of the Norwegian Veterinary Institute.

The Fish Health Report 2021 is mainly written without references in the text. For information about references, please contact the authors of each chapter.

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Cover image: Salmon lice (*Lepeophtheirus salmonis*) feed on mucus and skin cells that they scrape off the skin of fish using two serrated appendages (red). They use their teeth (blue) to move the food into the oral cavity. If the wound becomes deep enough, the lice also consume blood. The mouth is magnified 6000 times. The image is photographed with a scanning electron microscope and then colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

Contents

Introduction

By Edgar Brun

Health and welfare are two important components of sustainable aquaculture production. This year's Fish Health Report confirms once again that the health and welfare situation for Norwegian farmed fish is not good. Despite the fact that many companies use considerable resources in their efforts to promote more sustainable production, overall figures for fish mortality in the industry were far too high in 2021. More than 50 million fish die during the sea phase; a figure that has not changed significantly in the last five years. An additional 30 million fish are lost in each of the categories freshwater salmonid- and cleanerfish-production. Many companies and individuals are making progress and have achieved good results related to louse control and disease challenges in general. Nevertheless, the aquaculture industry as a whole still performs poorly where fish health and welfare are concerned.

This year’s report is strengthened through extensive collaboration between the Norwegian Veterinary Institute, fish farming companies and private diagnostic laboratories regarding diagnostic statistics for non-notifiable diseases. Secure data exchange between different operators provides the industry and public authorities with a solid foundation for knowledge-driven health and welfare work. Fish Health Services have also this year contributed to the Norwegian Veterinary Institute's annual survey with great commitment and expertise. Dissemination of the knowledge and assessments received from practitioners in the field regarding the daily and future challenges is important. Their experience and viewpoints are key input factors in identifying the correct priorities for health and welfare work for the Norwegian fish farming industry

The Norwegian aquaculture industry is currently riding on a wave of ambitious growth and market success that allows it to invest and develop despite the high costs of persistent health and welfare problems. Figuratively speaking, what we are seeing is basically a lifestyle problem. The industry currently has the economy to keep various ailments and diseases at bay through short-term, symptomatic treatments, but these do not ensure a sustainably robust future. Billions of dollars are being used on intensive treatments while large numbers of salmon die prior to harvest from various health issues. Despite this, the highest priorities within the industry appear to be increased production and identification of new technological opportunities that will allow further growth.

Fish in captivity today live with a number of diseases that have been present in Norwegian aquaculture for more than 20 years. We are happy to see a decline in PD for the first time in many years, while other viral and bacterial infections and direct production-related disorders show opposite tendencies. Various production related factors allow the spread of infectious diseases among operators along the coast. ISA is on the rise, with unknown consequences, and furunculosis is again rearing its head. Combating the salmon louse has become a routine part of farming. Lice are largely resistant to chemical treatments, and mechanical and thermal treatments have a great cost – in the form of reduced fish welfare, stress and weaker fish with a significant mortality rate.

Is there a way out of these problems? We know there is a large and growing gap between companies that do well and those that do poorly when it comes to health-related problems and mortality. The industry itself is in possession of data that could be utilised for significant improvement of the situation. We read of the good intentions laid

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

out in the Hurdal Platform by the Norwegian Government and the New Aquaculture Strategy, a precondition of which is that the challenges for the health and welfare of our fish must be overcome before new growth is allowed. Good intentions alone are not, however, going to improve the health and welfare of our fish. Clear demands must be made of the industry, prepared by the industry itself in cooperation with research institutions and the public authorities. Relevant research based knowledge related to biology, health and welfare generated by the Norwegian Veterinary Institute and other institutions must be as readily accepted by decision-makers as novel growth-based production technologies currently are. Expertise in disease prevention is fundamental for further development of the industry, and quantifiable health and welfare parameters must be considered as licencing prerequisites. The authorities are responsible for ensuring that production frameworks also safeguard health, welfare and the natural environment. The traffic light scheme is one example of this. It can and should be improved. No scheme is perfect if exemptions are permitted that nullify the intended effects of the measures imposed.

Expansion of the aquaculture industry, both at sea and on land, is currently technology driven. Whether this path will result in the desired levels of expansion, remains to be seen. While the current regulatory framework for expansion of the industry encourages multi-million dollar investment in new technologies, one important unknown variable remains: a thorough understanding of the biological processes upon which of this huge technological 'experiment' is based. The Norwegian Veterinary Institute and other research environments will be important providers of knowledge related to fish healt and welfare, transmission of infections and environmental concerns. Such biological knowledge is crucual in order to find the balance between health and welfare on the one hand and technological development on the other.

Summary

By Cecilie Walde and Ingunn Sommerset

The mortality rate is a crude but solid indicator of fish health and welfare in aquaculture, and based on the numbers reported in 2021, the situation has not improved. There are many different causes of mortality, such as infectious diseases, poor environmental conditions, injury (trauma) and lack of physiological adaptation. The interaction between these can be complex. We would like to highlight some of the most important health challenges that we have identified in the Norwegian aquaculture industry and wild salmonids in 2021, as well as serious diseases that are constantly drawing closer to Norwegian waters.

Mortality in Norwegian aquaculture

Salmon and rainbow trout have a two-part life cycle, with the first part of life lived in freshwater (hatcheries/juvenile production) before being transferred to seawater (ongrowing facilities). Chapter 2 describes mortality at the hatchery and juvenile production fase and ongrowing phase in more detail.

Mortality in juvenile fish (larger than 3 grams) was reported to the Norwegian Food Safety Authority to be 33.4 million salmon and 1.9 million rainbow trout in 2021. This level has been relatively stable over the past five years. It is worth noting that the quality of the data for salmonids in the juvenile phase is not as good as for salmon in the ongrowing phase, which makes calculating annual mortality percentages difficult.

The number of salmon that died during the sea phase was 54 million in 2021 (15.5 percent). This is a higher number of individuals than in 2020, and even the record year 2019 where the algae catastrophe in Nordland and Troms alone killed about 8 million salmon. In 2021, we have not identified any particular event which could be linked to the high mortality registered for the seawater phase. The number of registered disease diagnoses, number of delousing treatments and welfare incidents, as well as results from the fish health survey based on questionnaires sent to fish health personnel, indicate that the causes of mortality in 2021 were, as in 2020, compounded. There are still relatively large differences in the geographical distribution of mortality, although the differences between different production areas (PO) were somewhat smaller in 2021 than in previous years (see Chapter 1, Figure 1.1, for an overview of the different production areas).
In PO2–5, the mortality rate was around 20 percent. For PO1 and the area from PO6 and northwards the mortality rate was less than 14 percent. For rainbow trout, the mortality rate was 14.8 percent, which can be interpreted to be a slightly downward trend.

Mortality data for cleanerfish in general and per species in particular is inadequate, but previous reports have indicated a near total mortality of cleanerfish throughout the production cycle. The number of cleanerfish used in Norwegian salmon cages in 2021 was 40.6 million individuals (figures reported as of 17.02.22).

Mandatory reporting of fish diseases

Notifiable diseases among fish, i.e. diseases that one is required by law to notify the Norwegian Food Safety Authority about, are as per March-2022 divided into List 1 (exotic), List 2 (non-exotic) or List 3 (national). The Norwegian Veterinary Institute is a National Reference Laboratory and shall confirm any suspected listed disease, and assist the Food Safety Authority in keeping up-to-date records of the number of detections. Based on monitoring programmes and ongoing diagnostic examinations, no diseases have ever been detected on List 1 in Norway. List 2 and List 3 diseases with the number of detections are shown in the table on page 7.

Infectious salmon anaemia (ISA) (List 2) was confirmed at 25 sites in 2021, two more than in 2020. One has to go back to the ISA epidemic of 1989-1992 to find a higher number of annual ISA cases, which is worrying. Although the prevalence of ISA is commonly higher in northern than southern production areas, prevalence varies from year to year. ISA must therefore be taken into account and considered as a potential differential diagnosis along the entire coast.

The serious viral diseases of Infectious Haematopoetic Necrosis (IHN) (List 2) and Viral Haemorrhagic Septicemia (VHS) (List 2) have not been detected in Norway in 2021. These diseases are found in other European countries, and the detection of IHN in Denmark and Finland in 2021 gives cause for vigilance.
In the case of Pancreas Disease (PD) (List 3), we saw a welcomed reduction in the number of new cases recorded in 2021; 100 new PD cases were registered, compared with 158 the year before. The reduction is mainly related to a decrease in SAV3 cases in PO5 and fewer SAV2 cases in PO6. As in 2020, no new PD outbreaks were reported in the monitoring zone outside the endemic area, which is positive in preventing the spread of infection northwards.

Of the notifiable bacterial diseases, furunculosis (caused by *Aeromonas salmonicida* subspecies *salmonicida*) (List 3) was detected in two hatcheries and three salmon ongrowing facilities. All three detections at the ongrowing facilities could be linked to the sea-transfer of infected smolt from the two hatcheries. Systemic infection with *F. psychrophilum* in rainbow trout (List 3) was detected in rainbow trout fry at one inland facility in 2021. Bacterial Kidney Disease (BKD) (List 3) was not detected in wild or farmed salmonids in Norway in 2021. In 2021, Viral Nervous Necrosis (VNN) was detected in farmed halibut, a disease not recorded since 2013.

In the case of salmon louse (List 3), the average number of adult female lice per farmed fish for the whole country in 2021 was approximately the same as in 2020. 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. This increase was due to the fact that the seasonal increase in lice larvae production in the summer came earlier than in previous years. Lice larvae production was highest in areas PO2, PO3, PO4 and PO6.

Non-notifiable reporting of fish diseases

The statistical data for this year's report has been further

The table shows the total number of new diagnoses of list 2 and list 3 diseases per farming site or river for the years 2013-2021. The number of diagnoses at the site level relates to new diagnoses following fallowing. This means that the real number of infected sites can be higher, as there may be farms holding fish diagnosed the previous year.

	List	2013	2014	2015	2016	2017	2018	2019	2020	2021
Oppdrettsfisk: Laksefisk										
Infectious salmon anaemia (ISA)	2	10	10	15	12	14	13	10	23	25
Pancreatic disease (PD)	3	100	142	137	138	176	163	152	158	100
Furunculosis	3	0	1	0	0	0	0	0	5	5
Bacterial Kidney Disease (BKD)	3	1	0	0	1	1	0	1	1	0
Systemic F. psychrophilum in rainbow trout	3	3	2	3	4	1	4	4	2	1
Farmed fish: Marine species										
Francisellosis (cod)	3	1	1	0	0	0	0	0	0	0
Viral Nerve Tissue Necrosis (VNN), nodavirus	3	1	0	0	0	0	0	0	0	1*
Furunculosis (lumpfish)	3	0	0	1	4	0	0	0	3	0
Wild salmonids (water courses)										
Gyrodactylus salaris	3	1	1	0	0	0	0	1	0	0
Furunculosis	3	0	0	2	1	2	0	2	0	0

*One verified VNN outbreak, and one suspected incidence (detection of nodavirus by PCR), both in farmed Atlantic halibut.

expanded through agreements with several fish farming companies on access to diagnoses made by private laboratories for a selection of important, non-notifiable fish diseases. Since the data this year comprises a larger proportion of locations than last year, in addition to data for several new diseases, this year's figures are not directly comparable to last year's figures (see Chapter 1 Statistical Basis).

In the survey, Cardiomyopathy Syndrome (CMS) was, as in 2019 and 2020, ranked as the leading cause of mortality in salmon in the ongrowing phase. In total, CMS was recorded at 155 sites in 2021, which is similar to 2020 (154 sites). For Heart and Skeletal Muscle Inflammation (HSMI), more cases were recorded in 2021 compared to 2020; 188 cases compared to 161. For Infectious Pancreatic Necrosis (IPN), the situation still seems relatively stable and with a low incidence.

The situation regarding bacterial diseases in farmed salmonids in Norway has been quite stable for many years, and the consumption of antibiotics is still very low. However, in the last two to three years there has been a worrying increase in some bacterial diseases. The number of pasteurellosis outbreaks in farmed salmon in Western Norway increased markedly in the period 2018-2020. The number of detections in 2021 was still high, and the disease was detected at 45 sites, which is a decrease from 2020 (57 positive locations). In the survey, winter ulcer was ranked higher than in previous years as the cause of reduced welfare and as an increasing problem. Ulcers were also stated as the main cause of declassification at harvest. *Moritella viscosa*-associated winter ulcers and tenacibaculosis (non-classic winter ulcers) are not subject to mandatory reporting and are relatively easy to diagnose in the field. Nevertheless, combined figures from the Norwegian Veterinary Institute

Ingunn Sommerset, main editor of the Fish Health Report 2021. Photo: Eivind Senneset

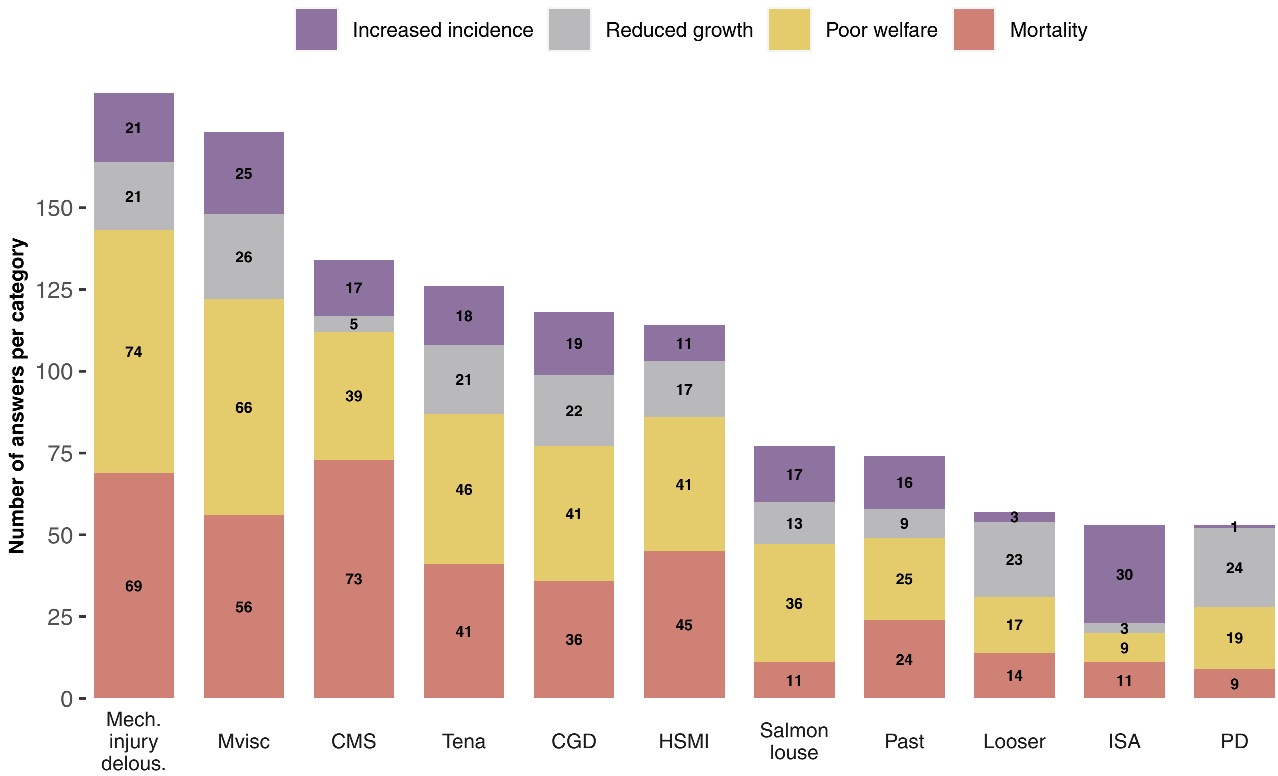


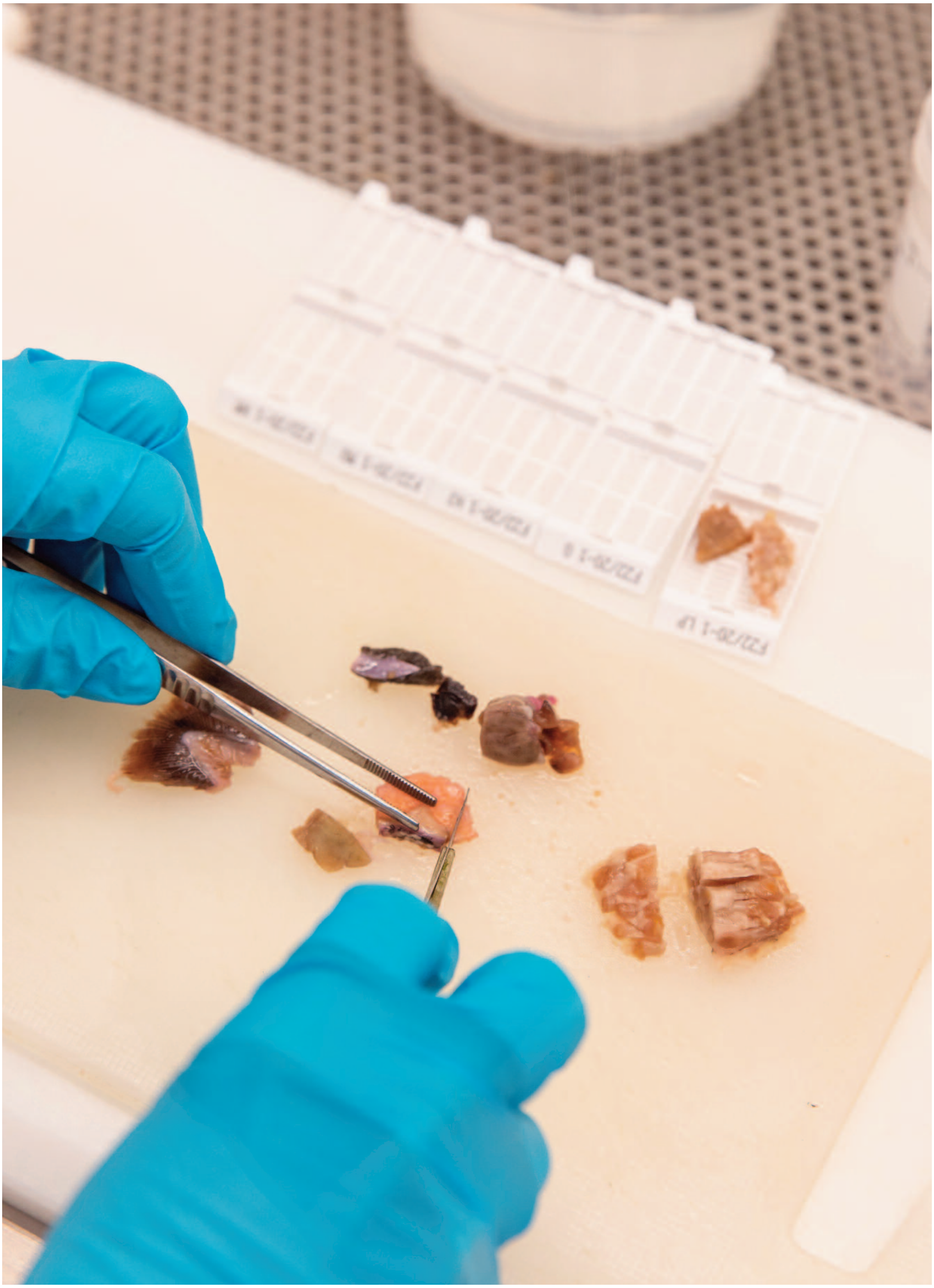
Figure: The 10 most important health problems of salmon in ongrowing facilities (sea water sites). Results from the 2021 survey among fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents were asked to indicate the five most important health problems on a list of 32 different problems. The respondents (N = number of persons who answered the question) were asked whether the problems were related to mortality (N=88), reduced welfare (N=87), poor growth (N= 73) or were perceived as a growing problem (N=69).

Abbreviations: Mek.skad.lus = mechanical damage related to delousing, Mvisc = infection with *Moritella viscosa* (classic winter ulcers), CMS = cardiomyopathy syndrome, Tena = infection with *Tenacibaculum* spp. (non-classical winter ulcers), CGD = gill disease complex/multifactorial, HSMI = heart and skeletal muscle inflammation, Salmon louse = infestation with salmon lice, Past = infection with *Pasteurella* sp. (pasteurellosis), Looser = runt fish/emaciation, ISA = Infectious salmon anaemia, PD = pancreatic disease.

and private laboratories show the detection of *M. viscosa* and *Tenacibaculum* sp. at 204 and 159 sites in 2021, respectively.

Vagococcus salmoninarum, which causes a disease called cold water streptococcosis, was detected for the first time since the early 1990s (referred to in Chapter 5.8). This shows that a broad cultivation-based diagnostic approach is important for detecting rare and new bacterial diseases.

In 2021, a new parasite was found, described in salmon and rainbow trout. The species, which is given the name *Salmoxcellia vastator*, belongs to the X-cell parasites group. Since 2000, the Norwegian Veterinary Institute has sporadically detected characteristic lesions in salmonids in the sea phase, where a parasite disease has been suspected. All these cases turned out to be caused by this newly described parasite (see Chapter 7.6).



Preparation of fish tissue samplesfor microscopy. Photo: Eivind Senneset

Fish welfare - salmonids and cleaner fish

The number of reported welfare incidents from hatchery production continues to increase. In 2021, the Food Safety Authority received 188 reports – compared to 162 in 2020. However, it is unclear what the increase in the number of reported incidents is caused by. The Food Safety Authority received 1535 reports of welfare incidents in 2021 for ongrowing/broodstock facilities, which is a slight reduction from 2020 (1623 reports), but still higher than in 2019 (1489 reports). There is a slight decrease in the number of weeks of non-medicinal delousing in 2021 (2822) compared to the peak year 2020 (2962), with a clear reduction in the number of weeks of thermal delousing.

Nevertheless, these are high numbers; and for farmed fish in the sea phase, the number of delousings as well as the methods applied, that mainly require extensive fish handling, remains a major welfare problem. This applies both to salmonids and to cleanerfish, where injury associated with non-medicinal delousing once again is ranked at the top as the main cause of reduced welfare in the fish health survey. Of the fish health personnel who answered questions about observed salmon disease outbreaks in the first two weeks after non-medicinal delousing, 79 percent said they have registered ulcers, 42 percent that they have registered CMS and 39 percent HSMI.

Cleanerfish face major welfare challenges from disease, delousing operations and a lack of control over mortality in the cages. Although less clenearfish were used in 2021, compared to 2020 and 2019, more than 40 million individuals were transferred to Norwegian salmon sea cages in 2021. Production-related disorders and lack of good methods for sorting out cleaner fish prior to mechanical and thermal delousing of salmon, present major welfare challenges. Suitable methods for anesthesia and euthanisation of cleanerfish in harvest facilities are also lacking. Of infectious diseases, bacterial diseases are ranked highest. Welfare and infectious diseases of cleaner fish are covered in Chapters 3 and 10.

Wild salmon

Norway has a special responsibility to safeguard wild Atlantic salmon. In 2021, the wild Atlantic salmon was listed as in danger of extinction in the Norwegian Red List for Species. This is despite measures such as the establishment of national salmon watercourses and national salmon fjords, the quality norm for wild populations of Atlantic salmon and salmon lice-induced mortality in wild salmon smolt as an indicator in the Traffic Light System. There were reports of disturbingly high incidences of pink salmon (an exotic species) in Norwegian rivers in 2021. The pink salmon poses a health threat to both farmed and wild salmonids. There is great concern about the ecological and economic consequences this has for Norway. Read more about the health situation of both wild salmon and other wild fish in Chapter 9.

1 Statistical Basis for the report

By Britt Bang Jensen and Ingunn Sommerset

The data in the Fish Health Report is collected from four different sources: Official data, data from the Norwegian Veterinary Institute's (NVI'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.

Official data

All listed diseases must be reported to the Food Safety Authority.

In addition, the Regulations state that: "In increased mortality, with the exception of mortality that is obviously not caused by disease, health controls must be done without unnecessary delay to identify the cause. The health control should be carried out by a veterinarian or fish health biologist. The Norwegian Food Safety Authority shall be notified immediately in case of undeclared increased mortality in aquaculture facilities or aquaculture areas for mollusks, or for any other reason of suspected disease on lists 1, 2 or 3 in aquaculture animals."

Based on monitoring programmes and ongoing diagnostic examinations, no diseases have ever been detected on List 1 in Norway. List 2 and List 3 diseases with the number of detections are shown in the table on page 7 in the Summary. The figures are based on data from the

Fisken i oppdrettsanleggene lever i dag med en rekke sykdommer som vi til dels har hatt i Norge mer enn 20 år. Foto: Rudolf Svensen, UWfoto

NVI, which assists the Norwegian Food Safety Authority (NFSA) in keeping an up-to-date overview of the listed diseases. The NFSA notifies the NVI of diseases detected by external laboratories such that these are registered alongside detections made by the NVI (see below). As the National Reference Laboratory (NRL), the NVI shall, in principle, confirm all diagnoses of notifiable diseases made by external laboratories.

The official statistics of diseases in this report relate to the number of new sites (also called locations) /new identifications following fallowing. As some farms may hold fish diagnosed the previous year (typically PD in the endemic zone), the actual number of affected sites may be higher.

Data from the National Veterinary Institute

The NVI receives samples for diagnostic examinations from a number of providers of fish health services. These are examined at the Institute's laboratories in Harstad, Bergen and Ås. All information generated from submitted diagnostic samples is stored in the institute's electronic journal system ("prøvejournalsystem", PJS). Data from PJS has been extracted and sorted so that only samples submitted for diagnostic purposes are used in the Norwegian Fish Health Report. Samples sent in for purposes of research, ring tests and monitoring programmes etc. are excluded.

For each disease or agent, the number of farms in which a diagnosis has been made in at least one fish are counted. We commonly receive several submissions from individual farms in the course of a year, but farms are only counted once in relation to any specific disease or agent.

Data from private laboratories and compiling data

Non-listed diseases are non-notifiable and private laboratories perform a substancial share of diagnostics tests for the Norwegian aquaculture industry. That is why data from the NVI alone cannot give a complete picture of the national situation. We have asked the largest and many of mid-sized fish farming companies in Norway to contribute with data to the Fish Health Report for 2021. In total, 23 fish farming companies approved the disclosure of data on the following non-listed diseases and associated disease-causing agents in 2021:

- Heart and skeletal muscle inflammation and (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

The data has been extracted from electronic journal systems at PatoGen AS and Pharmaq Analytiq AS. All data was checked and authorised by the respective farming companies before use. For each disease or agent, we compiled the data lists from the various laboratories, including data from the NVI, such that specific diseases/agents were only registered once for each farming site.

The exact coverage of Norwegian salmonide framing sites, obtained by the agreements with the 23 companies, are difficult to calculate for the selected non-listed diseasese in 2021. There was a monthly average of 613 active salmonid farming sites in 2021 (ongrowing, broodstock, hatcheries and R&D facilities), which reported biomass via the "AltInn" portal to The Directorate of Fisheries. We received data on the eleven diseases mentioned above from 591 sites, but 62 of these are not included in the 613 sites that reported to Altinn.

For the non-listed diseases, the same disease/agent may have been identified previously in the same batch of fish in 2020 as in 2021, so the statistics do not necessarily describe the number of new cases in 2021. This is in contrast to how numbers are reported for notifiable diseases (described above).

Data from the survey

As in previous years, the NVI utilised an electronic survey to gather additional field information from fish health services and fish health personnel employed by farming companies as well as inspectors from the Norwegian Food Safety authority.
In the survey, the respondents were asked to rate (among other things) how important they perceive various diseases in hatcheries, ongrowing facilities 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 lice treatments and about fish welfare assessed

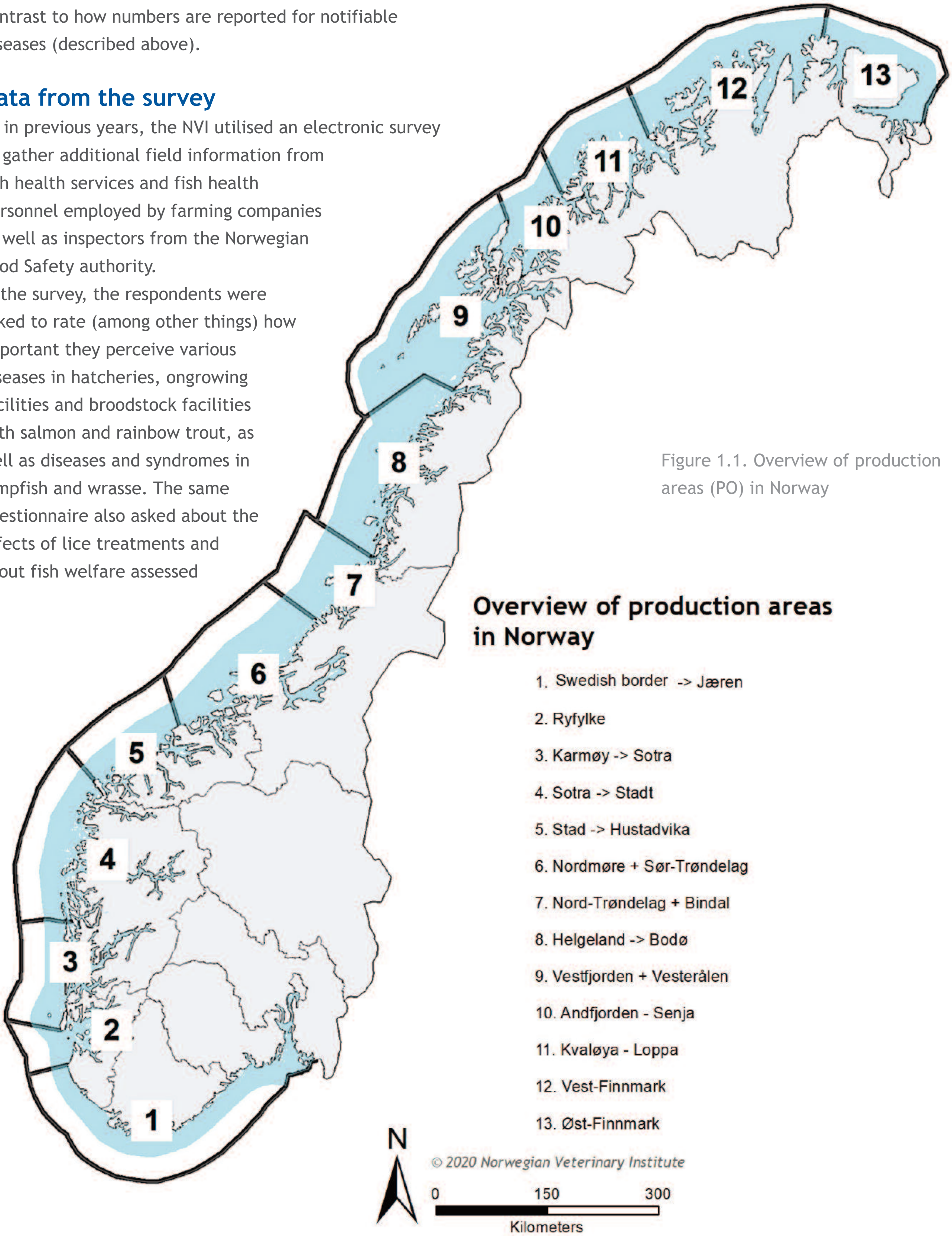


Figure 1.1. Overview of production areas (PO) in Norway

according to different parameters, as well as allowing free text to be entered under the various topics.

In total, the questionnaire was sent out to 195 people working with fish health supervision in either private fish health services or fish farming companies. Of these, we received responses from 36 people working in private fish health services and from 44 people working as fish health personnel at a fish farming or breeding company. The total number of responses from fish health personnel was 80. We also sent the questionnaire to 86 inspectors at the Food Safety Authority and received responses from 20 of these. In total, 100 respondents responded to the questionnaire. All were offered to be mentioned by name as contributors to the report. These are listed on the last page of the report.

The survey data was used in Chapter 3 (Fish welfare) and in most of the different infectious- and non-infectious disease chapters of this report. An overall ranking of various disease and welfare challenges is shown in Appendix A-E.

Geographical distribution

In the previous issue of the Norwegian Fish Health Report, the number of disease outbreaks have been shown per county. As a number of changes have been made to region boundaries
and as ‘Production area legislation’ came into force from 15th october 2017 and now regulates commercial farming of salmon, trout and rainbow trout within 13 geographically defined areas, The Norwegian Fish Health Report, with few exceptions, reports, statistics for production areas rather than regions. The thirteen production areas (abbreviated as "PO" in the rest of the report) with a geographical description are shown in Figure 1.1.

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.

2 Changes in infection risk

By Åse Garseth, Victor H. Silva de Oliveira, Kari Grave, Kari Olli Helgesen, Mona Dverdal Jansen, Jorun Jarp, Arve Nilsen, Sonal Patel, Leif Christian Stige and Edgar Brun

In this chapter, we try to focus on some of the main trends and changes that we consider important enough to highlight as factors affecting the current health and welfare situation and that can create new challenges and assumptions in the future.

2.1 Mortality and production

Some production statistics

Preliminary harvest statistics for 2021 indicate an increase of about 160 000 tons from 2020 for salmon, but a decrease for rainbow trout of 8000 tons. This year's increase in salmon production is thus greater than it has been in recent years (Table 2.1.1). The number of fish reported at the end of 2021 is somewhat less than in 2020, but nevertheless indicates a high production also for 2022. Preliminary figures for hatchery fish transferred to sea are relatively stable over the years of about 300 million. Based on the Biostatistics Register (Directorate of Fisheries), 40.6 million cleanerfish of different species were utilsed in 2021. Over the past five years, there has been a downward trend in the use of cleanerfish for delousing in salmon cages. Cleanerfish are discussed in Chapter 10.

Table 2.1.1 Production data for farmed fish based on available figures from the Biomass Statistics (Directorate of Fisheries, dated 20.01.2021) and the Aquaculture Statistics (as of 27.01.2022), ref. **www.fiskeridir.no.** The annual mortality percentage for salmon and rainbow trout is based on monthly mortality rates; see the calculation method in the text. UT = data not available

	2017	2018	2019	2020	2021
Number of sites					
Salmonids - hatchery production, number of permits	220	217	221	227	227
Salmonids - ongrowing production, number of sites at sea	986	1015	966	986	990
Salmonids - ongrowing production, number of sites, on land (fresh water and salt water)	UT	UT	43	48	58
Marine fish, number of sites, sea	58	42	64	36	41
Biomass at end of year, in tons					
Salmon	797 000	814 000	811 958	896 961	868 693
Rainbow Trout	35 700	40 400	47 094	40 625	36 984
Harvest figures, tons in round weights					
Salmon	1 237 000	1 279 000	1 361 747	1 400 117	1 561 302
Rainbow trout	61 600	66 700	79 600	92 793	84 077
Hatchery fish transferred to sea, in millions					
Salmon	299	304	288	290	304
Rainbow trout	17.1	20.0	20.8	17.5	13.0
Cleanerfish	54.6	48.9	49.1	42.2	40.6
Post sea-transfer mortality, in millions					
Salmon	45.8	46.3	53.2	52.1	54.0
Rainbow trout	2.4	2.8	3.1	2.8	2.7
Mortality, in percent					
Salmon	15.5	14.7	16.1	14.8	15.5
Rainbow trout	17.5	16.5	16.3	16.0	14.8

Mortality and loss of fish during the sea phase

Salmonid losses during the production period in seawater are reported to the Directorate of Fisheries, distributed between these categories: dead fish/mortality, rejected, escaped or other. Dead fish include fish that have been registered as dead for various reasons. Rejected means trash fish that are sorted out during harvest. Other is the loss of fish registered with a cause other than dead fish, rejected and escaped. Dead fish is generally an indicator of the quality of fish welfare and fish health.

The total number of dead salmon in the sea phase was 54 million in 2021. Calculation of annual percentage mortality was done as in previous reports (2019, 2020), using mortality rates which is were converted into percentages. The monthly mortality rates for each site are calculated first, which then allows the average monthly rate to be calculated. These monthly average values are finally summed and converted to percent of dead fish per year.

As a percentage, this represented a probability of a fish dying during 2021 of 15.5 percent (Table 2.1.1). The mortality for salmon in the sea phase does not appear to show any decline when we look at production as a whole in recent years. For rainbow trout, the mortality was 14.8 percent (about 3 million), which can be interpreted to be a slightly downward trend. Nevertheless, the bigger picture is that sea mortality is stable.

There are still major differences in the geographical distribution of mortality (Table 2.1.2). Table 2.1.2 only reports percent recorded dead fish, not other reasons for loss. In PO2-5, the mortality rate is around 20 percent, while the figures for PO1 and the area from PO6 and northwards are all below 14 percent. The figures for rainbow trout will naturally vary somewhat more over the years, since there are few sites with this species. For more figures, see **http://apps.vetinst.no/Laksetap.**

Another way to calculate mortality (in percent) is per production cycle. Calculated mortality for production cycles, which are completed each year, are based on reports from commercial sites licenced to produce fish

Table 2.1.2 Mortality percent in the production of salmon and rainbow trout in 2019-2021 by production areas. Mortality is calculated as described in the text. For percent mortality per county, or for several years ago, please refer to the interactive application: **http://apps.vetinst.no/Laksetap/**

Salmon				Rainbow trout			
Production area	2019 % mortality	2020 % mortality	2021 % mortality	Production area*	2019 % mortality	2020 % mortality	2021 % mortality
1	10,8	11,3	10,4	-	-	-	-
2	15,7	14,4	19,8	2 & 3	19,7	15,0	17,8
3	19,1	19,9	19,9				
4	19,4	27,2	22,5	4	17,2	17,1	15,0
5	15,0	15,2	18,7	5	8,8	10,4	15,7
6	12,1	13,5	14,0	6 & 7	18,2	20,0	10,8
7	7,9	10,5	10,8				
8	10,2	9,7	12,1	-	-	-	-
9	28,8	9,6	13,6	9 & 10	8,1	9,9	4,8
10	23,0	10,2	10,9				
11	10,7	15,7	12,6	-	-	-	-
12	8,2	11,1	13,0	-	-	-	-
13	16,1	6,7	10,2	-	-	-	-

*Production areas with fewer than 5 sites have been merged.

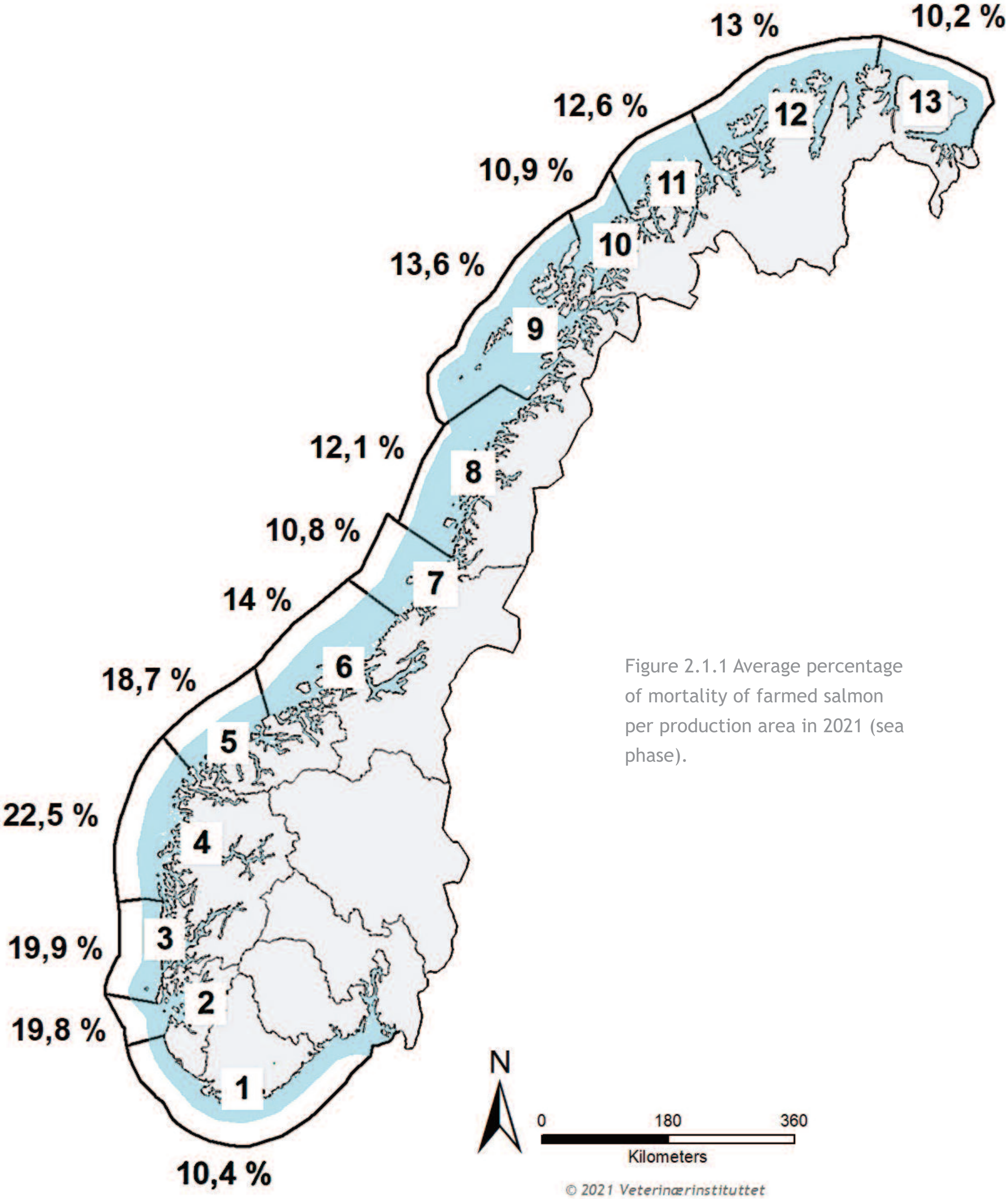


Figure 2.1.1 Average percentage of mortality of farmed salmon per production area in 2021 (sea phase).

for food consumption. Broodstock, fish from research and development concessions, teaching concessions etc. are not included. We calculated the total mortality for fish from sites that were completely harvested during the year in question, assuming these sites had complete production cycles with fish stocked for at least 12 months prior to harvest. For production cycles completed in 2021, the median mortality was 17.4 percent, while 50 percent of the mortality lay between 10.3 and 26.7 percent (Table 2.1.3). Thus, there is considerable variation in mortality between the individual production cycles. The median value is almost identical over the past five years and shows that, as a whole, the mortality rate through one production cycle is stable but high. However, the breadth of variation shows that – although the industry as such is struggling with a median mortality rate of 17 percent during a production cycle – there are producers who manage to carry out a cycle with a mortality rate down to lower than 10 percent.

For this report, we do not have a good overview of the cause of dead fish, but much of the differences between production areas can be attributed to disease-related problems (including salmon lice) and are discussed elsewhere in the report. An ongoing collaboration between the Norwegian Seafood Federation, AquaCloud, the Norwegian Veterinary Institute and individual industry operators to categorise the causes of death may provide a picture of the main reasons that we hope to present in next year's report.

Mortality and loss in juvenile production

During production of juvenile fish, mortality is the only form of loss to production registered, along with total number of fish held and mean weight. The quality of data relating to total mortality is lower during this stage of production compared to the marine phase of culture, partly due to the fact that such data has historically been analysed to a limited degree, resulting in poor feedback to the farms concerned and subsequently low motivation to improve the situation. Production routines during the hatchery phase also make gathering of data at the group level difficult.

At fish hatchery facilities, some losses related to destruction 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. This is in contrast to the figures from the Fish Health Report for 2020. Fish in this weight class account for about 45 percent of the total mortality in the hatchery phase. Figure 2.1.3 shows the mortality rate reported to the Food Safety Authority from 2011 to 2021 in the salmon and rainbow trout hatchery phase. In 2021, 33.4 million salmon and 1.9 million rainbow trout larger than 3g were reported to the Food Safety Authority. The increase we see during this period for salmon can have many causes, but if we look at the last five years, it is fair to say that annual mortality is about 30 million individuals, albeit with a slightly increasing trend. In 2019, we saw a peak

Table 2.1.3 Median mortality in salmon (percentage) for completed production cycles. The historical mortality data for 2017-2019 has changed since the previous reports due to the use of production cycles shorter than 12 months. For calculation method, see the text.

	2017	2018	2019	2020	2021
Median mortality in percent for all sea-transferred salmon production per year	17,2	17,4	15,0	17,9	17,4
1st to 3rd quartile (50% of mortality percents lies within this interval)	11-26,3	11,0-25,3	9,6-24,9	10,8-26,9	10,3-26,7

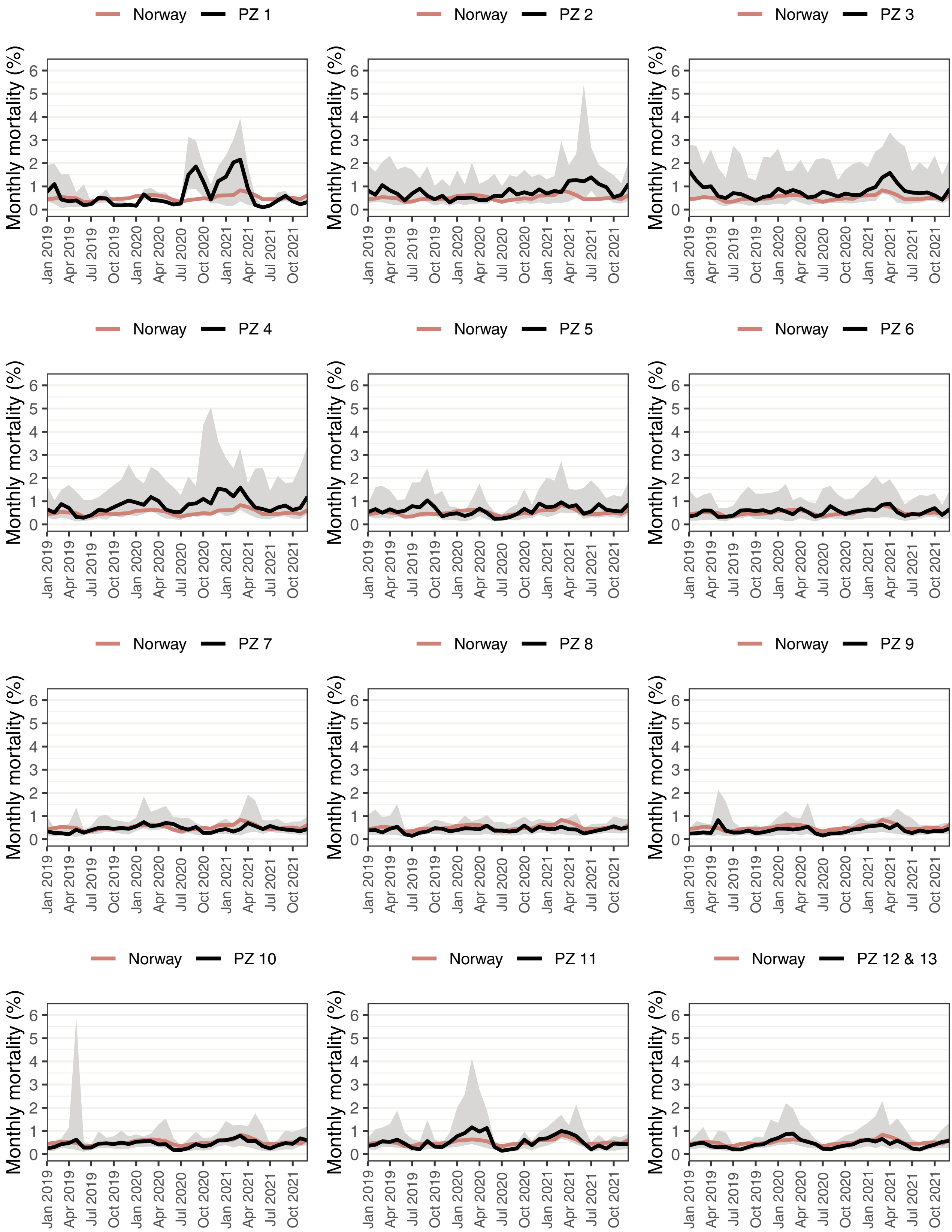


Figure 2.1.2 Mortality development for 2019-2021 in various production areas. Entire lines are medians, grey areas show the dispersion in the mid-50 percent of sites. 25% of the sites are higher than the grey area, 25% are lower.

of about 44 million that we do not have any explanation for. The distribution between the weight classes appears to be fairly stable in number for the different years. However, since the number of fish in the different weight classes remains unknown, it is not possible to say anything about the percentage distribution for mortality. For rainbow trout, annual mortality over the past five years has been between two and three million fish, one tenth of the mortality rate in salmon production.

Mortality is a rough indicator for health and welfare, but at the same time it provides a final sum of many more fine-meshed variables. A biologically robust hatchery fish is a prerequisite for good survival and well-being after release into the sea.

2.2 New animal health legislation in EU and EEA

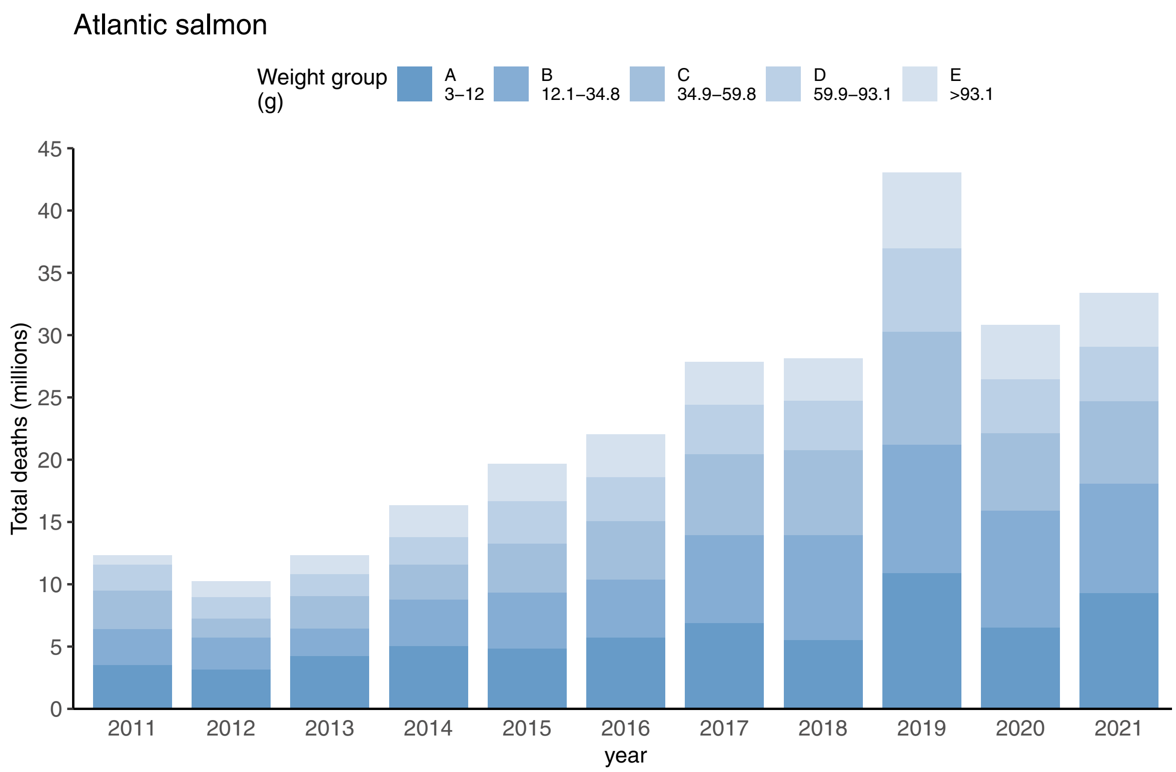
The EU adopted a new animal health directive in 2016 (2016/429) with a transition period of five years until 21 April 2021. The Animal Health Regulations are fully applicable to aquatic animals, land animals and animal products in Norway as an EEA country. The Animal Health Regulations will fully apply in Norway when all national adaptation regulations are in place.

The Act is based on the EU's previous strategy that 'prevention is better than cure'. The new Animal Health Regulations clarify the responsibilities of industry practitioners, veterinarians and governments, sets stricter requirements before setting up fish farms and is based on risk-based supervision and monitoring of facilities. Infectious diseases are categorised with common principles for handling (eradicated, fought, controlled and monitored) in order to obtain adequate regulations for preventing and controlling diseases in the EU/EEA.

The EU has categorised diseases according to specific criteria and mapping susceptible species and vectors that may pose a risk of spreading the diseases. The new Animal Health Regulations lists 13 specific infectious diseases in aquatic animals, which means they are covered by common rules for prevention, combating and controls. None of the five listed A-diseases that can affect aquatic animals occur in Norway. Diseases of category A should be eradicated immediately if detected in the EU/EEA. Of the other eight diseases, seven are categorised as C, which means EU requires that spread to a country/region that has been declared free of the disease should be prevented. Voluntary combat programmes can be established for facilities, areas or countries. Norway is declared free of four category C diseases; IHN and VHS, as well as *Marteilia refringens* and *Bonamia ostrae* (with the exception of a geographical area that has not formally regained free status). Import to Norway can only be allowed from export entities that have the same status as Norway. Since these diseases are actively monitored in Norway, exporting facilities must be able to document at least equal status and monitoring. The Norwegian Food Safety Authority shall be notified in advance of such transport. The last of the 13 specific infectious diseases is the Koi-Herpes Virus (KHV). In Norway, we had one outbreak of KHV in a private koi pool in 2019. The disease is placed in category E on EU's List of Diseases, i.e. that the disease should be monitored. Since Norway wants to maintain its own national disease list, KHV will most likely be listed as a List-3 disease so that various measures can be implemented in the event of detection.

Infectious Salmon Anaemia (ISA) with the ISA-virus (ISAV HPR-deleted) is listed as a category C disease. The Fish Health Report refers to an increase in incidences of ISA cases. The new Animal Health Regulations require Norway to actively choose an eradication strategy which aligns with that specified in the Disease List (2018/1882) or introduces stricter management.

Management in accordance with the requirements for category C can be achieved by establishing a voluntary combat programme. If ISA is to be fought more strictly (according to category B), the combat plan must be approved by EU/EEA. Continuing current management procedures in Norway must also be approved by EU/EEA.



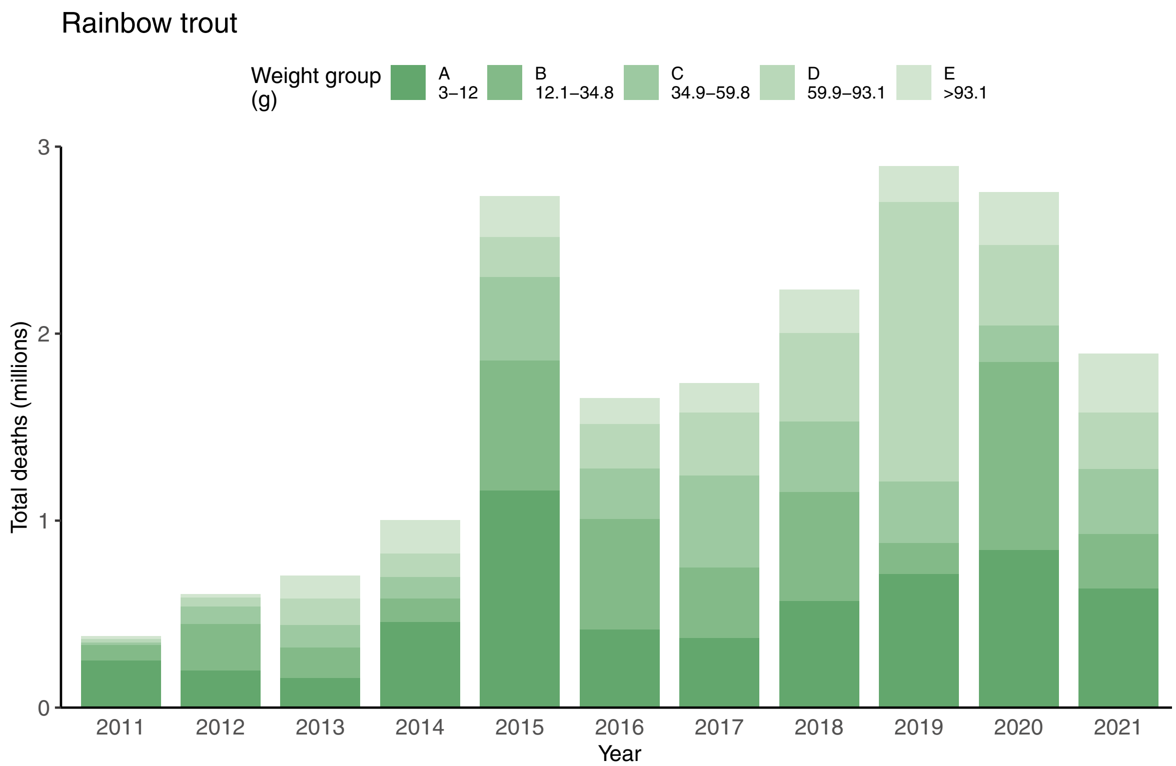


Figure 2.1.3 Mortality of salmon and rainbow trout in hatcheries (in number of individuals) reported to the Norwegian Food Safety Authority, divided into different weight classes.

In the Animal Health Regulations, only the disease-causing ISAV HPR-deleted is listed, while both ISAV HPR-deleted and the non-disease-causing ISAV HPR0 are listed by the World Organization for Animal Health (OIE). This means that ISAV HPR0 nevertheless becomes part of the conditions for international trade in aquatic animals. The occurrence of ISA cannot be without also considering the presence of ISAV HPR0. Vaccination is proposed as a means of lowering infection pressure, but many unanswered questions related to how the vaccine works and how the ISA virus behaves in infected, vaccinated fish remain. This results in professional uncertainty regarding control programmes that include vaccination.

Since ISAV HPR0 occurs in salmon in different production phases, it can also be challenging to screen the different phases of the production chain from each other in terms of infection. This requires sufficient biosecurity barriers to declare free from outbreaks and to prevent outbreaks of ISA even if some segments and/or production phases manage to eliminate occurrences.

The new Animal Health Regulations bring together EU/EEA legislation within animal health, with only a few exceptions. However, this is comprehensive and complex legislation, and compliance with increased requirements for approval and registration of fish farms, transport, risk-based supervision, monitoring and combat is not easy. Implementation may be resource-intensive for governments and industry, so it may be appropriate to assess opportunities for utilising data related to localisation, health and production to arrive at comprehensive decision support to prevent and manage disease.

2.3 Infectious salmon anaemia (ISA) - a persistent challenge

The trend of a high number of confirmed ISA cases also continued in 2021 with 25 cases. This is two more than in 2020, and a total of 15 more than the average in the period 1993 to 2019. One must return to the ISA epidemic in 1989-1992 to find a higher number of annual ISA cases than in 2021. Fourteen of the sites were covered by existing ISA control regulations at the time of ISA was suspected, four in an eradication zone and ten in a surveillance zone. A detailed analysis of the ISA situation for 2021 is given in Chapter 4.2. Although the number of ISA cases in 2021 is relatively similar to that observed in 2020, the incidence per production area is different. Figure 2.3.1 shows the annual prevalence of ISA in ongrowing facilities per production area over the past six years. Although the prevalence is typically higher in northern than southern production areas, the variation between the years shows that ISA must be taken into account and considered as a potential differential diagnosis along the entire coast. Three of the facilities with confirmed ISA in 2021 held ISA-vaccinated fish.

The Norwegian Veterinary Institute already described the increase in the number of ISA cases as worrisome in 2020, and the situation has not improved for 2021. In this year's survey, fish health personnel and inspectors from the Norwegian Food Safety Authority were asked separate questions for the first time about ISA (infection with virulent ISAV-HPR-deleted) and infection with non-virulent ISAV (ISAV HPR0). The results show that ISA was ranked at the top of the list of growing problems at ongrowing facilities/fish farms. At broodstock farms, ISA and ISAV shared HPR0's top spot, while at hatcheries only nephrocalcinosis was ranked higher than ISAV HPR0 as an increasing problem. This shows that the Norwegian Veterinary Institute's concern about the incidence of ISA and ISAV HPR0 is also shared by fish health personnel and the Food Safety Authority's inspectors.

The disease-causing variant of the ISA virus (ISAV HPR-deleted) is developed from the non-disease-causing variant (ISAV HPR0), and such a transition is a possible explanation in cases where disease outbreaks cannot be traced back to a probable known source of infection by ISAV HPR-deleted. Phylogenetic analyses show that there were more incidents of the ISAV-HPR-deleted associated outbreaks in 2021 from sea sites and ISAV HPR0 were identified at hatchery sites that supplied smolt to these locations.

The Organization for Animal Health (OIE) has listed both ISAV HPR-deleted and ISAV HPR0, and both are therefore notifiable infections for OIE member countries. Despite this, ISAV HPR0 is not subject to notification in Norway, and detections of ISAV HPR0 are not registered in a central register with subsequent reporting to OIE. The lack of a national overview of the occurrence of ISAV HPR0 makes it difficult to obtain scientific knowledge about the real importance of ISAV HPR0 for the development of ISA. Since 2019, active monitoring of ISAV HPR0 has been carried out in hatcheries under the auspices of the Norwegian Food Safety Authority. In 2021, eight out of 78 hatcheries in the monitoring programme (10 percent) tested positive for ISAV HPR0, compared with 14 percent (six out of 42) in 2020 and 7 percent (five out of 74) in 2019. Facilities with RAS technology appear somewhat overrepresented among facilities with proven ISAV HPR0, and ISAV HPR0 has also been proven on fish that have not had contact with seawater. For sea sites, information from monitoring of ISA control areas, the monitoring programme for ISA-free zones and segments as well as diagnostic examinations at the Norwegian Veterinary Institute show a total of 34 sea sites with proven ISAV HPR0 in 2021. Given that ISAV HPR0 results in a short, transient infection and that the statistical data available is limited, these figures probably represent a considerable underestimate of the real number of hatcheries and sea sites that test positive for ISAV HPR0 in one year. On the basis of these aspects, the Norwegian Veterinary Institute believes that a duty to report ISAV HPR0 should be introduced without administrative consequences. This will give research institutions and the government more knowledge and improve our overview of the ISAV HPR0 situation in the Norwegian aquaculture industry, while not resulting in significant losses for the industry.

In connection with the Animal Health Regulations, a new management strategy for ISA is being worked out in

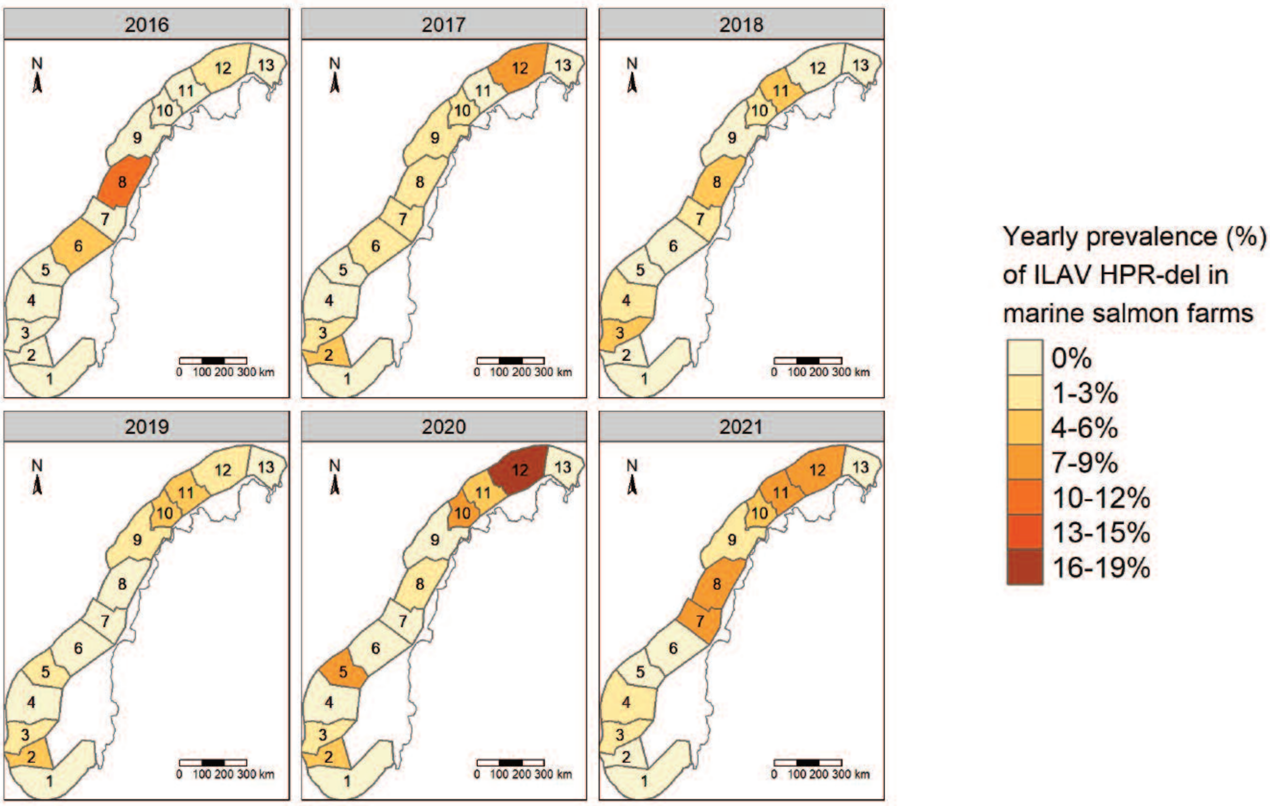


Figure 2.3.1 Annual prevalence (%) of confirmed ISA cases in fish farms per production area 2016 - 2021.

Norway (see Chapter 2.2), and the Food Safety Authority issued a consultation on future management of ISA in December of 2020. In the consultation letter, the Norwegian Food Safety Authority recommended a strategy of public combating of ISA, while one of the three alternative strategies only involved voluntary combat. The Norwegian Veterinary Institute wrote in its consultation response that ISA, as the most serious viral disease in Norwegian salmon farming, must be controlled via the maintenance of a public combat programme. Previous ISA epidemics in Norway, the Faeroe Isles and Chile show how serious the situation can become when ISA cannot be controlled. The persistently high incidence of ISA over the past two years further underlines the need for strong public management of ISA.

While the Norwegian Veterinary Institute collects data on vaccine status for fish at sites with proven ISA, there is no national public overview of the general vaccine status of fish. However, there appears to be an increasing degree of vaccination being used to combat ISA. In 2021, ISA was detected at three sites with fish vaccinated against ISA.

Vaccines that are available on the market have been documented to reduce the incidence of signs of disease, clinical effects and death. There is no evidence that the vaccine blocks the excretion of viruses in vaccinated fish that become infected. Fewer visible clinical signs linked to ISA infection in vaccinated fish may result in ISA not being diagnosed (underdiagnosed), and sites with ISA-positive fish may be left as sources of infection. The fish can then be transported/slaughtered without knowledge of a possible ISA diagnosis. This can contribute to camouflaged dissemination and construction of endemic ISA areas with reservoirs in the environment and repetitive ISA problems in the long term. There is a great need for more knowledge about the ISA vaccine and how it possibly affects viral evolution and excretion of the virus in infected individuals.

2.4 Antibiotic consumption

The consumption of antibacterial agents, measured in kgs of active substance, has historically been used as an indicator for occurrence of bacterial diseases. Vaccines against cold-water vibriosis and furunculosis were adopted in the late 1980s and early 1990s, respectively, and since then the consumption of antibiotics in kgs has been very low (source: **https://www.vetinst.no/overvaking /antibiotic resistance norm-vet)** despite a sharp increase in the production of fish. For the years 2015-2021, antibiotic consumption in kgs was higher in 2017, 2018 and 2021 compared to the other years (Table 2.4.1). The reason for this is a few treatments at a few sites with large salmon in these three years; for example, for 2021 a single prescription accounted for 600 kgs of the total amount (949 kgs) of antibacterial agents reported to the Veterinary Drug Registry (VetReg).

Table 2.4.1 Antibacterial agents used for farmed fish (kgs of active substance). Data is based on data from the Veterinary Prescription RegisterRegister (VetReg). For 2015-2020, the figures have been validated against sales figures reported by the Norwegian Institute of Public Health; figures for 2021 are preliminary. Data extracted from VetReg 28 January 2022.

Antibiotics	2015	2016	2017	2018	2019	2020	2021
Florfenicol	188	136	269	858	156	115	892
Oxolinic acid	84	66	343	54	66	107	57
Oxytetracykline	-	-	-	20	-	0,72	-
Enrofloxacin	0,02	0,05	0,01	-	0,01	0,12	0,25
Amoxicillin	-	-	-	-	-	0,09	-
Total	273	201	612	931	222	223	949

The number of treatments is a better indicator of the occurence of bacterial diseases per fish species and production stages than the total amount (kgs) of active substance. Figure 2.4.1 shows that for salmon and marine species, the number of treatments was somewhat higher in 2021 compared to the period 2015-2020.

Previously, the number of antibiotic treatments for cleanerfish has been considerably higher compared to number of treatments of fish farmed for food. However, there has been a large decrease in the number of antibiotic treatments of cleanerfish; In 2016, 126 treatments of cleanerfish were carried out, while in 2021 this figure was 4.

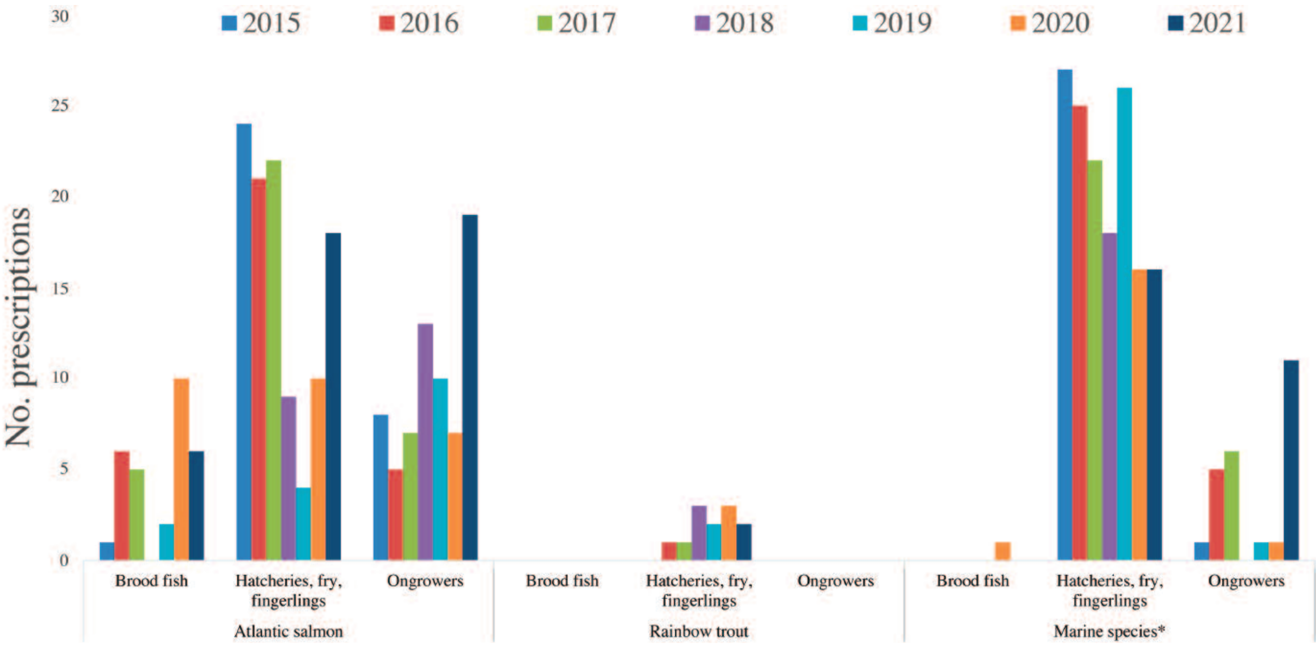


Figure 2.4.1. Number of treatments with antibacterial agents divided by fish species and production stages in the years 2015-2021. The number of treatments represents the number of prescriptions obtained from the veterinary prescription register (VetReg) (data extracted 28 January 2022). * Cod, halibut, turbot, spotted wolffish

2.5 Bacterial infections – increasing occurrence

After many years of relatively stable incidence of bacterial diseases in farming, the situation appears to be changing. This gives cause for concern.

Increasing incidence and/or significance is recorded both for diseases caused by known bacterial fish diseases such as yersiniosis, furunculosis, vibriosis and typical winter ulcer, but also diseases related to more opportunistic environmental bacteria such as Tenacibaculum spp. The reasons for the changes are probably complex. The increase in the fish pathogenic bacteria is linked to the spread of infection from reservoirs with farmed or wild fish, and must be controlled through biosecurity measures. Not least, it is necessary to have a good overview of the health situation so that sick fish are not put out to sea or moved.

Increased incidence of disease caused by more opportunistic bacteria is either due to reduced resistance in the fish, changes in the properties of bacteria or changes in infection dynamics as a result of external conditions. There is particular reason to point out the increase in the use of operations that require intensive handling of fish, such as in delousing.

Operations that require intensive handling of fish can cause damage to the skin and mucus layers, and cause stress to the fish. The skin, together with gills and intestines, is the fish's main barrier against the penetration of bacteria and other infectious agents. Through experiments, the Norwegian Veterinary Institute has shown that thermal delousing results in massive shedding of *Yersinia ruckeri*, from latently infected fish.

It is difficult to get a good overview of these skin problems as they are not part of a systematic registration. In the survey, however, winter ulcer scored high among fish health personnel as the cause of reduced welfare, and as a growing problem in salmonids at ongrowing facilities. The ulcers are also cited as the main cause of declassification at harvest.

Classic furunculosis was in 2020 registered at six ongrowing facilities in the Namdal region. In 2021, furunculosis was identified in salmon at two hatcheries and three fish farms that received smolt from these hatcheries. One of the fish farms was required to empty at risk of infection to wild fish and other fish farms.

Available data indicates that furunculosis is not common in wild salmon, except in some rivers in the Namdal region and one area in Nordland. The favourable situation we have had in aquaculture in recent years can probably be attributed to little infection in farmed fish due to effective vaccines, favourable climatic conditions and low incidence in wild fish. A continued low infection load in farmed fish is a prerequisite for preventing new reservoirs from being established in the wild fish population or strengthening existing reservoirs.

Pasteurellosis has increased in scope – both in terms of the number of positive sites and in geographical distribution – after the disease was first rediscovered in 2018. There is currently no vaccine available, and much is unknown about the epidemiology of the disease.

Climate change must be expected to affect the occurrence and composition of bacterial diseases in aquaculture. A shift towards a higher incidence of pathogenic bacteria normally associated with warmer water is likely, but we also see that coldwater bacteria such as *Flavobacterium psychrophilum* can also cause disease even at high temperatures. This may be due to a genetic breadth within the bacterial families that allows for adaptation to warmer climates. We can thus both keep the 'old' disease-causing bacteria we have today and at the same time get new ones.

Norwegian salmon farming has been in a particularly favourable situation when it comes to bacterial challenges. However, both climate change and new modes of operation indicate a more demanding future scenario of infection. Pasteurellosis is an example of how vulnerable the industry is to new contagious infections, and how important it is that changes in disease scenarios are identified quickly and handled in an open collaboration between industry, government and research institutions. Important measures are: monitoring for early detection, rapid professionally-based decisions and the ability to implement them to prevent new infections from gaining a foothold and establishing themselves. A professional understanding of changes and the possibility of rapid vaccine development will depend e.g. on having an accessible biobank. This provides opportunities to follow developments in various infectious agents through continuous characterisation and comparison of new and old isolates.

2.6 IHN – one of our biggest known health threats

Infectious haematopoietic necrosis (IHN, see Chapter 4.7) is an endemic disease in mainland Europe (ref. EU Reference Laboratory, Figure 2.6.1).
In the winter of 2017/2018, IHN was detected for the first time in Finland in rainbow trout in sea and inland farming. IHN was first detected in Denmark in May of 2021. The disease was detected in rainbow trout in a total of 11 dam farms and put-and-take lakes. In December 2021, Denmark gave up its IHN-free status. This entails a greater freedom for the relocation of fish within the country, but also provides significant trade

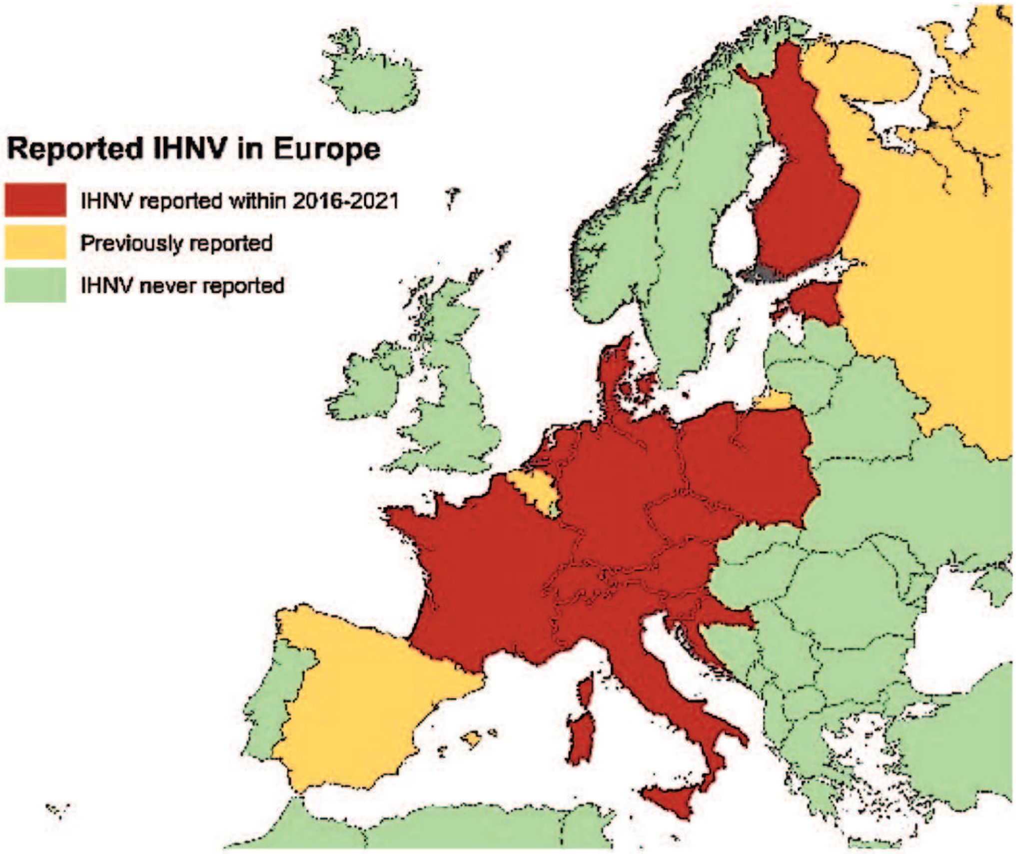


Figure 2.6.1 Overview of IHN virus (IHNV) in Europe, based on OIE-WAHIS (as of August 2021).

disadvantages for Danish breeders. In connection with the outbreak in Denmark, IHN was again detected in Åland in facilities that had imported fish from infected facilities in Denmark. IHN has been found in Russia, but there is little up-to-date data regarding the occurrence of IHN. IHN has never been detected in Norway and Sweden.

Atlantic salmon, sea trout/brown trout and char are all susceptible to IHN. Fry are generally more susceptible to the disease than older fish. In the event of sexual maturation, susceptibility increases again and infected fish can then secrete large amounts of virus with genital products.
This indicates that IHN is getting ever closer to Norway and that the likelihood of introduction of the disease increases. In essence, we can envision the following introductory paths as most relevant;

1. Import of fish (including cleanerfish), roe, fish products and transport water
2. Inward migration of infected wild fish
3. Ballast water
4. Tourism fishing

Ad 1. For the period 2017-2021, we had one import of live rainbow trout into Norway. It came from Denmark in 2020, and went to VESO, Namsos, where the fish were used in experiments and then euthanised. During this period, no live salmon or other salmonids were imported to Norway. On the other hand, rainbow trout are regularly imported from Sweden to Norway for rakfisk production (i.e. partially fermented trout). Sweden imports some roe and fry, among other places from Denmark. We are seeing increasing activity in inland farming. These are also subject to health inspections in the same way as other aquaculture activities, but the Norwegian Veterinary Institute receives few enquiries or diagnostic cases from inland farming. It will be vital that these facilities are also included in the overall picture to ensure disease prevention and good preparedness for the entire aquaculture industry.

Turbot are imported from Spain and France, but is not considered a species susceptible to IHN. Significant amounts of wild-caught wrasse come from Sweden, but wrasse as a group are not considered susceptible. Imported aquarium fish often have unknown infection status, and both goldfish and koi can be PCR positive for the IHN virus (IHNV). We assume that the virus does not replicate in these species.

Even if a species is not registered as susceptible, it may still be exposed to viruses and become passive carriers of infection. Similarly, transport water for imported fish may contain viruses. This water is rarely or never checked, and it is released freely into the environment. Import of genital products, which can also be infectious, are only registered from Scotland, Sweden and Iceland – all of which are IHN-free zones.

Ad 2. IHNV can be introduced via

- Wild Atlantic salmon returning from marine migration.
- Pink salmon from Russia.
- Anadromous and non-anadromous species that migrate in waterways that Norway shares with our neighbouring countries.
- Sea trout from Danish rivers that migrate up to the Norwegian coast

The extent or manner to which there is contact between salmonids in the marine migration phase is unknown, but fish from different geographical locations have migration zones that overlap significantly. The spread of infection across national borders via rivers and lakes is generally a threat both through natural migration and illegal transfer of fish. In the north, there are several watercourses that link Norway with our neighbouring countries that can potentially bring infection into Norwegian populations. Pink salmon is not described as a species susceptible to IHN, but we must assume it is a possible passive carrier of

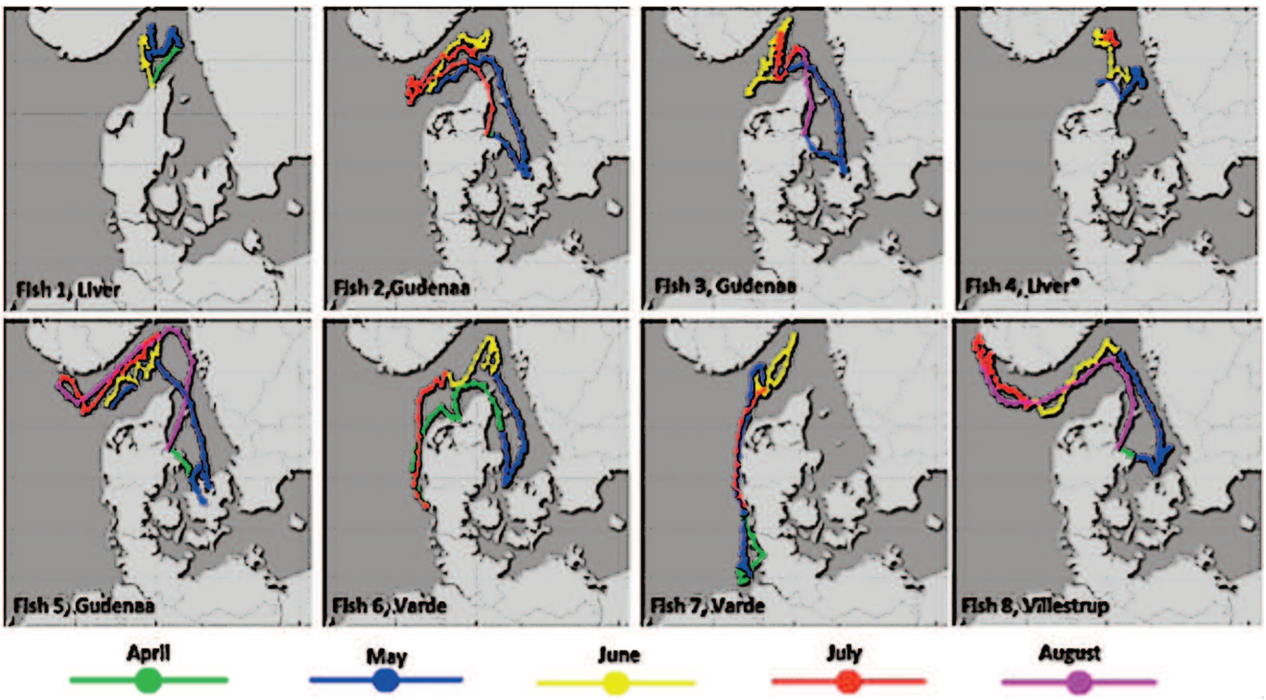


Figure 2.6.2 The figure shows that the mark spawned sea trout from Denmark wander in Skagerak and can wander all the way up to the coast of Norway (Kristensen et al. 2019).

infection. Adult sea trout from Denmark migrate in the Skagerak and can wander all the way up to the coast of Norway. These migrations show that sea trout may share a contact surface with Norwegian salmonids (Figure 2.6.2).

Ad 3 and 4. Ballast water is known to bring various forms of microorganisms with it. The Ballast Water Regulations stipulate requirements for disinfection and discharge, but also have exceptions that allow ballast water from as far away as Brittany area to be released freely into Norwegian coastal waters.

Due to the parasite *Gyrodactylus salaris*, there is great attention and respect for avoiding the spread of infection into healthy rivers among Norwegian and foreign salmon and sea trout fishermen. This general attitude can help reduce the likelihood of introduction and spread of other infectious agents through tourist-related recreational fishing.
The fish health services and diagnostic laboratories must be vigilant in relation to this disease in their routine diagnostics. IHN may be clinically similar to VHS and have a creeping spread without high initial mortality. In case of unexplained mortality, one should always have IHNV in mind as a possible diagnosis for early detection.

After the outbreaks in Denmark, the Food Safety Authority expanded its routine monitoring programme to include samples from rainbow trout in inland farming, brown trout in restocking and ongrowing facilities as well as a larger number of pink salmon for IHNV in 2021.

2.7 Salmon lice and lice management

The salmon louse is a key issue in the health and welfare of fish at marine salmon farming facility. This is because salmon lice are a parasite with a pathological potential for the host, but not least because of the control measures that are put in place to keep lice numbers below the limit values stated in the Salmon Lice Regulations **(https://lovdata.no/dokument/SF/forskrift/2012-12-05-1140).** These limits are set lower than the number of lice that exerts significant damage to farmed fish, in order to provide better protection to the wild salmonids. Lower lice limits lead to more treatment for salmon lice and each treatment has its potential side effects. The side effects depend on the health of the fish, the method of treatment chosen and the method of implementation. In general, treatment methods with little handling cause fewer side effects for the fish, in the form of injuries or increased mortality.

The total amount of medicinal and non-medicinal treatments to combat salmon lice has increased by 79 percent from 2012 to 2021, while the number of active fish farms increased by 8 percent (Figure 2.7.1). One of the reasons for the increase in the number of treatments is probably that each treatment has become less effective, and partly due to the development of resistance, so more frequent treatments are needed to keep lice levels down.

Developments in the use of treatment methods to combat salmon lice have moved towards increased use of methods that require more handling of the fish, from 2016 through 2020, with a slight reduction/flattening of developments in 2021 (Figure 2.7.1). There are several reasons for this development in the choice of control methods. Preventive methods and continuous delousing (cleanerfish/laser) have long been highlighted as the most gentle methods of lice control, but so far and at most facilities this has not proven to be sufficient to achieve lice numbers that are low enough. Medicinal methods are usually more gentle on the fish than the non-medicinal methods, but extensive resistance to the drugs as well as the environmental aspect of the use of drugs mean that their use was greatly reduced starting in 2017. The non-medicinal methods have dominated since that year and use has increased year after year until 2021 when we saw a slight reduction/flattening in use for the first time. The non-medicinal methods that have dominated since 2016 are those that require the most handling (thermal and mechanical delousing), while there are feed treatments with very few health and welfare side effects, which are most commonly used in the medicinal methods (see Chapter 7.1 Salmon Lice for details). It is thus the use of non-medicinal methods to

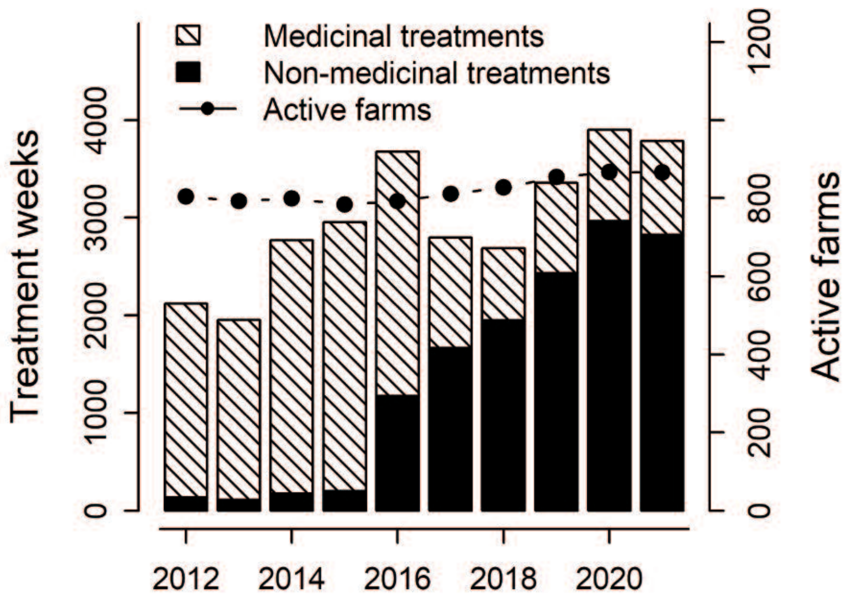


Figure 2.7.1 Number of reported medicinal and non-medicinal treatments to combat salmon lice and the number of active fish farms from 2012 to 2021. The treatments are for weeks in which the sites reported that they carried out lice treatment to the Norwegian Food Safety Authority (data extracted from BarentsWatch on 20.01.2022). The number of active fish farm with salmon or trout in the sea for the year in question.

control lice numbers that leads to the negative health and welfare effects for which salmon lice become an indirect cause. See Chapter 3 Fish Welfare for more details on the welfare effects of such treatment.

2.8 Pink salmon - a new health threat

2021 was a new record year for the invasion of pink salmon into Norwegian fjords and rivers. A total of 111 657 pink salmon (191 tons) were registered in the rivers and 38 900 (72 tons) in the sea salmon fishing statistics (SSB).

The alien species was registered along the entire coast, but was most numerous in Troms and Finnmark County with 98 percent of river catches (SSB). Despite great efforts in direct-action fishing, pink salmon have spawned in Norwegian rivers in 2021, so we expect pink salmon to return from the sea in record numbers also in 2023. The population of pink salmon is maintained because the species is considered and managed as an important marine resource in Russia, and because self-producing populations are gradually established in Norway. Climate change is beneficial for the pink salmon, and there is little doubt that we will have to live with this alien species in the years ahead. In several of the fjords and rivers in the far north of the country, the pink salmon are more numerous than indigenous wild salmonids. The pink salmon move in large shoals in the fjords before going up into the rivers to spawn. In the event of large occurrences, the shoals will probably influence infection dynamics between the fish farms and between farmed and wild indigenous salmonids.

Health monitoring of pink salmon in 2021 did not identify any notifiable diseases/infections , but as in 2019, piscine orthoreovirus-1 was detected. In 2021, the Norwegian Veterinary Institute diagnosed haemorrhagic septicemia caused by *Aeromonas hydrophila* in a pink salmon found dead in the Gjersjø River in the Municipality of Follo. *Aeromonas hydrophila* occurs naturally in the environment and in the fish's intestines, but can cause disease in fish, humans and a wide range of other animal species when conditions are right for it. All pink salmon die after spawning, and in large quantities the decay and decomposition will affect water quality both through nutrient supply and bacterial growth. There is a great need to professionalise direct-action fishing of pink salmon and disposal of the catch. There is also a great need for more knowledge about how the species affects ecosystems, what consequences it has for water quality and for infection loads for humans, wild fish and farmed fish.

2.9 IPN – new challenges

Relatively few outbreaks of IPN are still recorded at ongrowing facilities and hatcheries for salmon production. IPN has for many years been managed well by using QTL roe combined with the systematic extinction of house strains.

A large proportion of Norwegian farmed salmon are vaccinated with a combination vaccine that also includes an IPNV component. However, the efficacy of the vaccine is uncertain. After the detection of a new IPNV variant, it is now reported that IPN is a growing problem with somewhat increased mortality, reduced growth and reduced welfare. Although overall the number of IPN detections has not increased in the last two years, the reports indicate that efforts must be made to map mechanisms for IPN QTL salmon for protection against the new IPN variant, investigate whether breeding programmes can contribute to further improved IPN-resistant roe, combined with optimising the vaccine. Currently, there is no detection of IPN at fish farms with rainbow trout.

2.10 New aquaculture technology, health and welfare

Different types of semi-enclosed facilities have been developed and tested in several locations along the coast. The results so far have shown that it is possible to prevent lice infection and collect part of the organic material that comes from surplus feed and fish faeces at this type of facility. Semi-enclosed facilities are less flexible and are more vulnerable to currents and waves than ordinary open cages and will initially be best suited to the most sheltered coastal sites.

For semi-enclosed facilities in the coastal zone, the most immediate gain is the possibility of using deep water to provide complete protection against infection from salmon lice. This effect, combined with structural adaptations for how the facilities are located, can greatly reduce infection load between the facilities and thus also from farming to wild fish. The current treatment regime against lice is based on the use of wellboats or specialised delousing barges. The frequency of lice treatments and the relocation of vessels between sites pose a risk of spreading infectious diseases such as ISA and PD. Better lice prevention will also result in increased fish welfare through reduced use of cleanerfish and lower fish mortality after lice treatment, especially in the largest fish that are most susceptible to treatment. A lowering of the risk of spread of infection for pathogens such as ISA virus, may also be possible. However, for pathogens other than lice, movement of the industry offshore or adoption of fundamental structural changes will almost certainly make a far greater contribution to a reduction in infection pressure than current semi-enclosed farm designs. The situation would be different should such facilities incorporate treatment systems for of inlet and/or waste-water.

One method of using semi-enclosed facilities is to produce medium-sized fish (post-smolt) up to about 1 kg, and then move the fish into open cages for production until harvest. In this way, the time the fish is exposed to lice infection is reduced and the large fish can be moved out to more exposed and less infection-laden locations than are possible to use in normal sea-transfer of smolt. It has not been shown that deep water provides protection against agents other than salmon lice, moving fish from semi-enclosed facilities (without treatment) to open facilities will therefore entail a risk of spreading a number of agents, in the same way as when moving fish between sites with open cages.

For what we call off-shore aquaculture, locating sites farther out from the coast will cause the facilities to be exposed to more powerful currents and larger waves; aquaculture at sea is therefore also called exposed aquaculture. Relevant areas are defined in a zone from one nautical mile (nm) off the coastline and within Norway's exclusive economic zone (200 nm off the coastline). The areas selected for impact assessment by the Institute of Marine Research and the Directorate of Fisheries so far are 10/11 Frøyabanken, 2 Norskerenna south and 7 Tromsøyflaket. The first application for site clarification came to the Directorate of Fisheries as early as 4 January 2021. A steering group for sea-based aquaculture was established in the Ministry of Trade, Industry and Fisheries (NFD) comprised of representatives from NFD, the Directorate of Fisheries and the Norwegian Food Safety Authority with subgroups for aquaculture technology, land use and EHS. In a broader perspective, the focus on new technology and new forms of use at sea must be based on the guidelines set by the international ocean panel (High Level Panel for a Sustainable Ocean Economy), where Norway now holds the chair position (www.oceanpanel.org). The panel has set up several main recommendations concerning aquaculture at sea, including that decision-making processes should be research-based and that offshore measures should be assessed based on the full and real value of the sea and sea areas.

The Institute of Marine Research has used an infection model for salmon lice, and believes that facilities located at a distance of up to 20 to 30 nautical miles from the coast should be managed in connection with the zoning regime for facilities inside the coast. For facilities farther out, there will be little spread of infection to the coast, but when establishing more and large facilities on more open seas, some form of zone division across the direction of coastal currents will also be required.

In 2021, the Norwegian Veterinary Institute was part of a Green Platform project that will work on, among other things, infection monitoring and controlling the spread of infection using both semi-enclosed facilities and off-shore aquaculture. At exposed sites there will be greater forces from currents and waves into the facilities, and the consequences it can have for the fish must also be closely monitored. For salmon in most locations, the current speeds are low to moderate, but periods of very strong currents may occur at some depths and the effect this has on fish behaviour and welfare must also be mapped. For cleanerfish that have far poorer swimming capacity than salmon, exposed sites will be largely unsuitable. The welfare of salmon will also be affected by large waves, and it will be important to develop technologies and operating methods gradually to ensure good welfare along the way.

Offshore facilities can provide better infection control due to increased distance to other fish sites, but open facilities will always be exposed to a certain amount of waterborne infection. These farms are also large and require stocking with large numbers of fish. High densities of fish may be negative once infections are allowed to enter. Water exchange and maintenance of sufficient oxygen levels may be challenging. Operating offshore facilities depends on refilling with large post-smolt from facilities closer to the coast, and in doing so it is also possible that infection is brought in from there. SINTEF has shown that in their experimental farm off the coast of Frøya (an island on the west coast of Norway) that even in exposed sites a build-up of particles and infectious agents is possible around the farm. The effect of infection and increased microbiological load on wild fish around the facilities and any escape from these large populations makes it important to chart developments from the time that the facilities become operational.

Offshore aquaculture involves the exploitation of a new territory and has from the industry's point of view been presented with opportunities for rapid upscaling. Aquaculture at sea requires large amounts of fish that would entail significant challenges in the event of outbreaks of disease. It is striking how little attention is paid to the welfare, health and infection challenges this type of production can entail, both internally at the sites and for the surrounding environment. There is little knowledge about the spread of infection, fish health and fish welfare when operating at such exposed sites, although several projects have been initiated to look at some of these issues. But the results from these may again come after the historically major players that want to control developments. Biology and ecology can again become the losers.

The total number of dead salmon in the sea phase was 54 Million in 2021. Photo: Rudolf Svensen, UWphoto

3 Fish Welfare

By Kristine Gismervik, Ewa Harasimczuk, Kristoffer Vale Nielsen, Siri Kristine Gåsnes, Brit Tørud and Cecilie M. Mejdell

The Animal Welfare Act demands that farmed fish shall have an environment and care that ensures good welfare throughout the whole farming cycle. The act applies equally to all fish in aquaculture, including lumpfish and wrasse species used as cleaner fish to remove salmon lice.

Animal welfare can be understood based on 1) the biological functioning of the animal, with good health and normal development, 2) the animal's self-perceived situation with an emphasis on emotions such as fear and pain, and 3) the most natural life possible. Animal welfare may be defined as the individual's mental and physical state while coping with its environment, or the quality of life as perceived by the animal itself. When evaluating fish welfare it would seem sensible to focus on these approaches.

Good health is a precondition for good welfare. Both intensity and duration of pain and discomfort are important animal welfare parameters. That fish survive is no guarantee that their welfare is satisfactory. In practice, fish welfare will be influenced by a combination of factors such as disease, environmental conditions, nutrition and production technologies, including handling.

It is important that attitudes and vocabulary, both in terms of legislation and in everyday use, contribute to increasing awareness that fish are living animals and that they can experience both good and poor welfare. The so-called “Harvesting Legislation” (“Høstingsforskriften”) that came into force on 1 January 2022 have replaced words such as "fishing and capture" with "harvesting of resources", which has generated strong reactions, not least among fishermen. The government points out that the term "harvesting" should cover fishing of fish, catching shellfish and marine mammals, but also harvesting seaweed and kelp. Redefining the harvest of animals that occur in fishing and capture to the same as harvesting plants undermines the work of animal welfare in fisheries. Harvesting in agriculture means "mowing, cutting, picking and collecting, bringing under the roof various grains, berries and crops" (naob.no/ordbok), and the Norwegian term “høsting” (harvesting) is not used for euthanising/slaugthering either cows or sheep in barns. Paragraph 20 of the Animal Welfare Act states: *Hunting, capture and fishing shall be carried out in a manner that protects animal welfare*. It can hardly be defined as protecting animal welfare to eliminate conceptual definitions for management which distinguish live animals from plants. Research shows that the nuances not visible in a language are not seen either. A systematic comparison of the public legislative framework for fish farming and poultry revealed that generally less positive wording was used relating to welfare in farmed salmon. A potentially contradictory goal between economics and animal welfare in the mission statement to the Aquaculture Operations Regulations may give a misconception that economics should be emphasised over health and welfare. Such differences and different uses of concepts can do something to us, and affect how we interpret legislation. Paragraph 3 of the Animal Welfare Act states that animals have their own value, regardless of how they are used by or usefulness to humans. Fish health personnel and research institutes have a particular responsibility to promote better fish welfare, disseminate knowledge and promote positive attitudes related to fish welfare to the industry and the population in general.

3.1 Welfare indicators

Welfare indicators are often divided into environmentally based indicators, i.e. measuring something in the environment of the fish like water quality, and animal-based indicators, where measurements are taken from the fish. The animal-based indicators are either group-based like mortality or schooling behaviour, or individual-based like scoring the external injuries seen on a fish. Good welfare indicators should be simple to measure and easy to interpret. Part of the challenge regarding use of welfare indicators is possessing enough knowledge of biological variation, threshold values, and identify indicators that can be correlated to the fish’s own experience of good welfare. Good fish welfare is more than an absence of poor welfare. The ethical norms for what is acceptable as satisfactory in terms of welfare are changing as we gain knowledge and develop better methods for evaluating how the fish experience their situation.

The Fishwell Project gathered knowledge about welfare indicators for farmed salmon and rainbow trout into two books (published in 2019 and 2020) that provide good background knowledge to further develop and collect welfare protocols that can be applied in practical ways. The LAKSVEL Project (FHF-901554) includes a practical scoring protocol as a contribution to further developing welfare monitoring of salmon at Norwegian fish farms.

Dead fish represent the most reported indicator associated with fish welfare (See chapter 2). However, without additional information, this indicator provides little information on the actual fish welfare or the possibility for repeated incidences of mortality. Mortality categorisation is a way to identify the probable cause of death. The categories can include disease, mechanical injury, environment-related, smoltification-related, production-related, predators and other known and unknown causes. A collaboration was initiated in 2021 between the industry represented by the Norwegian Seafood Federation, Aquacloud and the Norwegian Veterinary Institute to put in place a reporting system on the causes of mortality based on more defined categories.

3.2 Fish welfare and health in legislation and management

It is important that legislation and public management of fish welfare and health are fit for purpose, and that they enable extraction of relevant statistics. There is room for improvement in legislation, industry reporting to the public authorities and how the public authorities are organized (Norwegian Fish Health Report for 2019). There is great potential for improvement if we use the Animal Welfare Act as a legal basis for other legislation that is actively enforced. There is also a great need to get indicators of fish welfare and health into a system that regulates growth and other developments in the aquaculture industry. Systems must be established that reward those who invest in welfare. Data related to

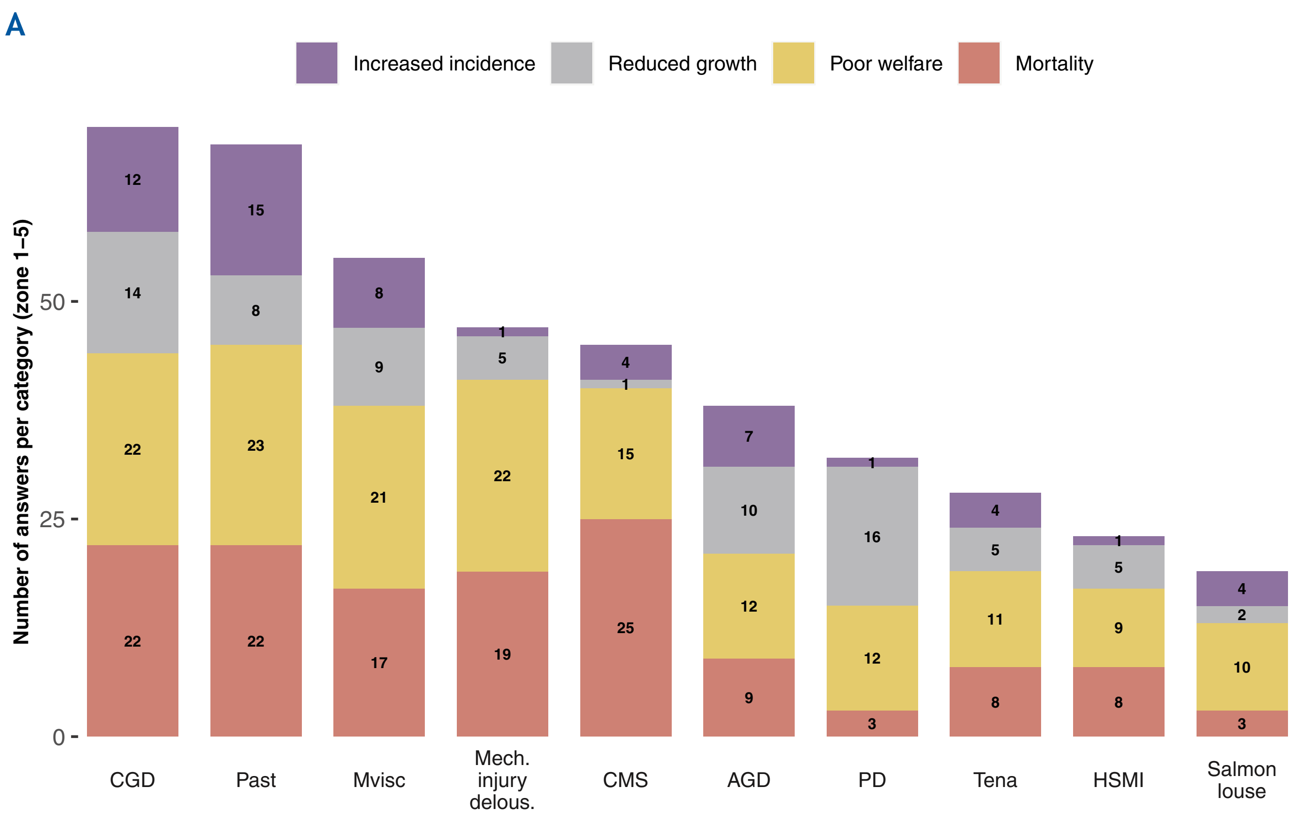
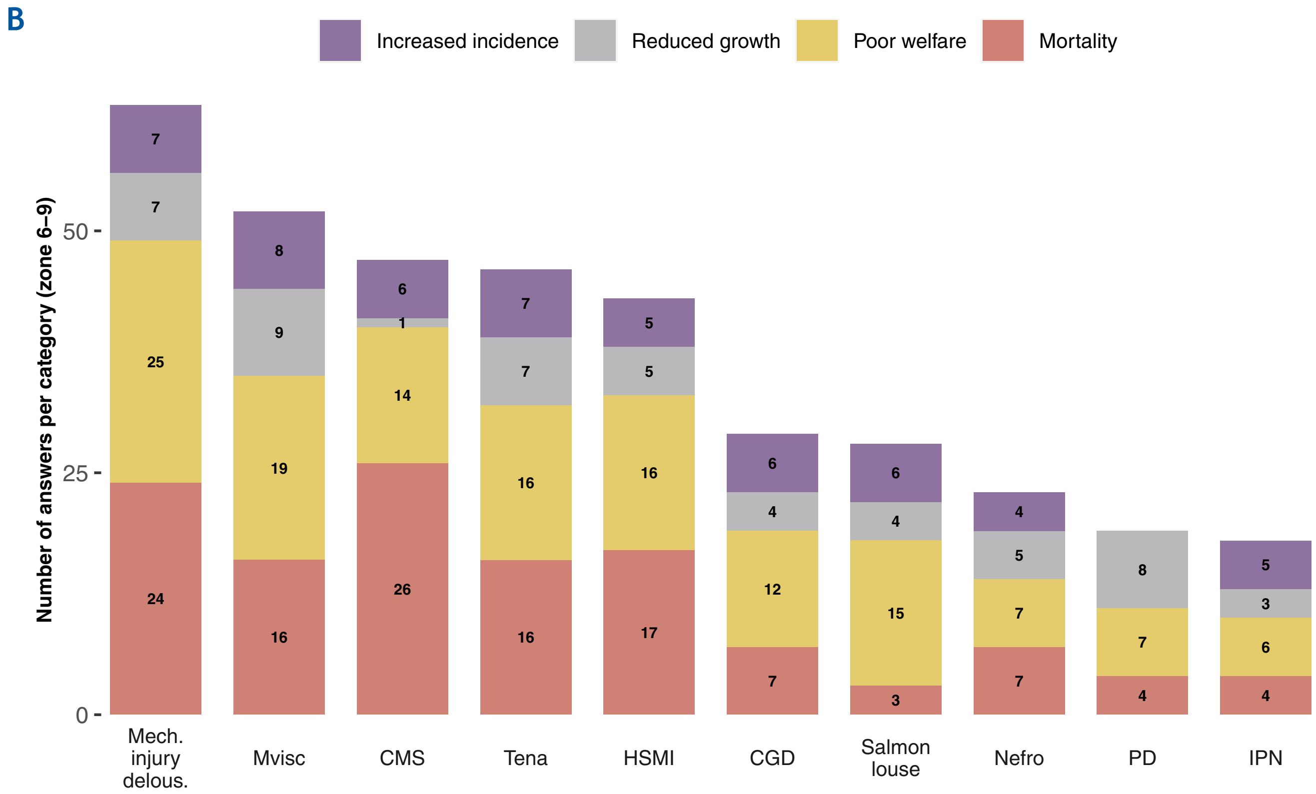
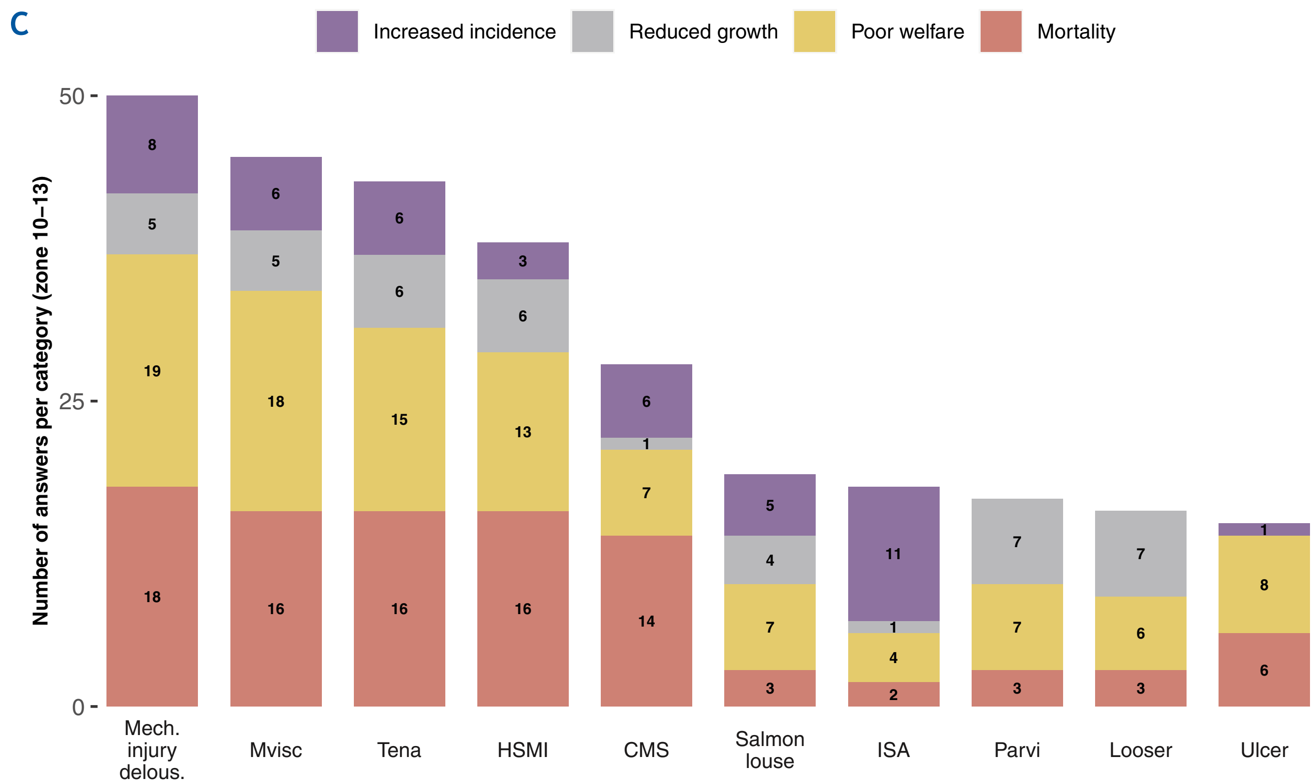


Figure 3.2.1 A-C. The 10 diseases or welfare problems in salmonids farms that received the most crosses per merged production area in A: PO1-5 (N=27), B: PO6-9 (N=30), C: PO10-13 (N=13). N= number of respondents, who in our survey are mainly fish health personnel. See Appendix B1 for an explanation of abbreviations for each disease/problem on the x-axis, as well as a full overview for the whole country.


B
Increased incidence
Reduced growth
Poor welfare
Mortality
Number of answers per category (zone 6–9)
0
25
50
Mech. injury delous.
Mvisc
CMS
Tena
HSMI
CGD
Salmon louse
Nefro
PD
IPN


C
Increased incidence
Reduced growth
Poor welfare
Mortality
Number of answers per category (zone 10–13)
0
25
50
Mech. injury delous.
Mvisc
Tena
HSMI
CMS
Salmon louse
ISA
Parvi
Looser
Ulcer

continuous updates of fish groups from roe to harvest and significant operational changes or technological developments taking place in the industry will facilitate comparisons and interpretations over the years, and reveal trends. The Norwegian Standard NS 9417 Salmon and Rainbow Trout – A Unified Terminology and Methods for Documenting Production is currently under revision; this work can contribute to easing such comparisons. In the long term, this will improve our knowledge base.

A better knowledge base, based on reports made to the public authorities, will increase our ability to understand complex relationships between fish welfare and health. This may result in national figures that include geographical differences and trends. For e.g. salmon reared in the sea, different diseases and welfare problems will occur in different geographical areas. This is illustrated in Figure 3.2.1, which is based on this year's survey and the number of crosses for which each of the top 10 health and welfare problems were ranked for each geographical area (PO), respectively for PO 1-5, PO 6-9 and PO 10-13 (see the geographical description of POs in chapter 1, Figure 1.1, and the abbreviations for health problems in Appendix B1). The trends shown here must be interpreted carefully, partly because some of the respondents' were not possible to place geographically and had to be omitted. Still, the figure illustrates the fact that diseases and welfare problems that are very significant in some areas are less important in other areas. Examples include the increasing prevalence of pasteurellosis, gill disease in southern areas while, in the middle of the country, mechanical injuries related to delousing, salmon lice, Moritella viscosa and CMS were considered most significant. In the northernmost regions, we see that mechanical harm from lice treatment is increasing and for which the respondents worry the most, more than winter wounds caused by Moritella viscosa and Tenacibaculum. In addition, we also see that ISA is increasing in the north.

3.3 Welfare challenges and new technology

All new technologies must, by law, be demonstrated as providing acceptable animal welfare before being taken into use (Pharagraph 8 of the Animal Welfare Act and Pharagraph 20 of the Aquaculture Operations Regulations). This provision has been in force for a number of years and is repeated in several special regulations concerning aquaculture animals.

For commercialisation of new technologies/methods, both the farmer and the marketer of the new technology/method have a responsibility to update and make guidelines available and to optimise equipment as they become available. To date, such documentation has not always been made available and that which has been made available has not always been of satisfactory scientific quality. In addition, it may be difficult to access user manuals of technical equipment from the equipment supplier as this year's survey shows (see Chapter 3.12).

Much of the technology development in recent years has involved alternative methods of delousing or new technology that prevents contact between fish and lice. Major development projects are also underway that explore aquaculture in more exposed sea areas. In 2021, the Food Safety Authority received ten reports on testing of new technology, in accordance with Pharagraph 20 of the Aquaculture Operations Regulations. Due to differences in how these are reported/registered, the real number of ongoing trials is probably higher. The methods/technology tested were (number of cases in parentheses): Automatic counting and weighing (1), delousing method after completion of approved trials (3), removal of NH4 in RAS (1), cage technology (4) and pumping systems for moving fish (1). Applications in accordance with the laboratory animal regulations are not included (see Chapter 3.4).

In this year's survey, there were several free text replies that can be linked to the use of new and/or advanced technology. The respondents reported challenges related to RAS facilities, the need for improved equipment, human error, often large numbers of fish involved in undesirable incidents and the need for change of attitude in the industry. The number of welfare incidents reported to the Norwegian Food Safety Authority also reflects the significance of the problem, and a greater degree of gradual testing is called for equipment and facilities.

3.4 Welfare challenges for laboratory fish

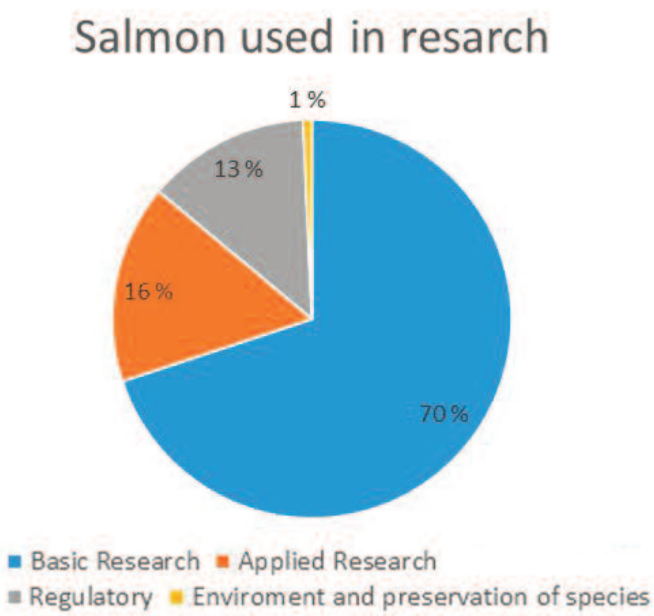
In 2020 Norway used 2.28 million laboratory animals (2021 numbers not available per March-2022). Fish accounted for 95 percent of this, and Atlantic salmon was

[1] Annual Report for 2021 (Norwegian Food Safety Authority, use of animals in experiments) is not available, therefore figures for 2020 have been used.

the most common species. The number of fish used in experiments varies from year to year because the need for large trials in the aquaculture industry is not constant. Compared to other European countries, Norway is at its peak in terms of the number of fish used in animal experiments. This is because Norway is among the countries with the highest level of production of farmed fish. Moreover, experiments on fish will often have a high number of animals compared to experiments use the more traditional species such as mice and rats. In 2016, two large field experiments with delousing agents were carried out using 10.6 million salmon.

There is a great variation in the loads the fish are exposed to in experiments. Example of trials which involves high load/harm to the animals are some common vaccine efficacy trials and vaccine batch testing. Here, infectious diseasees are experimentally inflicted on the fish and often death is the end point. Other types of experiments may be more similar to the load accepted during normal operation, but nevertheless requires application. The current regulations require that all burdensome animal experiments must be re-evaluated. Of the 21 experiments that were evaluated in 2020, 19 of them used fish as laboratory animals.

Despite an unacceptably high mortality rate among cleaner fish species due to lack of welfare, there were only six trials related to the health and welfare of cleaner fish in 2020. The Regulations on the Use of Animals in Experiments promotes the principle of the 3Rs: Replacement (replacement of laboratory animals with alternatives), Reduction (reduction of the number of laboratory animals) and Refinement (improvement of animal experiments to reduce pain and suffering). The high number of laboratory animals in Norway shows the need for broad commitment to finding good substitutes for the use of animals in experiments. Such a broad commitment and systematic work on knowledge sharing could be coordinated through a national 3R center. Through such a center, one could also solve a major problem; transparency. One problem in planning for



Basic Research	
Basic Research	948167
Other	197283
Salmon lice	17786
Ernæring	8457
Surveillance juvenile fish	5107
Welfare	4762
Bacteriology	2340
Pharmacokinetic, fish medicine, sedations methods	1923
Parasitology	1530
Disease transfere	840
Pigmentation	766
Surveillance wild fish	599
Fish vaccine	400
Viral diseases	60
Totalt use of fish	1190020

Figure 3.4.1 Distribution of salmon (laboratory animals) that has been used for basic research, applied research, regulatory and environmental and species management. Basic research is further specified with the topic and number of fish, where numbers are based on data from the Norwegian Food Safety.

laboratory experiments on fish, is that information from research with negative results often are unavailable/not published. Therefore, experiments with a high number of individuals may be unnecessarily repeated or performed in a suboptimal way. As a start towards better knowledge sharing, we show the distribution of salmon here for which laboratory animals were used in 2020 (Figure 3.4.1).

3.5 Welfare challenges in juvenile production

Rapid growth is important for increased economic value in fish farming, but increased resilience and resistance to disease is just as important. At new RAS facilities, it is not uncommon for the temperature to be kept steady at 13-14 °C from initial feeding to sea-transfer to produce the greatest quantity of stocking fish in the shortest possible time. At the same time, some producers are now going the oposite direction; they are of the opinion that the salmon will be less robust later in life if it is driven too intensively in early life phases.

Experiments conducted at Nofima show that the temperature in the period from fertilisation to eyed roe has a major impact on the growth pattern of today's farmed salmon. Salmon and other osseous fish have two types of muscle cells, one with large and one with a small diameter. The roe incubation temperature affects the relationship between the two types of muscle fibres. The experiment looked at roe incubated at 4 °C until the eyed roe received a greater proportion of muscle fibres of small diameter compared to incubation of 8 °C. A larger proportion of muscle fibres with a small diameter resulted in reduced growth in the hatchery phase, but the best growth after smoltification and up to harvest. Further research is needed to gain knowledge as to whether incubating roe at 4 °C up to the eyed roe stage provides a more robust salmon or not.

Post-smolt production on land has become a more widespread practice due to the problems of salmon lice in the sea. Before 2011, the Aquaculture Operations Regulations prohibited the production of salmon over 250 g in hatchery facilities. This was increased to 1000 g, and in 2016 the weight restriction was repealed. The definition of hatchery-produced fish (settefisk) was changed to: *roe and fish produced for transfer to other sites or other types of production. Fish that are planned to be moved according to an approved operating plan pursuant to § 40, are not considered hatchery fish.* This means that the hatchery phase is extended with a post-smolt phase on land. Experiments conducted at Nofima have shown that the most efficient production regimes with post-smolt in landbased RAS facilities did not provide as good growth in the sea phase as with the sea-transfer of traditional smolt. Experience so far shows that landbased production after smoltification is challenging. Therefore, two FHF-funded projects are now underway that address different production RAS methods to find out what provides the best growth and survival in the sea phase. Since the number and size of post-smolt has increased so rapidly, in some cases it has had major negative consequences. In order to find good solutions, research should address the entire life cycle from roe to harvest.

Fish need to experience good water quality, which is important for its welfare. Different types of facilities have different challenges with regard to water quality, and the topic is further discussed in Chapter 8.5.

In the survey's free-text response, fish health personnel reported problems in hatcheries with intensive production, which are often characterised by e.g. high densities (biomass) that lead to reduced water quality and reduced welfare. Several also comment on a relationship between nephrocalcinosis and high densities, and that the focus on producing large smolts results in an increase in nephrocalcinosis and HSS. The hot and dry summer of 2021 presented challenges at flow-through facilities. Water shortages during cold periods have also been a problem in 2021. Problems with high CO_2 values are also mentioned in flow-through facilities in combination with high water temperatures, increases in nephrocalcinosis, episodes of reduced oxygen levels and inadequate monitoring of water quality parameters. Several RAS facilities report a lack of control over water quality parameters, such as a low-grade total gas saturation that is believed to cause poor welfare, high CO_2 values and high turbidity. RAS facilities reported problems during first feedings related to gill irritation, exacerbated by high density and overfeeding. Human error and technical defects as well as facilities that are not suited for the biology of the fish are also mentioned as challenges during the hatchery phase in general. There has been an increase in the number of welfare

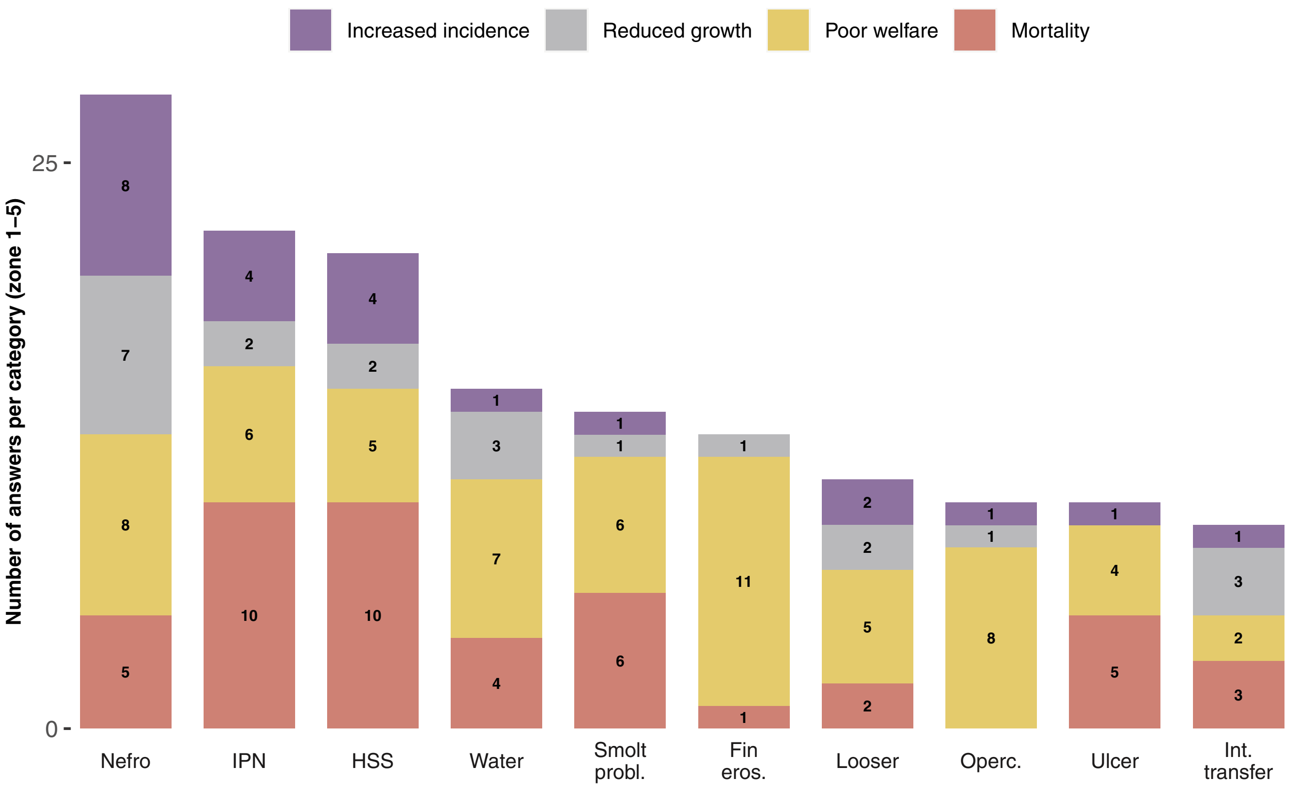


Figure 3.5.1A The 10 diseases or welfare problems in salmon hatcheries that received the most crosses per merged production areas in PO1-5. See Appendix A1 for an explanation of abbreviations for each disease/problem on the x-axis, as well as the full overview for the whole country.

related incidents in juvenile production facilities reported to the Norwegian Food Safety Authority also in 2021 (table 3.5.1). It is unclear if this increase is due to increase in the number of incidents, better routines for notification among the producsers, increased production of juvenile fish in general or other conditions.

In the survey, fish health personnel were asked to provide five answers for conditions they thought had the greatest negative impact on welfare, mortality and growth in 2021, and whether the incidence was increasing. It is clear that the biggest challenges is related to non-infectious diseases and production related challenges (see Appendix A1 for salmon juvenile fish and A2 for rainbow trout juvenile fish). There are only small changes from the answers from the survey in 2019 and 2020. To look at possible geographical differences, see Figure 3.5.1, which shows the ten highest ranked problems in hatcheries in southern and central parts of the country, respectively. The northernmost production areas are not shown in a separate figure due to few respondents. Infectious Pancreatic necrosis (IPN) may appear to be a larger problem for salmon in hatcheries in the southern part of Norway (PO1-5).

In 2021, a mortality of 33.4 million salmon and 1.9 million rainbow trout over 3 g were reported to The Norwegian Food Safety Authority (NFSA) (see Figure 2.1.2 in Chapter 2.1). The projects Småfiskvel and Setfiskvel examined mortality in the hatchery phase. It was found

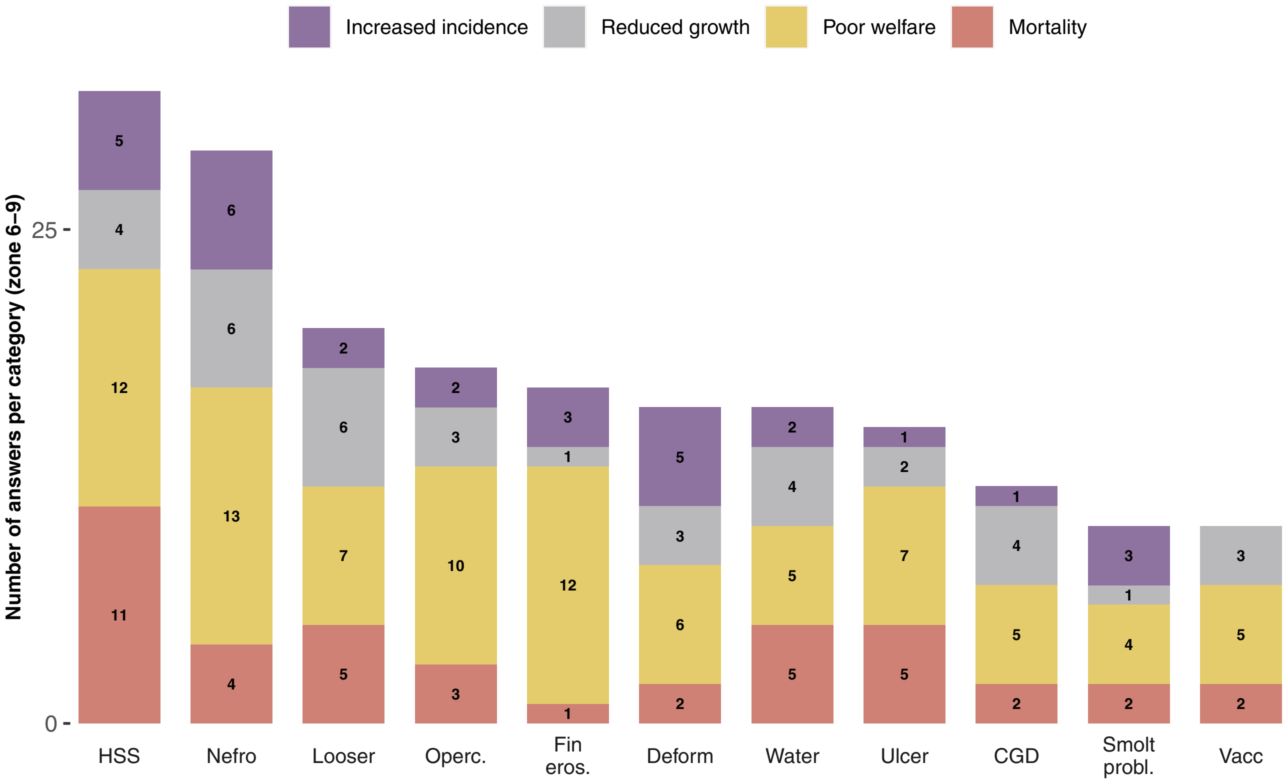


Figure 3.5.1B The 10 diseases or welfare problems in salmon hatcheries that received the most crosses per merged production areas in PO6-9. See Appendix A1 for an explanation of abbreviations for each disease/problem on the x-axis, as well as a full overview for the whole country.

that fish under 3 grams had the highest mortality rate, and that mortality decreased as the fish became larger. There were also geographical differences, with the northernmost region having significantly higher mortality rates compared to the southwest region. Mortality was highest in summer and lowest in winter, and mortality increased during the period of the study from 2011-2019. One important finding in these studies was that the mortality reporting to the authorities from the hatchery must be improved in order for them to be used in a good way.

The transfer from landbased hatcheries to sea farms is a critical period for the fish, where it will undergo major physiological changes while being transported to a sea site. How the fish are doing in the hatcheries, and how robust it is, has an impact on how it manages the transition to the sea. Several studies have shown that the mortality rate after sea transfer is high, and a 2021 study found that 32 percent of mortality in the first 180 days after sea transfer is associated with suboptimal smolt quality. In 2021, the NFSA issued the following statement in a letter to fish health personnel and fish farmers: "*Reported data for mortality at sea farms and reports to the NFSA on welfare related incidents show that there is a high mortality rate on fish in some facilities immediately after the transfer of smolt to sea or relocation of fish*. This raises questions about whether the health status has been adequately mapped before transfer, and whether testing and documentation of the physiological status of the fish has been good enough."

Table 3.5.1 Number of welfare incidents reported to the Food Safety Authority based on type of incident for years 2018-2021. The reporting here relates to hatchery fish. Data from the Food Safety Authority such as it was registered in their digital reporting system (MATS). The difference in figures from the The Norwegian Fish Health Report for 2020 is due to updated figures from the Norwegian Food Safety Authorities.

Welfare incidents in hatchery fish				
Cause	2018	2019	2020	2021
Other	26 (45%)	46 (47%)	84 (52%)	103 (55%)
Unclarified mortality	27 (47%)	46 (47%)	50 (31%)	47 (25%)
Pumping	1 (2%)	2 (2%)	13 (8%)	21 (11%)
Vaccination	2 (3%)	3 (3%)	12 (7%)	16 (9%)
Forces of Nature - storm, currents	1 (2%)	-	3 (2%)	1 (1%)
Fire	-	1 (1%)	-	-
Counting	1 (2%)	-	-	-
Total	58	98	162	188

3.6 Welfare challenges related to salmon lice, with emphasis on thermal and mechanical delousing

Non-medicinal treatment that requires handling the salmon has proved to be a major welfare challenge. If the salmon is ill or weakened by infection, it very often does not tolerate handling as well. Besides salmon, non-medicinal treatment must take particular account of the cleaner fish that otherwise risks dying. As methods for removal of cleaner fish prior to delousing are challenging, it has proven difficult to combine good fish welfare for cleaner fish with non-medicinal delousing (see also chapter 3.10 Welfare Challenges for cleaner fish).

Non-medicinal delousing consists mainly of three different principles; thermal (hot water), mechanical (various water flushing systems) and the use of fresh water. There are also some methods that combine the different principles. Non-medicinal combination methods came around 2020 involving post-flushing based on other treatment principles. In thermal delousing, the temperature in the water bath is adjusted based on the temperature of the sea, treatment outcome and fish welfare. In 2021, fish health personnel reported that the temperature used is usually between 29 and 34 °C for about 30 seconds. Of 72 respondents, approximately 31 percent reported 33-34 °C, 38 percent 31-32 °C, 13 percent 29-30 °C, 6 percent 28 °C, 3 percent 27 °C or less as most common treatment temperature, and 11 percent answered "don't know."

For all non-medicinal delousing that require a lot of handling, the fish must also be crowded before being pumped into the delousing system. The crowding itself has proved to be a major welfare risk. Thermal and mechanical treatment as well as freshwater treatment involve a lot of handling and a number of situations in which stress will occur, and the risk of mechanical damage to gills, fins, eyes, skin etc. Harmful changes to water quality such as a fall in oxygen saturation or gas saturation may occur.

Water temperatures used in thermal delousing have been shown to be painful for fish. Salmon show discomfort and pain behaviour at water temperatures above 28°C. Faster swimming was observed, along with collision with the tank wall, surface splashing, side-wise bending of their bodies as well as shaking its head. Head shaking was also recorded at lower temperatures. From other literature we know that juvenile salmon (between the

Salmon lice (*Lepeophtheirus salmonis*) enlarged 60 times. Image taken with scanning electron microscope and then coloured. Photo: Jannicke Wiik-Nielsen.

stages of fry and smolt) and smolt in experiments die within 10 minutes at temperatures around 30-33 °C. In 2021, a new study invistigated salmon that were exposed twice to a water temperature of 34 °C for 30 seconds at a 23-24 day interval. An increased incidence/severity of various injuries, decreased growth, and a strong behavioural reaction to treatment was found. It has recently also been shown that thermal delousing can cause gill damage, altered gene expression and an increased amount of gill pathogens. Affected gill tissue was relatively small, but it was concluded that it can reduce total gill capacity.

The Norwegian Food Safety Authorities clarified in 2019 that all use of thermal delousing above 34 °C is prohibited, and further stated that thermal delousing with water from 28 °C and higher would be phased out within two years, unless new knowledge documents that it can be used in a manner that protects fish welfare. Documentation of welfare-based justifiable use is still lacking, but the prohibition was not implemented (mattilsynet.no, press release 19.04.2021).

Delousing systems are constantly evolving, and non-medicinal methods have increased sharply in use every year (Table 3.6.1). 2021 was the first year where we see a seemingly reduced use. Despite a slight reduction from 2020, the number of treatments is considerably higher than in 2019. Thermal delousing has since commercialisation of the method around 2015 been most commonly used. In 2021, number of thermal treatments has been reduced compared to 2020. In addition, we see a possible increase in the use of combination treatments. Table 3.6.1 shows reported combinations for the same facility in the same week, all of which are thus not real combination methods; e.g. one may have deloused a cage with thermal and another cage with mechanical in the same week. As for fresh water, its use also continued to increase in 2021. The distribution of the various methodologies within production areas is illustrated in Figure 3.6.1. As the map shows, there are some areas where thermal methods are almost exclusively used, such as PO4, while PO6 has the highest number of mechanical processing weeks. Other areas such as PO9 have a more 50/50 distribution between treatment principles. There are also large differences in the number of delousing weeks between the different POs. The three POs with the most delousing weeks in 2021 are PO6 (609), PO3 (563) and PO4 (540). In 2021, a new delousing drug containing the active substance imidacloprid has been added (see Chapter 7.1 Salmon Lice). This was primarily used in PO6 in 2021, and thus does not explain the reduction of non-medicinal treatments.

In 2021, The Norwegian Food Safety Authority received 1535 reports of welfare incidents from fish/broodstock facilities. This is a slight reduction from 1623 reports in 2020. Of reported incidents in 2021, 741 (48 percent)

Table 3.6.1 Number of weeks of non-medicinal delousings reported to The Norwegian Food Safety Authority as of 16.01.2021. The processing methods are divided into four categories: Thermal (hot water), mechanical (various water flushers), freshwater etc. The combination categories indicate whether several delousing methods have been reported for the same plant in the same week. The category "other" is for reports that have not been categorised into 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
Thermal	0	0	3	36	685	1246	1330	1449	1723	1453
Mechanical	4	2	38	34	311	236	423	673	812	851
Freshwater	0	1	1	28	73	75	84	148	234	313
Thermal + mechanical	0	0	0	0	12	42	35	56	57	30
Thermal + freshwater	0	0	0	0	16	21	17	27	23	64
Mechanical + Fresh Water	0	0	0	0	7	1	7	7	18	32
Therm. + mech. + freshw.	0	0	0	0	0	0	1	0	0	3
Other	132	108	136	103	75	52	69	88	95	76
Total weeks	**136**	**111**	**178**	**201**	**1179**	**1673**	**1966**	**2448**	**2962**	**2822**

[1]The difference in figures from the Fish Health Report for 2020 is due to updated routines for identifying error reports, updated routines for identifying type of processing based on text descriptions in reporting forms and late incoming forms.

were related to non-medicinal delousing that involved handling the fish (see Table 3.6.2). It may be a cautious trend that the proportion of incidents concerning non-medicinal delousings has decreased somewhat, which for 2021 also coincides with a slight decrease in reported delousing weeks (Table 3.6.1). The seriousness and extent of registered incidents varies, different companies can have different thresholds for reporting, and the summarized reports do not identify the fish species involved. When collecting figures for 2021 from the Food Safety Authority, there were also major adjustments to the data for 2020 (64 reports were added) due to delayed reporting/lack of updates, a trend that was also seen last year. Efforts are now being made to improve the systemisation of our knowledge and lessons learned from reported welfare incidents, while the Food Safety Authority has prepared a supervisory template and professional support for its work to follow up such incidents.

As of 2020, we know that several companies have started an "emergency slaughter practice" at the sea cage site, having a slaughter boat lying standby in case of high levels of morbidity during delousing. The survey asked how often the respondents had experienced use of such boats or having been on standby in delousing operations in 2021. Of 78 respondents, 51 percent answered the option "never/very rarely"; 4 percent said "rarely"; 17 percent "occasionally"; 18 percent "often"; and 8 percent answered "very often." Three percent answered "don't know." This is similar to last year, with a possible increase for those who said "often". It seems that the trend of frequent use of such boats is used differently geographically; everyone who answered "often" and "very often" stated PO3-6 as their base of experience. Those who said "occasionally" are mainly related to PO2-7. It is important that such a practice does not increase the willingness to take risks when delousing, and that one does not consciously take the chance and treat weakened fish. It is also important for our knowledge base to register fish harvested in this way separately so that it is still possible to assess the consequences to fish welfare of different delousing methods.

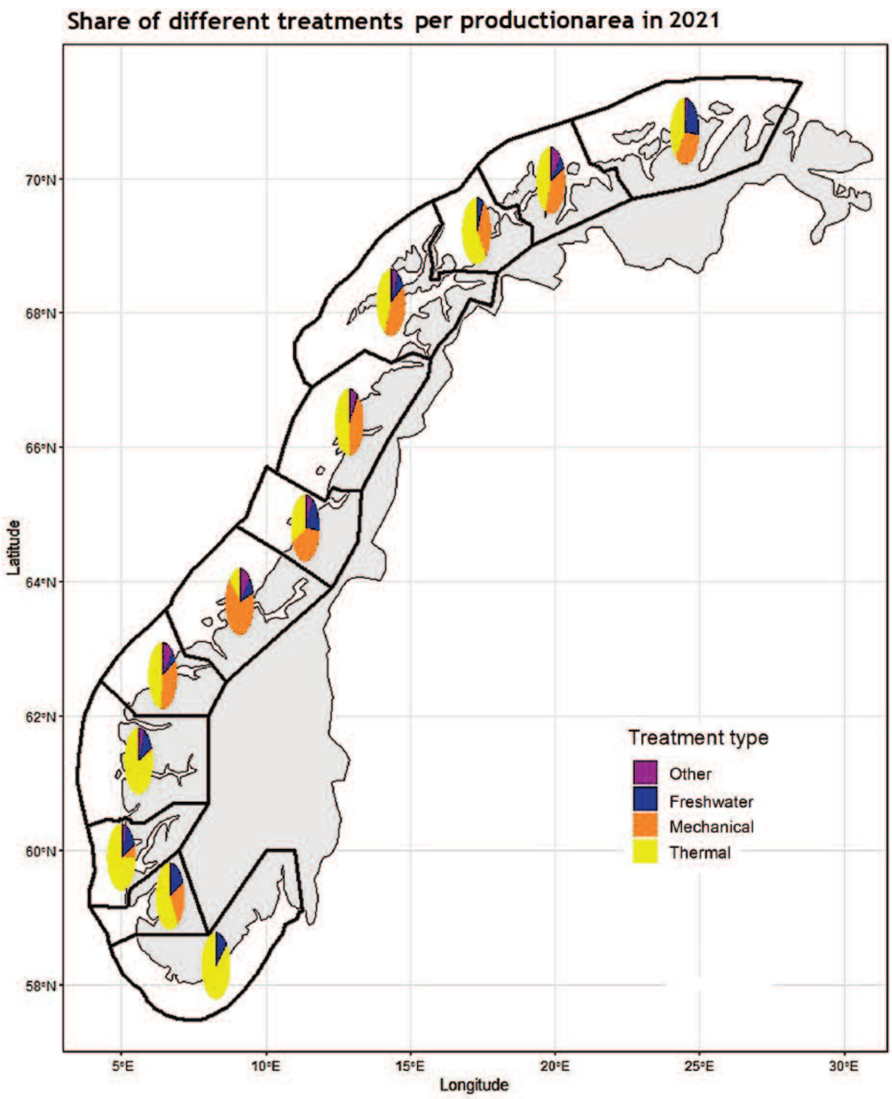


Figure 3.6.1 Distribution of non-medicinal delousing methods used per production area (PO1-12) in 2021.

Table 3.6.2. Distribution of reported welfare incidents to the Food Safety Authority based on types of incidents. The reports relate to fish in ongrowing/broodstock facilities. Data from the Food Safety Authority such as it was registered in their digital reporting system (MATS).

Number of reported welfare incidents for ongrowers/broodstock	2018	2019*	2020*	2021
Non-medicinal delousing with handling	629 (61%)	906 (61%)	873 (54%)	741 (48%)
Unclarified mortality	196 (19%)	251 (17%)	282 (17%)	256 (17%)
Other	112 (11%)	178 (12%)	312 (19%)	360 (24%)
Handling	40 (3.9%)	60 (4.0%)	78 (5%)	70 (5%)
Medicinal delousing with handling	40 (3.9%)	55 (3.6%)	19 (1.2%)	34 (2.2%)
Grading/pumping	7 (0.7%)	18 (1.2%)	16 (1.0%)	15 (1.0%)
Forces of nature	09 (0.6%)	25 (1.5%)	20 (1.3%	
Medicinal delousing without handling	9 (0.9%)	9 (0.6%)	6 (0.4%)	10 (0,7%)
Non-medicinal delousing/preventive, without handling	3 (0.3%)	3 (0.2%)	9 (0.6%)	28 (1.8%)
Jellyfish attacks			3 (0.2%)	
Decreased sensitivity/resistance	1 (0.1%)	0	0	1 (0.1%)
Total	1037	1489	1623	1535

*Fewer reports in the Fish Health Report for 2020 caused by delayed reporting (statistics now updated).

There is still a lack of knowledge about how the total number of lice treatments or handling in general and the intervals between these actually affect the fish. The importance of the impact of frequent delousing on skin and mucosal surfaces including the gills remains poorly documented. The knowledge base in terms of elevated mortality seen in thermal and mechanical delousing is increasing.

The survey ranks Mechanical Damage from Delousing at the top of causes that reduce welfare and increase mortality in fish farms with salmon and rainbow trout as well as in sea facilities with broodstock (see appendices B1, B2, C1, C2). Delousing methods also have huge impact on the welfare for lumpfish and wrasse species, see Chapter 3.10 Welfare Challenges for Cleaner fish.

A total of 78 respondents shared their experiences of welfare with delousing methods in this year's survey. A summary of the delousing techniques for which the respondents had experience in 2021 is provided in Figure 3.6.2. Compared to the 2020 survey, fewer people seem to have experience with optilicers (from 67 to 50 percent) and FLS (from 41 to 28 percent), and a few more have experience with thermolicers (from 79 to 85 percent). Unsurprisingly, experience with medicinal treatment has increased from 44 to 59 percent in 2021, where a new drug with the active substance imidacloprid was available in 2021 (see Chapter 7.1 Salmon Lice). In addition, experience in the "other" category continues to increase, which includes combination methods.

How effectively non-medicinal delousing is in removing salmon lice may depend on many factors (e.g. treatment principle, pressures, temperatures, treatment time, crowding), but also on the development of tolerance/resistance in lice. The survey asked if the respondents had seen any changes in the delousing effect of non-medicinal treatments. One-third of the 45 respondents reported that the delousing effect has been

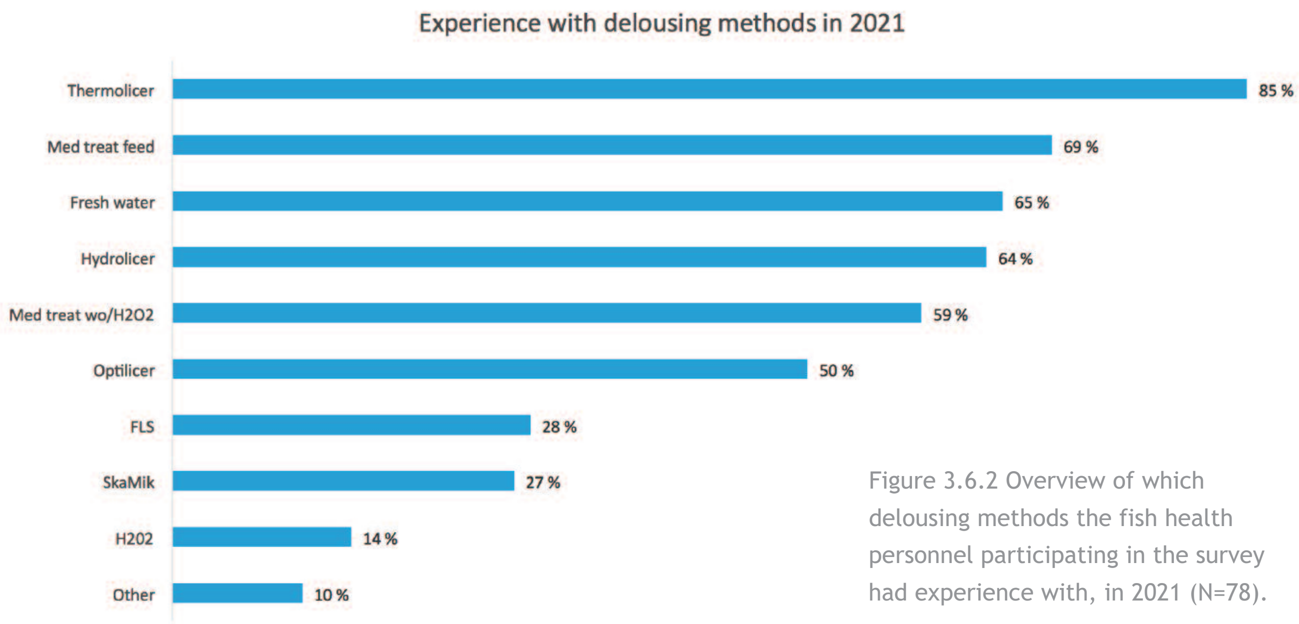


Figure 3.6.2 Overview of which delousing methods the fish health personnel participating in the survey had experience with, in 2021 (N=78).

reduced (either for thermal, fresh water or mechanical), while the same number stated that it is unchanged. Some mention they have seen good effect. In particular, some mentioned that delousing in warm seas is problematic to reach a desired effect in terms of thermal delousing, and that re-infection is very common. Three mentioned that they have seen good effects with combination methods. General comments mentioned that the effect is too poor compared to mortality. It also mentioned one example where the delousing temperature was set "carelessly" for the maximum delousing effect with subsequent mortality as a result.

When asked about the highest temperature for heated water as a treatment for salmon lice in 2021, no one reports higher than 34 °C. Of 54 respondents, about 50 percent stated that the highest temperature was about 34 °C (from 33.5-34.0), 30 percent reported about 33 °C, 9 percent reported about 32 °C and 11 percent reported 31 °C or lower. The lowest treatment temperature used is stated at 18 °C in a sea temperature of 8 °C.

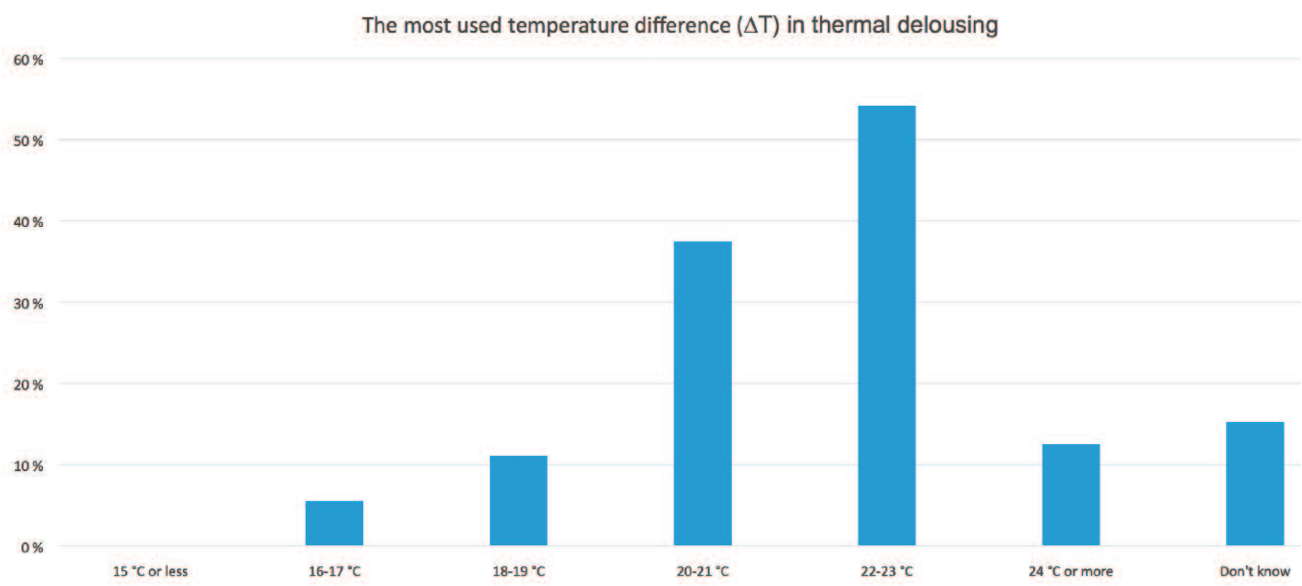


Figure 3.6.3 Responses from fish health personnel about the most common temperature difference (ΔT) between sea and treatment water where thermal treatment was used as delousing method, in 2021 (N=72).

When asked what was the most common temperature difference between sea and treatment water, more than 50 percent of respondents answered 22-23 °C (Figure 3.6.3), which was approximately the same as in 2020. The share of respondents that answered 20-21 °C appears to have decreased in 2021 compared to 2020.

The survey asked about experiences of the frequency of injuries or mortality associated with different delousing methods (see Figure 3.6.4). The trends in the types of injuries most recorded by fish health personnel are about the same as the previous year, perhaps with a slight increase in some injuries such as gill bleeding and fin injuries. For mechanical delousing, scale loss is most commonly registered while acute mortality is most commonly associated with thermal delousing. Some respondents answer "don't know" for both brain haemorrhage and fracture injuries, which probably reflects the fact that this type of injury is less often checked. The figures must be interpreted with caution, and only as trends. In the survey, fish health personnel were also asked if there had been a change in the severity of external injuries in connection with non-medicinal delousing in 2021 compared to 2020. Thirty-eight percent answered that there had not been a change, 25 percent said there had been an improvement, and 4 percent said there had been a deterioration. Thirty-three percent answered "don't know" (N=76).

Several respondents commented that the welfare of treated fish depends on the general health status of the fish prior to delousing, crowding or pumping. Fish with circulatory disorders and poor gill health are said to endure thermal treatment poorly, and gill bleeds can be observed. In general, ulcer injuries are commonly seen. Flushing with scale loss that cause ulcers that persist at low temperatures is stated as worrisome, and it is stated that thermal is preferred for cold temperatures. One

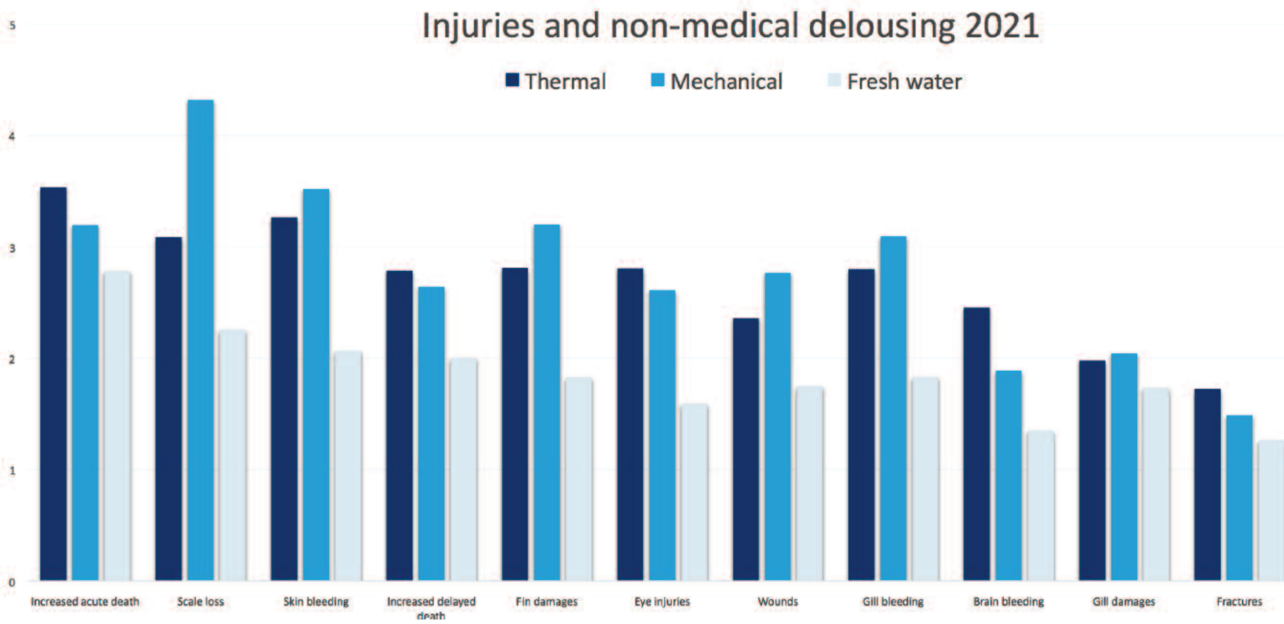


Figure 3.6.4 Average frequency of injuries or mortality experienced by fish health personnel in connection with various delousing methods in 2021. On a scale from 1 = never seen/very rarely to 5 = seen in almost all fish. For the two questions about mortality, answer option 5 = almost all delousings methods. "Don't know" as an answer option is not reproduced here. Increased acute mortality means >0.2 percent for the first 3 days after delousing, increased delayed mortality means up to 2 weeks after treatment. The number (N) who shared the experiences varies slightly between the different injuries, and is between 62-70 for thermal delousing, 51-56 for mechanical and 47-50 for freshwater.

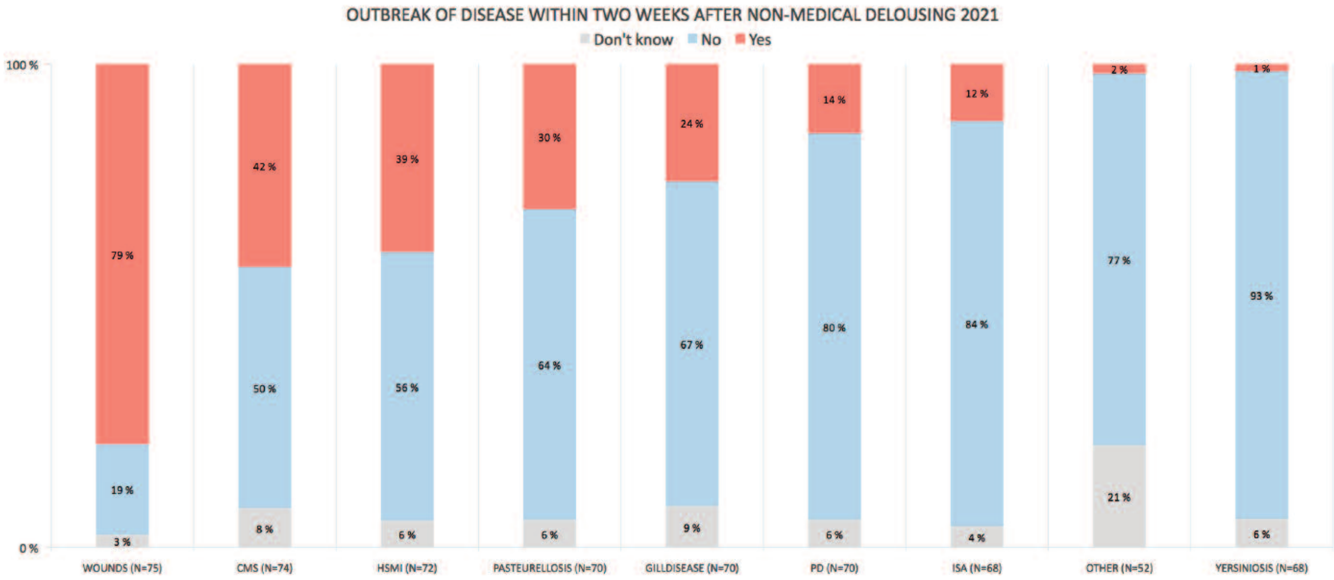


Figure 3.6.5 Outbreaks of diseases within two consecutive weeks after non-medicinal delousing in 2021. Results of the survey among fish health personnel.

stated that the average mortality rate is lower after departing from thermal methods, espceially repeated treatment resulted in mortality. Another said that deviant behaviour were observed several weeks after thermal treatment and panic was observed during treatment. When it comes to freshwater treatment, one episode of panic was mentioned during release of the fish back to the cage, as well as poor water quality (H_2S). Some mentioned improvements with non-medicinal methods.

The underlying or active diseases such as CMS, HSMI, PD AGD or poor gill health were reported to result in significant mortality in association with non-medicinal delousing. See also the individual chapters describing the diseases, including Chapter 4.5 CMS. In the survey, 'skin lesions' were the most commonly reported disease problem following non-medicinal delousing (see Figure 3.6.5). Water temperatures are often decisive as to whether skin lesions develop post-treatment.

3.7 Welfare challenges associated with transport

Farmed fish are transported both as fry, smolt, harvest-ready fish and as broodstock. Transport to sea sites and sorting and relocation in the sea phase constitute major operations involving a large number of individuals, large boats or vehicles and advanced technology. Today, there is limited knowledge about how such operations affect fish welfare, but we know that it sometimes has a clear negative impact on fish welfare.

The Food Safety Authority received 19 reports of welfare incidents related to transport in 2021. There is no great variation from year to year in the number of reports regarding transport. Of the 19 reported incidents in 2021, seven were categorised as transport damage, one as water quality, one as valve damage and 11 were indicated as "other". For transport of cleaner fish, see Chapter 3.10.

3.8 Welfare challenges associated with slaughter

Slaugther of fish involves a risk of suffering and all fish must be rendered unconscious prior to bleeding. The slaughter process of farmed fish is largely automated. The likelihood of the fish being inflicted damage, pain, fear, stress and other discomfort is influenced not only by how well the stunning and bleeding works, but also how the handling is done at the forefront. Both crowding, pumping, live cooling, time outside the water and the design of pipes/chutes are important.

The stunning methods permitted for salmonids are percussive or electrical stunning, or a combination of these. The aim of stunning or anaesthetising is to render the fish unconscious and thereby unable to experience discomfort during bleeding. The fish should remain unconscious until it dies of blood loss. Previous research shows that both methods can function satisfactorily based on the consideration of fish welfare, provided that the systems are used and maintained properly. For the percussive method, using a non-penetrating captive bolt, the fish must be hit with sufficient force in the right place on the skull, slightly behind the eyes, so the fish is rendered unconscious. This causes a severe concussion and preferably bleeding in the posterior/lower area of the neurocranium where the blood vessels enter the scull. For effective stunning by percussion machines, the fish must have approximately equal size and head shape and be pointed in the right direction as it enters the device. In case of electrical stunning, the fish must also be pointed in the right direction, with the head first, or that current only passes when the head of the fish is inside the stunning device, because electric shock that effects parts of the body before brain functions cease is painful. The current running through the brain should be sufficient to cause instant unconsciousness. Using insufficient current, the fish may take too long to enter unconsciousness or the musculature may be paralysed and the fish rendered immobile yet still conscious.

In the 2021 survey, 28 respondents replied that they had responsibility for a total of 58 harvest facilities. The majority (18 out of 28) supervised only one harvest facility, and 7 supervised two; only 3 had experience from at least 5 harvest facilities. The respondents were asked how they assessed the quality of stunning in the two anaesthetising systems (see Figure 3.8.1). When asked whether they had experience with the two method, 22 answered percussive stunning and 23 electrical stunning. Nevertheless, a high proportion said "don't know" (37 and 40 percent) when asked whether they believe the method provided satisfactory fish welfare. The reason for this high percentage may be that those who do not supervise welfare at the harvest facilities also responded; not just, as some wrote in the comments, it was challenging to assess the quality of stunning methods. Figure 3.8.1 shows the responses from the respondents who had an opinion on stunning quality and fish welfare for the method in question, which was 12 respondents for each of the methods.

The methods being considered here, with reservation to the limited number of respondents, are seen as equally good, while last year the percussive method was considered the worst. There is still a clear potential for improvement in the practice of stunning for harvest. Among those who had an opinion, half of the respondents consider that fewer than 99 percent of the fish are adequately stunned. This means that very many individual fish are not stunned well enough prior to bleeding.

In the comments section, several indicated that they consider the electrical method to be more straightforward, while others wrote that it is difficult to verify the quality of the method used. Shock to the fish's body before being rendered unconscious is identified as a problem, and inadequate maintenance and control are other challenges. For the percussive stunning method, challenges mentioned included that the capacity was exceeding by pumping in too many fish, inadequate settings for the size of the fish, and insufficient capacity of back-up stunning. The suggested causes are that the fish enter the system wrongly way so that the blow is misplaced due to variable fish size. Good stunning methods for other species are also being called for, including lumpfish. When asked if back-up systems for stunning work satisfactorily, i.e. in case the fish are not stunned by the first method, about the same number

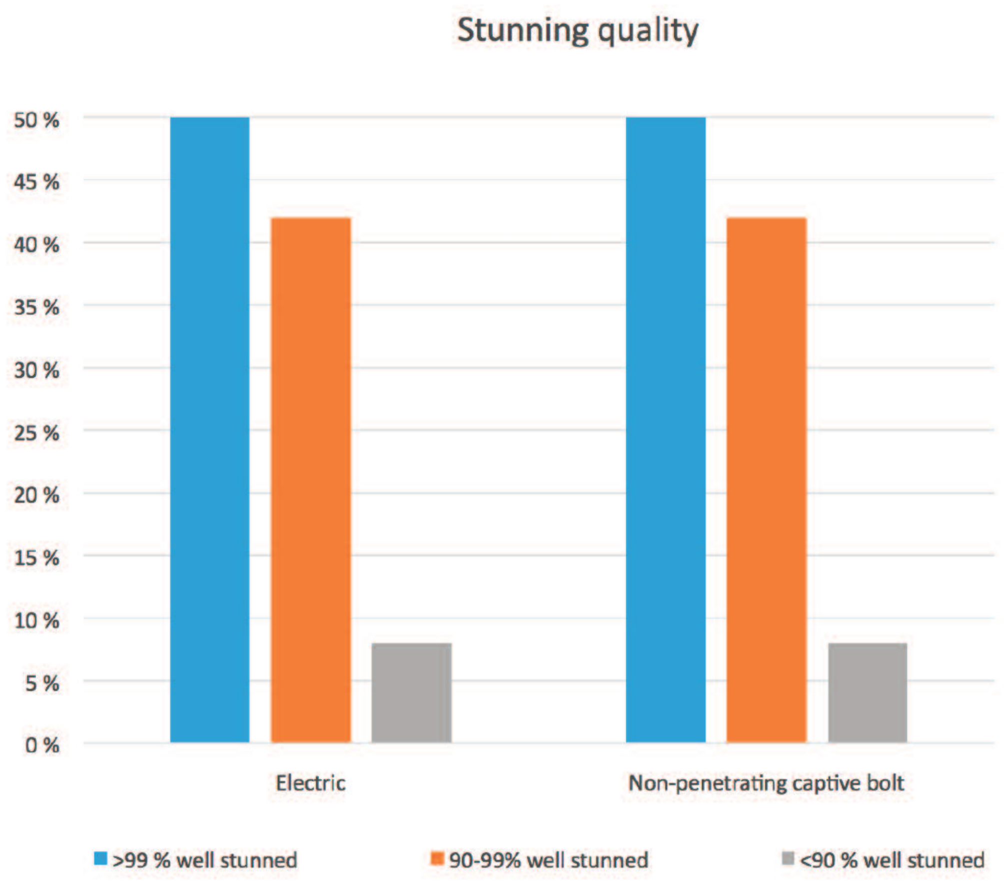


Figure 3.8.1 The chart shows the respondents' assessment of the percentage of fish that are adequately stunned with the methods of electricity and percussion. The number of respondents was 12 for each method.

answered "yes" (48.1 percent) and "don't know" (44.4 percent), and only 2 out of 27 answered "no".

Correctly performed percussive stunning results in loss of consciousness due to concussion, which often leads to death in advance of bleeding. Electrical stunning leads to normally a short-lasting loss of consciousness and requires rapid bleeding. For electrical stunning, it is therefore essential that the fish is bleed immediately after being stunned. Cutting a single gill-arch results in a slower bleed than cutting all gill arches. Fifteen respondents stated that they had experience with automated bleeding systems, of which 40 percent considered these systems to work very well, 33 percent considered them satisfactory and 27 percent considered that they were often faulty. Compared to 2020, both the proportion who believe it works very well and the proportion who reported frequent errors increased. Automatic bleeding is poorly effective if the fish are not positioned correctly or are not motionless. A high number of misplaced cuts were named as a reason why some harvest facilities have moved away from automatic bleeding, as misplaced cuts can cause declassification. In the comments section, it is mentioned that automatic bleeding with manual control works excellently, that it requires continuous monitoring to make sure that all fish are bled, and that errors are related to the unequal sizes of the fish. Misplaced cuts in conscious fish are unacceptable, based on animal welfare considerations.

The consideration of product quality and the consideration of fish welfare usually work in the same direction at the harvest facilities. Fish that are stressed prior to harvest enter rigor mortis more rapidly after harvest and develop a harder stiffness compared to fish that are not stressed. This reduces the possibility of pre-rigor filleting. Moreover, the end pH of the fillet is higher, which reduces its shelf life as a fresh product.

It can be beneficial for fish welfare to harvest fish directly from the sea cages, given that the stunning and bleeding work satisfactorily. Welfare consequences of pumping to wellboats, transport to harvest facilitiess and any stay in waiting cages followed by pumping done at the harvest facilitiess are all relatively significant, especially for sick fish. Harvest boats where the fish are pumped up straight from the farming cage, then stunned and bled on board and transported to shore for further processing, are now in use (see Chapter 3.6 Welfare challenges related to salmon lice).

Measures to improve fish welfare at harvest facilitiess must also include the individual fish that are graded out. This includes cleaner fish, stow-aways like small saithe – but also salmonids that are to be graded out/discarded for any reason. These fish should be given the same welfare concerns as those with commercial value. Several survey respondents stated that cleaner fish do not have their own or suitable facility for stunning/killing. How welfare standards are maintained for cleaner fish at these the farms is therefore uncertain.

After harvest, the fish are often sorted into the qualities Superior, Ordinary and Production. There can be various reasons for declassification of a fish such as sexual maturation and causes that indicate impaired welfare before stunning/killing, such as ulcers, injuries and deformities. Other causes of declassification, such as incorrect cuts, are probably inflicted on the fish after it had died.

The survey asked "What proportion of salmon is declassified approximately from Superior to other qualities?". Of 38 respondents, 7 (18 percent) responded that 1–5 percent are declassified, 8 (21 percent) that 6–10 percent are declassified, 6 (16 percent) that 11–15 percent are declassified, 4 (11 percent) that more than 15 percent are declassified and 13 (34 percent) responded "don't know". In the free text field, it was mentioned that the proportion of declassified fish varies with the season and region, and that they found it difficult to give a fairly adequate answer to the question.

Furthermore, they were asked to state the three main reasons for the declassification of salmon at harvest facilitiess, by scoring with up to 3 crosses. The causes of declassification ranked as most important were ulcers, sexual maturation and deformities (Figure 3.8.2). One respondent mentioned "Damage from mechanical delousing" under "other".

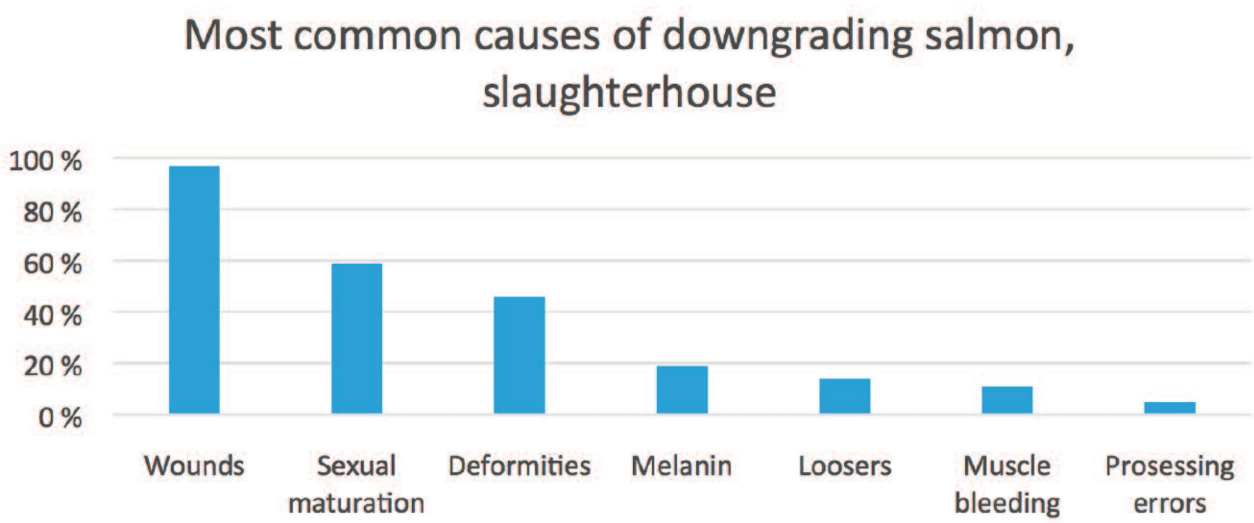


Figure 3.8.2 Most common causes of declassification in salmon harvest in 2021. 37 respondents answered the question: Specify the three main reasons for the declassification of salmon at harvest facilitiess.

3.9 Welfare challenges associated with feed and feeding

Correct nutrition is essential for normal development and growth of all animals. Nutritional requirements change throughout the life cycle and the needs of individual animals may also differ. Commercial feeds are designed to satisfy the needs of the majority of fish at particular stages of development and will only rarely include a surplus of any valuable ingredient. Especially for new species, knowledge about the need for nutrition is inadequate. Changes in feed composition due to changes in the cost of raw materials or due to environmental concerns e.g. increased use of plant-based ingredients in salmon feed, may result in health and welfare-related side effects in the fish and should therefore be monitored closely both in the short and long terms.

Method of feeding and quantity of feed provided directly influence fish welfare via altered fish behaviour. One example was increased competition between fish leading to aggression. This may result in injury and under-nourishment in some fish. Too much feed can negatively affect water quality and, in addition, it is not sustainable to let feed go to waste. Starvation of fish is a routine method before transportation and before various handling situations. This is done to empty the intestine and reduce the metabolism of the fish, which contributes to better water quality and that the fish's oxygen consumption decreases. Both help the fish to tolerate treatment better. It is also performed prior to harvest to maintain quality and reduce contamination of the finished product. There is limited knowledge about how starvation affects the welfare of fish, but it has been shown that post-smolt of Atlantic salmon apparently were not harmed after up to four weeks of starvation.

3.10 Welfare challenges in cleaner fish use

"Cleaner fish" are lumpfish and various wrasse species used to combat salmon lice. Despite inadequate scientific documentation of their effect as salmon lice eaters, 40.6 million cleaner fish were used in 2021 (see Table 2.1.1). This is a decrease from the previous year.
The most common wrasse species used as cleaner fish are corkwing wrasse, gold-sinny wrasse, ballan wrasse and rock cook. They are mostly wild-caught. The majority of the wrasse released in fish farms are caught nearby, but transportation over long distances also occur. There are significant welfare challenges associated with their capture, storage, transport and biosecurity. The impact fishing of the wrasse species has on the wild populations and on the ecosystem from which they are removed is unknown. This also applies for the areas in which the fish are transferred, also in regard to transfer of disease and the genetic consequences of interbreeding with local fish if they escape.

Lumpfish make up the majority of farmed cleaner fish and is today Norway's second largest farmed fish species in number. The advantage of farmed cleaner fish is a lower risk of transmission of diseases, more stable quality and it reduces the risk of over-burdening the wild stocks. Vaccination of farmed cleaner fish against the main bacterial diseases can contribute to a lower mortality rate and better welfare. Unfortunately, this year there are also reports in the survey of a lack of effect from cleaner fish vaccination.

There are major differences between the natural habitat of cleaner fish and the farming environment in the cages. Lumpfish swim poorly, so sites with strong currents are a great challenge. Lumpfish also tolerate high temperatures poorly, and summer temperatures in Southern Norway make an additional strain. Their transfer to sea should therefore be avoided during the summer. A study revealed that ballan wrasse are also poor swimmers and do not thrive in moderate to strong currents. They also have low activity at 5-10 °C. Skeletal deformities in farmed ballan wrasse are common and assumed to influence both welfare and the effectiveness to eat lice.

Adjustems are made for the cleaner fish in order to increase their welfare, such as vaccination, setting out hiding areas in cages, suitable feed and feeding strategies. Nevertheless, the mortality rate is still too high and the welfare and disease challenges are too great (see Chapter 10 Health situation for cleaner fish). Perhaps the cleaner fish simply does not have the prerequisites for thriving or adapting to conditions on salmon farms.

In the survey, non-medical delousing, emaciation and crater disease are mentioned as the problems that lead to mortality and reduced welfare in lumpfish stocked in salmon cages. Looking at geographical differences in the

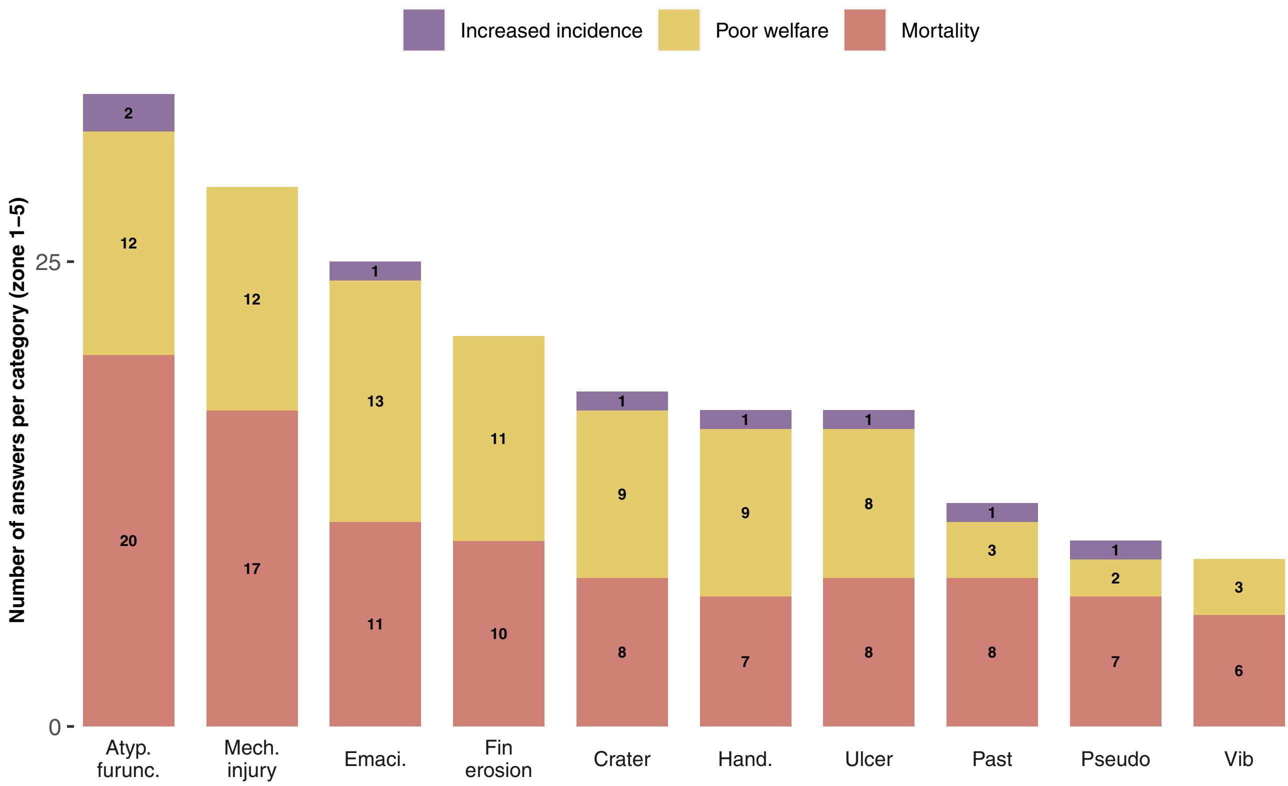


Figure 3.10.1 Fish health personnel have ranked the three most important problems in relation to mortality, welfare and increasing incidence of lumpfish that go into cages with salmon for P01-5. See Appendix D2 for an explanation of abbreviations for each disease/problem on the x-axis.

responses, it is evident that PO 1-5 indicate atypical furunculosis, non-medical delousing and emaciation as the main causes of mortality and reduced welfare (Figure 3.10.1). The fact that atypical furunculosis is mentioned as an important cause suggests that the vaccine has a lack of effect. This was also highlighted in the survey. In PO6-9, non-medical delousing, crater disease and emaciation are mentioned as the main causes of mortality and reduced welfare, and there are also several who mentioned that the incidence is increasing (Figure 3.10.2). It also mentioned that mortality could have been reduced if a vaccine against crater disease was available.

The survey also asked this year whether cleaner fish mortality after transfer to sea cages with salmonids was approximately the same level, higher, lower or "don't know". The mortality situation for both lumpfish and wrasse has not changed since last year. It is disturbing that the proportion who answered "don't know" for lumpfish and wrasse were 38 and 56 percent, respectively. The high "don't know" percentage illustrates the fact that it is extremely difficult to evaluate the welfare of cleaner fish because it is difficult to estimate when and how many of these fish die during the farming cycle. It is therefore difficult to estimate annual changes in mortality or to establish whether any corrective measures have had an effect.
The free text comments made it apparent that fish health personnel are concerned about the high mortality and poor health status of cleaner fish. They stated that there is neither capacity nor good enough routines to safeguard cleaner fish. They also mentioned that

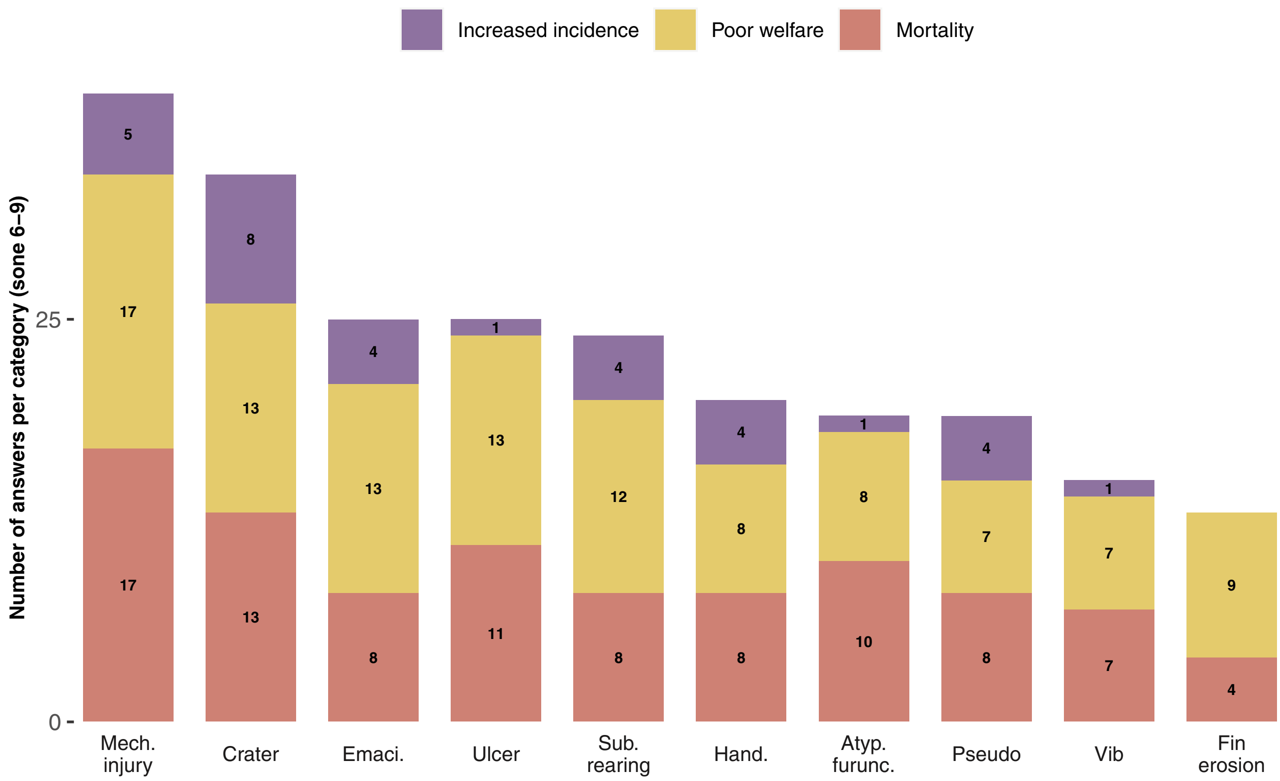


Figure 3.10.2 Fish health personnel have ranked the important problems (max. three) in relation to mortality, welfare and increasing incidence in lumpfish that go into cages with the salmon for PO6-9. See Appendix D2 for an explanation of abbreviations for each disease/problem on the x-axis.

adequate supervision is challenging, despite the existence of the Cleaner fish Guidelines. Furthermore, inadequate removal of cleaner fish is mentioned prior to salmon handling operations, and that it is difficult to implement measures for the cleaner fish where this is necessary. There are also several who said cleaner fish are used to a lesser extent than before or completely stopped its use due to the health and welfare challenges associated with its use.

It is also mentioned that the quality of lumpfish that are being released is better, and that transport by wellboat has been a good measure and that systematic work to reduce mortality has yielded results.

When asked whether stunning and euthanisation routines for cleaner fish during harvesting result in satisfactory welfare, 52 percent of the 27 respondents replied 'yes', 18 percent replied 'no' and 30 percent said 'don't know'. It was also pointed out in the comments for stunning and euthanisation of cleaner fish, that they are pumped into the harvest facilitiess together with the salmon and sorted too late in the process. Several people pointed out the problem of electric stunning not being approved for lumpfish. If the euthanasia of lumpfish is to take place in a manner compatible with animal welfare, this must be dealt with.

Lumpfish and wrasse used as cleaner fish face significant welfare challenges because of their health situation and the lack of control on mortality. It is also registered that new cleaner fish are released into cages during disease outbreaks among the cleaner fish. This is contrary to the regulations, which state that no new fish can be released in facilities with clinical diseases if there is reason to believe that the fish that are released can also become ill. All fish species that are kept in Norwegian fish farms are equally protected by the Animal Welfare Act. It is therefore a great paradox that other fish species (cleaner fish) are used as an aid in the production of salmonids, when this causes very high mortality and a number of health and welfare challenges.

The use of cleaner fish should be reduced in the short term, a trend we are already see. If it cannot be documented in the near future that cleaner fish can live good lives in the cages and contribute significantly to salmon lice control, the use of cleaner fish must be phased out as stated in the new Aquaculture Strategy issued by the Solberg Government (June 2021).

3.11 Welfare challenges in wild fish - commercial fisheries

In commercial fisheries, the number of individual fish caught can be enormous. It has been considered unavoidable that these fish die as a result of asphyxiation. To the extent there have been protests against fisheries, these have often revolved around overfishing, dumping of catches and the fate of by-catch such as whales, seals and seabirds drowning in fishing nets etc. Concerns are also raised about the destruction of the seafloor from bottom trawling. There is also a concern about the destruction of coral reefs, cold-water corals found along the Norwegian coast and that create a rich ecosystem that is important for a lot of marine life. Reefs of cold-water corals can be found in current-rich places at a depth of 100-500 meters: along the edge of the continental shelf, on elevations inside the shelf and in some deep fjords. Trawling was banned in the most vulnerable zones starting in 1999.

If fish caught in large numbers, e.g. from nets or trawls, are to be immediately killed instead of being suffocated or squeezed to death, industrial solutions are required in a similar way to those used to stun and bleed farmed fish in the fish harvest facilitiess. In the case of net fishing, many of the fish will be dead when the net is drawn up, depending on how long the gear has been in the sea, and the fish will have undergone a shorter or longer struggle leading to death. Research is now underway to investigate and compare the welfare consequences and product quality related to different types of capture technology, with the aim of improving methodologies.

Fish welfare has long been on the agenda in the aquaculture industry, and the fishing industry is slowly following suit. In Norway, the Council on Animal Ethics put this on the agenda in a report in 2014. In 2018, Nofima published the report Anaesthetics and Bleeding of Fish on Board Vessels, which showed that electric stunning and percussive machines also work on cod (Nofima Report 28 – 2018). Stunning of such fish before bleeding is both an animal welfare measure and an EHS measure. This percussive stunning method is only possible where the individual fish are treated separately.

In recent times, some steps have been taken to prevent and get control of extensive "ghost fishing". For example, crab pots have stood out without daily care and maintenance, and stray fish and crabs caught in such devices suffer for a long time before slowly starving to death. In order to get control of these deviations the frequency of checks and maintenance and stricter requirements have recently been introduced to improve fish welfare and sustainability. Unfortunately, in their need to simplify the regulations, the wording of the new regulations has equated capture/trapping (fangst) of animals with harvesting (høsting) of seaweed and kelp. This is a setback in terms of better attitudes towards animals in fisheries. Replacing fishing and capture/trapping with the word 'harvesting' (høsting) has also generated strong reactions among fishermen. When it comes to simplifications, other examples are seen: that fishing in the sea for live storage has been put into separate regulations, which makes the provisions easier to find.

For handling and killing wild fish in recreational fishing, reference is made to the Norwegian Fish Health Report for 2020, while welfare challenges in the case of "catch and release" are described in the Norwegian Fish Health Report for 2019.

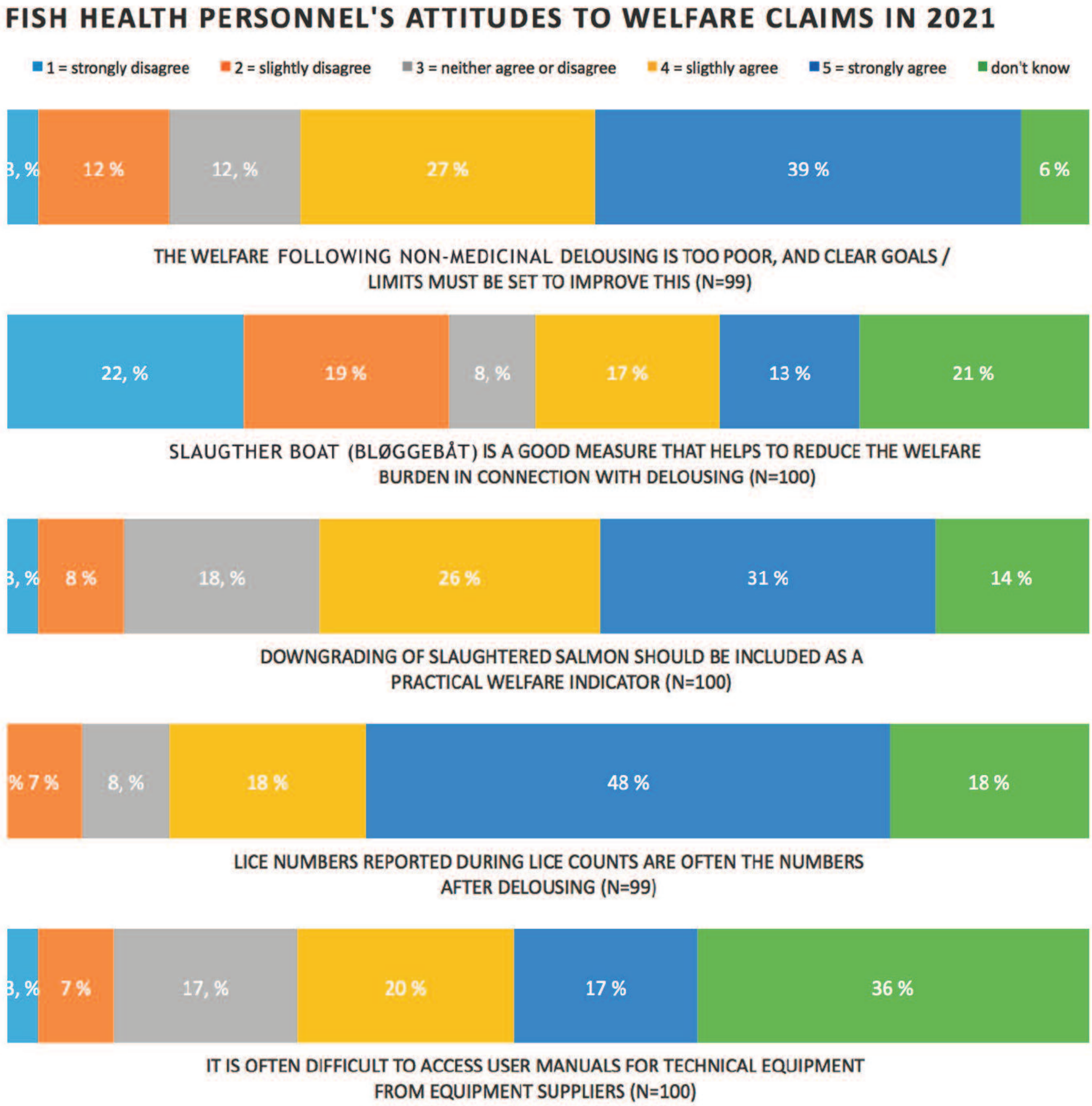


Figure 3.12.1 Distribution of responses to various welfare claims in the 2021 survey.

3.12 Attitudes surrounding fish welfare

Since attitudes and knowledge levels affect the extent to which we are prepared to allow the fish to suffer, it is interesting to hear the opinion of fish health personnel. Fish health personnel have a special responsibility to contribute to good fish welfare. The viewpoint of people on animal welfare and thereby public regulations also influence individual attitudes. In this year's survey, participants were asked the degree to which they were in agreement with various statements related to welfare based on their own experiences and views in 2021. The results are shown in Figure 3.12.1.

3.13 Overall assessment of fish welfare in 2021

Several hatchery projects have highlighted the importance of seeing the entire life cycle of salmon in terms of welfare and mortality. Nevertheless, there has still been no change in the requirements for reporting dead fish to the Food Safety Authority (see the Fish Health Report for 2019). It is desirable that the various fish groups are monitored from hatching until harvest. This will allow identification of those areas of production which are most challenging in terms of mortality. Some hatcheries have changed production systems and reduced intensity during the early life stages, but high temperatures in RAS facilities have resulted in fish outgrowing the farm. Nephrocalcinosis, shortened gill covers, fin erosion, HSS, smoltification and water supply problems are also reported as challenging. The number of reported welfare incidents from hatchery facilities continues to increase, which is worrying. In 2021, the Food Safety Authority received 188 reports – compared to 162 in 2020. However, it is unclear what the increase in the number of reported incidents is caused by.

For fish farmed in the sea, the number of delousing treatments and the methodologies used continue to represent a significant welfare concern, both for the treated salmon and the cleaner fish present in the cages. General handling and in particular the crowding prior to transfer of fish to the delousing unit is hard on the fish. There is still a lack of knowledge on the tolerance limits related to repeated treatments and restitution time. The number of weeks of non-medicinal delousing is somewhat reduced compared to 2020, but higher than in 2019. Thermal delousing with exposure to high water temperatures that are unphysiological for the fish causes both pain and panic behaviour, and major welfare consequences are still reported. Experiences indicate that fish in poor health, i.e. due to poor gill health, tolerate such treatment extremely poorly. For those systems utilising mechanical lice flushing technologies, scale loss is commonly reported leading to increased susceptibility to winter ulcers at low water temperatures. Ulcer development has major welfare consequences, and 79 percent of the respondents reported ulcer outbreaks in the two consecutive weeks after non-medicinal delousing in 2021.

In total, the Food Safety Authority received 1535 reports of welfare incidents in 2021 from ongrowing/broodstock facilities; a slight decrease from 1623 reports in 2020, but still higher than in 2019 (1489). The proportion of reports related to non-medicinal delousing with handling is somewhat decreasing. The same applies to the number of weeks of non-medicinal delousing for 2021, where thermal delousing has the most decrease.
We still believe there is an under-reporting in lice numbers; 66 percent of the professionals in the survey said they "strongly agreed" or 'somewhat agreed' agree to the claim that lice numbers reported in delousing weeks are the real figures after delousing. In 2021, a somewhat increasing practice has been reported that slaugther boats are located at the cage edge for emergency slaugther of morbid fish. It is important that this practice does not increase the willingness to initiate risky delousing procedures. It is additionally important that the number of fish harvested in this way are registered as such, to ensure that the risk of mortality associated with delousing is not underestimated. When it comes to harvest, there are reports of improvement in reported effect with stunning machines but, overall, the respondents consider that the proportion of 99 percent of fish to be adequately stunned must be raised.

Cleaner fish face major welfare challenges from disease, delousing operations and a lack of control over mortality in the cages. A lot of work is being done to improve the situation. Still, very few (only six) animal experiments with the aim of improving the welfare of cleaner fish, was registered in 2020. Compared to previous years, several comments have been made in the free text field which proposed prohibiting the use of cleaner fish. The use of cleaner fish should be reduced in the short term, a trend we are already seeing. The government's Aquaculture Strategy for 2021 states that, if it cannot be documented in the near future that cleaner fish can live good lives in the cages and contribute significantly to salmon lice control, the use of cleaner fish must also be discontinued.

With regard to the use of new and complex technology, the Food Safety Authority and the survey reported on technical problems and human error. Incidents of this kind are of great importance, as operational accidents often harm many individual fish. For operational planning, spacious safety margins should be set, and daily tasks and operations should be assessed and managed with the aim of lowering the risk of reduced animal welfare.

Fish health personnel are strongly committed to the fight for improved fish welfare, health and biosecurity measures and face different problems in the various production areas. However, they also need management systems that facilitate and reward good animal welfare, and that the opposite does not pay off, in order to match the principles of the Animal Welfare Act and the welfare reported in farming.

CEO Torill Moseng and board member Eirik Welde on a visit to a fish farm in Harstad in 2021.
Photo: Harrieth Lundberg, Norwegian Veterinary Institute

4 Viral diseases of farmed salmonids

By Cecilie Walde

In 2021, as in the previous year, three viral diseases dominated diagnoses at the national level: cardiomyopathy syndrome (CMS), heart and skeletal muscle inflammation (HSMI) and pancreas disease (PD). As in 2020, an increase in the number of ISA cases was observed, although not as noticeably as in 2021. The serious viral diseases Infectious Haematopoetic Necrosis (IHN) and Viral Haemorrhagic Septicemia (VHS) were also not detected in Norway in 2021, but the detections of IHN in Denmark and Finland give cause for unease and vigilance.

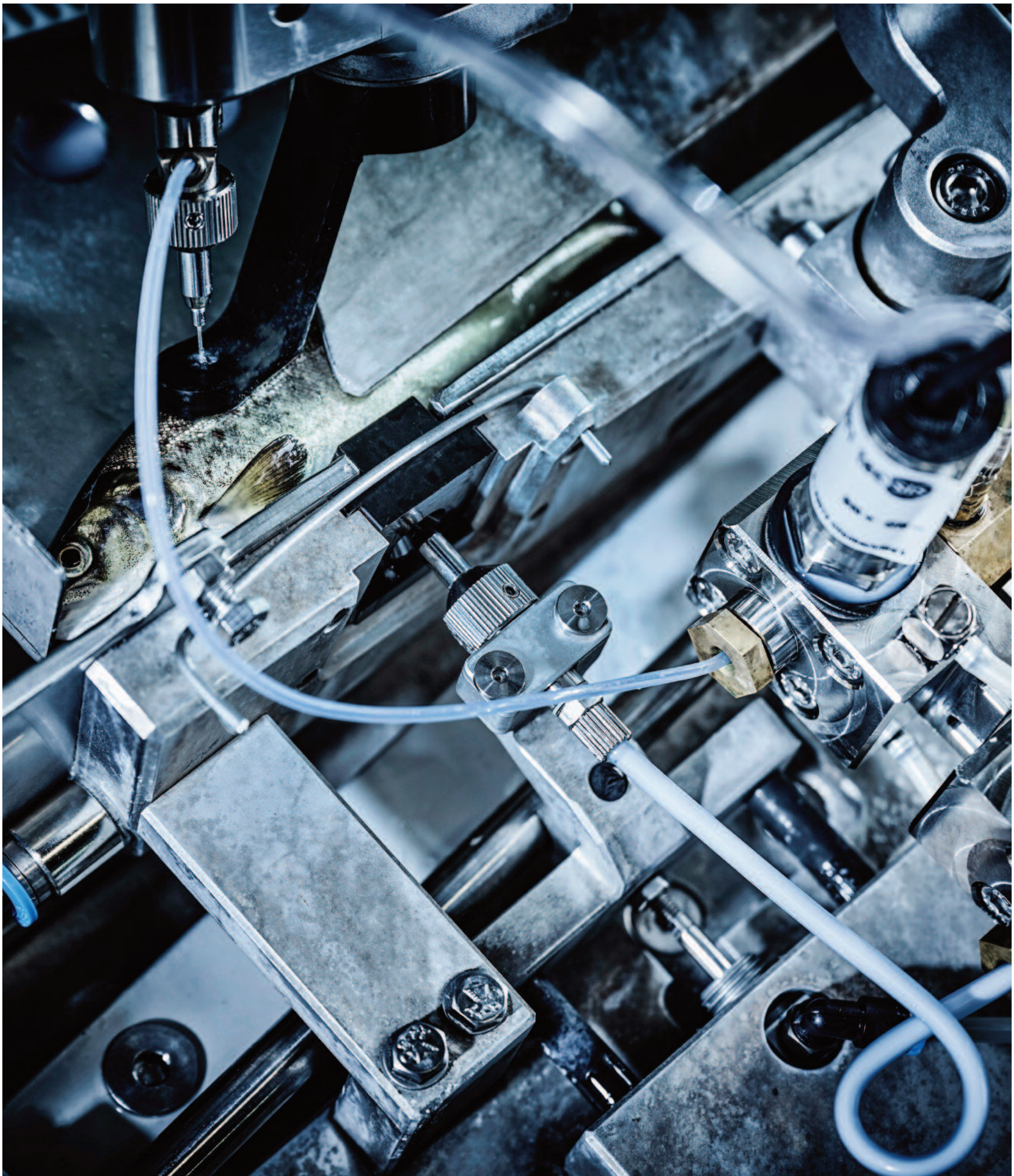
For the listed diseases ISA (List 2) and PD (List 3), ISA was confirmed in 2021 at a total of 25 sites and PD in a total of 100 sites. We are therefore seeing a slight increase in the number of ISA cases compared to 2020, which gives cause for concern. This is also reflected in the survey, where ISA is ranked as the disease with which the greatest concern is associated as a growing problem in the industry in 2021. The incidence of ISA changes from year to year, and last year ISA was detected along the entire coast, from PO3 in the south to PO12 in the north. A significant reduction in the number of new cases of PD was recorded in 2021. The reduction is mainly related to a decrease in SAV3 cases in PO5 and SAV2 cases in PO6. In 2021, no infection with SAV2 and SAV3 was registered in the same facility, nor was SAV detected in the three northernmost counties.

The virus that causes the severe listed disease IHN (List 2) has never been detected in Norway, but in May 2021 the IHN virus was first detected in Denmark and then in several facilities in Åland, Finland. The cases in Åland could be traced to imports from Denmark. Nor was the second severe listed disease VHS (List 2) detected in Norway in 2021, and no outbreaks were reported in nearby waters. By 2021, nine VHS outbreaks have been reported in five European countries, a slight increase from the previous year. Given the serious consequences of an IHN or VHS outbreak in Norway, constant vigilance is important such that infected fish may be rapidly destroyed.

CMS, HSMI, IPN and salmon pox are non-listed viral diseases, making it challenging to estimate their incidence. For CMS, the number of cases appears to be relatively stable. For HSMI, a few more cases were registered last year compared to 2020. It is uncertain whether there has been a real increase since access to data has changed (see Chapter 1 Statistical Basis). The survey also supports these observations, and CMS was ranked as the leading cause of mortality in salmon in the sea phase when fish health personnel along the entire coast were asked. For IPN, the situation still seems relatively stable and with a low incidence.

Table 4.1 Number of farming sites (salmonids) with viral diseases detected for the period 2011-2021. For ISA and PD, new sites where these diseases were detected are shown, for other diseases, diagnoses made the same calendar year are shown. * For the period 2011-2019, the number of positive sites is based on cases submitted to the Norwegian Veterinary Institute, but for 2020 and 2021, data made available from private laboratories is included (see Chapter 1 Statistical Basis).

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ISA	1	2	10	10	15	12	14	13	10	23	25
PD	89	137	99	142	137	138	176	163	152	158	100
CMS	74	89	100	107	105	90	100	101	82	154*	155*
HSMI	162	142	134	181	135	101	93	104	79	161*	188*
IPN	154	119	56	48	30	27	23	19	23	22*	20*



Vaccination is an important biosecurity measure in the Norwegian aquaculture industry. The image shows machine vaccination of salmon, in which one vaccine is given in the back dorso-lateral muscles and another vaccine is given in the abdomen. The fish is pre-stunned and the correct location of the needle is calculated by the machine for each individual. Photo: MSD Animal Health.

4.1 Pancreas Disease (PD)

By Hilde Sindre, Sonal Patel and Britt Bang Jensen

The disease

Pancreas Disease (PD) is an important and serious viral disease of salmonid fish farmed in the sea, caused by salmonid alphavirus (SAV). Diseased fish display extensive pathological changes in the pancreas and inflammation in the heart and skeletal musculature.

There are currently two ongoing PD epidemics in Norway. Subtype SAV3 has been widespread in Western Norway since its introduction from the Bergen area in 2003-04. Following the introduction of a new sub-type, marine SAV2, PD caused by this sub-type has spread rapidly in Central Norway since 2010. Most cases of SAV3 PD occur south of Stadt, while nearly all SAV2 cases are registered north of Hustadvika in Møre og Romsdal.

Mortality among fish affected by PD with SAV3 varies from low to moderate, but single outbreaks with high mortality also occur. While almost all SAV2 infections are associated with low levels of mortality, high levels of mortality may occur in individual cages. SAV infections often lead to increased feed conversion and development of runts. PD outbreaks frequently lead to extended production times due to persistently reduced appetite, and losses due to reduced market quality are commonly experienced.

Disease control

PD is a notifiable disease in Norway (national list 3). Since 2014, infections with salmonid alphavirus (SAV) isis included in the list of infectious fish diseases at the World Organization for Animal Health (OIE). As a consequence, countries that can document a freedom from this disease can refuse to import salmonids from SAV-affected areas in Norway.

To reduce the spread of infection, legislation relating to PD has been in place in Norway since 2007. The most recent legislation was introduced in 2017 (Regulations 2017-08-29 #1318). In the newest Regulations, a PD zone is defined between Jæren in the south and Skjemta in Flatanger in the north (the previous border between southern and northern Trøndelag). The remainder of the coastline is divided into two surveillance zones stretching from both sides of the PD zone to the borders of Sweden and Russia, respectively.

The main reservoir of SAV is infected farmed fish. Since 2017, intensive health monitoring, regulated through the PD Regulations, has made it possible to detect SAV early to prevent/reduce more spread of infection and disease. According to legislation, monthly samples must be taken from 20 fish from all marine sites and other sites utilising untreated seawater holding salmonids. All samples must be screened for SAV by RT-PCR and the results reported to the Norwegian Veterinary Institute and the Food Safety Authority. A focus on coordinated sea transfer within large fallow zones and various measures concerning the transport of smolt and fish for harvest are important mitigating measures. As of January 1rst 2021, the Food Safety Authority requires the treatment of transport water both inside and outside the PD zone. To prevent the spread of SAV in the surveillance zone, speedy harvesting and removal of infected populations are worthwhile mitigating measures.

Commercial vaccines against PD are available, and vaccination is standard practice in Western Norway (PO2-PO5). Mandatory vaccination against PD in the area from Taskneset (Fræna) in the south to Langøya near Kvaløya (Sømna) in the north (corresponding to PO6 and PO7), Article 7 of the PD Regulations, is currently on hold and postponed until the Ministry decides otherwise.

Vaccination against PD has only had a limited effect compared to protection achieved by vaccinating against most bacterial agents. However, vaccination against PD does reduce the number of outbreaks and can lower overall mortality. Vaccination also results in reduced viral shedding from infected fish. New vaccines, based on DNA-technology, have recently been released on the market to combat PD. Field reports suggest that these vaccines may have a better effect than previously available vaccines, although this has not yet been documented. According to figures from the sale of vaccines reported to the Veterinary Drug Registry, the number of vaccine doses for PD has increased, especially for the DNA vaccine, leading to a higher vaccine coverage in endemic areas. There is ongoing research at the Norwegian Veterinary Institute to increases our knowledge about the effects of vaccination on PD outbreaks.

The Norwegian Veterinary Institute is both a national and international reference laboratory for SAV. The Norwegian Veterinary Institute cooperates with the Food Safety Authority on daily updates of maps for such groups as Barentswatch. Quarterly reports of the number of PD cases are also published online: www.vetinst.no

For more information about PD, see the fact sheets: **https://www.vetinst.no/sykdom-og-agens/pankreassykdom-pd**

The Health Situation in 2021

Official data

A total of 100 new cases of PD were detected in 2021, a significant reduction from 158 in 2020. The reduction is mainly related to a decrease in SAV3 cases in PO5 and fewer SAV2 cases in PO6. In 2021, no co-infection with SAV2 and SAV3 was registered in the same facility, and the three northernmost counties had no detections of SAV

Due to an outbreak of PD within the surveillance zone north of Skjemta in Flatanger (Nord-Trøndelag) in 2017, and a new PD outbreak in 2019, a control zone was established to prevent and control PD and to combat pancreas disease in aquatic animals. This zone covers Flatanger (now Namsos), Nærøysund, Leka, Bindal, Brønnøy and the municipalities of Sømna in Trøndelag and Nordland. Due to detection of PD-virus belonging to SAV3 in a site in the Municipality of Smøla in Møre og Romsdal and Trøndelag, a control zone was established in April 2019 to prevent, limit and control PD caused by SAV3 within the municipalities of Smøla, Aure, Heim and Hitra. Following an outbreak of PD-SAV2 in Tysvær (Rogaland), a control zone was established in December 2019 incorporating the municipalities of Tysvær, Vindafjord, Suldal, Stavanger and Hjelmeland in this county. Similarly, in February 2020, a control area was established to prevent, limit and combat PD with SAV2 in the municipalities of Stad, Kinn and Bremanger in Vestland County.

Statistics and diagnosis

The statistics presented here relate to the number of PD cases detected at individual farms or new detections following a period of fallowing. This means that the real number of infected sites in any particular year are much higher, as there are already infected fish in the sea diagnosed the previous year.

Pancreatic Disease is defined here as both "detected PD" and "suspected PD". In order for the diagnosis "detected PD" to be made, histopathological findings consistent with PD and PD virus must be detected in the same individual. The diagnosis "suspected PD" is made when only PD virus, histopathological changes characteristic for PD or antibodies against PD virus in serum/plasma (blood)) are found. In cases where fish, diagnosed with suspected or detected PD, have been moved to a new site, this site is also categorised as PD detected, without new investigations being carried out at the site. The statistics presented here include both detected and suspected cases shown together.

SAV3

SAV3 PD occurs mainly in PO 2, 3 and 4, Ryfylke to Stadt i.e. the southernmost area of the PD zone. There was a significant reduction in the number of detections of SAV3 infections from 110 in 2020 to 71 in 2021. Typically, most cases are observed in early summer (June-July). In 2020, however, cases peaked in April, while in 2021 there was a peak in the number of cases in February/March, with more than half in PO4. In PO2, PD was first recorded in 2004. In this production area, there was a slight reduction from 18 cases in 2020 to 15 for this area. As before, the main area for SAV3 detections were in PO3 and PO4, but in 2020 PO4 (Nordhordland to Stadt) had significantly more reported detections of SAV3 than PO3. However, in this area we also find the most marked reduction in the number of PD cases from 2020 to 2021, with a decrease from 56 to 32, while PO3 had a slight decrease from 26 to 22. There was a significant reduction in PD cases in PO5 as well (Stadt to Hustadvika) from 10 to 2. No SAV3 was detected in PO6 to PO13 (Nordmøre to East Finnmark). No cases of co-infections of SAV2 and SAV3 in the same farm were detected in 2021.

SAV2

The main area for SAV2 is PO6 (Nordmøre and Sør-Trøndelag). For SAV2, there was also a significant reduction in the number of new recorded cases from 50 in 2020 to 29 in 2021. Apart from one case in PO5, all detections were made in PO6. In PO7-PO13, SAV2 was not detected in 2021, the same as in 2020. Nor were there

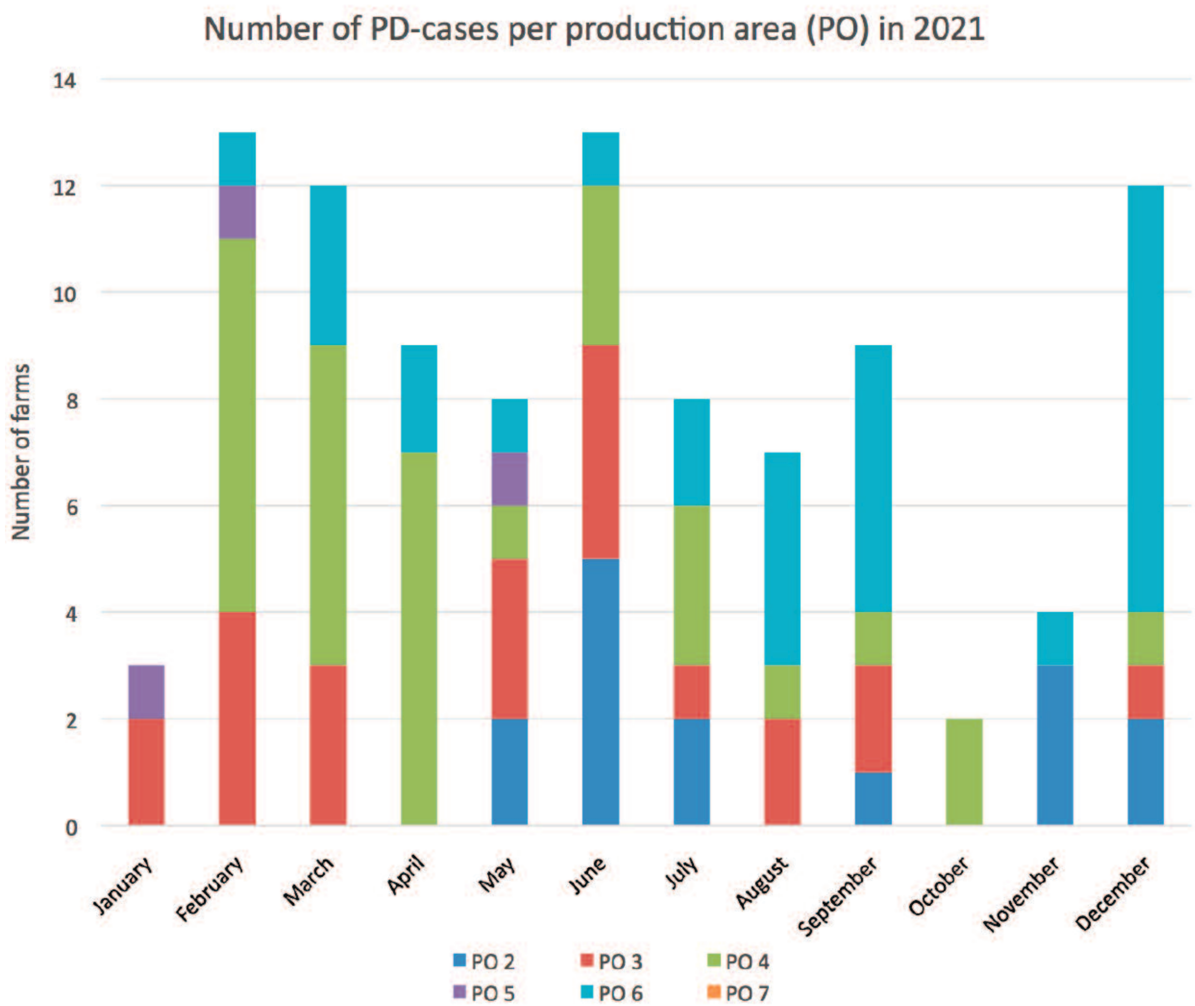


Figure 4.1.1 Map of new sites with PD cases in 2021 per production area and month.

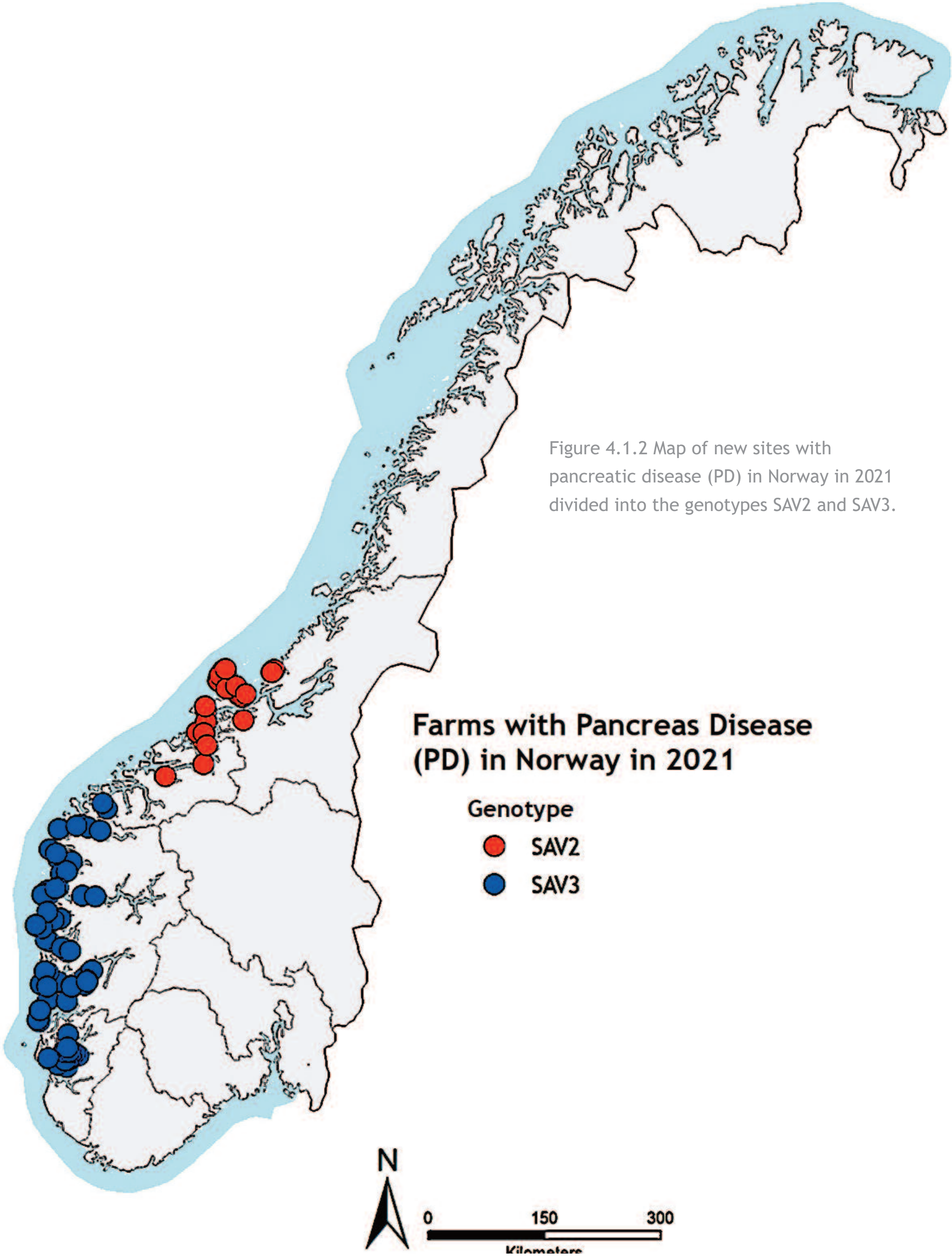


Figure 4.1.2 Map of new sites with pancreatic disease (PD) in Norway in 2021 divided into the genotypes SAV2 and SAV3.

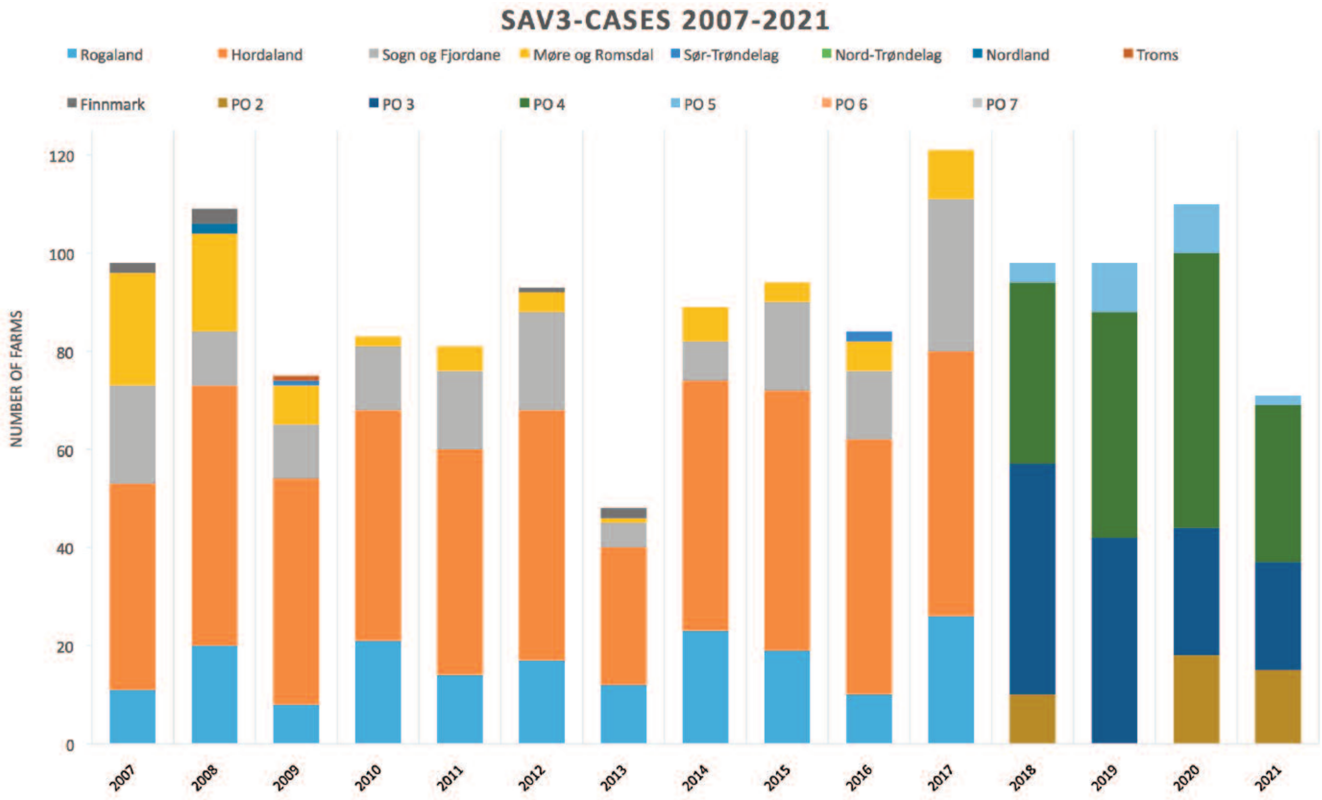


Figure 4.1.3 Distribution of the number of new PD cases (genotype SAV3) per county (2007-2017) and per PO (2018-2021). See Figure 1.1 for a geographical description of each PO.

any detections of SAV2 in PO2, a decrease from 3 in 2020. Based on this, all cases of of SAV2 and SAV3 in 2021 were within what is defined as endemic zones of the 2 genotypes in the Regulations.

The Annual Survey

As in previous years, the Norwegian Veterinary Institute has carried out a survey amongst fish health personnel and inspectors at the Norwegian Food Safety Authority. This year's survey shows that many of the respondents still perceive PD as a significant viral disease grow-out fish and broodstock farms with salmon, but in recent years it has been overtaken by both CMS and HSMI in terms of mortality and welfare. For rainbow trout, PD is still considered one of the main disease challenges together with ulcers caused by mechanical lice treatment and nephrocalcinosis. As previously, the disease is especially linked to poor growth and reduced welfare, in addition to elevated mortality (for details, see Appendix B1-2 and C1-2).

Of the respondents with experience with vaccination against PD (N=43), approximately 50 percent (21 out of 43) stated that they have not observed PD disease after vaccination. A further 37 percent (16 out of 43) reported that there has been less disease than in non-vaccinated fish. Some of the respondents link this to vaccination with the DNA vaccine. For a discussion of the possible side effects of PD vaccination as well as an assessment of vaccine efficacy, see Chapter 8.6.

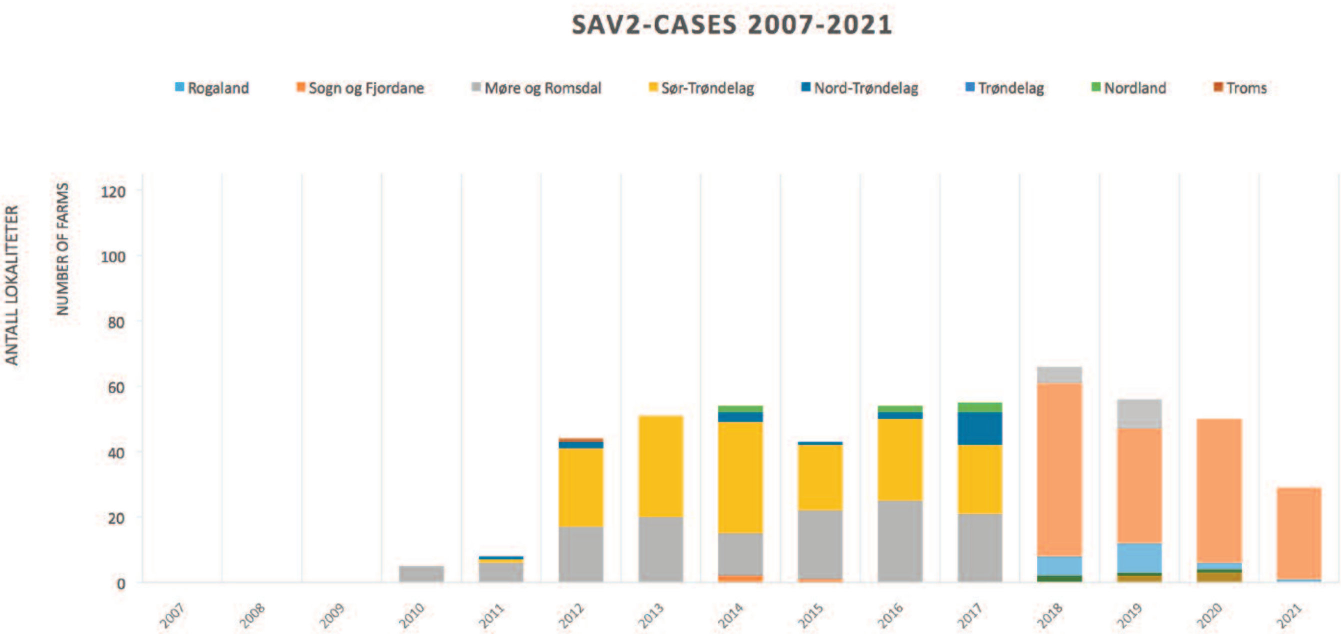


Figure 4.1.4 Distribution of the number of new PD cases (genotype SAV2) per county (2007-2017) and per PO (2018-2021). See Figure 4.1.3 for colour coding of the bars and Figure 1.1 for a geographical description of each PO.

Evaluation of the PD situation

The incidence of PD cases is still high and is a challenge for the industry, which entails considerable costs and welfare challenges.

Virus infection can precede visible signs of disease, resulting in a subclinical infection. Frequent screening for SAV is therefore important for early detection of the virus. There may also be a low prevalence of PD or individuals with very low viral amounts at a site, which can lead to a negative screening result, even if the disease is present. PD is a typical stress-related disease. Subclinical infections can develop into serious outbreaks following e.g. handling during delousing. SAV is transmitted directly through sea water, or during transport of infected populations between sites.

The numb of new detections increased dramatically after the implementation of new regulations requiring monthly screening for SAV in 2017. Without this frequent screening regime, some of these virus findings would probably have remained undetected as subclinical infections. It is likely that some of these infections would have developed into full-blown clinical disease at some point. There has been a significant reduction in the number of cases of PD caused by both SAV2 and SAV3 in 2021.

After expansion of the northern limit of the PD-zone in 2017, cases of PD have been detected in one area (near Buholmråsa in Trøndelag) that was previously free of PD. However, no new outbreaks have been reported in this area since 2019, which is positive in terms of preventing the spread of infection northwards.

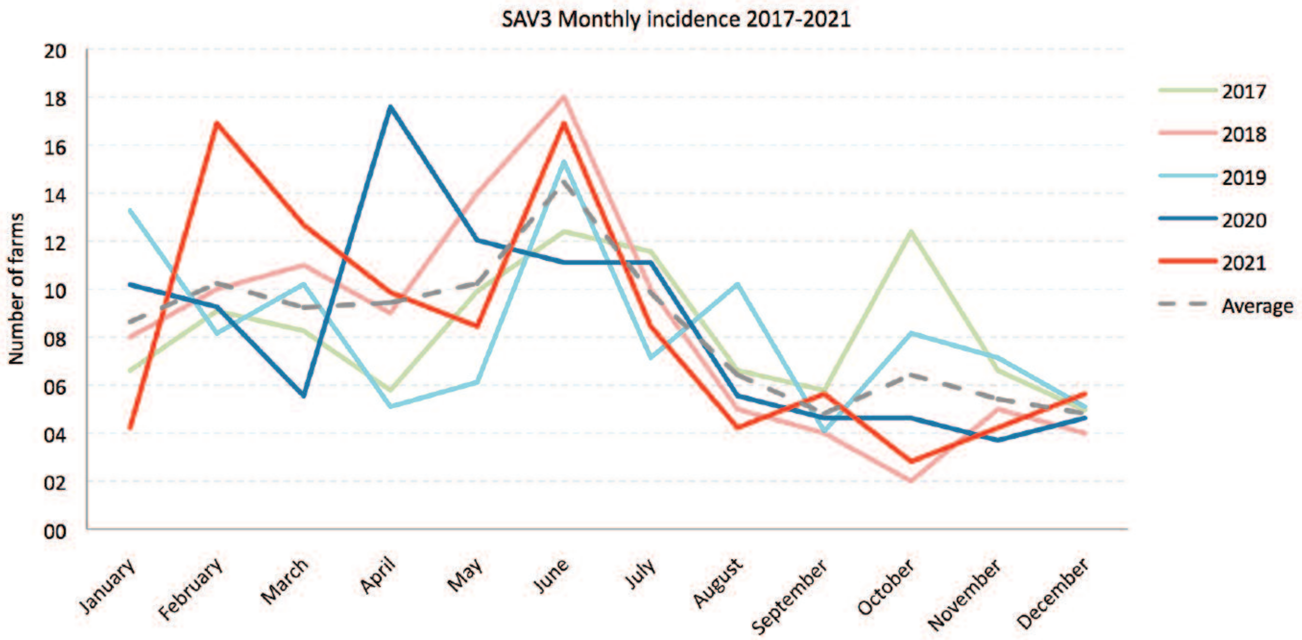


Figure 4.1.5 Monthly incidence rate for SAV3 from 2017 to 2021.

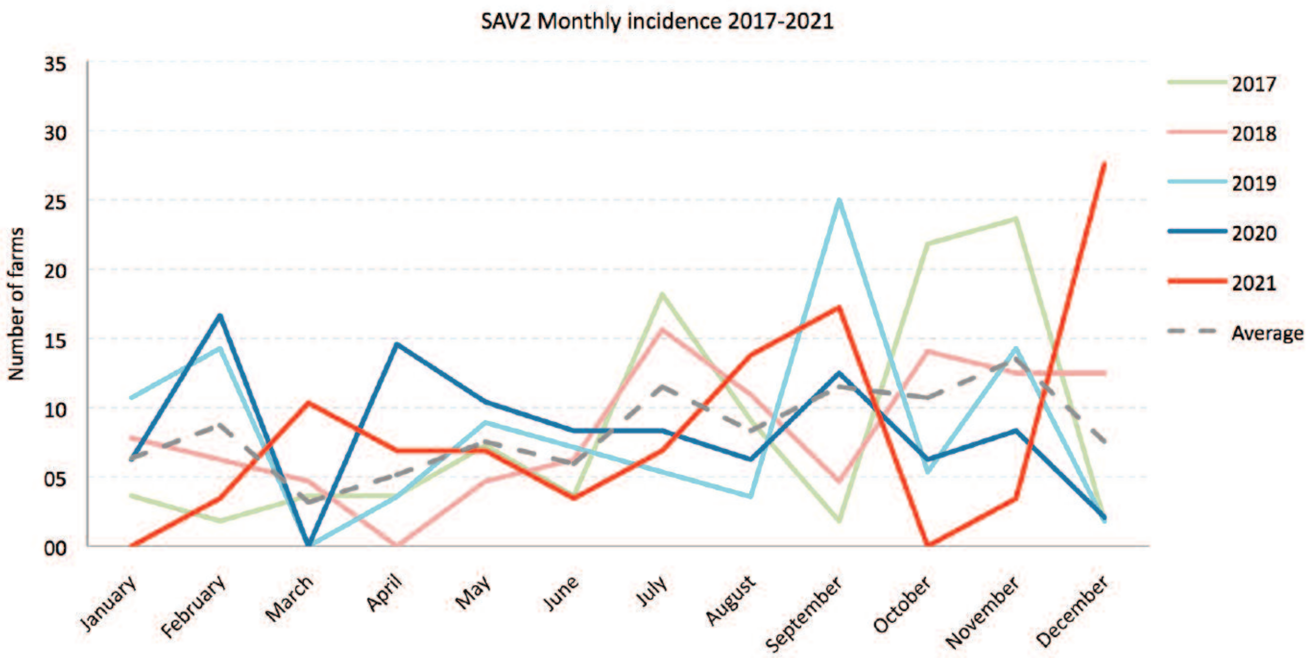


Figure 4.1.6 Monthly incidence rate for SAV2 from 2017 to 2021.

4.2 Infectious salmon anaemia (ISA)

By Mona Dverdal Jansen, Torfinn Moldal, Monika Hjortaas, Geir Bornø, Johanna Hol Fosse and Ole Bendik Dale

The Disease

Infectious salmon anaemia (ISA) is a serious and infectious viral disease in fish caused by the infectious salmon anaemia virus (ISAV). Natural outbreaks of ISA have only been identified in farmed Atlantic salmon. The virus primarily colonises surface organs (gills and skin), before attacking the circulatory system. On post-mortem examination, the main findings include pale gills (serious anaemia, lack of red blood cells) and various signs of circulatory disturbance, blood vessel damage including a fluid-filled abdomen (ascites), oedema, bleeding in the eye, skin, inner organs and necrosis (Figure 4.2.1).

ISA may be compared to a smouldering fire, as the fish may be infected for extended periods and display few or no signs of infection prior to the outbreak of a clinical disease. Commonly, only a small proportion of the fish in an affected population may be infected and diseased, and the daily mortality rate in cages with sick fish is similarly low, usually 0.5-1.0 ppt. In such cases, it can be very difficult to detect the virus, and therefore it may be necessary to examine a large number of fish using PCR to detect infection at a facility.

ISA virus can be differentiated into either nonvirulent ISAV (ISAV HPR0) or virulent ISAV (ISAV HPR-deleted). ISAV HPR-deleted develops from ISAV HPR0 through a process that involves changes in the amino acid sequence differences within the hypervariable region (HPR) of the gene encoding the hemagglutinin esterase protein (HE) and around the cleavage site of the fusion protein (F). ISAV HPR0 is now widespread in farmed salmon with transient infections with ISAV HPR0 normal in broodstock, hatcheries and in ongrowing fish. A recently published article from the Faroe Islands describes how so-called house strains of ISAV HPR0 can be established in hatcheries. The same article showed that the ISAV HPR0 variants in hatcheries were not closely related to the variants found in the broodstock. This suggests that real vertical transmission of ISAV HPR0 does not occur frequently. Experience from several Norwegian hatcheries also suggests that ISAV HPR0 can persist over several years.

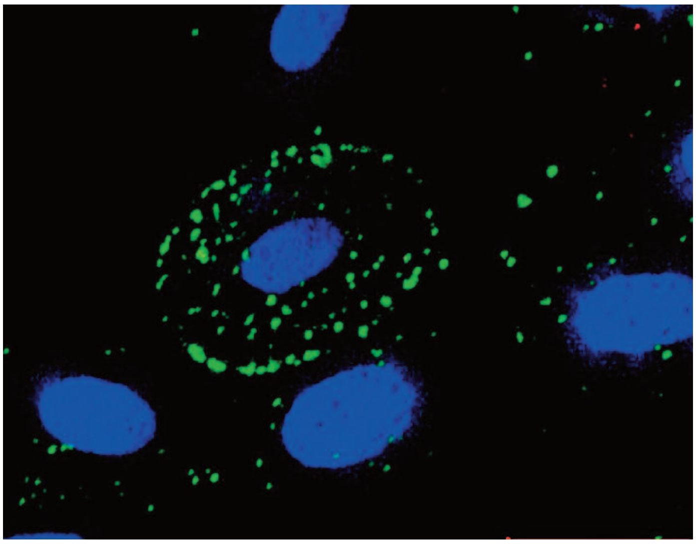
We have inadequate knowledge of the risk of finding ISAV HPR0 for the development of the ISAV HPR-deleted, both in terms of ISAV HPR0 reservoirs, how often ISAV HPR0 develops into an ISAV HPR-deleted and what drives this development. However, a compilation of epidemiological data suggests that a low proportion of ISAV HPR0 infections leads to the development of virulent ISAV HPR-deleted. However, the development of ISAV HPR-deleted from ISAV HPR0 is the most likely explanation when isolated outbreaks occur, and it is scientifically documented that such transitions can take place in the field. The Norwegian Veterinary Institute published information that supports the contention that isolated ISA outbreaks can be related to poor biosecurity routines and stress.

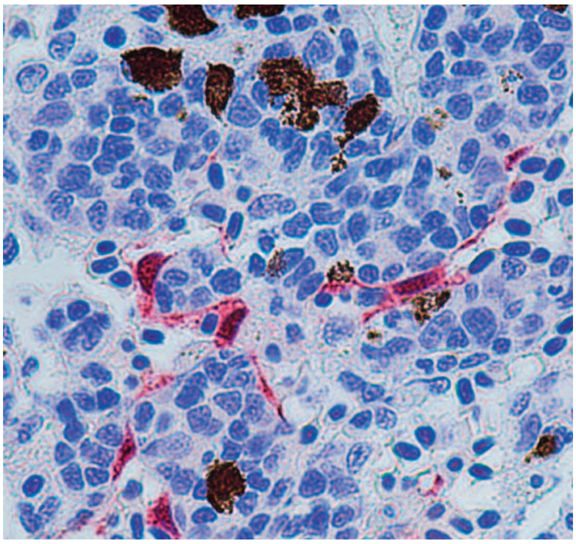
Disease control

ISA is a notifiable disease in Norway (List 2) and EU, while Infections by the ISA virus (ISAV HPR-deleted and ISAV HPR0) are listed by the World Organization for Animal Health (OIE). Outbreaks of ISA are combated by implementation of strict countermeasures. As a rule, a containment area consisting of protection and surveillance zones is established around the affected ISA site. As a result of EU introducing new animal health regulations, a new management plan for ISA is currently being drawn up in Norway (see Chapter 2.3).

For more information about ISA, see the fact sheets:
https://www.vetinst.no/sykdom-og-agens/infeksios-lakseanemi-ila

Figure 4.2.1. Clinical signs of ISA include pale gills, dark liver, and bleeding in internal organs and eyes (top panels). ISAV replicates in cells lining the inside of Atlantic salmon blood vessels (lower right panel, ISAV labelled red). When the virus is excreted into the blood stream it coats the surface of red blood cells (lower left panel, ISAV labelled green). Photo: Frieda Betty Ploss, Adriana Magalhães Santos Andresen and Johanna Hol Fosse.





The Health Situation in 2021

Official data

In 2021, ISA was confirmed at a total of 25 sites; two in PO3, one in PO4, one in PO5, one in PO6, four in PO7, five in PO8, two in PO9, three in PO10, two in PO11 and four in PO12. In addition, at the end of the year, there were five non-confirmed ISA cases based on detection of the virulent ISA virus. PO2 had two non-confirmed cases, while PO7 and PO8 had one case each. One of the non-confirmed cases in PO2, as well as the non-confirmed case in PO7, had been harvested. The second non-confirmed case in PO2 had the diagnosis confirmed in January 2022 and will be included in the statistics for confirmed ISA cases in 2022. For the non-confirmed case in PO8, the disease-causing ISA virus was detected in one in ten samples at the first sampling after the suspicion arose, but has not been detected since despite repeated sampling over eight months.

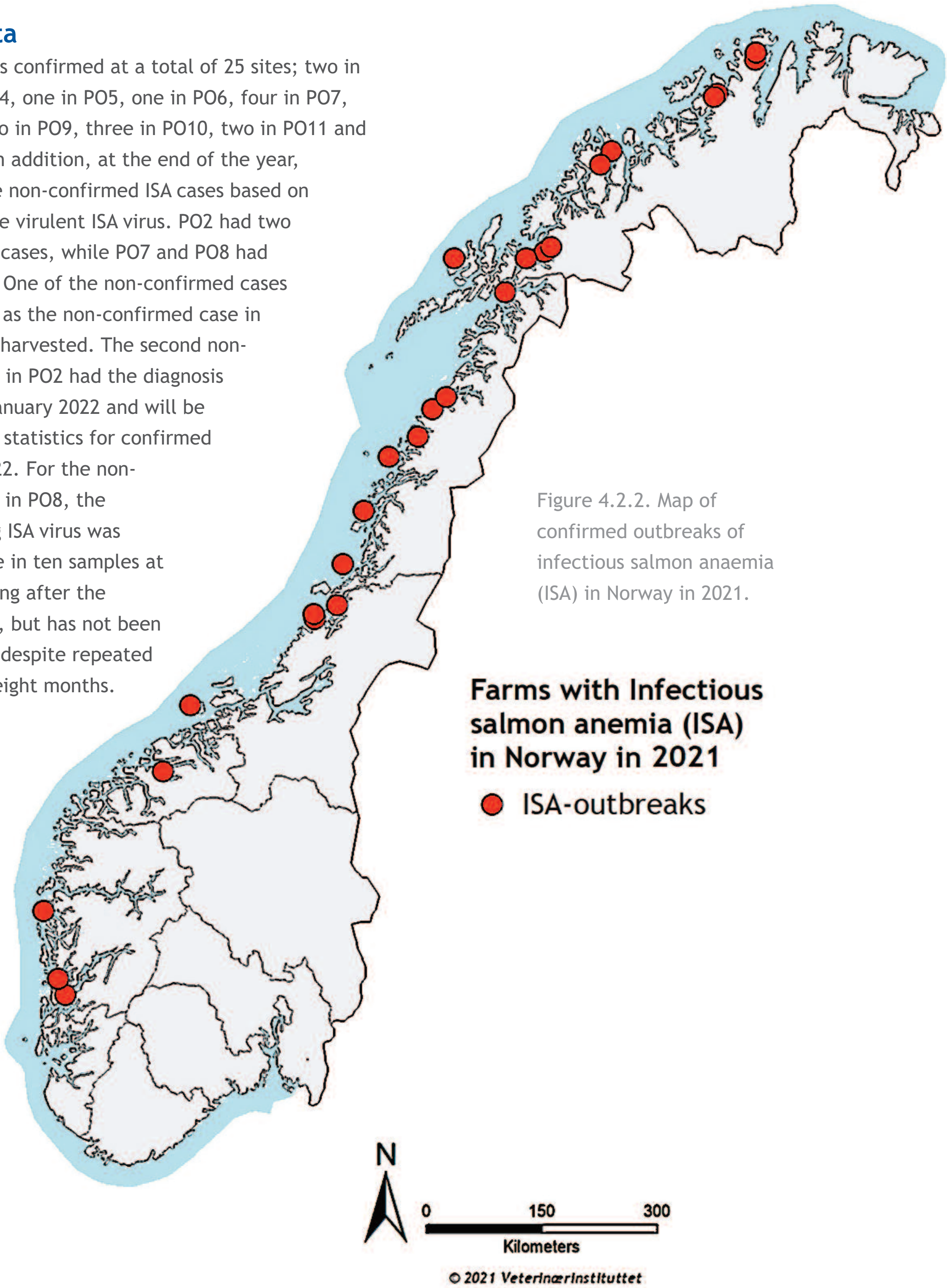


Figure 4.2.2. Map of confirmed outbreaks of infectious salmon anaemia (ISA) in Norway in 2021.

The Annual Survey

In this year's survey, separate questions were asked for the first time about ISA (infection with virulent ISAV HPR-deleted) and infection with non-virulent ISAV (ISAV HPR0). The results show that ISA was ranked at the top of the list of growing problems at ongrowing farms, while ISAV HPR0 is at tenth place (see Appendix B1). At broodstock farms, ISA and ISAV HPR0 shared the top spot for increasing problems (see Appendix C1), while at hatcheries only nephrocalcinosis was ranked higher than ISAV HPR0 as an increasing problem (see Appendix A1).

Evaluation of the ISA situation

In 2021, ISA was confirmed in all POs from area 3 in the south to area 12 in the north (Figure 4.2.2). The 25 cases were divided into one broodstock site, one hatchery and 23 sea sites with ongrowing fish. Fourteen of the sites were covered by existing ISA containment area regulations at the time of ISA suspicion, with four located in an ISA

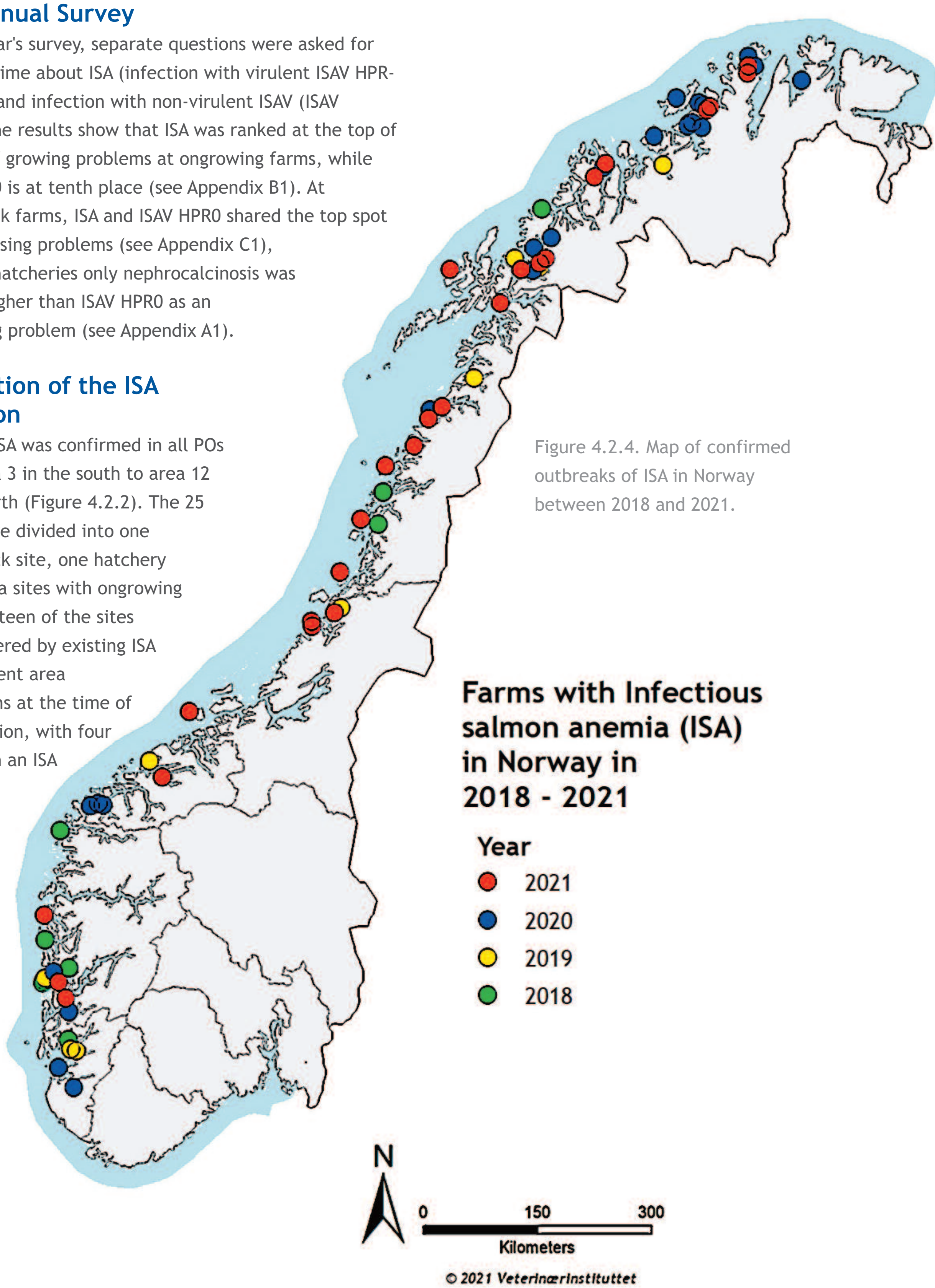


Figure 4.2.4. Map of confirmed outbreaks of ISA in Norway between 2018 and 2021.

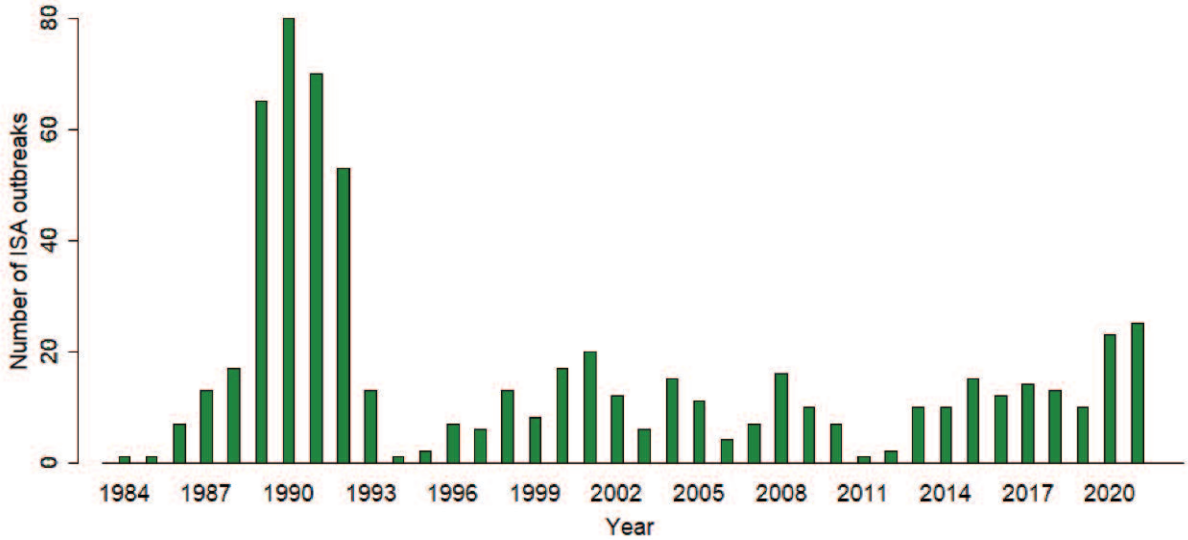


Figure 4.2.3. Summary of annual outbreaks of ISA in Norway for the period 1984 to 2021.

protection zone and ten located in an ISA surveillance zone. At two of the sites, the fish are reported to have been vaccinated against ISA. One of the sites had triploid salmon. Between 1993 and 2020, between one (1994, 2011) and 23 (2020) ISA outbreaks were registered annually, with an annual average of ten cases. The number of confirmed cases in 2021 is thus the highest since 1992 (Figure 4.2.3) and continues the trend from 2020 with a high incidence of ISA. In recent years, both local epidemics, with several outbreaks of related ISA viruses in a relatively limited geographical area, and scattered outbreaks along the entire coast have occurred. The geographical distribution of confirmed ISA cases in Norway in 2018 to 2021 is shown in Figure 4.2.4.

Phylogenetic analyses based on sequences for segment 5 and segment 6 show that virulent ISA virus detected at sites in PO2 and PO3 in 2021 are related to viruses detected in the same area during recent years. One of the sites where ISA was confirmed in 2021 is owned by the same company that owns one of the sites where ISA was confirmed in 2020. However, viruses detected at the two sites have different, non-compatible deletions in HPR, which argues against horizontal transmission. There is no known connection between the sites where virulent ISA viruses were detected in 2021 and earlier years. One possible explanation for the fact that related ISA viruses are observed in outbreaks in the area over several years may be that ISAV HPR0 circulates in the sea and gives rise to virulent ISA virus.

ISA viruses detected in connection with the ISA outbreak in PO4 were related to ISAV HPR0 detected at the hatchery that had delivered smolt to the site with ISA outbreaks. ISA viruses detected at the site with ISA outbreaks in PO5 are closely related to viruses detected at a site in PO4 in 2018. However, viruses detected at the two sites have different, non-compatible deletions in HPR.

Viruses detected at the site with confirmed outbreaks in PO6 and one of the sites with confirmed outbreaks in PO7 are not closely related to viruses detected at other sites in recent years. Viruses detected at the other sites in PO7, on the other hand, are closely related. The deletions in HPR indicate that there may have been horizontal transmission between the three sites with confirmed ISA. This is also supported by epidemiological information. However, the deletions in HPR for viruses detected at the site where the fish were harvested without ISA being confirmed is not compatible with the deletions in HPR for viruses detected at the three sites with confirmed diagnosis. However, viruses detected at these four sites in PO7 are also closely related to viruses detected at several sites in PO8 and PO9 in 2020 and 2021, including ISAV HPR0 detected at two hatcheries that have delivered smolt to several of the sea sites in PO7, PO8 and PO9 where virulent ISA viruses have been detected in 2020 and 2021. Based on segment 6 sequences, viruses detected at one of the sites with ISA outbreak in PO8 in 2021 are closely related to viruses detected at the site with non-confirmed ISA in PO8 and also ISAV HPR0 detected at one of the hatcheries that have delivered smolt to the site with confirmed outbreak. In addition, at one of the sites in PO7, a virus variant has been detected that, based on the sequence of segment 6, is different from the viruses detected in other samples from the same site. However, the sequence for segment 5 is similar to the sequences detected in other samples from the same site.

Identical viruses have been detected at one of the sites where ISA has been confirmed in PO9 and one of the sea sites where ISA has been confirmed in PO10. Viruses detected at the site with confirmed outbreaks in PO10 are related to the virus detected at the other sea sites with confirmed ISA in PO10 in 2021. The sea site had recently received smolt from the hatchery in question. In 2019 and 2020, ISA was confirmed at a total of three sites that had received smolt from the same hatchery, and in all cases, the ISA viruses were closely related to ISAV HPR0 detected at the hatchery.

Identical viruses were detected at the two sites with confirmed ISA in PO11, and it is considered likely that horizontal transmission occurred in this case. At two of the sites with confirmed ISA outbreaks in PO12, a virus was detected that was identical or very closely related to a virus detected on a nearby site in the autumn of 2020. It is considered likely that it is a matter of horizontal transmission. At one of the other sites with confirmed ISA in PO12, viruses that are closely related to viruses detected at several sites in PO10 have been detected in recent years. Otherwise, there is no known connection between the sites. At the last site with confirmed ISA in PO12, viruses related to viruses detected at one site in PO9 and two sites in PO12 had been detected in 2017. The sites had received smolt from the same hatchery.

A summary of 2021 shows several relatively small ISA epidemics where identical or closely related viruses were detected at nearby sites, which were affected by ISA in a relatively short period of time, and where horizontal transmission between the sites is likely. Several other outbreaks can be linked to detections of ISAV HPR0 at hatcheries that had delivered smolt to the affected sea site. In addition, at several sites, viruses that are related to viruses detected at other sites have been detected in other locations over the past few years, but with no other known connection between the sites. One possible explanation is that ISAV HPR0 is circulating in an area that gives rise to the virulent ISA virus.

In light of the Norwegian Veterinary Institute's position as international and national reference laboratory for ISA, all quality assured ISAV sequences for gene segments 5 and 6 recovered during diagnostic and surveillance work are published in GenBank. Sequence designations are based on the geographical origin and year as well as the Norwegian Veterinary Institute journal number. In addition, the site number, site name, date of sampling and species are reported.

Since 2019, a monitoring programme for ISAV HPR0 has been underway in hatcheries, where around half of Norwegian hatcheries are tested for ISAV HPR0 at one sampling every two years. In 2021, eight out of 78 hatcheries in the monitoring programme (10 percent) tested positive for ISAV HPR0. Corresponding figures for 2019 and 2020 were 7 percent (five out of 74) and 14 percent (six out of 42) positive hatcheries, respectively. Given that ISAV HPR0 produces a short-term and transient infection, that the farms were tested only at one sampling time, and that only a proportion of the tanks in each hatchery were sampled, this is probably a significant underestimation of the number of hatcheries positive for ISAV HPR0 within a year. Further details can be found in the report from the 2021 surveillance programme for ISAV HPR0 in Norwegian hatcheries.

There are no official surveillance for ISAV HPR0 at sea sites, and the Norwegian Veterinary Institute does not currently have a comprehensive overview of detections of ISAV HPR0 in Norwegian sea sites. According to data from the surveillance for ISAV HPR-deleted in ISA containment areas and ISA-free zones and segments, as well as diagnostic examinations at the Norwegian Veterinary Institute, ISAV HPR0 was detected at a total of 34 sea sites in 2021. As for the hatcheries, the statistics for sea sites are considered to represent a considerable underestimate of the true prevalence of ISAV HPR0.

The trend of an increasing number of ISA outbreaks and more cases of sequence similarities between ISAV HPR-deleted and ISAV HPR0 continued in 2021, which the Norwegian Veterinary Institute considers troubling. Results from the annual survey amongst fish health personnel and inspectors at the Food Safety Authority reveal that ISA and the occurrence of ISAV HPR0 is considered to be an increasing problem in the industry.

Successful control of ISA is based on prevention of spread through early diagnosis and rapid removal of diseased fish from the affected farm. Furthermore, ISAV HPR-deleted infections in fish for export can trigger serious reactions to Norwegian salmon exports as exemplified by reactions following such discoveries in 2015 in China. Since the autumn of 2015, the industry, the fish health services and the Food Safety Authority, have collaborated on systematic surveillance in ISA containment areas. The surveillance involves monthly inspections and sampling to detect ISAV HPR-deleted ISA at the earliest possible time.

Successful prevention of ISA is better than combating it. It is likely that the occurrence of ISAV HPR0 is an important risk factor for outbreaks of ISA. Increased knowledge about reservoirs of ISAV HPR0 and the drivers behind the transition from ISAV HPR0 to ISAV HPR-deleted will be important for designing better control strategies against ISA in the future.

Successful control of ISA is based on prevention of spread through early diagnosis and rapid removal of diseased fish from the affected farm. Photo: Mari M. Press.

4.3 Infectious pancreatic necrosis (IPN)

By Irene Ørpetveit and 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 most susceptible age groups. Mortality varies between negligible and up to 90% 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 favourable 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-ogog-agens/infeksiøs-pankreasnekrose-ipn**

The Health Situation in 2021

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 20 different sites in 2021. This is on 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 (0), PO3 (3), PO4 (3), PO5 (2), PO6 (6), PO7 (1), PO8 (0), PO9 (3), PO10 (1), PO11 (0) and PO12 + PO13 (1). If we only surveyed agent detection (mainly analysed by real-time RT-PCR), IPN virus has been detected on 65 sites divided from PO1-7, PO9-10 and PO12-13. Of these sites, about 50% state that they do not have clinical significance.

The Annual Survey

QTL stocks are widely used for both salmon and rainbow trout and almost all fish are vaccinated against IPN. IPN is perceived as a more important problem in 2021 than the previous year, and IPN is ranked among the five most important increasing problems in the hatchery phase for both salmon and 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 appendices 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.

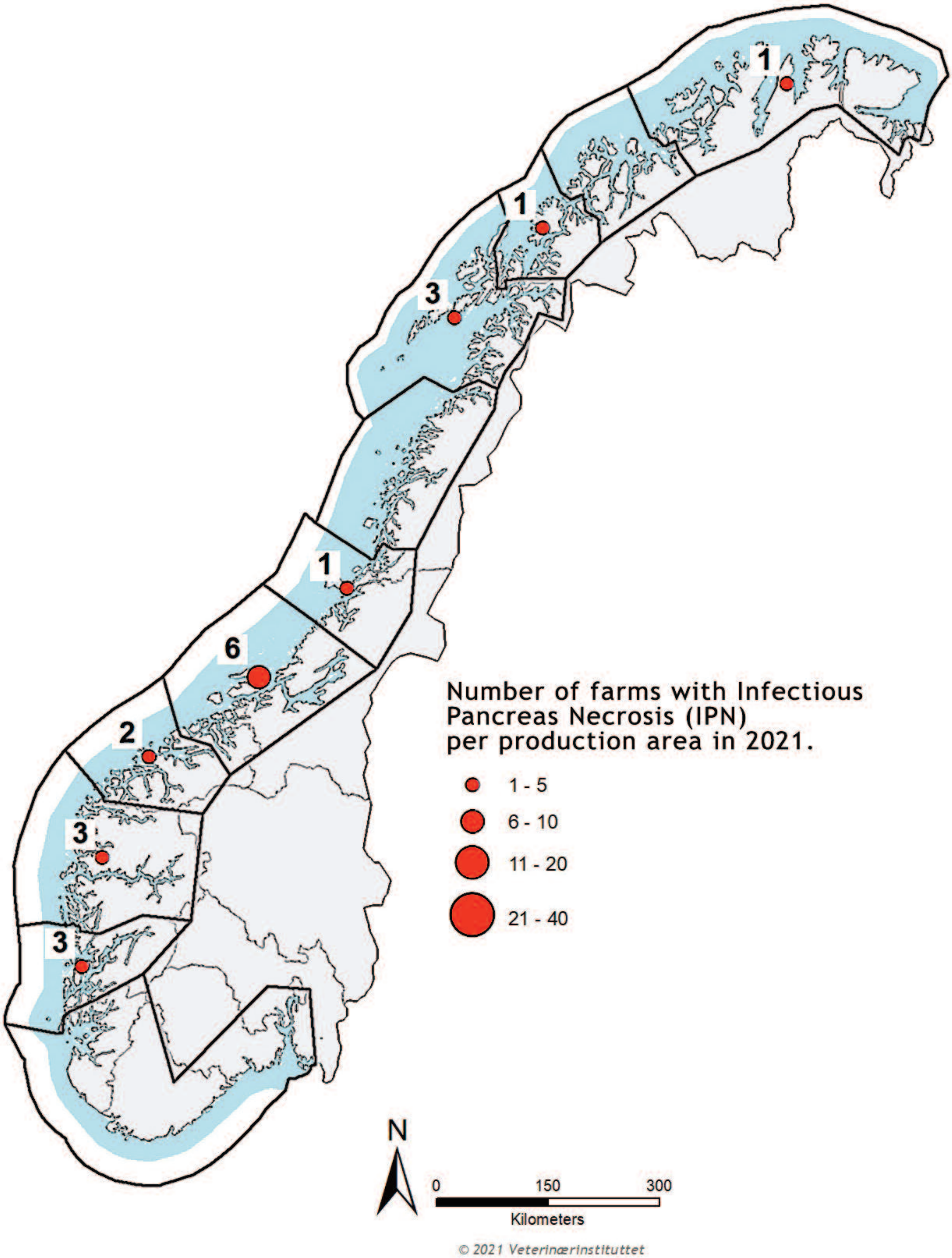


Figure 4.3.1 Distribution of registered IPN outbreaks in Norway 2021.

4.4 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 in Norwegian farmed salmon, and was first detected in 1999. The disease usually occurs in the first year at sea, but outbreaks occur throughout the sea phase and can also be detected in hatchery facilities. The fish develop gradually more pronounced inflammation of the heart in the period before and during the clinical disease outbreak, which can last for several weeks. During clinical outbreaks of the disease, inflammation of the red skeletal muscle is a common finding. HSMI may result in a variable degree of mortality, from zero to 20 percent, and losses are often associated with stressful management routines. Salmon dying with HSMI often display signs of circulatory disturbance.

In 2013-14, an HSMI-like disease with cardiac inflammation was detected in Norwegian rainbow trout. These outbreaks were identified in freshwater and in fish transferred to sea from infected hatcheries. Sick fish could become very pale, which is a sign of pronounced anaemia. Anaemia, by comparison, is not common in HSMI in salmon.

Piscine orthoreovirus (PRV) was identified in HSMI-affected salmon in 2010 (PRV-1). In rainbow trout with HSMI-like disease, another genotype of PRV was described in 2015 (PRV-3, formerly also called virus Y or PRV-Om). Another variant of PRV (PRV-2) is described in Japanese coho salmon, but not in Norway. PRV-1 from salmon and PRV-3 from rainbow trout have a total genetic similarity of around 90%, while parts of the viral genome display only 80% similarity. The aetiological relationship between PRV-1 and HSMI in Atlantic salmon was confirmed following experimental challenge experiments performed in 2017, and the relationship between PRV-3 and HSMI-like disease in rainbow trout was confirmed in a similar fashion in 2019.

While PRV-1 is widespread and has been identified in both wild and farmed salmon, infected salmon do not necessarily develop HSMI. In recent years, several genetic variants of PRV-1 have been found and virulence differences have been identified (Figure 4.4.1). Variants from before the first known outbreaks of HSMI in 1999 belong to a genetic group perceived as low virulent, while isolates from field outbreaks in later years has given HSMI experimentally, and belong to the virulent group of PRV-1. The condition and susceptibility of the infected fish will also contribute to the outcome of infection and stress will also increase mortality levels. Infection with PRV-3 is still detected in Norwegian rainbow trout, but no serious disease outbreaks have been recorded since 2015. PRV-3 is also detected in wild sea trout (see Chapter 9.4).

All known genotypes of PRV infect red blood cells (Figure 4.4.2) and can be detected in most of the fish's blood-filled organs from early in the course of infection. PRV-1 in salmon can also be detected in blood and blood-filled organs long after the onset of the disease, often right up to harvest. In contrast, rainbow trout often appear to rid themselves of PRV-3 completely following infection. Fish developing HSMI usually have large numbers of virus present in heart and muscle cells, the concentration of which then falls as the organs heal. This is because the inflammation of the heart and muscle during HSMI is part of the immune system's attack on virus-infected cells.

Disease control

There is no official control programme for HSMI in Norway and the disease has not been notifiable since 2014. The reason for this is that the virus is very widespread in farmed salmon, and often viral identification is not associated with clinical disease. PRV-3 in rainbow trout is less prevalent, but can similarly be detected without the infection being related to disease. Nor is it mandatory in PRV-3-mediated HSMI-like disease.

There are no PRV vaccines available on the market, although moderate levels of protection against HSMI have been demonstrated by experimental vaccines. Treatment of HSMI with anti-inflammatory components in feed is reported to have some effect and HSMI QTL strains of salmon are now available that are more resistant to HSMI.

One can reduce losses due to HSMI by avoiding operational routines that can stress the fish. Experimental studies have shown that salmon with HSMI are sensitive to stress in combination with reduced oxygen saturation in the water, a situation that can occur after crowding of the fish, during transport or lice treatment. This may be related to infection of red blood cells leading to reduced levels of haemoglobin and reduced oxygen transport or to reduced cardiac capacity.

Most outbreaks of HSMI are seen after sea transfer, and the most important reservoir for PRV-1 is probably farmed salmon in the sea phase. The virus may also be found on occasion in hatcheries. It appears that effective control of the disease in the hatchery phase is important for identification of PRV3 infection in rainbow trout.

There are indications that many hatcheries suffer repeated PRV re-infection, and that it is difficult to eradicate the virus. PRV is a naked virus (lacking a membrane envelope) and may therefore be resilient to standard disinfection routines. A number of operators have initiated an eradication campaign against PRV in infected hatcheries/juvenile production facilities and there is now increasing knowledge regarding inactivation of the virus. The virus appears to tolerate high temperatures and UV treatment, but not strong acids or bases. Intake of seawater that has not been disinfected satisfactorily seems to increase the risk of infection with PRV-1. There may be reason to believe that controlling the occurrence of PRV in hatchery facilities may affect the occurrence in the sea phase.

For more information on HSMI and HSMI-like diseases, see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/hjerte-og-skjelettmuskelbetennelse-hsmb

The Health Situation in 2021

Data from the Norwegian Veterinary Institute and other sources

In 2021, heart and skeletal muscle inflammation was diagnosed in 188 sites with Atlantic salmon. The number is based on combined statistics from the Norwegian Veterinary Institute system and reports from fish farming companies (see Chapter 1 Statistical Basis). The vast majority of the detections were in ongrowing facilities. The Norwegian Veterinary Institute's cases included six hatcheries where HSMI was detected (seven in 2020). As in previous years, the majority of HSMI cases were diagnosed from PO6 (Nordmøre and Sør-Trøndelag) and northwards. PO6 and PO8 (Helgeland to Bodø) had the most detections. HMSI is found throughout the year, but in 2021 about 75 percent of the Norwegian Veterinary Institute's cases were registered in the period January-July. In the data collected, as in previous years, there are many detections of PRV-1 without any diagnosis of the disease.

Five cases of infection with PRV-3 were recorded in rainbow trout in 2021. In three of the cases, detections were associated with disease.

The Annual Survey for 2021

In the annual survey for 2021, respondents were asked to

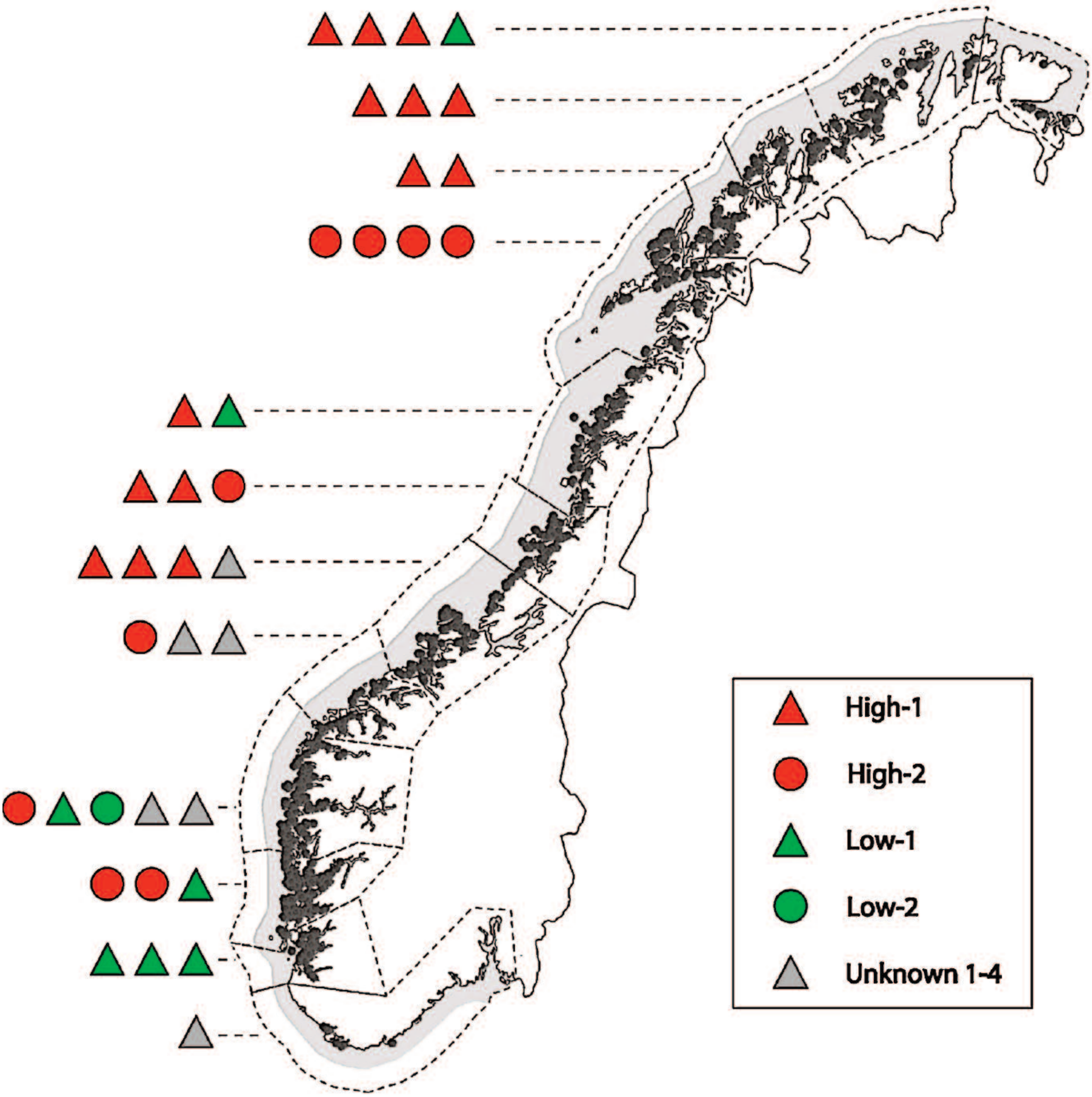


Figure 4.4.1 Geographical distribution of genogroups of PRV-1 based on 37 "isolates" from fields mostly from samples collected in 2019. High- and low-virulent viruses were found in all regions, but there was a tendency that there were several high-virulent ones in Middle and Northern Norway (Vatne, N.A. et al., 2021).

cross off the five most important health problems associated with mortality, poor growth, poor welfare or thought to be an increasing problem. The survey was carried out for salmon and rainbow trout in hatcheries, ongrowing and broodstock facilities.

As in previous years, heart and skeletal muscle inflammation diagnoses were relatively rare in hatcheries. On a national basis, the disease collectively comes in 16th place out of 25 health challenges of importance to salmon in hatcheries. The disease scores low as a cause of increased mortality, reduced growth and reduced welfare – but it is described by some respondents as an increasing problem in the hatchery phase.

In the sea phase, HSMI comes in fourth place as a health problem resulting in increased mortality and reduced welfare, and also scores relatively high as a cause of reduced growth (7th place). HSMI is also mentioned by some respondents as an increasing problem, but ranks here slightly below the top spot (12th place). Overall, heart and skeletal muscle inflammation ranks sixth among the most relevant health problems for salmon at fish farms nationwide, but only CMS is considered more serious than HSMI.

HSMI-like disease (PRV-3) in rainbow trout is reported as irrelevant for hatcheries and broodstock farms in 2021, but is mentioned once in each of the four categories for increased mortality, reduced growth, reduced welfare and as a growing problem at ongrowing facilities (few respondents).

Evaluation of the HSMI situation

An increase in cases of skeletal muscle inflammation was recorded in 2021 with 188 detections compared to 161 detections in 2020. It is uncertain whether the increase is due to changes in the supply of data or if it is real. The survey supports some increase. Several respondents ticked HSMI as an increasing problem in 2021 for both hatcheries and ongrowing facilities.

Also in 2021, it was reported that some hatcheries and ongrowing facilities had major problems with recurring detections of HSMI over many months. HSMI-sick fish seem to endure non-medicinal delousing and other types of handling poorly, and such operations can lead to significant mortality. There are examples of hatcheries that had detections throughout the year in 2021. The possible increasing importance of HSMI in hatcheries is a result of failure to eradicate the virus and the occurrence of house strains which result in recurring outbreaks of disease. This may be due to the fact that the virus can withstand a lot, including UV treatment.

Some detections of PRV-1 were reported without any recorded disease and mortality. This may be due to the prevalence of genetic variants of PRV-1 with low virulence.

As in previous years, few cases have been reported where PRV-3 is associated with rainbow trout disease in the sea phase. There are still no registrations in hatcheries since the outbreaks in 2015.

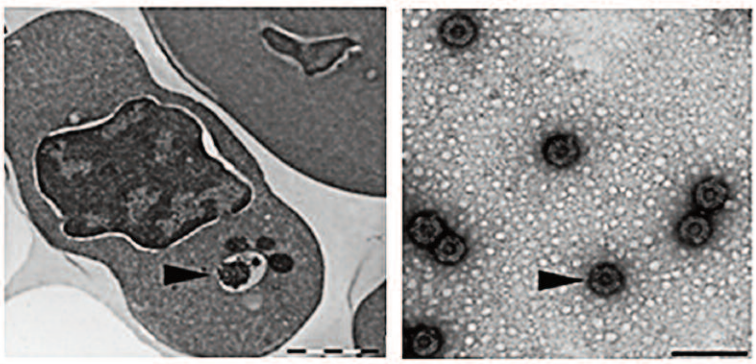


Figure 4.4.2 Inclusion in red blood cells with PRV-1 viral particles (pictured on left, measuring rod 2 µm) and cleaned virus (pictured on the right, measuring rod 100 nm = 0.1 µm) (Wessel, Ø. et al., 2019).

PRV-associated disease is also of international importance, and it is reported that PRV also causes diseases other than HSMI. In particular, PRV-1 has been associated with liver necrosis in chinook salmon in Canada, and PRV-2 is associated with anaemia in coho salmon in Japan. PRV-3 is associated with disease in rainbow trout in Denmark and the United Kingdom, and the virus is found in wild brown trout in several European countries. It has recently been shown that relatively small genomic differences in PRV1 affect the ability of the virus to cause disease and that it may be possible in the future to develop diagnostic tools capable of distinguishing between PRV isolates of varying virulence.

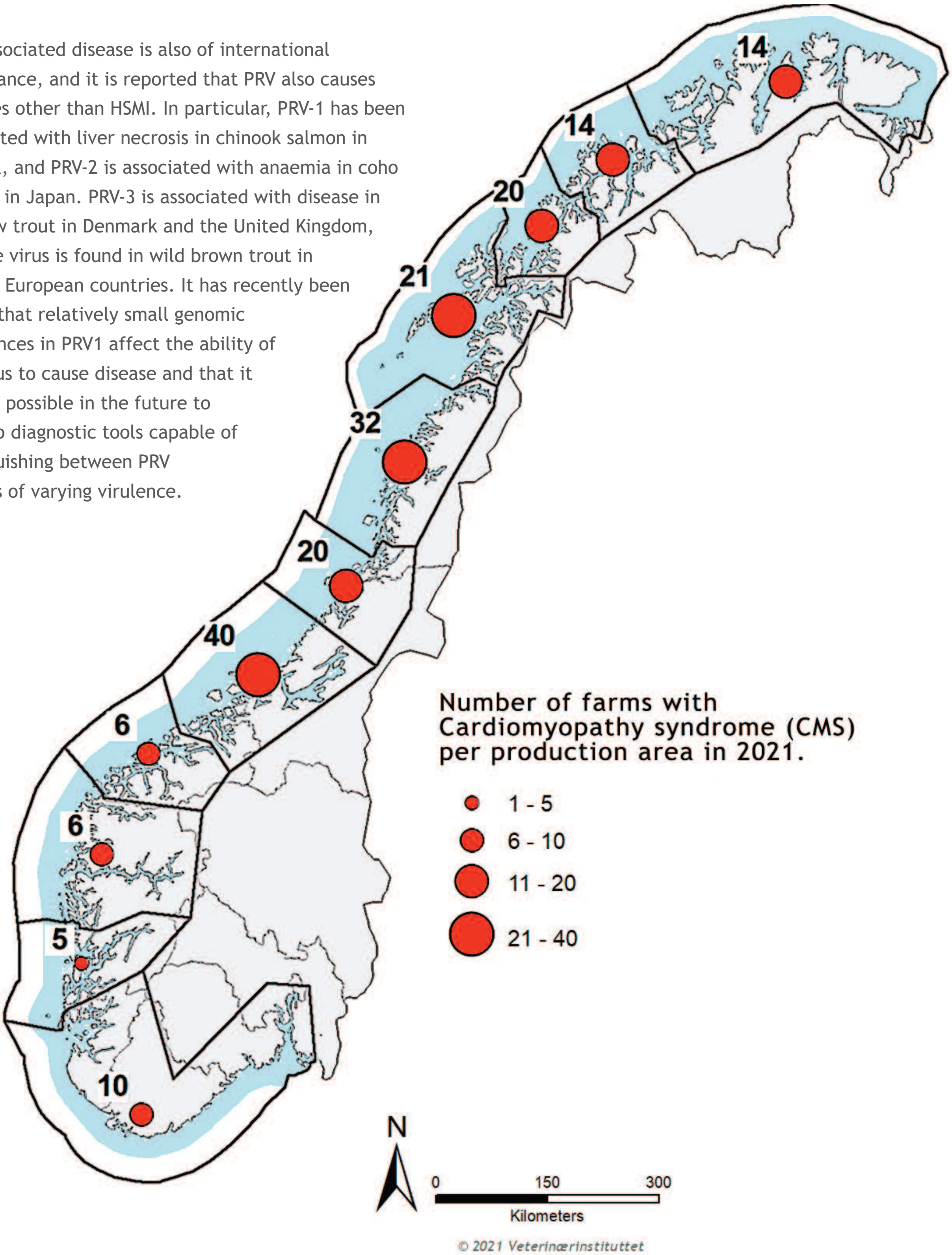


Figure 4.4.3 Number of sites with HSMI diagnoses in 2021 by production areas, based on coordinated figures from the Norwegian Veterinary Institute and private laboratories.

4.5 Cardiomyopathy syndrome (CMS)

By Camilla Fritsvold and Raoul Valentin Kuiper

The Disease

Cardiomyopathy syndrome (CMS), is a serious cardiac infection affecting sea-farmed Atlantic salmon. Since its first description in 1985, the disease is now widespread to all the Norwegian production areas (POs). CMS is a growing problem also in other salmon farming nations in the northern hemisphere such as Scotland, the rest of the UK, Ireland and the Faroe Islands, causing major challenges to the aquaculture industry, both regarding welfare and economy.

Together with salmon lice, CMS is now considered one of the most serious problems causing large losses for the Norwegian aquaculture industry, a high number of annual diagnoses over a period of several years resulting in large financial losses. As the disease normally affect large salmon late in the production cycle, causing mortality at the most economically unfavourable time, even CMS outbreaks with a moderate mortality rate result in significant economic losses. In recent years, CMS has also become more common in younger fish, and CMS outbreaks have been described only few months after sea transfer, causing disease and mortality in fish as small as 100-300 grams. The occurrence of the disease at a fish farm at this early stage is very unfavourable in economic terms, as this most often results in greater total mortality and the operation of the facility is affected throughout the production cycle. Mortality associated with CMS may appear as sparse or moderate for a long period of time, or as outbreaks with acute high mortality, often triggered by episodes inducing stress in the fish.

The disease is caused by the totivirus-like piscine

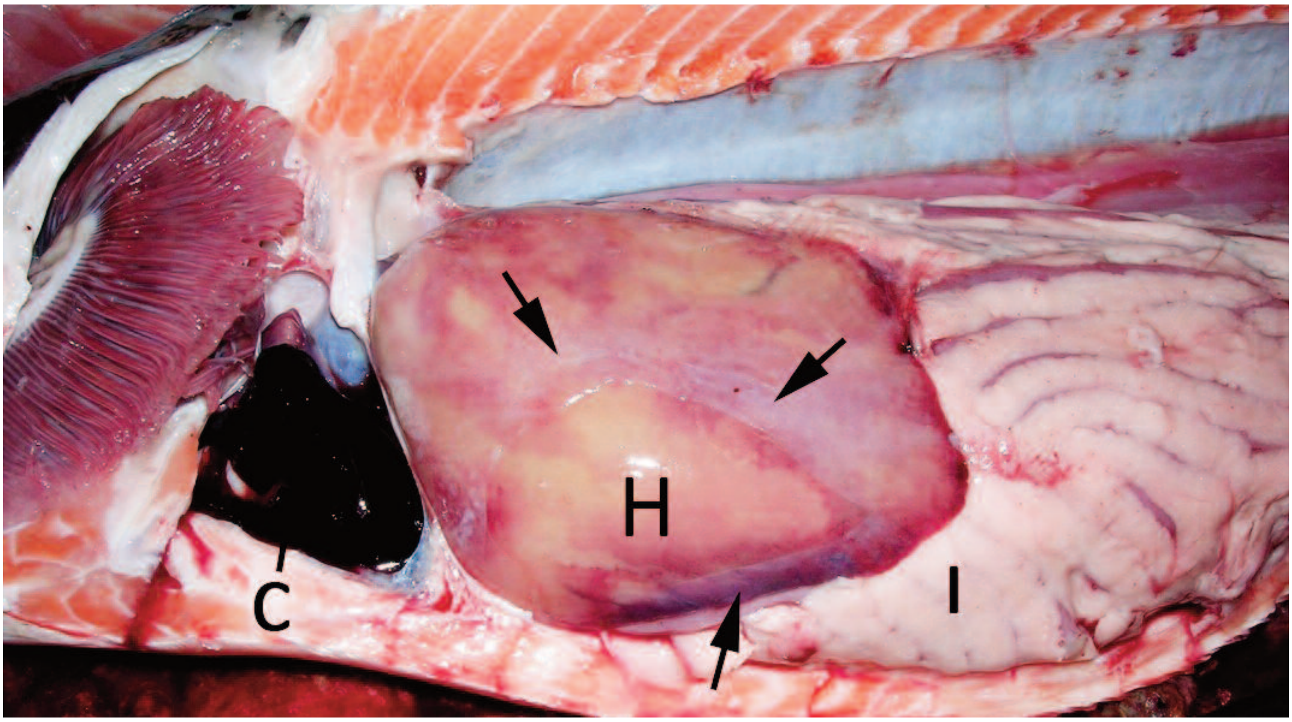


Figure 4.5.1 Post-mortem findings in CMS fish: Ruptured heart (C), almost completely covered in a blood clot filling the heart cavity, liver (H) with multifocal haemorrhages, discolouration and fibrin coating (arrows). G = gills, I = visceral adipose tissue (with pancreatic tissue) and intestines. The swim bladder can be seen as grey-white field above the liver and adipose tissue. Photo: Brit Tørud, Norwegian Veterinary Institute.

myocarditis virus (PMCV), a naked double stranded RNA-virus with a relatively small genome of around 6688 basepairs. It has been shown that the virus is transmitted horizontally. Investigation of samples from wild salmon, wild marine fish and environmental samples do not indicate that these represent a source of infection, and the most important and only known reservoir of infection is still farmed salmon. Some sites are affected more often by CMS than others and there may be yet unidentified reservoirs of PMCV-infection in the environment of the fish.

There may be few external findings in fish with CMS, but exophthalmus (protruding eyes), shell pocket oedema and small petechial bleedings on the surface of the abdomen are the most typical clinical findings. At autopsy, signs of circulatory failure such as ascites and a discoloured liver with fibrin layers are most often seen. In severe cases, a ruptured atrium with blood clots or a large blood clot covering the heart is commonly seen (Figure 4.5.1). A CMS diagnosis is currently based on histopathological examination only, determined by typical inflammatory changes in the inner, spongious layer of the atrium and ventricle, while the compact muscle layers of the heart are relatively unaffected.

In extreme cases, the wall of the heart may effectively burst. Real-time RT-PCR to detect PMCV is commonly used for screening of facilities without clinical findings in the fish, but can also be used to strengthen a histopathological diagnosis. The use of PCR for PMCV is increasing in routine diagnostics as well, and is useful to distinguishing CMS from differential diagnoses in uncharacteristic cases or in mixed infections. New in-situ techniques also look promising in terms of distinguishing the different inflammatory heart diseases by histological examination, and will be established for diagnostic use at the Norwegian Veterinary Institute (Figure 4.5.2). New research on non-lethal methods such as blood samples and mucous swabs show promising results, and may be used for PCR detection of PMCV in early stages of CMS infection without clinical signs, before the typical histopathological changes of the heart can be detected.

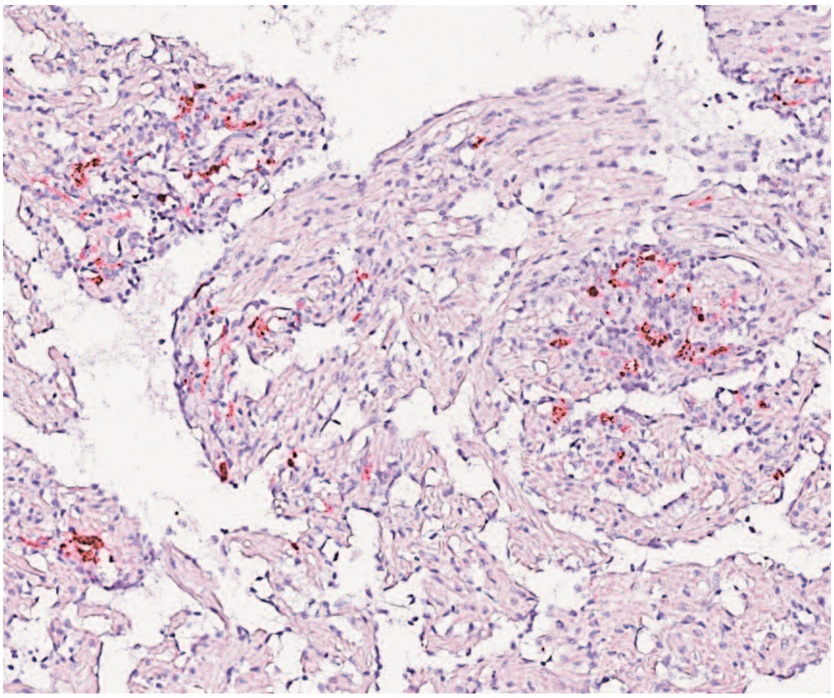


Figure 4.5.2 Detection of PMCV (ORF-1) with RNAscope in situ hybridisation in histological tissue section of cardiac atrium of salmon with CMS (infection trials). PMCV-specific RNA in areas with inflammation is marked with a dark reddish colour. Standard light microscope, 230x magnification. Photo: Camilla Fritsvold, Norwegian Veterinary Institute.

Clinically, the disease may resemble PD, ISA and HSMI, but moribund fish is unusual with CMS. Neither do CMS cause changes in exocrine pancreas or skeletal muscles. CMS has not been described in salmonid hatcheries, and although PMCV-specific RNA has been detected in low quantities in the freshwater phase of some hatcheries, no evidence of vertical transmission of CMS has been found.

There is a general lack of knowledge of the PMC virus, its infection pathways and the development of CMS (pathogenesis). How fish are infected, at which time point (s) the fish shed PMCV, and which factors induce 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. Another important question to address is why there may take from 3-13 months from the first detection of PMCV-positive individuals to clinical and histopathological CMS and mortality. The same applies to why PMCV in some cases can be detected soon after a fish group has been transferred to sea, without causing CMS or a CMS outbreak in the group during the rest of the sea phase.

Disease control

CMS is not a notifiable disease in Norway or by the World Organization for Animal Health (OIE). There is no public control programme for CMS in Norway. The virus and the disease are now present along the entire Norwegian coastline.

There are no available vaccines against CMS, but research for vaccine development continues. CMS-qTL smolts are available, as is functional feed, special feed developed for use with CMS, both intending to limit heart pathology and mortality from outbreaks.

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

The Health Situation in 2021

Data from the Norwegian Veterinary Institute and other laboratories

The figures for 2021 are, as in 2020, based on data available from private laboratories and the Norwegian Veterinary Institute. According to this coordinated data, CMS was detected at 155 individual sites, compared to 154 CMS positive sites in 20212021.
In 2021, 139 sites had PMCV detected via PCR compared to 121 in 2020. In many cases, the PMCV detections are not based on material of the same sampling or from the same individuals as the CMS diagnosis was based. In 2020, there were 12 cases with PMCV detections and CMS diagnosis based on the same material. In the Fish Health Report for 2021, figures are not available for the number of CMS diagnoses with PMCV detections in the same case. Based on the 2020 figures and the Norwegian Veterinary Institute's figures from 2021, most CMS diagnoses lack a concurrent detection of PMCV, which is mainly explained by the fact that CMS is a histopathological diagnosis, not requiring a PMCV detection. Since the disease is not, nor has been subject to notification, it is reasonable to assume that the number of disease cases are under-reported.

Diagnoses by production areas

The number of CMS diagnoses in the individual production areas (POs) is not comparable to last year's figures, since the data base is somewhat larger, but changes can be used as an indication of developments (Figure 4.5.3).

The three northernmost production areas (POs 11, 12 and 13) had relatively few cases of CMS, a total of 15 in 2021, which implies a slight increase compared to the previous year. In 2020, PO10 (Andøya to Senja, a relatively small PO in terms of area) had a total of 13 CMS diagnoses. This was reduced to 5 CMS cases in 2021.

PO9 (Vestfjorden and Vesterålen), PO8 (Helgeland to Bodø) and PO7 (Nord-Trøndelag with Bindal) all had an increase in the number of CMS cases last year. A larger increase, from 26 in 2020 to 39 CMS detections in 2021, is also seen for PO6 (Nordmøre and Sør-Trøndelag), which historically is a "hot spot" for CMS.

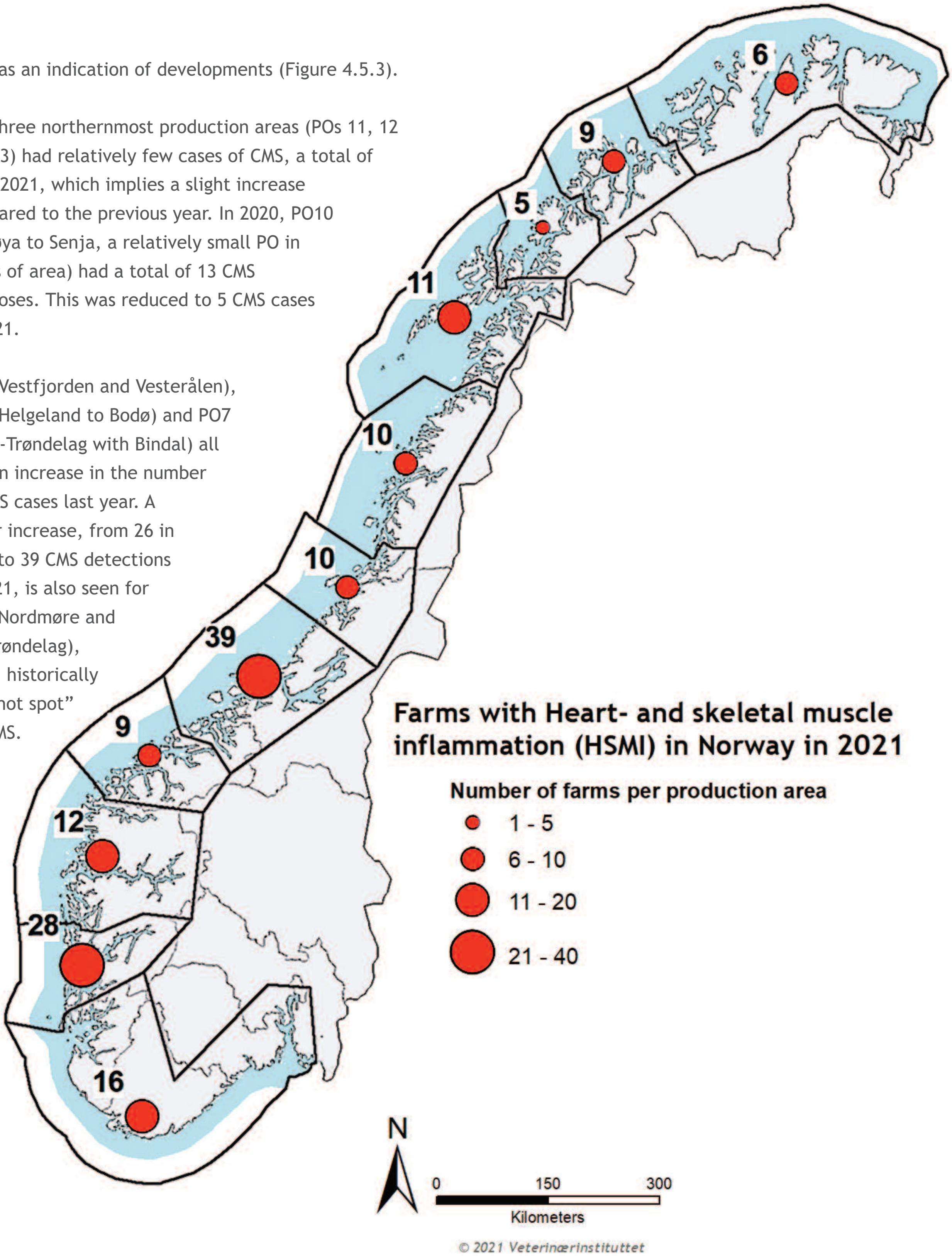


Figure 4.5.3 Number of CMS diagnoses in 2021 by production area, based on coordinated figures from the Norwegian Veterinary Institute and private laboratories.

For Western Norway south of Hustadvika, it seems that the increase in the number of CMS diagnoses observed over the past three years has finally stagnated somewhat or reversed: In PO5 (Stadt to Hustadvika) there was no change, and in all POs south of Stadt there was a slight reduction in the number of cases, most notable for the combined POs 1 and 2 (Swedish border to Ryfylke) with 16 registered CMS diagnoses in 2021, 9 less than the year before.

The Annual Survey

Based on the experience from their facilities and areas, personnel in the fish health services and the Food Safety Authority were asked to tick off up to five diseases or problems that they considered to be the main causes of, or that are of great importance to – mortality, reduced growth and welfare and whether the disease/problem is perceived as an increasing problem. As in 2018, 2019 and 2020, CMS is identified as one of the most important problems in both ongrowing facilities and broodstock farms for Norwegian salmon farming also in 2021 (see more details in Appendix B1-C2).

Mortality

CMS is ranked as the leading cause of mortality in both ongrowing and broodstock farms with salmon, out of 83 percent of the respondents. That broodstock farms consider CMS to be the most important cause of mortality is consistent with CMS normally appearing in larger fish. The fact that CMS is a major cause of mortality also in ongrowing facilities is serious and shows that CMS is no longer just a problem for broodstock and harvest-ready fish. See more details in Appendix B1-C2.

Reduced growth

As CMS most commonly affects large fish in the sea, it is not surprising that CMS is not considered one of the primary causes of reduced growth in ongrowing facilities for salmon. For broodstock farms, only four respondents ticked this category for 2021, and here CMS is ranged at the same level as *Pasteurella* sp. infections. (2 of 4 checkboxes). See more details in Appendix B1-C2.

Reduced fish welfare

For 2021, CMS and mechanical harm from delousing are ranked as the main causes of reduced welfare in broodstock of salmon, followed by infection with Pasteurella sp. Unlike broodstock, CMS is not considered to contribute as much to reduced fish welfare in ongrowing facilities as mechanical damage related to delousing, classic winter ulcers and tenacibaculosis (infection with *Tenacibaculum* spp.). See more details in Appendix B1-C2.

Increasing problem

CMS and salmon lice (grazing harm/infestation with *Lepeoptheirus salmonis*) is considered the 6th most important problem at ongrowing facilities, after ISA and ISAV HPR0 infections, classic winter ulcers, mechanical harm related to delousing, complex/multifactorial gill disease and tenacibaculosis. For broodstock, CMS and mechanical harm related to delousing share a divided 3rd place, after *Pasteurella* sp. infections. See more details in Appendix B1-C2.

Non-medicinal delousing and CMS

Because salmon lice have developed resistance to the most common medical lice treatments, the number of non-medical treatments to combat salmon lice has increased sharply per fish group in recent years (see Chapter 3 Fish Welfare and Chapter 7.1 Salmon Lice), and farmed salmon are deloused on average three times a year. All delousing methods used in Norway today involve some form of sorting, crowding, pumping and other stressors (mechanical impact/harm, for salmon high water temperature, pressure flushing etc.), all of which are stressful for the salmon. Various stressful events have been identified as a risk factor for CMS outbreaks, and stress associated with delousing is likely to contribute to latent, resting PMCV infections without clinical symptoms becoming clinical CMS. A large amount of inflammatory cells in the heart during CMS, especially in the anterior chambers, makes the atrial heart walls fragile, and fish with severe degrees of CMS therefore have a very low tolerance of stress. Moreover, a fish group usually has a complex overall disease picture, e.g. gill disease combined with HSMI and/or CMS, which in some cases causes disproportionately large mortality following delousing. CMS now occurring in smaller fish, with a considerable amount of time left in the sea prior to harvest, magnifies and prolongs the problems related to frequent delousing.

That non-medicinal delousing relatively often can be a trigger for CMS outbreaks and mortality is supported by the fact that 42 percent of the 74 respondents in the survey have experienced CMS outbreaks in the two consecutive weeks after non-medicinal delousing in 2021, - this is at the same level as last year. Ulcers are the most common finding after a delousing, while other diseases that affect the circulatory system such as HSMI and gill diseases, occur at approximately the same or at a slightly lower level than CMS (see Chapter 3, Figure 3.6.5).

Evaluation of the CMS situation

The new agreements regarding sharing of data related to disease diagnoses between the various laboratories offering histopathology based diagnostics, allows for identification of a more precise number of sites with first detection of CMS in 2021 than the Fish Health Report could present before 2020. This is because possible double registrations has been removed, and an increasing number of operators, both large and small, have submitted their registrations (see Chapter 1 Statistical Basis). At the same time, the presentation of these figures are has changed since 2020, to be stated per production area (PO) instead of by county. Direct comparison with figures from reports before 2020 is therefore difficult, but overall this gives a more complete and better overview than in previous fish health reports.

Because the data base has been further expanded from 2020 to 2021, and the number of detections is stated per PO from 2020, it is challenging to assess CMS cases in the very last few years in Norway as a whole.
Based on the number of detections and their prevalence, the incidence of CMS appears to remain relatively constant at a moderately high level. CMS ranks this year, as last year, as the main causes of mortality of salmon in the sea phase when fish health personnel along the entire coast are asked.

At the same time, there are still reports of major lice problems, increasing numbers of delousing and many cases of high mortality in the period after delousing. The management and stress of non-medical delousing methods appears to be essential as a triggering factor for many post-treatment CMS outbreaks and mortality. Whether repeated lice treatments of salmon with diseases like CMS or severe gill diseases can be justified, should become a topic of animal welfare discussion.

The CMS situation in Norway in 2021 is serious. CMS is still a major problem for the Norwegian aquaculture industry.

4.6 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. An abnormal swimming pattern with spiral swimming and flashing has also been observed. On post-mortem, swollen kidneys and pale liver with patchy haemorrhages can be observed, and histological investigation typically reveals haematopoietic tissue damage. 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 (List 2) which is controlled through destruction (stamping out) of all fish on an infected farm. Following confirmed diagnosis, control and observation zones are established. Vaccination is not relevant to the Norwegian situation.

For more information about CMS, see the fact sheet: **https://www.vetinst.no/sykdom-og-agens/viral-hemoragisk-septikemi-vhs**

The Health Situation in 2021

Official data

A risk-based monitoring programme is in place in Norway, based on examination of samples sent to the Norwegian Veterinary Institute for routine diagnostic investigation. In 2021, pink salmon, brown trout in cultivation and ongrowing facilities as well as rainbow trout in inland farming were also included in the monitoring programme. VHS was not identified in 2021 in Norway. The last Norwegian outbreak occurred in rainbow trout farmed in Storfjorden in Sunnmøre, in 2007-2008.

Evaluation of the VHS situation

In 2021, nine outbreaks were registered in five European countries according to EU's Animal Disease Notification System (ADNS). This is a slight increase from the previous year. No outbreaks were identified in countries neighbouring Norway in 2021. 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 cleanerfish 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 cleanerfish and farmed fish to be high. Given the serious consequences of a VHS outbreak, monitoring for VHS is important s infected fish may be removed as quickly as possible.

VHS was for many years 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 in connection with production in open cages in brackish water and sea in both Åland and the mainland from the early 2000s. In Åland, it took a long time for the combat programmes to succeed with the last detection in 2012. In 2017, France presented a plan to combat VHS, but there were still two VHS outbreaks in the country both in 2019 and in 2020 and one outbreak last year.

Figure 4.6.1 VHS in rainbow trout, multiple small haemorrhages. Photo: Ole Bendik Dale, Norwegian Veterinary Institute.

4.7 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. Like the VHS virus genus *Novirhabdovirus*, the IHN virus belongs to the Rhabdoviridae family. Outbreaks occur most commonly during the spring and autumn at temperatures between 8 and 15 °C.

Clinical observations indicate protruding eyes, and post-mortem findings include haemorrhage in internal organs, swollen kidneys and ascites. Histologically, disruption of haematopoietic tissues can be observed, and the disease is classified as 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 identified in a number of salmonid species including Atlantic salmon and rainbow trout. High mortality rates are reported in large sea-farmed salmon in British Columbia. The virus can be divided into five main types (U, M, L, J and E) based on phylogeographic differences that reflect their geographic origins. Genotypes U, M and L account for upper, middle and lower part 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 identified in Finland for the first time, and the virus was detected in six rainbow trout farms over the next few months. The infection was spread from state-owned broodstock farms and hatcheries that had delivered fish to ongrowing facilities in Bottenviken. The source of infection is not known, and the virus did not belong to recognised genotypes and did not result in clinical disease in infected fish.

IHN was first detected in Denmark in May of 2021. 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). On 10th10th December, Denmark informed the European Commission that it is giving up its free status for IHN. Denmark thus became one of 23 EU countries without free status. 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 restriction 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.

As a result of fish imports from Denmark, IHN was found in five facilities in Åland, Finland, in the period May to October last year. All rainbow trout from the infected facilities have been harvested or destroyed, and Finnish authorities have established a restriction zone around the infected areas. Fish farms in other parts of Finland have not imported fish from infected facilities in Denmark. The ongoing control programme for VHS in Åland has meant that the relocation of live or unsold fish from Åland to VHS-free areas in Finland has been limited for over 10 years. Further spread from Åland is therefore considered unlikely.

Disease control

IHN is a notifiable disease (List 2) which is controlled through destruction (stamping out) of all fish on an infected farm. Following confirmed diagnosis, control and observation zones are established. Vaccination is not relevant for the Norwegian situation.

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

The Health Situation in 2021

Official data

A risk-based monitoring programme is in place in Norway, based on examination of samples sent in for routine diagnostic investigation. In 2021, pink salmon, brown trout in cultivation and ongrowing facilities as well as rainbow trout in inland farming were also included in the monitoring programme. 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 2021, 24 IHN outbreaks were registered in six European countries according to EU's Animal Disease Notification System (ADNS). This is an increase compared to the previous year, which can be attributed to the outbreaks in Denmark and Finland. Loss of IHN-free status in Denmark has an impact on the overall risk picture.

Spread of infection is related to a significant degree to 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.

Introduction of new species into Norwegian coastal waters and rivers such as pink salmon 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 such that infected fish may be rapidly destroyed. Furthermore, all imported fish, including rainbow trout, from areas which are 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 spread of infection to wild fish with subsequent establishment of an endemic IHN situation.

Figure 4.7.1 Fish with circulatory disturbances, haemorrhage 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.

4.8 Salmon pox

By Mona Gjessing and Ole Bendik Dale

The Disease

Salmon pox is caused by infection with a large, complex DNA virus called Salmon Gill Pox Virus (SGPV). The disease was discovered in hatcheries in connection with dramatic elevated mortality rates. In some tanks, all the fish died within a few days and we found very characteristic gill changes with a lot of the salmon gill pox virus – and only salmon gill pox virus. The sick fish had circulatory disorders and congestion in addition to the gill changes. Sequencing the virus in 2015 provided better diagnostics that showed that several other disease manifestations existed. An important finding is that the salmon gill pox virus is often involved in what we now call complex gill disease (see Chapter 8.1).

The salmon gill pox virus has many genes that we do not know the function of, but by mapping gene expression in both viruses and hosts through the course of the disease, we have begun to understand more of the mechanisms of the disease. By investigating gene expression in the gills during different stages in the infection process, we have shown that infection with salmon gill pox virus disturbs the protective function of the gill mucus and that recruitment of inflammatory cells is abnormal. This may mean that the salmon gill pox virus 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 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 gave a shift to ATPase of the freshwater isotype that can worsen the outcome of sea transfer.

Infection is also found without visible disease developing. Genotyping of isolates from different fish groups in Norway, with different clinical histories, has not as yet provided indications of differences in virulence between isolates. Rather, it seems that serious illness develops due to several factors in addition to viral infection such as stress. This is supported by experimental work, where salmon treated with the stress hormone cortisol in combination with salmon gill pox virus infection have developed clinical disease. A recent study shows that mediators in the innate immune system in the gills increase in salmon gill pox virus infection, but that the stress hormone cortisol probably delays this response in the early stages of the course of infection, which shows how important it is to spare the fish from stress. Poor fish welfare can trigger a vicious circle.

About infection reservoirs and routes

The routes of infection are not yet known, but the newly developed typing system MLVA (Multi Locus Variable-number tandem repeat Analysis) can provide us with this knowledge through systematic use and connection to other epidemiological information.

As far as we know, it appears that only Atlantic salmon become infected with salmon gill pox virus. Salmon gill pox virus, 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 do appear to be more related than between countries. Some fjord systems and hatchery facilities seem to have their own house strains. We do not yet know if the re-infections are from the same source, or whether 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 has been found in wild Atlantic salmon from the east coast of Canada without any problems with the disease being reported. In Norway, salmon gill pox virus occurs among wild broodstock salmon, and a few 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. There is also a lack of basic knowledge for infection prevention, but in a new project funded by the Research Council of Norway, TRACEPOX, we plan to find measures that can help solve this.

The Norwegian Veterinary Institute has followed the salmon pox challenges faced by a particular farm over several seasons. Comparison of the virus isolates involved indicate that the farm has a house strain. In order to remove or reduce infection pressure, new washing and disinfection routines were therefore carried out. At the same time, they switched from a neutral disinfectant to an acidic one. Samples were taken of the fry at different stages and the salmon gill pox virus was not detected again in the facility 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. This suggests that there has been a new infection introduced into the facility, and shows how MLVA typing can help us understand infection pathways.

On suspicion of outbreak of salmon pox in a hatchery facility, feeding should be stopped, additional oxygen supplied and all stressful management routines halted to reduce the risk of mass mortality.

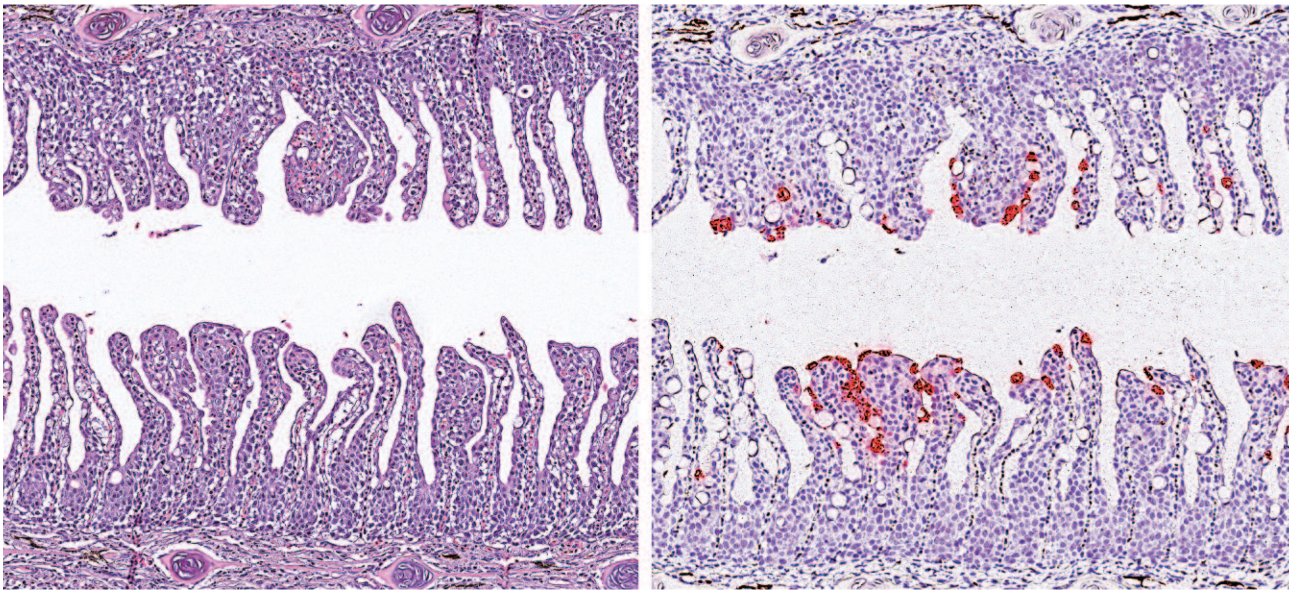


Figure 4.8.1 Gill tissue from complex gill inflammation has changed greatly due to several infections that cause a mixture of lesions and host responses. Using standard HE staining (left), it is very demanding to pick out cells that are infected and altered due to the salmon gill pox virus, while In 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 2021

Data from the Norwegian Veterinary Institute and other laboratories

There is a degree of uncertainty surrounding diagnosis of salmon pox in Norway concerning detection of infection with the salmon gill pox virus. Some fish farms routinely screen for the salmon gill pox virus, but it is demanding to get an overview of simultaneous histological examinations of any gill damage and the extent to which the salmon gill pox virus is the cause of the damage. Here, too, the choice of PCR method comes into play. The Norwegian Veterinary Institute's method detects the virus's DNA and it says something about 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 aimed at the virus' RNA detects the "building blocks" (transcripts) for new viruses and says little about the success of the production of a new pox virus – which seems to be linked to how much damage the virus does. In other words, it is very difficult to interpret the meaning of infection only detected with PCR for virus RNA.

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 study at a given time. We suspect that the salmon gill pox virus may be important initially, while other agents then become dominant. To help in the investigation of complex gill disease, a newly established in-situ hybridisation method (ISH) is very effective in picking out the changes the salmon gill pox virus creates (Figure 4.8.1).

Cases sent to the Norwegian Veterinary Institute show that in 2021, salmon gill pox virus was detected in two hatcheries and in five ongrowing facilities. Unfortunately, we do not have figures from other laboratories for this year. This year's figures represent probably only one part of the problems; 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.

The Annual Survey

In the survey, the salmon gill pox virus in terms of mortality and reduced welfare was assessed to be small. Compared to 2020, it is considered a slightly increasing problem at hatchery facilities. For the ongrowing facilities, the importance of the virus is also considered to be low in terms of mortality and reduced welfare. A few respondents however consider it to be an increasing problem during the ongrowing phase. Salmon pox is not reported as a problem in broodstock farms. The survey shows that gill disease is a very big problem, but it is difficult to distribute blame according to causes based on the current status of knowledge. For more details on the importance of salmon pox in different production phases, see appendices A1, B1 and C, and Chapter 8.1 Gill Health.

Evaluation of the salmon pox situation

The large outbreaks of salmon pox in hatcheries are thankfully rare, but have such major consequences for individual facilities when they arrive that mapping sources of infection is well worth our while to be able to work purposefully to stop infection. The salmon gill pox virus is more often involved in the development of complex gill disease which, especially in ongrowing facilities at sea, is very serious. Here it is important to find out whether the smolt got the infection from a hatchery, and if so, what it means for complex gill disease in the sea. Better knowledge about infection and reservoirs for the salmon gill pox virus is therefore important for taking appropriate countermeasures. To find out, the MLVA tracking tool can be used. The Norwegian Veterinary Institute encourages fish health services and others who suspect salmon pox to submit suitable samples for investigation using this method.

For more information on salmon pox, see the fact sheet: **https://www.vetinst.no/sykdom-og-agens/laksepox**

5 Bacterial diseases of farmed salmonids

By Jannicke Wiik-Nielsen and Duncan Colquhoun

The situation regarding bacterial diseases in farmed salmonids in Norway has been quite stable for many years, and the consumption of antibiotics is still very low. In recent years, however, there has been an increase in some bacterial diseases, and there is therefore reason to pay close attention to the situation ahead.

The Pasteurellosis epidemic in Western Norway is still ongoing and the disease was detected in 45 sites in 2021. In the annual survey of the Norwegian Veterinary Institute, pasteurellosis receives the highest score as a growing problem in farmed salmon in Western Norway.

Winter ulcer in the industry as a whole is considered relatively stable, but is worth noting that both classical and atypical winter ulcer are ranked high by fish health personnel as important causes of reduced welfare in ongrowing facilities for salmonids this year. Ulcers were also stated as the main cause of declassification at harvest. Compiled figures from the Norwegian Veterinary Institute, private diagnostic laboratories and the aquaculture industry show that classic winter ulcer/infection with *M. viscosa* was detected at 204 sites and infection with *Tenacibaculum* sp was detected at 159 sites in 2021. Since winter ulcer is non-notifiable and easy to diagnose in the field, the figures are probably under-reported.

Yersiniosis was detected at 19 sites in 2021, which is an increase from 14 positive sites in 2020. It is uncertain whether the increase is real or if this is due to increased data access. Nevertheless, there is reason to keep a close eye on developments ahead.

Of the reported bacterial diseases (List 3), classical furunculosis was again detected in 2021. *Aeromonas salmonicida* subspecies *salmonicida* was detected in salmon at two hatcheries and three fish farms. Systemic infection with *Flavobacterium psychrophilum* was detected in rainbow trout fry at an inland facility. Bacterial kidney disease (BKD) was not detected in wild or farmed salmonids in Norway in 2021.

Mycobacteriosis was detected in salmon at one hatchery and four ongrowing sites in 2021. The disease in non-notifiable. It is cited among the lowest ranked health problems in salmon in the survey.

Vagococcus salmoninarum, which causes the cold water streptococcus disease, was detected for the first time since the early 1990s. This shows that a broad cultivation-based diagnostic approach is important for detecting rare and new bacterial diseases.

The situation regarding bacterial diseases in farmed salmonids in Norway has been quite stable for many years. In the image, employees from the Norwegian Veterinary Institute in Harstad are at work in the field taking samples.
Photo: Siw Larsen, Norwegian Veterinary Institute.

5.1 Flavobacteriosis

By Hanne K. Nilsen

The Disease

The bacterium *Flavobacterium psychrophilum* causes the disease flavobacteriosis in fish in fresh and brackish water and can manifest in different ways. The disease is associated with topical infections but may also cause fin rot and ulcers which spread to inner organs resulting in high mortality.

Rainbow trout (*Oncorhynchus mykiss*) and silver salmon (*Oncorhynchus kisutch*) are considered particularly susceptible to the disease. If the bacterium appears in rainbow trout fry or small fish, it is common to see very high mortality in addition to ulcerations. In Norway, the disease causes welfare challenges in addition to being an important cause of death in rainbow trout released into brackish water systems, and internationally the disease still causes losses. It is not unusual to find the bacterium in skin lesions of salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in freshwater.

Disease control

F. psychrophilum transmits horizontally from fish to fish, and it is also probable that in some cases the infection can also spread vertically from parent to offspring. The development of vaccines is at the research stage and in several countries outbreaks of the disease are handled with antibiotics. International research groups are looking at the possibility of controlling outbreaks using bacteriophages. Good biosecurity measures such as disinfection of equipment, personnel and roe are important to prevent outbreaks.

Systemic infection with F. psychrophilum in rainbow trout is a notifiable disease in Norway (List 3).

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

The Health Situation in 2021

Official data

Systemic infection with *F. psychrophilum* was identified in one rainbow trout farm in 2021.

Data from the Norwegian Veterinary Institute

Rainbow trout

In late summer 2021, a systematic infection from *F. psychrophilum* was detected in rainbow trout fry at an inland facility. Elevated mortality was recorded about 3 weeks after starting feeding. Genotyping of isolates were grown from the outbreak detected in the ST92 variant, which was previously detected in this type of facility. This sequence type belongs to the same group of closely related variants of the bacterium associated with mortality in rainbow trout worldwide. Like other sequence types in this group, this variant showed impaired sensitivity to quinolone antibiotics.

Salmon and brown trout

Wound infection with *F. psychrophilum* was detected in smolt in one hatchery. There have been suspicions of infection with *F. psychrophilum* in salmon with ulcer development, and brown trout with tail rot in hatcheries. In these cases, the bacterium has not been detected by cultivation.

The Annual Survey

For rainbow trout in ongrowing facilities, 3 out of 12 respondents indicate that the disease causes problems with mortality, 1 in 9 agreed that it is associated with reduced growth and 4 out of 13 said reduced welfare. 1 in 7 indicated that the disease represents an increasing problem.

For salmon in hatcheries, 7 out of 47 respondents indicate that the disease causes problems with mortality, 5 out of 35 indicate that it is associated with reduced growth and 9 out of 51 that it reduces welfare. However, the situation in salmon appears to be stable, as no one considered the disease to be an increasing problem in this species of fish.

Evaluation of the Flavobacteriosis situation

In 2021, no flavobacteriosis was detected in large rainbow trout in the fjord system where F. psychrophilum was found in previous years. The disease was not detected in rainbow trout hatcheries during 2021. In salmon, submitted material does not provide a complete overview of the situation.

Successful management and control of serious outbreaks of flavobacteriosis depends on close cooperation between the farming industry, fish health services, the Food Safety Authority and research institutions.

Figure 5.1.1 Flavobacterium psychrophilum in Anacker and Ordal medium (AOA). Photo: Hanne Nilsen, Norwegian Veterinary Institute.

5.2 Furunculosis

By Duncan J. Colquhoun

The Disease

Classic furunculosis (infection caused by *Aeromonas salmonicida* subsp. *salmonicida*) is an infectious disease that can cause high mortality in salmonids in both freshwater and seawater. Other fish species such as turbot and lumpfish can also be affected at times. The illness is subject to notification (List 3) and the occurrence or suspicion of the disease must be reported immediately to the Food Safety Authority. Infections caused by other A. *salmonicida* subspecies are not subject to notification.

A. salmonicida belongs to the family Aeromonadaceae. Five subspecies have been described, *salmonicida, achromogenes, masoucida, pectinolytica* and *smithia*. Work carried out at the Norwegian Veterinary Institute has identified at least 23 different main genetic variants of the bacterium, which in most cases show a relatively high degree of host specificity to different fish species.

A. salmonicida subsp. *salmonicida* is often called "typical" or "classic" *A. salmonicida*, while all other varieties fall under the collective term "atypical" A. salmonicida. The diseases are therefore referred to as "classic furunculosis" and "atypical furunculosis".

All variants of *A. salmonicida* pathogenic for fish are non-motile short rods. *A. salmonicida* subsp. *salmonicida* produces abundant amounts of a brown, water-soluble pigment that can be seen by cultivation on media containing the amino acids tyrosine and/or phenylanine. Atypical varieties tend to grow a little slower, with smaller colonies and usually produce little or no pigment. A few non-pigment producing *A. salmonicida* subsp. *salmonicida* have been registered.

The main route of infection appears to be horizontal, i.e. from fish to fish. In Norway, salmon, brown trout (including sea trout) and char are most susceptible to infection. Outbreaks of furunculosis in Norway have mainly been linked to fish farms at sea and at hatchery farms that have used seawater in production, but outbreaks have also been recorded in freshwater without the use of seawater. Rainbow trout are considered more resistant to furunculosis, and the disease has not been detected in farmed rainbow trout in Norway in recent years. Furunculosis, on the other hand, is a significant problem in the breeding of rainbow trout in other countries, including Denmark. Salmonids can also be subclinically infected with *A. salmonicida* subsp. *salmonicida* without showing signs of disease. Such 'hidden' infections can be difficult to detect and the disease can develop over time, often after stressful handling, transport, sorting etc.

Disease control

Classical furunculosis is a notifiable (List 3, national disease) in Norway.

Generally, good hygiene combined with vaccination introduced in the early 1990s have contributed to the effective disappearance of the disease from Norwegian aquaculture. The disease is currently under extremely good control and very few outbreaks are registered.

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

The Health Situation in 2021

Official data

Furunculosis (*A. salmonicida* subsp. *salmonicida*) was detected in farmed salmon at two hatcheries and three ongrowing facilities in 2021. The two hatcheries are located in PO7 and PO8, while the affected fish farms are located in PO6, PO11 and PO12. All three detections at the ongrowing facilities could be linked to the sea-transfer of infected smolt from the two hatcheries where furunculosis was detected. *A. salmonicida* subsp. *salmonicida* was not detected in wild salmonids in 2021.

The Annual Survey

Furunculosis as a problem in farmed salmon scores very low in terms of mortality, growth and welfare, but 4 out of 69 respondents considered the disease an increasing problem (ref. ranking in Appendix B1). The corresponding figure for 2020 was 3 out of 71 respondents. This suggests that there is still a limited but real concern about developments in the furunculosis situation among fish health personnel in 2021.

Evaluation of the furunculosis situation

Despite the detection of furunculosis in Norwegian salmon farming in 2021, this must be considered an extremely satisfactory situation due to extensive use of effective vaccines. While available data does not indicate that wild reservoirs of *A. salmonicida* subsp. *salmonicida* is widespread in Norway today, wild fish reservoirs exist connected to a few rivers with outlets to Namsenfjorden in Trøndelag and possibly one connected to the Spilderelva river or surrounding areas in Nordland. That the disease can effectively spread among both farmed and wild fish is known from the last century when the disease was introduced from Denmark and Scotland. It is therefore important that the infection is not allowed to spread further in farmed fish from the geographical areas where the infection is already endemic. The fact that outbreaks continue to appear at uneven intervals in both wild salmon and farmed salmon, and that furunculosis is expected to have increased significance in warmer climates, means that we should keep the disease under strict control and that vaccination against furunculosis remains a necessary measure.

Figure 5.2.1 Salmon with furunculosis with typical bloody furuncles in the muscles. Photo: Geir Bornø, Norwegian Veterinary Institute.

5.3 Bacterial kidney disease (BKD)

By Duncan J. Colquhoun

The Disease

Bacterial kidney disease is a serious chronic disease of salmonids caused by the bacterium *Renibacterium salmoninarum*.

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 (such as KDM agar).

BKD was first identified in Norway in 1980 in juvenile fish produced from wild broodstock salmon. BKD outbreaks are most frequently identified in Western Norway where several rivers are most probably endemically infected. The bacterium can transmit vertically from parent to offspring. The disease can also transmit horizontally (faecal-oral route), and infected wild salmon are considered the main source of BKD infection to the few infections detected in Norway in recent years.

The disease only affects salmonids, and known susceptible species are salmon and brown/sea trout (*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 can occur.

Disease control

BKD is a notifiable (List 3) national fish disease in Norway. As no effective treatment or vaccine exists, general biosecurity measures, screening of broodstock and destruction of affected stocks are the only options for combating the disease.

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

The Health Situation in 2021

Official data

Bacterial kidney disease (BKD) is now detected only sporadically in Norway, from zero to three cases per year. BKD was not detected in wild or farmed salmonids in Norway in 2021.

Evaluation of the BKD situation

The current BKD situation in the Norwegian aquaculture industry is considered good, but it is important to be vigilant for the disease, especially during broodstock control.

5.4 Winter ulcer

By Duncan J. Colquhoun and Anne Berit Olsen

The Disease

Ulcer development during the sea phase is a serious fish welfare problem and results in both increased mortality and reduced quality during harvesting. The development of ulcers is a typical autumn and winter problem, but can occur all year round (Figures 5.4.1 and 5.4.2).

The term winter ulcer (classical winter ulcer) is primarily associated with infection with the bacterium *Moritella viscosa* (Figure 5.4.3), while tenacibaculosis (atypical winter ulcer) is used in cases in which ulcer development is associated with *Tenacibaculum* spp. infections. *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.

Classical winter ulcer develops mainly on the lateral surfaces of the fish (Figure 5.4.4), while tenacibaculosis most commonly manifests as deep lesions around the jaw (mouth rot) and head and as tail and fin erosion. Although both types of infection occur throughout the whole sea phase, tenacibaculosis is most commonly associated with acute disease in smolt that are recently transferred to the sea relatively recently in low sea temperatures. Atypical winter ulcer or tenacibaculosis is less common but can be very severe.

Outbreaks of both types of ulcers can often be linked to previous handling, such as during 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 identified in fish displaying skin lesions. *Aliivibrio wodanis* has been shown in infection trials to affect *M. viscosa* by inhibiting growth and virulence and is believed to help prolong the course of the disease.

M. viscosa was for many years perceived as a genetically conserved species, but based on genetic analyses, it can now be divided into several closely related sub-populations (clonal complexes, CC), where winter ulcer in salmon is mainly associated with members of CC1 and CC3.

Tenacibaculum spp. are naturally widespread in the marine environment, where they have an important ecological function in decomposition of organic material. During 2021, researchers at the Norwegian Veterinary Institute together with international partners described a previously undescribed *Tenacibaculum* species, *T. piscium*. This variant was detected in the ulcers, but is not currently linked to the development of serious wounds. Recent research confirms that tenacibaculosis in smolts that were recently transferred to the sea is associated primarily with *T. finnmarkense* and that two genomic variants of this species exist – i.e. genomovar *finnmarkense* and genomovar *ulcerans*. Both genomic variants are detected in tenacibaculosis outbreaks, but in a study conducted in 2018/2019 we found that a very homogeneous subset of *T. finnmarkense* genomovar finnmarkense was present in almost all investigated outbreaks along the Norwegian coast. The fact that several genetic variants of Tenacibaculum are usually detected in one outbreak, even different varieties of the same genomovar, indicates that colonisation of fish from the sea 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. Antibiotic treatments are performed on occasion, but the effect is variable.

As discussed above, a different genotype of

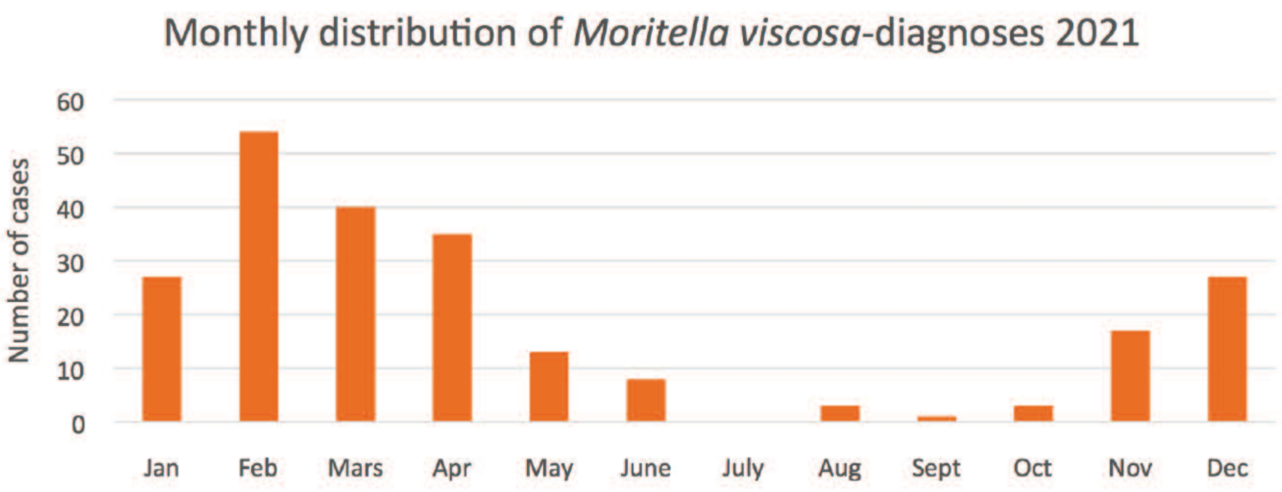


Figure 5.4.1 Monthly diagnostic detections of *M. viscosa* in the Norwegian Veterinary Institute's journal system in 2021.

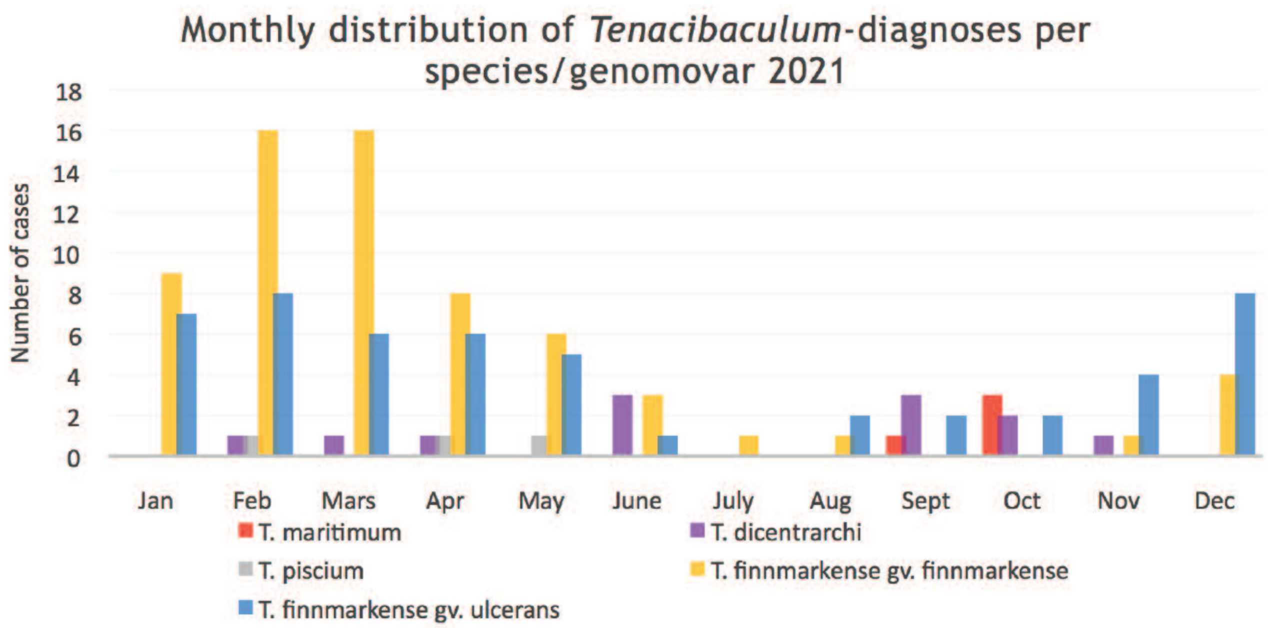


Figure 5.4.2 Monthly diagnostic detections of *Tenacibaculum* spp. in the Norwegian Veterinary Institute's journal system in 2021.

M. viscosa than most vaccines are based on, is associated with many outbreaks of winter ulcer. Whether this affects vaccine protection or not is still unknown.

Preventative measures related to production should be prioritised and fish displaying visible wounds should be removed from the cages. Practical experiences suggest 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 important.

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

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

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

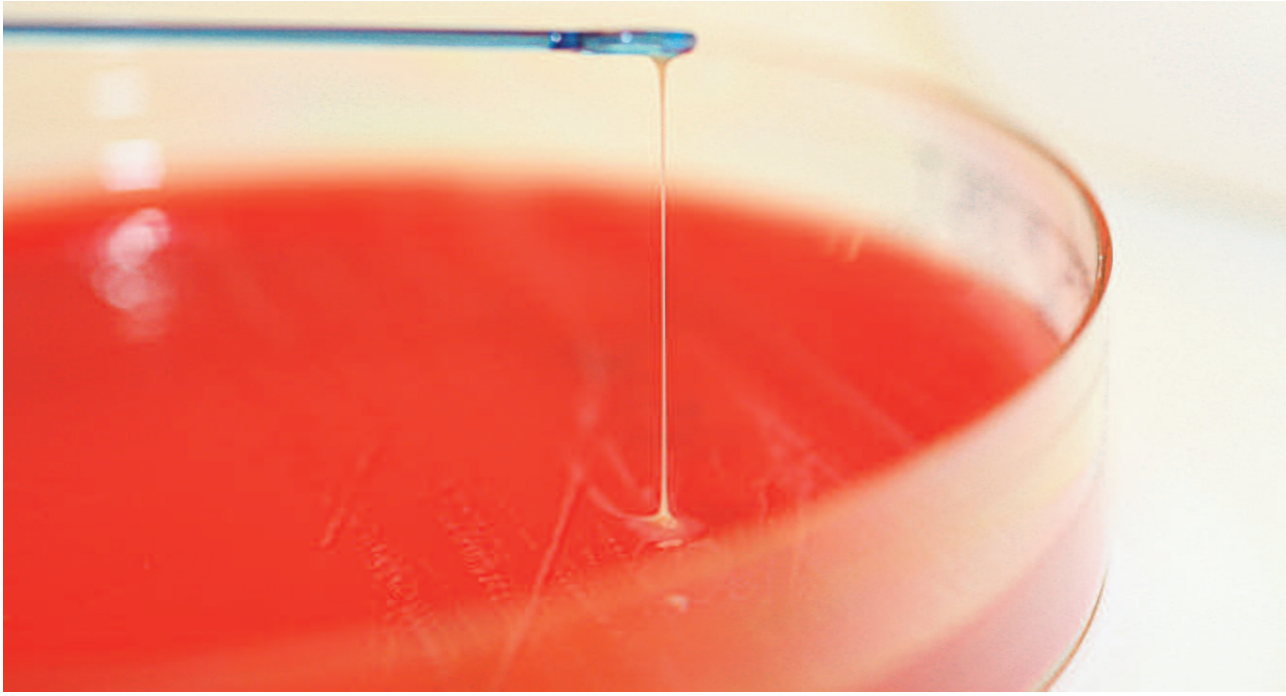


Figure 5.4.3 The bacterium *Moritella viscosa* grown on blood agar 2% NaCl where it often (but not always) forms viscous colonies, as in the photo. The bacterium causes classic winter ulcer in salmon.
Photo: Duncan J Colquhoun, Norwegian Veterinary Institute.

The Health Situation in 2021

Data from the Norwegian Veterinary Institute and other laboratories

Again in 2021, winter ulcer was diagnosed in farmed salmonids along the whole coastline. Due to the need for specific PCR or other molecular biology methods, there is little differentiation in the diagnostics between subtypes of *M.viscosa* and *Tenacibaculum* species/subtypes.

Compiled figures from the Norwegian Veterinary Institute, private diagnostic laboratories and the aquaculture industry show that classic winter ulcer/infection with *M. viscosa* was detected at 204 sites and infection with *Tenacibaculum* sp was detected at 159 sites in 2021. The geographical distribution indicates, perhaps somewhat surprisingly, that *M. viscosa* infections are more evenly spread along the entire coastline than previously thought. A relatively high proportion of the detections in 2021 were made in the south with approximately 40 percent of *M. viscosa* detections in PO1-5, of which ~16 percent were in PO3. Central Norway (PO6 and 7) accounted for about 17 percent of *Moritella* detections, while Nordland and the north (PO8-13) accounted for about 43 percent. The distribution of *Tenacibaculum* detections turned out to be quite similar to that of *Moritella* with about 38 percent in PO1-5, of which ~17 percent were in PO3. Central Norway (PO6 and PO7) accounted for about 17 percent, while Nordland and northward (PO8-13) accounted for about 45 percent. As mentioned above, winter ulcer is not a listed disease, so it is probably under-reported. Since the Norwegian Veterinary Institute is now collecting data from private diagnostic laboratories and companies in the industry, the situation as described for 2021 is not necessarily comparable to the situation reported in previous years.

Figure 5.4.4 Classic (typical) winter ulcer in salmon. The disease is caused by the bacterium *Moritella viscosa*. Photo: Duncan J Colquhoun, Norwegian Veterinary Institute.

The Annual Survey

In the survey, *Moritella*-associated winter ulcer and tenacibaculosis achieved third and fifth place ('ulcers' took eighth place) as the most important causes of mortality, and second and fifth place as an increasing problem in ongrowing sites for salmon. They were also ranked very highly as the most important contribution to reduced welfare, and were ranked 2 and 3. Both types of infection are also mentioned as the cause of reduced welfare for salmon broodstock (for more details, see appendices B1 and C1). *Moritella* and *Tenacibaculum* infections were also mentioned as increasing problems related to reduced welfare, reduced growth and increased mortality in rainbow trout in fish farms (see Appendix B2).

Mechanical injury following delousing is ranked first place as the cause of reduced welfare in salmon and second place among rainbow trout in fish farms. There can be little doubt that delousing associated injuries predispose for ulcer development. Avoidance of production factors that may predispose to ulcer development is therefore important.

Evaluation of the winter ulcer situation

Estimating the incidence of both types of infection is challenging. *M. viscosa*-associated winter ulcer and tenacibaculosis are not subject to mandatory reporting and are relatively easy to diagnose in the field. These infections are almost certainly under-reported based on the number of samples being sent to the laboratories. Winter ulcer in the industry as a whole is considered relatively stable, but is worth noting that both classical and atypical winter ulcer are ranked highly by fish health personnel as important causes of reduced welfare and an increasing problem at ongrowing facilities for salmonids in 2021. Ulcers were also stated as the main cause of declassification at harvesting.

5.5 Pasteurellosis

By Hanne K. Nilsen, Duncan Colquhoun and Snorre Gulla

The Disease

The term pasteurellosis encompasses diseases caused by different varieties/species within the bacterial genus *Pasteurella*. In Norwegian salmon, almost all outbreaks are caused by a variant that has not been officially named, but is currently known as *Pasteurella "atlantica* genomovar *salmonicida*". In 2020, *Pasteurella skyensis*, a bacterium that has caused major problems in Scottish salmon, was also detected for the first time in farmed salmon in Norway.

In lumpfish used as cleaner fish at fish farms, pasteurellosis is associated with the variant *P. "atlantica* genomovar *cyclopteri*" (see Chapter 10).

Pasteurellosis in Norwegian salmon was first detected in Northern Norway in the late 1980s. Outbreaks have since been detected several years apart also in salmon in Southern Norway. The situation since 2018 has become more serious with an increasing incidence in affected areas. The disease affects large fish at the end of the production cycle.

In salmon with pasteurellosis caused by *P. Atlantica* genomovar *salmonicida* is typically a clinical macroscopic finding with inflammation of the pericardium, abdominal wall and pseudobranchia, as well as findings of pus-filled boils in skeletal muscles and at the base of the pectoral fins. Protruding, partly bloody and inflamed eyes is a well-known characteristic, although it does not occur in all fish (Figure 5.5.1). Histopathological changes reflect the macroscopic picture with findings of acute and more chronic inflammation, plenty of inflammatory cells, tissue fluid, and short rod bacteria in affected organs. In salmon with *P. skyensis* infection, a more general sepsis picture is described with bleeding in the swim bladder and adipose tissue, in addition to pericardial inflammation and protruding eyes.

P. "atlantica genomovar *salmonicida*" has not been shown to be very virulent in infection trials. The bacterium's genetic material (DNA) using PCR was found on the surface of gills and skin in fish at ongrowing facilities. The bacterium can also be detected in water when examining environmental DNA.

Disease control

There are no commercially available vaccines, and the disease is not subject to notification. There are knowledge gaps about infection pathways and the reservoir is unknown. Outbreaks at nearby salmon sites may indicate that the disease is spread horizontally. Basic hygiene such as disinfection of equipment, personnel etc. is important for prevention of outbreaks.

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

The Health Situation in 2021

Data from the Norwegian Veterinary Institute and other laboratories

In 2021, the disease was detected at 45 different sites from PO2 to PO5, with the majority of positive sites in PO3 (Figure 5.5.2). All detections were made at sea and the majority of the detections were stated to be in connection with clinical disease. Typical symptoms have, as before, been pericardial and peritoneal inflammation, and boils in the skin (especially at the pectoral fins), musculature and internal organs.

The Annual Survey

For salmon in ongrowing facilities, 24 out of 88 respondents indicated that the disease causes problems with mortality, 25 out of 87 reduced welfare, and 16 out of 69 said the disease represents an increasing problem at a national level. Pasteurellosis is a disease that affects late in the production cycle, which is reflected in the fact that few respondents (9 out of 73) indicate that it is associated with reduced growth. For respondents belonging to PO1 – PO5, pasteurellosis receives the highest score as a growing problem in ongrowing facilities for salmon in 2021 and is also highly rated as the cause of reduced welfare and mortality (Figure 3.2.1, Chapter 3 Fish Welfare)

For salmon in broodstock farms, 3 out of 12 respondents indicated that the disease causes problems with mortality. Only a few respondents said reduced growth, welfare were affected, and that the disease represents an increasing problem.

Evaluation of the pasteurella situation

The number of detections in 2021 is still high, and the disease was detected at 45 sites, but we see a decrease from last year (57 positive locations). Pasteurellosis in salmon is now an established bacterial disease that threatens fish welfare and sustainability in the industry. Management of the disease depends on cooperation between research institutions, the industry and public authorities.

Figure 5.5.1 Eye damage in salmon with pasteurellosis. Photo: Hanne Nilsen, Norwegian Veterinary Institute.

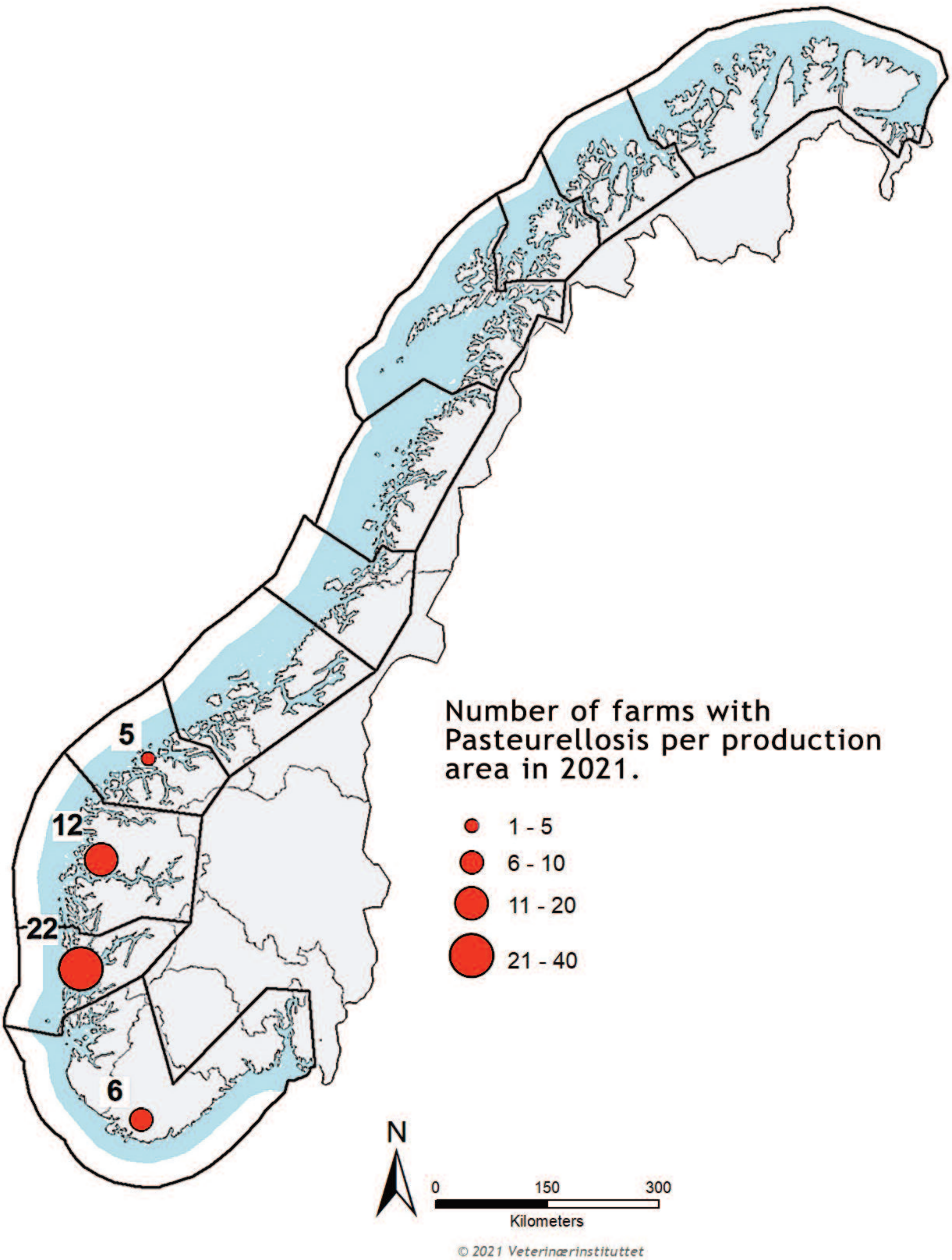


Figure 5.5.2 Number of pasteurellosis diagnoses in 2021 by production areas, based on figures compiled from the Norwegian Veterinary Institute and private laboratories.

5.6 Yersiniosis

By Snorre Gulla and Anne Berit Olsen

The Disease

Yersiniosis, caused by the bacterium Y*ersinia ruckeri*, can occur in several different types of fish, but is mainly known as a problem in salmonids. In Norway, the disease, which internationally is often called "enteric redmouth disease", is associated almost exclusively with Atlantic salmon. It often manifests itself as a septicemia with bleeding and circulatory failure (Figure 5.6.1).

The disease may occur both before and after release into the sea, but it is believed that the infection is probably introduced in the hatchery phase. While disease in the sea phase was previously and primarily observed shortly after transfer, from about 2014 to 2017, especially in Central Norway, more and more yersiniosis outbreaks were seen in large salmon in the sea. Findings suggest that many of these outbreaks may have originated from subclinical or latent infections that were activated and spread further in connection with the management and stress of delousing. Since 2017, the number of yersiniosis outbreaks in the sea has again decreased as a result of widespread use of injection vaccines against the disease.

Research at the Norwegian Veterinary Institute has shown that there is almost exclusively one specific genetic variant (clone) of *Y. ruckeri*, belonging to serotype O1, which since the mid-1990s has occurred in severe clinical yersiniosis outbreaks in Norway. Other indigenous clones of serotype O1 predominate in other countries. Furthermore, a number of other clones, belonging to serotype O1, O2 or others, have also been found in Norway. However, these have to a small/lesser extent been associated with clinical disease and are primarily found from other sources, such as clinically healthy fish and biofilm in fish farms without clinical yersiniosis.

Disease control

Water-based injection vaccines against yersiniosis before transfer to sea have become widespread in recent years due to the increasing problems experienced in salmon in the sea phase, and this seems to have had a good effect. There are also examples of hatchery facilities that have apparently succeeded in eradicating virulent *Y. ruckeri* by sanitization. Antibacterial drugs (likelylike primarily oxolinic acid) have to some extent been used for the treatment of yersiniosis. However, drug treatment may lead to the development of resistant strains of bacteria as documented earlier in Norway.

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

The Health Situation in 2021

Data from the Norwegian Veterinary Institute and other laboratories

In 2021, *Yersinia ruckeri* was detected at 19 sites (data compiled from the Norwegian Veterinary Institute and private laboratories, see Chapter 1 Statistical Basis). Available information on the aquatic environment for 16 of these showed that 9 were ongrowing facilities and 7 were hatcheries. The figures for 2021 represent a slight increase from 2020 (14 positive locations) but are still some distance from the peak in 2015 and 2016 with 34 positive sites in both years.

Among those cases where serotype is determined, serotype O1 dominates as in previous years, with serotype O2 detected at only one location. Geographically, most of the affected sites are located in western/Central Norway (PO3-7), and a few in Troms og Finnmark (PO10 and PO12).

The Annual Survey

As with last year, problems with yersiniosis in salmon scored relatively low in the survey compared to other challenges. The disease comes in 12th place for the country as a whole for the hatchery phase (Appendix A1) and it shared 28th place for the ongrowing phase (Appendix B1). For the hatchery phase, however, it is worth noting that yersiniosis scored the second highest if one looks only at the specific infectious diseases (passed only by IPN). There were also some respondents who checked yersiniosis as an increasing problem for salmon in the hatchery phase.

Evaluation of the yersiniosis situation

After increased vaccination led to a large decrease in the number of yersiniosis cases in the sea since 2017, this tendency now seems to have reversed. The reason for this is uncertain. There is currently no good overview of the proportion of sea-transferred salmon vaccinated against the bacterium, but if this proportion is now in decline, this may be a possible explanation. We are not aware that any detections made by the Norwegian Veterinary Institute in 2021 came from *Y. ruckeri*-vaccinated populations. Incidentally, the Norwegian Veterinary Institute recently showed that stressful handling such as thermal delousing stimulates increased excretion of *Y. ruckeri* from subclinically infected carrier fish. This may pose a potential risk of infection for naive fish treated together with these and/or later in the same water. In any case, yersiniosis is a disease one should be aware in the future.

Figure 5.6.1 Yersiniosis in hatchery salmon. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

5.7 Mycobacteriosis

By Lisa Furnesvik, Toni Erkinharju and Hanne Nilsen

The Disease

Mycobacteriosis is an infectious disease caused by mycobacteria. Several species have been described, but only a few are associated with fish.

The nomenclature in this group of bacteria has been proposed to be changed, but the proposed new names are under debate and both Mycobacterium and the proposed new genus names can be used. Of the best known, *Mycobacterium chelonae* and *M. salmoniphilum* have been proposed to be placed in the genus *Mycobacteriodes, M. fortuitum* in the genus *Mycolicibacterium*, while *Mycobacterium marinum* is still placed in the genus Mycobacterium. Recently described species are *M. shottsii, M. pseudoshottsii* and *M. salmonipilum*. Among these, *Mycobacteriodes (Mycobacterium) salmoniphilum* has been associated with fish disease in Norway.

Mycobacteriosis usually occurs as a chronic disease with varying mortality rates. Typical macroscopic findings in infected fish post-mortem are bright nodules (granulomas) withinin internal organs and swollen spleen and kidney. In tissue sections, granuloma formation can be seen in internal organs, sometimes with discoveries of Splendore-Hoeppli phenomena centrally within the granulomas (see Figure 5.7.1). Granuloma formation may be less pronounced in salmonids than in other fish species. Emaciation is a typical finding in fish that have been ill for a long time.

Infection most likely occurs by direct contact with infected fish, through feed or water. Vertical transmission (from parent to offspring) has been described in some fish species, but is not regarded as a major problem. Pasteurisation (heat treatment) of feed reduced the occurrence of mycobacteriosis in farmed fish considerably. The disease has a long incubation period, up to several weeks, and infected fish can be asymptomatic for several years after it has been infected. It is not fully known whether mycobacteria in fish are primary or secondary pathogens, but much suggests that infection weakens the fish's immune system and provides opportunities for secondary infections with other disease-causing agents.

Diagnostics

Clinical findings in individuals infected with mycobacteria are granulomas in internal organs and skin lesions. Mycobacteria can be stained in tissue sections using special dyes (Ziehl Neelsen) and/or by using antibodies targeting the bacterium (immunohistochemistry). The bacterium *M. salmoniphilum* grows at 22-30°C and is best cultivated on selective growth media such as Middlebrook 7H10-agar or CHAB agar, but it also grows on standard blood agar. The bacterium can also be detected by using molecular biological methods.

Disease control

No effective treatment for mycobacteriosis in fish currently exists. Mycobacteriosis in fish is difficult to treat with antibiotics due to the bacterium’s impermeable cell wall and granuloma formation within internal organs. To date, there are no approved vaccines for mycobacteriosis in fish.

For more information about mycobacteriosis, see the fact sheet:
https://www.vetinst.no/sykdom-og-agens/mykobakteriose-hos-fisk-mycobacterium-spp

The Health Situation in 2021

Data from the Norwegian Veterinary Institute

In 2021, infection with mycobacteria was detected in salmon at four sea farming sites and one hatchery. This is quite similar to last year's situation where there were five detections at sea farming facilities. The detections were made on the basis of histopathological investigations combined with bacteriological and/or immunohistochemical analyses. At two of the sites, the species *M. salmoniphilum* was identified by bacteriological examination and sequencing.

The Annual Survey

Mycobacteriosis was ranked by fish health personnel and inspectors at the Food Safety Authority amongst the least important diseases of salmon in hatcheries and ongrowing facilities at sea. Infection with mycobacteria is ranked tenth among rising problems in the hatchery phase (see Appendix A1).

Evaluation of the mycobacteriosis situation

Mycobacteriosis in fish is a non-notifiable disease in Norway, so there are no official statistics related to the number of outbreaks of this disease in salmonids. The disease was identified in one RAS hatchery and two sea farming facilities in the fall of 2018, while in 2019, mycobacteria were associated with granulomatous inflammation in the inner organs of salmon at seven sites. At one of these sites, the species *Mycobacterium salmoniphilum* was determined by bacteriological examination and sequencing. The same species was also identified in fish with mycobacteriosis at two sea farming sites in 2018. Mycobacteriosis was detected at five sea farming sites in 2020, of which M. salmoniphilum species was found at three of the sites. As mentioned above, mycobacteriosis was detected in salmon at four sea farming sites and one hatchery in 2021.

The species *M. salmoniphilum* was identified at two sites.

Regarding zoonosis, there is currently no basis for direct human consumption of mycobacteria-infected fish to represent any significant health risks. Most fish-pathogenic mycobacteria, as well as *M. salmoniphilum*, do not grow at 37 °C. Still, there are no reasons to declare that infected fish do not represent a zoonotic risk through contact transmission. This applies for the handling of non-processed infected fish, where it is possible that bacteria-infected material can come into contact with damaged skin. This is particularly relevant for persons with weakened immune defences.

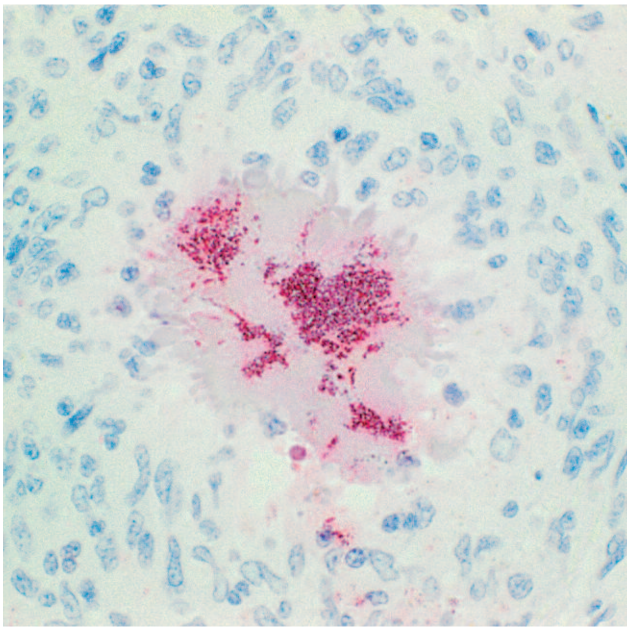


Figure 5.7.1 A Splendore-Hoeppli reaction containing mycobacteria, stained red by immunohistochemical method. Photo: Lisa Furnesvik, Norwegian Veterinary Institute.

5.8 Other bacterial infections of salmonids

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

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. These can be known pathogens that are almost always associated with disease outbreaks and opportunist pathogens that produce disease with mechanical damage, handling or environmental conditions, such as those related to water quality. This can trigger stress and weaken the fish. In addition, we commonly find environmental bacteria, which quickly penetrate and colonise dead or very weak fish.

During diagnostic work, it can therefore be challenging to evaluate the role of diverse bacterial species if any, in manifestation of the disease under investigation. Trends in culture-based bacteriology are continually monitored such that new pathogenic bacteria and bacterial diseases may be discovered as quickly as possible. The discovery of new "emerging" pathogens is an important justification for carrying out routine cultivation from sick fish.

The situation for bacterial diseases in Norwegian salmon farming has been fairly stable for many years, but in recent years some bacterial infections have resurfaced after years of absence or increased in prevalence e.g. furunculosis, yersiniosis and winter ulcer. New diseases such as pasteurellosis have also evolved (see Chapter 5.5 Pasteurellosis). The cause of the increase of these diseases is unknown, but it is conceivable that the transition to physical delousing as the dominant delousing methodology, and what this entails from increased stress and injuries, may have contributed. Nevertheless, the current situation regarding bacterial diseases in Norwegian salmon gives cause for reflection and concern.

Carnobacterium maltoaromaticum can at times be associated with cardiac and abdominal cavity inflammation in salmon broodstock and is to some extent also isolated from ongrowing and hatchery fish. The bacterium was detected in connection with diagnostic examinations at four broodstock sites, two ongrowing sites and three salmonid hatcheries sites during 2021. The bacterium was also detected in sexually mature brown trout at one site and in two wild salmon during the year. Isolation of *C. maltaromaticum* may not always be linked to disease.

Vagococcus salmoninarum was determined to be the dominant bacterial type in bacterial extraction from the heart cavity and abdominal cavity of salmon from a broodstock site in 2021. The last known detection in Norway was in the early 1990s. *V. salmoninarum* is a gram-positive rod-shaped bacteria and is described from other countries mainly as a pathogen for rainbow trout bred in cold water, and is the cause of the cold water streptococcosis disease. The bacterium has also at times been detected in other salmonids, including Atlantic salmon in Tasmania. The bacterium *V. salmoninarum* is not considered a 'primary' pathogen, but any outbreak in broodstock can cause significant mortality when it first occurs.

Rainbow trout is a robust species in Norwegian fish farming, and relatively few outbreaks of bacterial diseases are diagnosed in this type of fish. Infection with *Vibrio anguillarum* was detected at four sites with rainbow trout in 2021, one broodstock site and three ongrowing sites. The isolates from two of the outbreaks were serotyped to O1. Two of the detections (broodstock and one ongrowing facility) were linked to a single fish. One affected ongrowing facility reported low mortality with classic signs of vibriosis in dead fish. At one affected ongrowing facility, *V. anguillarum* was isolated from only one of several smears and as part of a mixed flora. The infection was of uncertain importance for the increased mortality as the facility reported.

Pseudomonas anguilliseptica is a widespread disease-causing bacterium for lumpfish in Norway and has been reported as pathogenic for salmonids in the Baltic Sea. In Norway, it was discovered in rainbow trout in 2019, but has not been detected by the Norwegian Veterinary Institute in salmonids since then.

Tenacibaculum maritimum is known to cause disease in many types of farmed fish in relatively warm seawater, including salmon farmed in the Pacific Ocean. The bacterium has sporadically been detected in gills in Norwegian farmed salmon as one of the Tenacibaculum species one can find in gill necrosis.
T. maritimum was not detected in salmon by the Norwegian Veterinary Institute in 2021, but has been reported several times by external laboratories and breeders.

Cold-water vibriosis, caused by *Vibrio salmonicida*, was not detected in salmon or other fish species in 2021.

Atypical *Aeromonas salmonicida* was detected by the Norwegian Veterinary Institute in connection with acutely elevated and sustained mortality in a salmon farm that used freshwater supplemented with seawater in 2021. Infection with atypical *A. salmonicida* in salmon is unusual in later years since vaccination against *A. salmonicida* subsp. *salmonicida* (furunculosis bacterium) usually provides good protection also against atypical varieties.

Piscirickettsiosis, caused by *Piscirickettsia salmonis,* remains a serious problem in Chilean salmon farming. The Norwegian variant of the bacterium is usually associated with low mortality. *P. salmonis* was not detected in Norwegian salmon in 2021.

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, UWphoto

5.9 Antibiotic sensitivity

By Duncan J. Colquhoun and Hanne Nilsen n

The Norwegian Veterinary Institute monitors antibiotic sensitivity in a large number of bacterial isolates cultured from diseased fish each year. Smaller numbers of isolates from wild fish, mainly salmonids, are also tested each year. The results of this monitoring reveal a favourable situation in which a very low incidence of antibiotic resistance in current disease-causing bacteria is found in Norwegian fish farming.

Although antibiotic treatment of farmed fish in Norway is rare, it is at times necessary to control outbreaks of bacterial diseases (mainly with oxolinic acid and florfenicol). It is important that antibiotic consumption remains as low as possible. Antibiotic consumption is known as one of the main causes of bacteria becoming resistant to antibiotic treatment.

There exist few signs of increasing resistance amongst bacteria we identify from diseased fish in Norway. As in previous years, in 2021 we have again identified reduced sensitivity to oxolinic acid in *Flavobacterium psychrophilum* isolated from sick rainbow trout. The same applies to *Aeromonas salmonicida* subsp. *salmonicida* isolated from a salmon hatchery in PO6 and a ongrowing facility in PO12 that received smolt from the affected hatchery.

No reduced sensitivity to antibacterial agents has been demonstrated in fish-pathogenic bacteria isolated from cleanerfish in 2021.

Figure 5.9.1 Bacterial colonies from fish cultivated on blood agar (right). Tested for sensitivity to various antibiotics (left). Photo: Eivind Senneset.

6. 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 (egg fungi). 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.

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 in the EU system. 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 the hatching period, the main preventive measure is to remove dead eggs and remnants of organic matter often.

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

The Health Situation in 2021

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 requests for advice outside the diagnostic service in which *Saprolegnia* was related to high mortality in start-feeding fry and roe. In 2021, *Saprolegnia* was identified in 15 submissions, of which 11 were from salmon. *Exophiala* was identified from two salmon and one turbot. Systemic mycosis was only diagnosed in two salmon and one lumpfish in 2021.

Data from other laboratories

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

The Annual Survey

Information from respondents to our annual survey indicates that fungal diseases are not considered an important problem.

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 may appear to be effectively controlled by preventive measures.

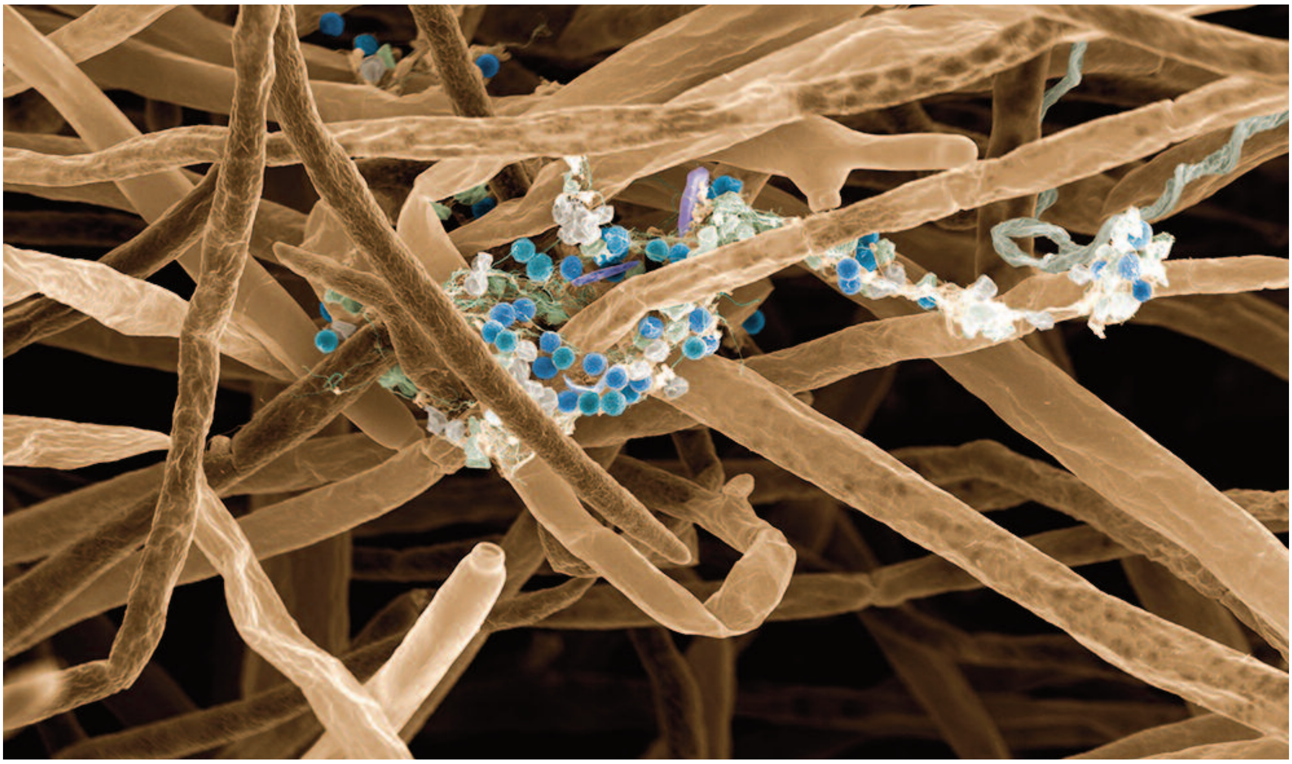


Figure 6.1 *Saprolegnia* spores and hyphae, magnified 500 times. Image taken with scanning electron microscope and colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

7. Parasite diseases of farmed salmonids

By Geir Bornø

Amongst the parasitic diseases and diseases in general, the salmon louse (*Lepeophtheirus salmonis*) continues to represent one of the most significant challenges to salmonid farming. In 2021, lice levels were approximately at the same level as in 2020, but with somewhat fewer motile lice per fish in 2021. 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.

Salmon louse resistance to pharmaceutical treatments remained widespread in 2021 along the coast, and non-medicinal treatments and other non-medicinal measures now dominate delousing strategies. Medicinal treatments for salmon lice have levelled off after a decline in recent years. There is also a decrease in non-medicinal treatments in 2021 compared to 2020. Thermal treatment is still the most widespread delousing method in the industry, but a slight decrease in the number of treatments was registered compared to 2020. The number of freshwater treatments has increased significantly from 2020.

In the survey, increased mortality after delousing is still emphasised as very significant. There are also strong indications that physical injuries resulting from these types of delousing are associated with reduced fish welfare.

Caligus elongatus still seems to be a problem in 2021. *Caligus elongatus* have been a challenge in some areas, especially in the north. There have been reports of cases where this type of louse has been such a major problem that it has been treated specifically against this parasite. Treatment against both forms of lice, salmon louse and Caligus elongatus, is given at the same time in individual cases.

The parasite *Parvicapsula pseudobranchicola* is reported in previous reports to be particularly problematic in farming in the two northernmost counties. In 2021, as the year before, this parasite presented major challenges in terms of mortality, growth and welfare, especially in Troms and Finnmark. The parasite has been detected in several production areas in 2021, but apparently only diseases related to the parasite were found in the northernmost counties.

The amoeba *paramoeba perurans*, which causes amoebic gill disease (AGD), was detected throughout the year from Vestland to Nordland. Both disease and the finding of the parasite have been detected at a significant number of sites in 2021. In complex gill disease in salmon in the sea, this can be present together with other parasites such as *Desmozoon lepeophtherii*.

There are other parasites commonly found in farmed salmon that may be problematic. An increase in tapeworm (*Eubothrium* sp.) infection has been observed in sea-farmed salmon since 2010. The tapeworm problem seems to be greatest in salmon in the sea, especially in Southwest Norway, Western Norway and in Central Norway. *Ichthyobodo necator* (salmon in freshwater), *I. salmonis* (salmon in freshwater and sea) and *Trichodina* spp. commonly occur as single-celled parasites in Norwegian fish farming. Most detections of both tapeworm and single-celled parasites are made by the fish health services. The survey emphasises problems with these parasites as relatively low for the whole country as a whole, but problems with tapeworms appear to be increasing.

In 2021, a new parasite was found and described for salmon and rainbow trout. The species, which is given the name *Salmoxcellia vastator*, belongs to the X-cell parasites group. Since 2000, the Norwegian Veterinary Institute has sporadically detected a condition in salmon and rainbow trout in the sea phase with characteristic lesions, where a parasite disease has been suspected and these cases are all caused by this newly described parasite. Parasites in this group have provided pathology and mortality in farmed cod, and this, together with the fact that the infections can make fish unsuitable for human consumption, means that one should pay attention to this new parasite disease in the Norwegian aquaculture industry.

Counting lice. Photo: Kristine Gismervik, Norwegian Veterinary Institute.

7.1 Salmon louse – *Lepeoptheirus salmonis*

By Leif Christian Stige, Lars Qviller and Kari Olli Helgesen

The Disease

The salmon louse (*Lepeophtheirus salmonis*) is a naturally occurring crustacean parasite for salmonid fish in marine environments in the northern hemisphere (Figure 7.1.1). The life cycle comprises eight developmental stages separated by exoskeleton molts. 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 lice burdens may be fatal.

Lice 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 set 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 methods now dominate. Farmers commonly now use a combination of preventative measures including continual delousing (mainly cleanerfish) and both non-medicinal and medicinal methods.

The increased frequency of treatment and increased use of non-medicinal combating methodology 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: **https://www.vetinst.no/sykdom-og-agens/lakselus**

Figure 7.1.1. Salmon lice at different stages. Photo: Åkerblå.

The Health Situation in 2021

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 7.1.2). The highest numbers of adult female lice were recorded in October 2021 (week 42) and the highest numbers of other mobile stages (pre-adults and adult males) per fish were two weeks earlier in the same month (week 40). The lowest number of adult female lice per fish was seen in May (week 20), while the lowest number of other mobile lice per fish was seen in April (week 16). The lice level as a whole in 2021 was approximately the same as in 2020 and in the five-year period 2015-2019, but with somewhat fewer mobile lice (an average of 0.59 mobile lice per fish in 2021 compared to 0.64 in 2020 and 0.70 in the five-year period 2015-2019, while the average number of

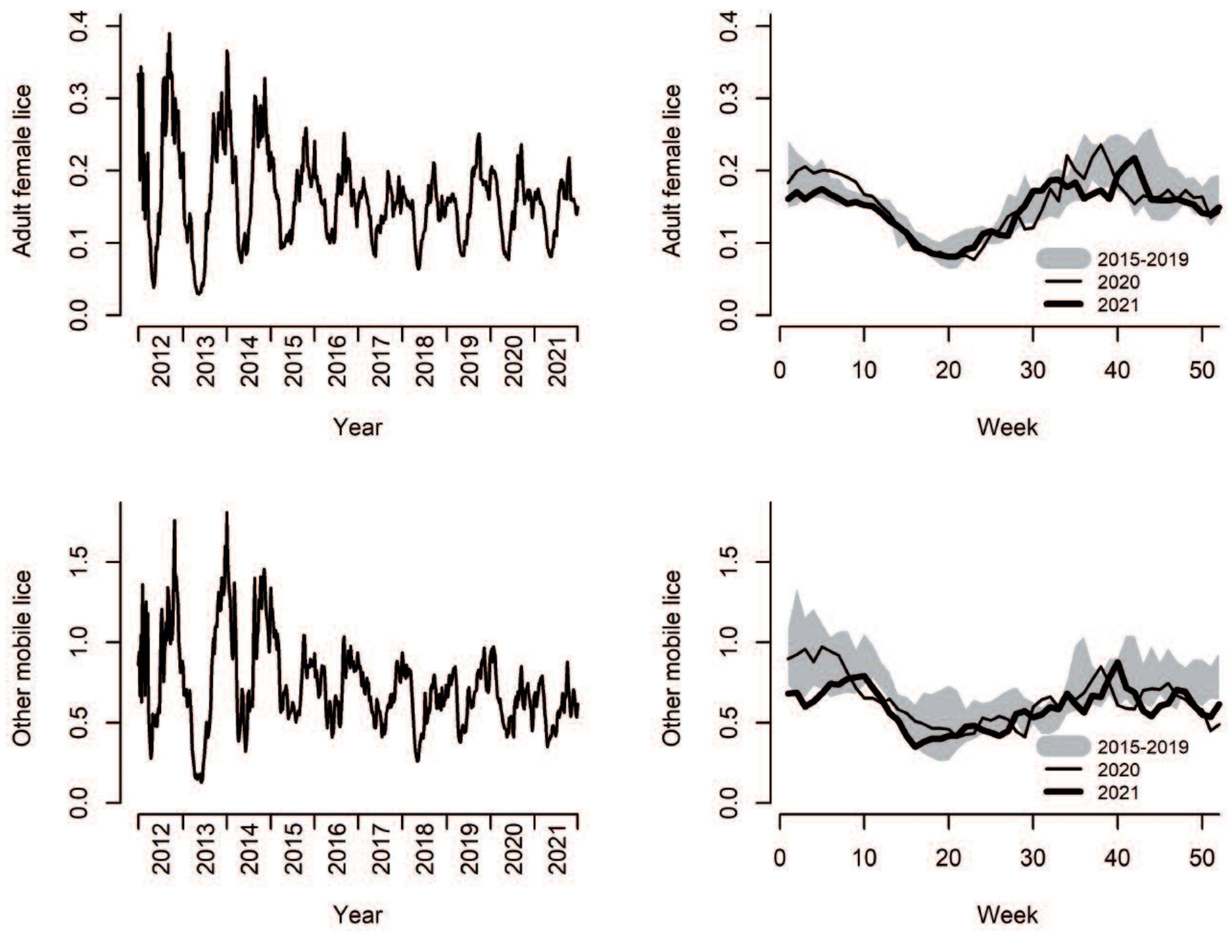


Figure 7.1.2 Average weekly salmon lice numbers reported from all marine fish farms with salmon or rainbow trout throughout the country over the period January 2012 to December 2021 (reported to the Norwegian Food Safety Authority as at 16.01.21). Upper panels apply to adult female lice and lower panels other mobile stages of lice (pre-adult lice and adult male lice). The panels on the right show the seasonal development for each of the last two years (lines) and the range in variation over the previous five years (shown as grey field).

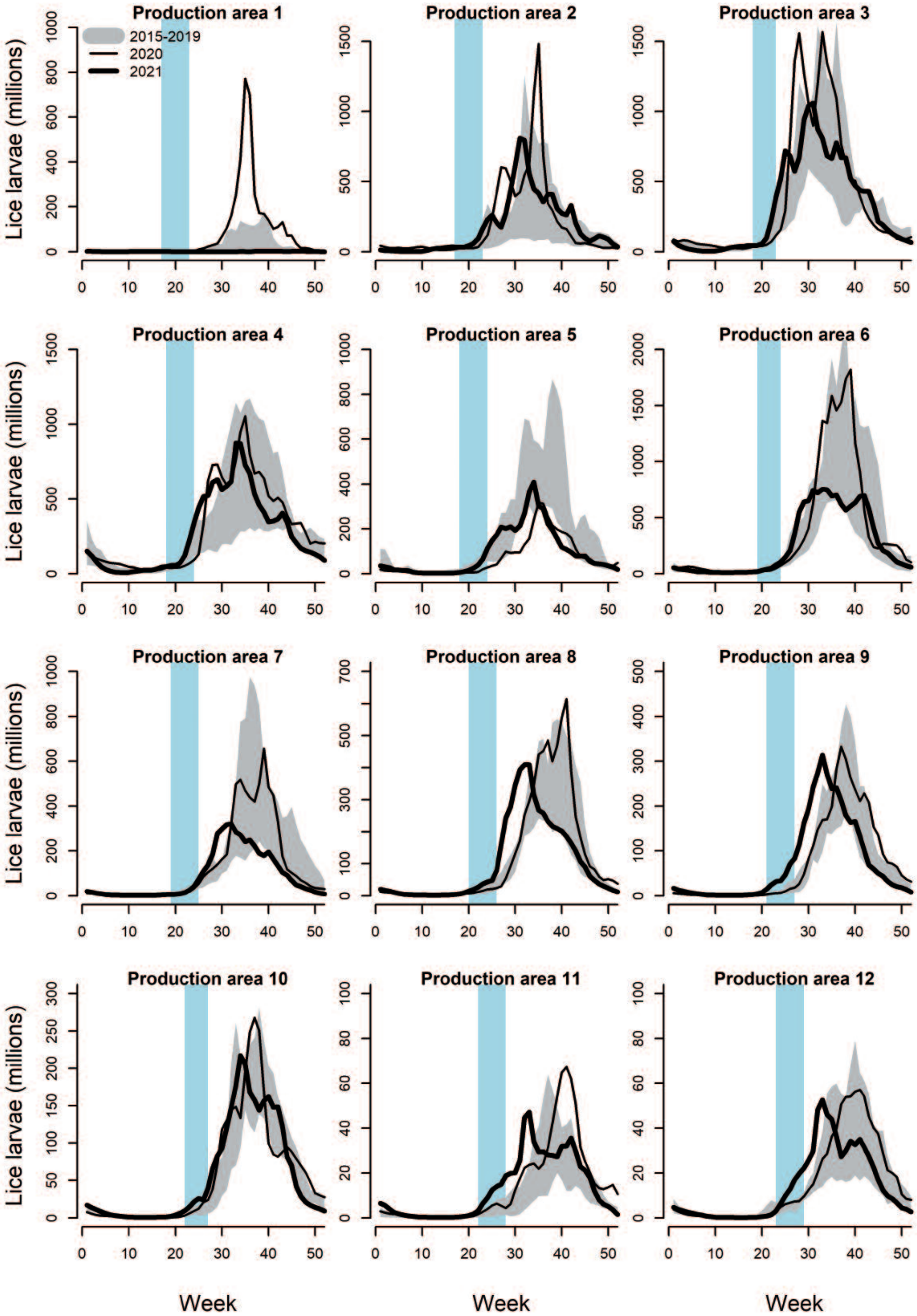


Figure 7.1.3 Calculated total production of salmon lice larvae (in millions) per week at all sites within each production area. The lines show the seasonal variation for each of the last two years. The grey fields show the range in variation over the previous five years. Note that the y-axis scale is different for different production areas. Production area 13 is not included. This area had insignificant larva production throughout the period (with the highest larva production estimated at 5.1 million larvae at week 42 in 2020). The blue fields show the typical outward migration period for wild salmon smolt in each area.

adult female lice was 0.15 in both years 2021 and 2020 and 0.16 in the five-year period 2015-2019).
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, Figure 1.1). Each area is considered separately in association with the so-called Traffic Light System regulating further expansion of the aquaculture industry. For a discussion of the Traffic Light System and status in 2021, see Chapter 9.6 Salmon Lice and Sustainability.

The highest larva production in 2021 occurred in PO2, PO3, PO4 and PO6 (Figure 7.1.3). PO5 experienced an increase in larva production from 2020 to 2021. In PO1, PO2, PO3, PO4, PO6, PO7 and PO8, there was a reduction in the production of salmon lice larvae from 2020 to 2021, while there were only small changes in the northernmost POs (PO9-13). Regarding larva production during the period of outward migration of wild salmon smolts (as described by Kristoffersen et al. 2018) an increase in production was observed from 2020 to 2021 in all production areas except for areas PO1 and PO13. Larva production during the outward migration period was also high compared to the previous five years. The high larva production during the migration period in 2021 was due to the fact that the seasonal increase in larva production in the summer occurred earlier in the year than has been usual in recent years. In PO1 and PO13, larva production during the migration period remained low and stable.

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 7.1.4). The median value of the average production of lice larvae per fish per week was highest in PO2-4, 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 2021 is summarised in Tables 7.1.1. and 7.1.2. Counting medicinal treatments is based on the number of registered requisitions 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 at the entire farm.

Table 7.1.1 shows a sharp reduction in the number of medicinal prescriptions for lice agents from 2014 to 2018, which has levelled off. 5 percent more prescriptions for lice agents were prescribed in 2021 than in 2020, but 4 percent fewer than in 2019. At the active substance level, the figures show that the increase in azametifos prescriptions, seen since 2019, continued in 2021. The decline in hydrogen peroxide prescriptions, seen since 2016, also continued in 2021. Prescriptions of pyrethroids and flubenzurons decreased from 2020 to 2021, while emamektin benzoate increased somewhat. Emamektin benzoate was the active substance that was prescribed the most in 2021 (61 percent of prescriptions). The relatively 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. 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 *Caligus elongatus*.

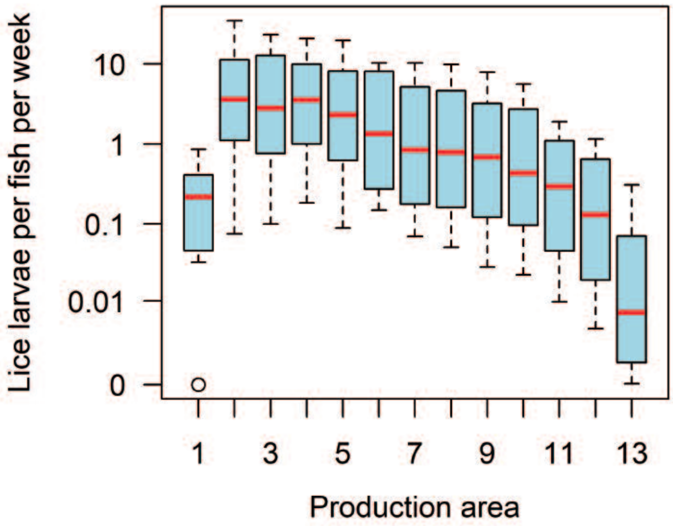


Figure 7.1.4 Estimated average production of lice larvae per fish per week within each production area (PO1-13) in 2021. The red lines represent the median values, while 50% of the values are within the blue boxes.

Table 7.1.1 Number of prescriptions of a given category for active substance for lice treatment in 2011 – 2021. 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) 28.01.22.

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

Table 7.1.2 Number of non-medicinal treatments reported [1]. The treatments are weeks in which sites have reported that they have carried out non-medicinal treatment against lice to the Food Safety Authority as of 16.01.22. 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
Thermal	0	0	3	36	685	1246	1330	1449	1723	1453
Mechanical	4	2	38	34	311	236	423	673	812	851
Freshwater	0	1	1	28	73	75	84	148	234	313
Thermal + mechanical	0	0	0	0	12	42	35	56	57	30
Thermal + freshwater	0	0	0	0	16	21	17	27	23	64
Mechanical + Fresh Water	0	0	0	0	7	1	7	7	18	32
Therm. + mech. + freshw.	0	0	0	0	0	0	1	0	0	3
Other	132	108	136	103	75	52	69	88	95	76
Total weeks	**136**	**111**	**178**	**201**	**1179**	**1673**	**1966**	**2448**	**2962**	**2822**

[1]The difference in figures from the Fish Health Report for 2020 is due to updated routines for identifying error 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 delousings increased each year from 2013 to 2020, but decreased by 5 % from 2020 to 2021. The decrease from 2020 to 2021 was due to a 14-percent decrease in thermal treatments (including weeks in which several non-medicinal methods were used). However, the number of freshwater treatments increased by 50 % and mechanical delousing by 3 %. Nonetheless, thermal delousing was still the most common non-medicinal delousing method in 2021 (55 % of the reported non-medicinal delousings, including weeks in which several non-medicinal methods were used). In around 5 % of the weeks in which non-medicinal delousing was registered, several other types of delousing were registered in the same farm (not necessarily in the same cage). The most frequently registered combination was thermal delousing and freshwater treatment. This is in contrast to previous years, when thermal and mechanical delousing was the most common combination. In addition to medicinal and non-medicinal treatments, various preventive methods against salmon lice and methods for continuous delousing were used, including lice curtains and cleaner fish.

Figure 7.1.5 shows the results of the 2021 monitoring programmes for salmon louse resistance performed by the Norwegian Veterinary Institute under contract from the Norwegian Food Safety Authority. This programme utilises bioassays (resistance testing in which live salmon lice are exposed to different levels of anti-louse substance) for the substances azamethiphos, deltamethrin (a pyrethroid), emamectin benzoate and hydrogen peroxide. As previously for 2020, the map indicates widespread resistance to emamectin benzoate, deltamethrin and azimethiphos in salmon lice from different farming sites along the coast. However, there has been a tendency towards reduced resistance to azametifos and deltamethrin starting in 2017. This corresponds to a reduction in the use of these drugs (although the prescribing of azametifos has increased in recent years, prescribing is still low compared to the years before 2017). For hydrogen peroxide, the map shows a degree of resistance in some areas while other areas showed satisfactory sensitivity. The reasons for continued resistance to anti-louse substances despite low use the latest years are probably that resistance genes are now well established within the louse population of both wild and farmed salmon and that all use of medicine selects for resistance.

The Annual Survey

In our annual survey of fish health personnel in the fish health services, the Food Safety Authority and farming companies, respondents were asked to comment on salmon lice in general and injuries arising from delousing procedures in particular. From a list of 33 health and welfare problems relevant for ongrowing facilities for salmon, respondents were asked to cross off the five most important diseases/conditions that result in mortality, reduced welfare, reduced growth or was an increasing problem in 2021. Damage after delousing was considered the most important cause of reduced welfare, the second most important cause of mortality and as the third most important increasing problem in fish farms with salmon. Reduced welfare and mortality caused by the lice themselves are considered a minor problem compared to other diseases and injuries after delousing. When asked similar questions regarding rainbow trout in fish farms, there were significantly fewer respondents, but the picture is largely similar to that of salmon. Mechanical damage after delousing was considered the most important, and salmon lice were considered the fourteenth leading cause of death in rainbow trout. Similarly, mechanical damage after delousing was considered the second most important cause of reduced welfare, and salmon lice came in tenth place in this ranking. No one considered salmon lice or mechanical damage after delousing to be a growing problem for rainbow trout.

The survey responses also show that salmon lice, and especially treatments for salmon lice, can be a problem in broodstock farms for salmon. Mechanical damage from delousing ranks among the top five causes of mortality and reduced welfare, and two out of eight respondents believe such damage is an increasing problem. A minority reported salmon lice as an important cause of mortality

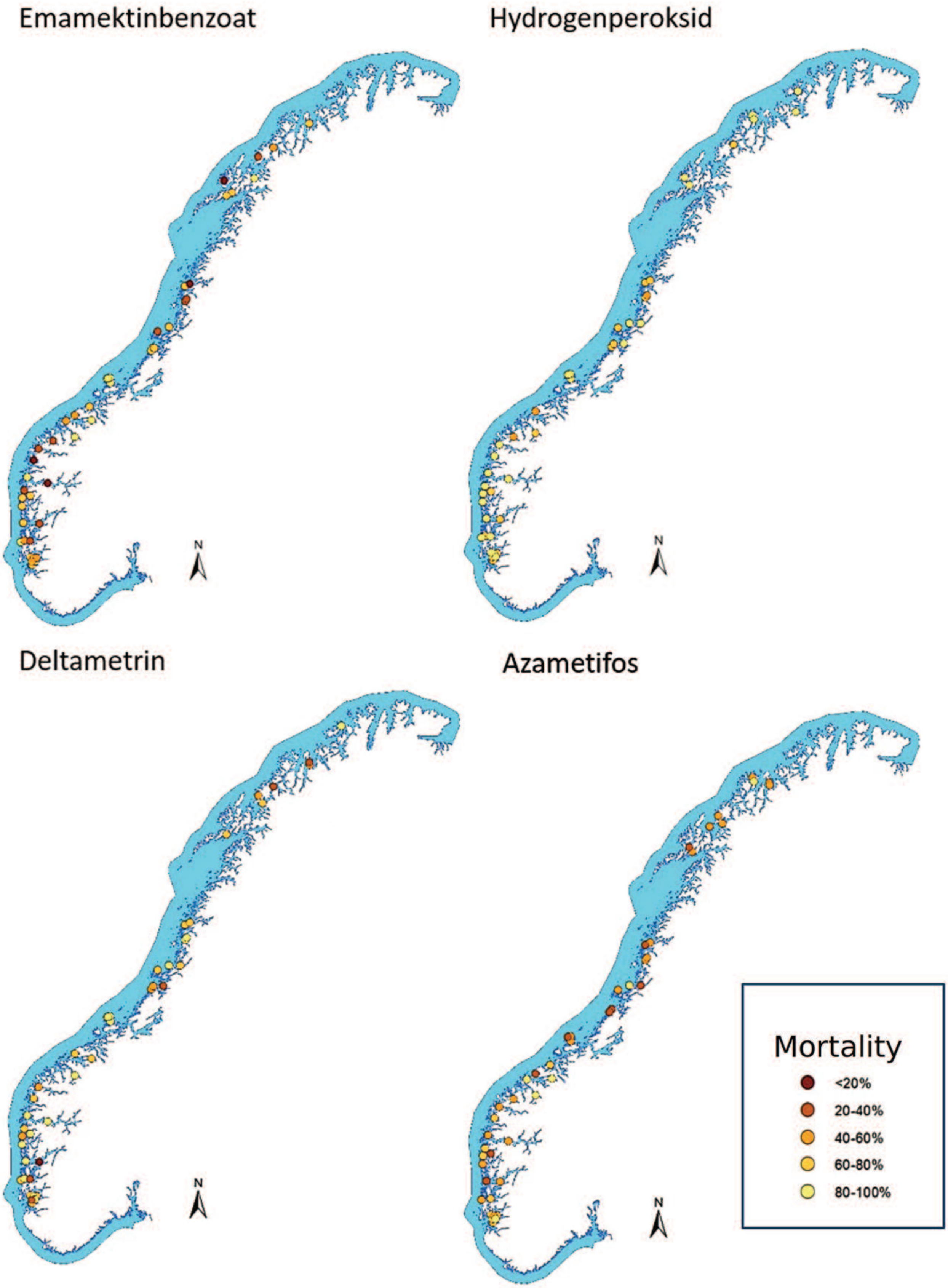


Figure 7.1.5 Mortality of lice in bioassay (toxicological resistance test on live lice) with emamektin benzoate, hydrogen peroxide, deltamethrin and azamethiphos. Darker colours represent lower mortality at exposure to a certain concentration of the active substance and therefore more resistant lice.

(1 in 12 respondents), reduced welfare (1 in 9 respondents), and as a growing problem (1 in 8 respondents). We only received six responses about rainbow trout broodstock, but mechanical damage after lice treatment is also reported as a major cause of reduced welfare and death.
In addition, they reported lice skirts use as a cause of problems to water quality, and that ever larger wellboats make mooring in connection with treatment increasingly challenging in the event of a strong current.

When questioned on mortality in relation to delousing, a score of 1 means this was seldom/never seen, while a score of 5 means it is nearly always seen in delousing. N is the number of respondents who replied to that particular question. Increased acute mortality (over 0.2 % mortality in the first three days after a delousing) received an average score of 3.5 for delousing using heated water (N=69), 3.2 for delousing with flushing and/or brushing (N=56) and 2.8 for the use of fresh water for delousing (N=50). The average score for increased mortality over the first two weeks post-delousing (increased delayed mortality) were respectively 2.7 (N=68), 2.6 (N=56) og 2.0 (N=49) for thermal, mechanical and freshwater delousing. Increased acute mortality was thus observed most often during thermal delousing, followed by mechanical and least commonly in freshwater delousing among the non-medicinal delousing methods. A similar ranking was also reported between the various methods in 2017, 2018, 2019 and 2020. Increased delayed mortality was observed most often during thermal delousing, followed by mechanical and least commonly in freshwater delousing among the non-medicinal delousing methods. Specific welfare concerns surrounding non-medicinal louse treatment are discussed in Chapter 3 Fish Welfare.

Summary of the salmon lice situation

The average number of adult female lice per farmed fish for the whole country was as a whole in 2021 approximately the same as in 2020 and in the five-year period from 2015 to 2019. However, the production of salmon lice larvae during the wild salmon outward migration period, which in addition to the number of lice per fish depends on the sea temperature and the number of farmed fish, was higher than in previous years in most production areas. This increase was due to the fact that the seasonal increase in lice larvae production in the summer came earlier than in previous years. Lice larvae production was highest in areas PO2, PO3, PO4 and PO6.

We saw somewhat reduced use of non-medicinal lice treatments compared to 2020 (an overall reduction of 5 percent), and somewhat increased use of medicinal treatments (overall increase of 5 percent). The reduction in non-medicinal treatments was due to fewer thermal treatments (a decrease of 14 percent), while the number of freshwater treatments increased (an increase of 50 percent). Thermal treatments are still the most commonly used non-medicinal lice treatment. We also note that the use of azametifos has increased for the third year in a row, and that in 2021 for the first time in many years a drug with a new active substance against lice was registered; imidacloprid. The prevalence of resistance to drug treatments was still large. This means that at most sites one would expect a bad effect from any drug treatment with the agents that have been on the market for a long time.

Since 2017, the majority of salmon lice treatments have been non-medicinal. In 2021, non-medicinal measures were reported to be used almost four times as often as medicinal measures. Fish health personnel reported (via our annual survey) that thermal and mechanical treatments in particular often resulted in increased post-treatment mortality. This probably means a lot to the overall mortality of salmon and rainbow trout in the sea, as 2429 weeks of treatments with these methods were reported in 2021. In addition, damage after delousing was chosen by fish health personnel as one of the main causes of reduced welfare in both salmon and rainbow trout in this year's survey. This further underlines the relationship between salmon lice treatments and fish welfare. The number of thermal and mechanical treatments has increased significantly in most years since 2016, without a corresponding decrease in the number of medicinal treatments. The welfare challenges associated with this increase are discussed in Chapter 3.

7.2 *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 lice *Lepeophtheirus salmonis*. Like its relative, it lives on the skin of fish in saltwater, but it has much lower host specificity than salmon lice which is found only in salmonids. To date, *C. elongatus* have been found on about 80 species of marine fish, including salmonids, cod, saithe, pollock fish, 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 lumpfish 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 for other parasitic copepods such as the salmon lice and the species is very capable of shifting between hosts. As a consequence, wild fish can easily infect salmon and vice versa under farming conditions. Salmon, and any cleanerfish in the cages, can also become infected by *C. elongatus* from fish outside the cages. This can be observed as an increase of adult lice without a development of the lice population in the cage over time.

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

Caligus elongatus is easily distinguished morphologically from salmon lice by having so-called lunula on the underside at the very front of the cephalothorax (head part). In lice counts, *C. elongatus* can be distinguished from salmon lice partly because they are more translucent, are less colourful, are smaller and often more mobile than salmon lice. However, it requires practice to differ between the two species. The mobility of *Caligus elongatus* can also cause them to detach from the host defect before they are recorded during censuses. 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, especially from the northern regions, 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 *C. elongatus*.

The Health Situation in 2021

The Annual Survey

The majority of respondents who assessed *Caligus elongatus* consider the parasite to be associated with reduced welfare in fish production of salmon. A few consider that it contributes to mortality. *Caligus elongatus* contribute to reduced growth in the fish, and several respondents have also indicated that *C. elongatus* is a growing problem for salmon in fish farms. There were few respondents from broodstock farms, but those who have responded see *C. elongatus* as a problem that can contribute to reduced welfare of the fish. *Caligus elongatus* infection was not registered as a problem in rainbow trout in either ongrowing facilities or broodstock farms.

Evaluation of the *Caligus elongatus* situation

C. elongatus infections do not appear to have increased in number in 2021.

7.3 *Parvicapsula pseudobranchicola* (parvicapsulosis)

By Haakon Hansen, Lisa Furnesvik and Geir Bornø

The Disease

Parvicapsulosis has been known from Norwegian farmed salmon since 2002 and is reported to be particularly problematic in Troms and Finnmark. Parvicapsulosis, caused by *Parvicapsula pseudobranchicola*, may result in high mortality in ongrowing facilities.

P. pseudobranchicola is a eukaryotic parasite belonging to the class Myxosporea. This parasite has a complex life cycle with a polychaete worm as its main host and fish as the intermediate host. Although *P. pseudobranchicola* primarily causes disease in fish farming in the northern regions, the parasite is common in wild salmonids (salmon, sea trout and sea char) along the entire Norwegian coast. As the target organ for this parasite is the pseudobranch, an organ that is most likely involved in the blood and oxygen supply to the eye, infections may lead to reduced vision or blindness.

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

Figure 7.3.1 Fish with the disorganised swimming behaviour characteristic for fish suffering from parvicapsulosis. Photo Mathias Overrein, Åkerblå.

The Health Situation in 2021

Data from the Norwegian Veterinary Institute and private laboratories

If the figures from the Norwegian Veterinary Institute and the private laboratories are compiled, parvicapsulose would be detected at 21 unique sites with salmon. Of the 21 sites, 9 of them were in PO12 and 13. The remaining detections were divided into PO9 (three sites), PO10 (four sites), and PO11 (five sites). Detections were reported for *P. pseudobranchicola*, using PCR, from a total of 22 sites. Most of the detections were made in PO9-13, but there are also six detections of the parasite in PO7 and one in PO1. However, only PO9-13 reported parasites that caused disease.

The Annual Survey

Parvicapsulosis has for many years been a recurring problem in salmonids farms in the northernmost regions, and the survey for 2021 also shows this (see Figure 3.2.1 C in Chapter 3 Fish Welfare). Many respond that parvicapsulosis reduces welfare and it is stated that infection with this parasite still presents major challenges both in terms of mortality and growth. Parvicapsulosis is not considered to be an increasing problem in ongrowing facilities, based on the survey responses.

Evaluation of the parvicapsulosis situation

Parvicapsulosis remains an important disease in salmon farming. Although the parasite 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. Based on what is known about the prevalence of the parasite, it is likely that the figures for the number of detections underestimate the real prevalence in farmed fish.

There are no treatments available and further research on this disease is made difficult as the final host for the parasite remains unknown. The disease causes increased mortality, reduced welfare, and reduced growth. A few detections of the parasite have been made in ongrowing facilities in other regions, but parvicapsulosis does not appear to pose any major challenge in more southern parts of the country.

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

By Geir Bornø and Haakon Hansen

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 were 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. *Paramoeba 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. This 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 7.4.1). Amoebas can be detected in fresh smears from the gills that are examined under a microscope (Figure 7.4.2) 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 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 has been developed for classifying the macroscopically visible changes associated with AGD. This scoring system is an important tool for the Fish Health Services. After repeated treatments, scoring of gills can be difficult and it 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 Norwegian Veterinary Institute's fact sheet: **https://www.vetinst.no/sykdom-og-agens/amobegjellesykdom**

Figure 7.4.1 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.

The Health Situation in 2021

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 then used to confirm the suspicion.

Compiled data from the private laboratories and the Norwegian Veterinary Institute show findings of disease caused by AGD at 68 sites, with salmon (64) and rainbow trout (4). The most reported detections are from PO3 and PO6, with 22 and 20 sites respectively, but detection of disease has been made from PO1 through PO7. PCR examinations show the findings of the parasite at 131 different sites from PO1 through PO7. The most detections were in PO3 with 58, and in PO1 and PO2 a total of 28 detections and PO4 had 26 detections. 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 2021 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 2021. See appendices B1-2 and C1-2 for details from the 2021 survey.

The use of lice skirts is reported to present greater challenges in relation to AGD problems than conventional open cage solutions.

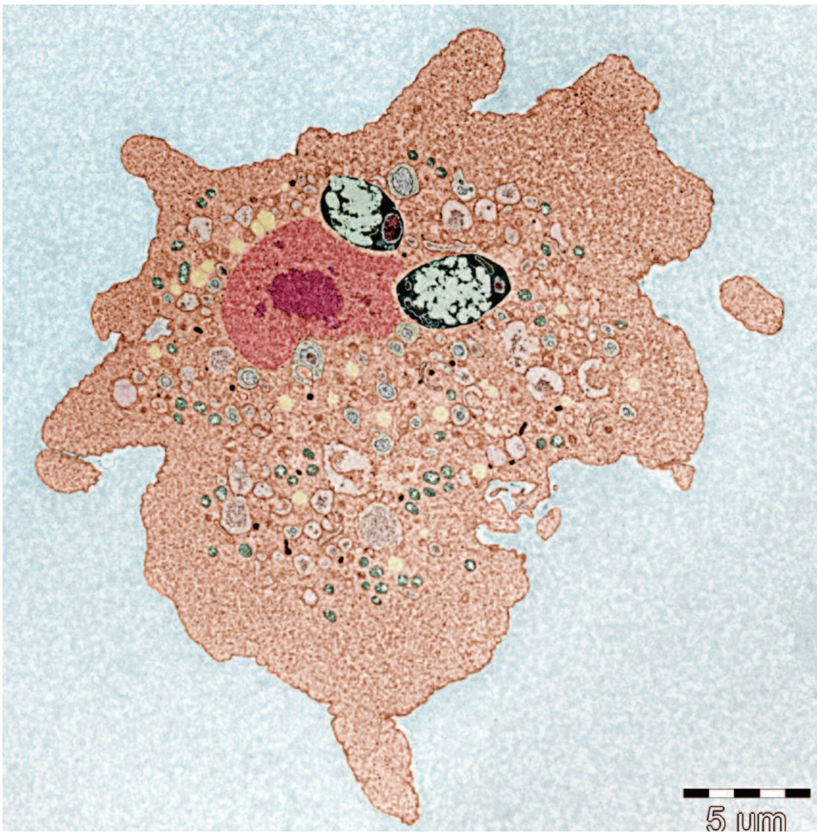


Figure 7.4.2 Transmission electron microscopy image of the amoeba *P. perurans*. The section shows the nucleus, two parasomes and internal structures. The image is colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

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 year.

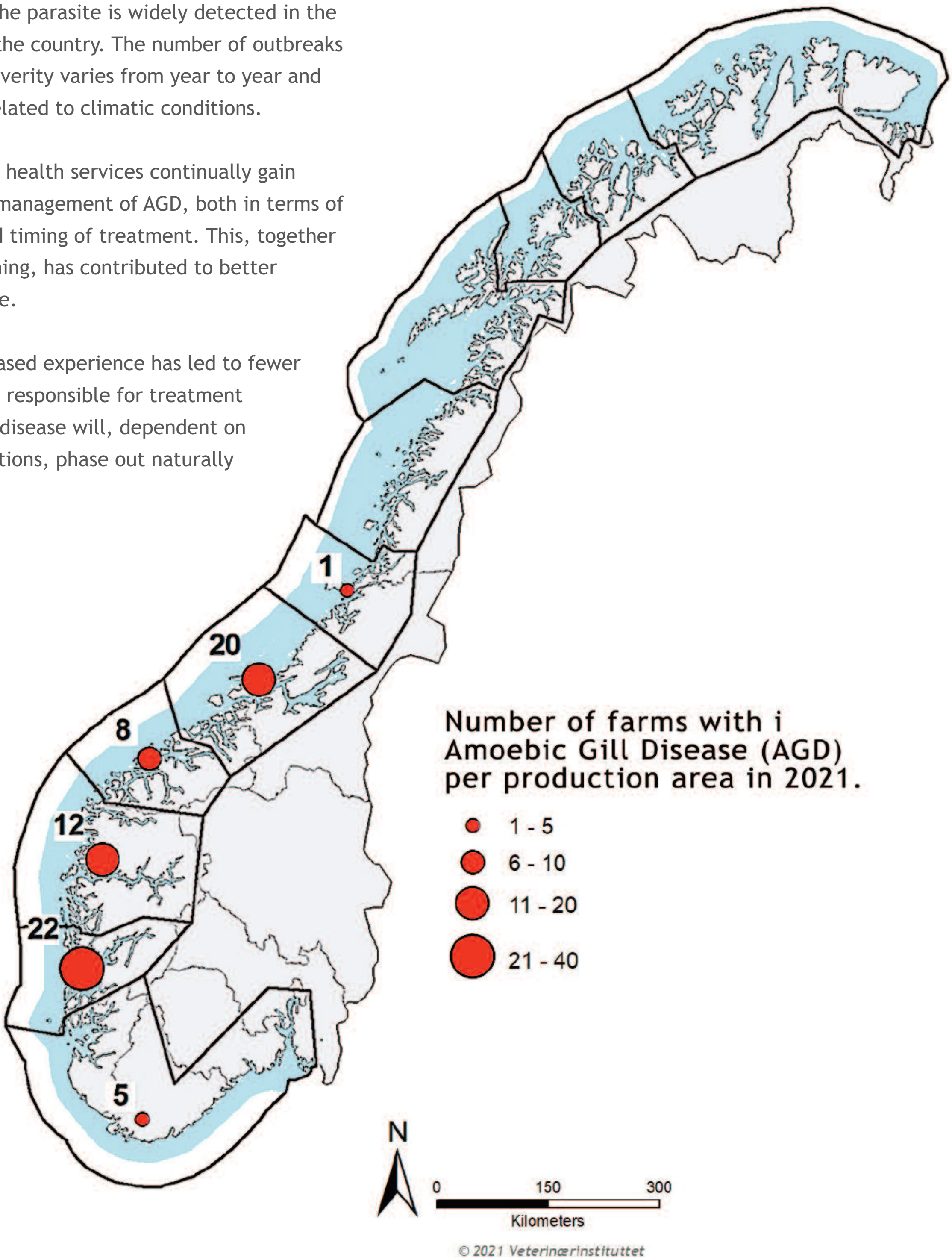


Figure 7.4.3 Number of AGD diagnoses in 2021 by production areas, based on coordinated figures from the Norwegian Veterinary Institute and private laboratories.

7.5 Tapeworms – *Eubothrium* sp.

By Haakon Hansen and Geir Bornø

The Disease

Tapeworms (Cestoda) belong to the flatworms (Platyhelminthes), which as adults may be found as parasites in the intestines of animals. Tapeworms have complex life cycles involving several host species. Fish can act as both intermediate and final host for species of tapeworms. Farmed salmon in the sea phase become infected by *Eubothrium* sp. 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 coelom 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

Eubothrium sp. are treated with Praziquantel, but there have been reports of lack of effect and the use of Praziquantel has fallen in recent years.

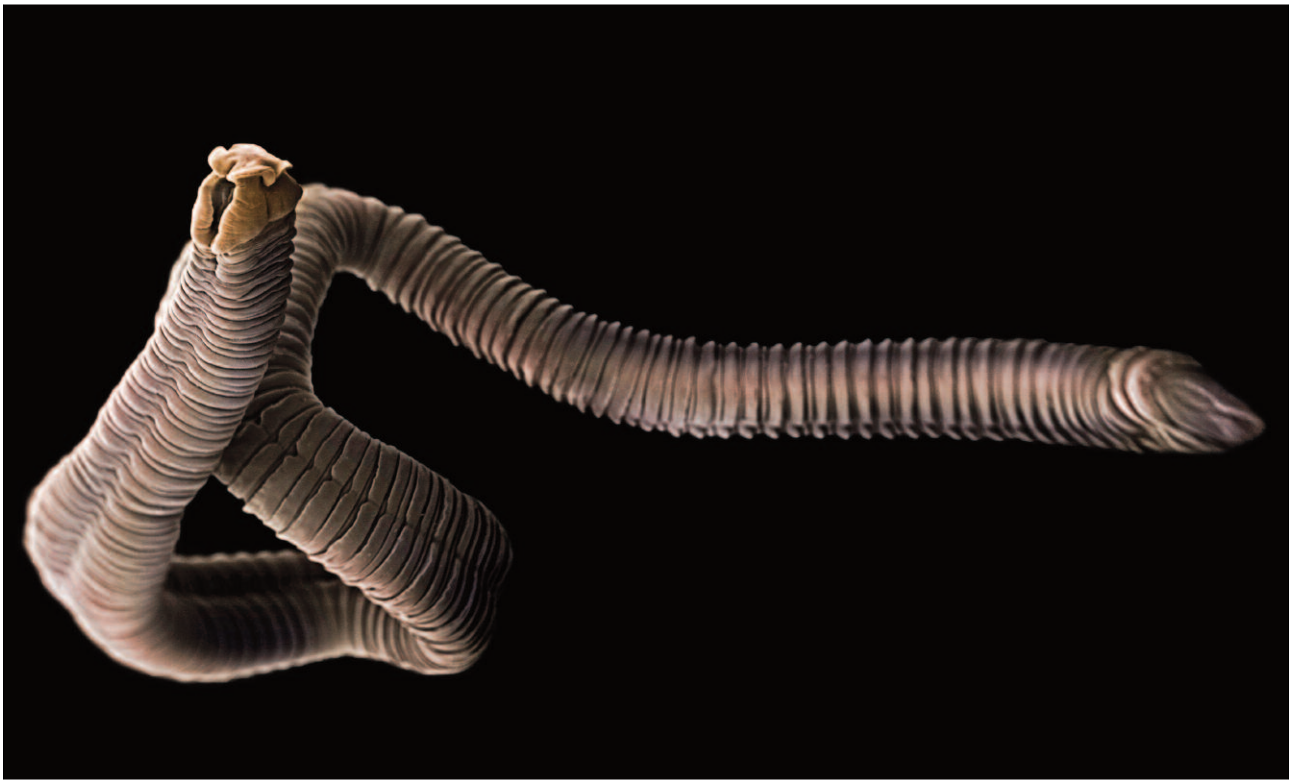


Figure 7.5.1 Tapeworm (*Eubothrium crassum*), magnified 50 times. Image taken with scanning electron microscope and colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

The Health Situation in 2021

Data from the Norwegian Veterinary Institute

In 2021, the Norwegian Veterinary Institute detected tapeworms in salmon at 16 farms, compared with 19 sites the year before. The majority of the facilities with tapeworm detection were located in the southwest and central parts of the country in PO2-6.

The Annual Survey

Of those respondents who consider tapeworm a problem in ongrowing facilities, most consider it a problem in relation to reduced growth. There is also feedback that tapeworms lead to reduced fish welfare in salmon, but tapeworms are not considered important in relation to mortality. For broodstock farms for salmon, no one has answered that tapeworms are considered an important cause of either mortality, growth or welfare. For ongrowing and broodstock farms of rainbow trout, tapeworms are considered by some to contribute to reduced growth and welfare, and one respondent considers that the parasite contributes to increased mortality. One respondent also considers that the parasite is a growing problem for broodstock.

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. As a rule, the parasites are not determined to species, but it is believed that by far most or all of the detections belong to the same species. The industry indicate that infections with tapeworms is persistent and in some areas, a growing problem.

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

7.6 X-cell parasite - *Salmoxcellia vastator*

By Anne Berit Olsen, Jannicke Wiik-Nielsen, Mona Gjessing, Bjørn Spilsberg and Haakon Hansen

About the parasite and the disease

A new parasite was described in 2021 from salmon and rainbow trout. The species, which is given the name *Salmoxcellia vastator,* belongs to the group X-cell parasites (Karlsbakk et al. 2021). Since 2000, the Norwegian Veterinary Institute has sporadically detected a condition in salmon and rainbow trout in the sea phase with characteristic lesions, where a parasite disease has been suspected. Closer examination shows that all these cases are caused by this newly described parasite.

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, see Figure 7.6.1. Degeneration and inflammation occur in the tissues, and by histopathological examination the disease is characterised by characteristic X-cells in the lesions, see Figure 7.6.2.

The Norwegian Veterinary Institute has detected the infection 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 % has been reported.

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 2021

Few cases have been detected in 2021, but some mortality has been observed over time.

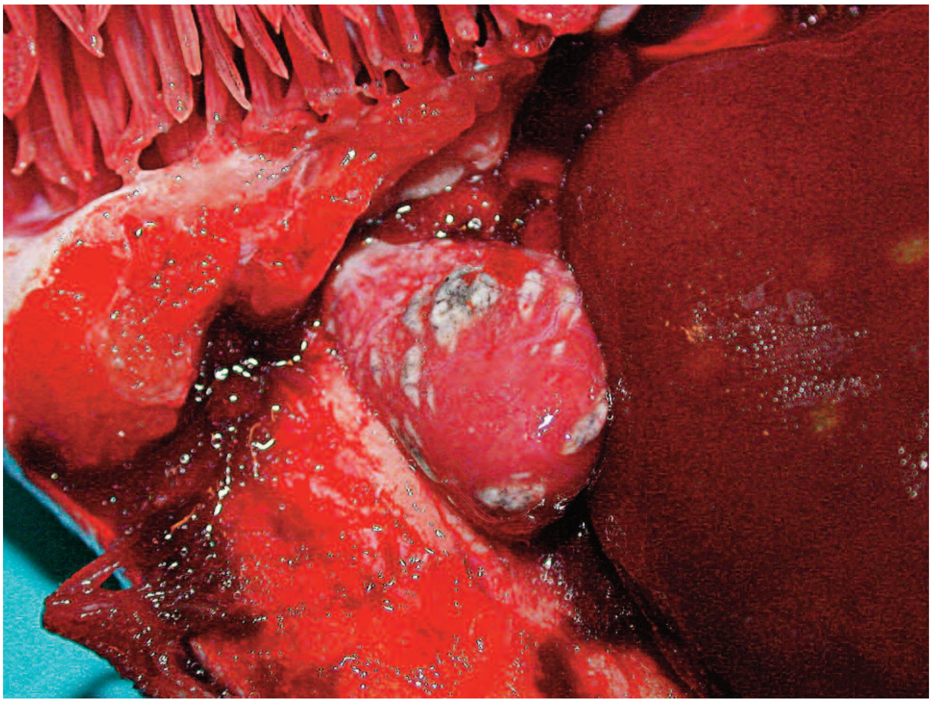


Figure 7.6.1 A common finding in salmon and rainbow trout infected with the X-cell parasite is white irregular nodules and spots on and in internal organs, as here in the heart of an adult rainbow trout. Photo: Anne Berit Olsen, Norwegian Veterinary Institute.

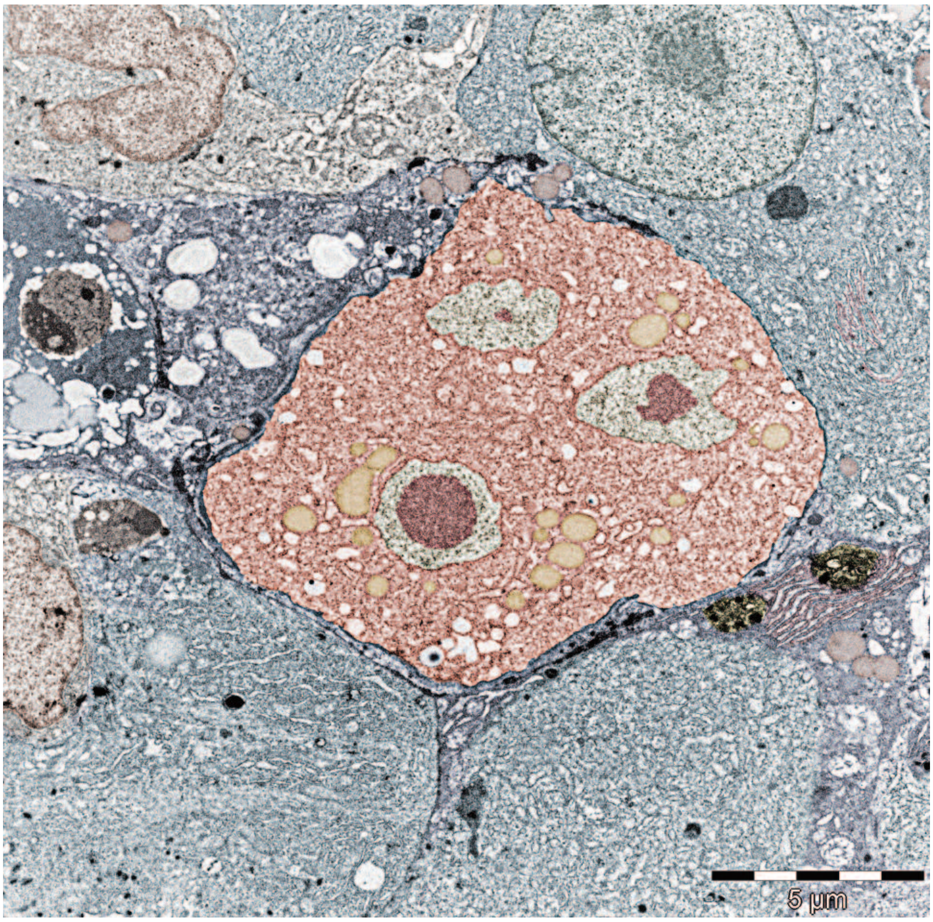


Figure 7.6.2 Tissue section of X-cell parasite in the liver. The parasites differ in shape and size and can have many nuclei. In this case, the parasite has three visible nuclei and is surrounded by liver cells and inflammatory cells. The image is taken with an transmission electron microscope and coloured to visualise details. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

8.0 Other health problems in farmed salmonids

By Geir Bornø

In this chapter, other health problems are discussed in farmed salmonids that are not caused by infectious agents. In some cases they are called non-communicable diseases, production disorders or external environmental problems. The chapter describes health problems such as gill disease (Chapter 8.1), poor smolt quality and runt syndrome (Chapter 8.2), nephrocalcinosis (Chapter 8.3), haemorrhagic smolt syndrome (Chapter 8.4), water quality (Chapter 8.5) and vaccine damage (Chapter 8.6).

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 2021 survey in which complex gill disease is ranked as one of the most important increasing health problems in ongrowing salmon. Complex/multifactorial gill disease is considered one of the main causes of reduced welfare. Complex gill disease is also ranked relatively high among current disease problems in terms of reduced growth, increased mortality and as an increasing problem in the ongrowing phase.

Smoltification problems and development of runts continues to be considered an important problem along the whole coast. When it comes to smoltification problems in salmon in the hatchery phase, results from the survey show that there are similar experiences as last year, and this is ranked as the fifth most important cause of mortality and as a growing problem. Causes of suboptimal smoltification and runt development are often complex and difficult to define.

In 2021, nephrocalcinosis and HSS are stated to be the biggest challenges in salmon hatcheries with regard to reduced growth and mortality (see Chapters 8.3 and 8.4). It can be assumed that HSS is a contributing factor to the mortality associated with smoltification problems in hatcheries. The cause of this disease remains unknown and it is speculated that it may be related to osmoregulatory failure during smoltification. The problem is considered by some respondents to be a growing problem. Nephrocalcinosis (kidney calcification, kidney stones) is well known in farmed fish and is perceived as a production disorder and is stated to be one of the main causes of reduced growth.

Good water quality is absolutely necessary for good fish health. While there have been previous incidences of hydrogen sulphide poisoning in RAS facilities, fewer problems are now reported. It is reported that there are some challenges in relation to water quality. In particular, facilities that receive water from rivers can experience unstable conditions. Metal problems related to intake water and the accumulation of aluminium and copper on the gills are found in freshwater facilities with a large supply of new water, where water sources often show a large seasonal variation. CO^2 is still reported to be a challenge in both RAS and through-flow facilities.

Farmed salmon in Norway are usually vaccinated against furunculosis, vibriosis, cold water vibriosis, winter ulcer (*M. viscosa*) and IPN. It has been common to vaccinate against PD in Western Norway (endemic area for SAV3), but PD is also vaccinated against in other areas. In Trøndelag and parts of Western Norway, it is also common to vaccinate against yersiniosis. Vaccination against ISA in Norway was limited until 2020, but an increase was reported in 2021. There is only a limited selection of vaccines for marine fish.

The Norwegian Veterinary Institute occasionally registers tissue damage related to injection with oil-based vaccines. In the survey, a small number consider vaccine side effects to be a major problem compared to other disorders. However, some indicate that vaccine side effects are a welfare problem, and that there is some increased mortality in relation to this during the hatchery phase.

Netting over the cages protects against predators that can cause damage to the fish. Photo: Eivind Senneset.

8.1 Gill health

Av Anne Berit Olsen, Arve Nilsen, Ole Bendik Dale og Mona Gjessing

About gills and gill problems

Gill anatomy and function

The gills of fish are multifunctional organs. They have several critical physiological functions including excretion of nitrogenous waste products, gaseous exchange, osmoregulation, pH-regulation and hormone production.

The gills have a surface area equivalent to the whole body surface of the fish and are therefore of importance for the fishes physiological condition and health (Figure 8.1.1). In addition to diffusely distributed immune/defence cells and immunological components in mucus cells, the gills have aggregates of more specialised lymphoid tissues at the bases of the filaments, which are considered specialised immunological organs. As only a thin cell layer separates the outer environment from circulating blood, the gills, as the skin and intestine, have an important barrier function and represent the first line of defence. At the same time, close contact with the external environment makes the gills very exposed to injury. Much remains to be learned related to gill health and the effect of gill injuries on fish physiology.

Gill disease

Gill disease affects both farmed salmon and rainbow trout throughout the whole life cycle from yolk-sac larvae to broodstock, and represents a significant welfare challenge. Causes of gill injury can include poor handling, poor water quality, algae and jellyfish or infectious agents such as virus, bacteria, fungus or parasites. Injured gills may be more susceptible to infection.

As environmental conditions and fish physiology differs in freshwater and seawater, different gill complaints are observed during the hatchery and marine phases of production. In the hatchery phase, water quality parameters and incorrect feeding strategies may increase the risk of gill disease. When water treatment systems do not work optimally, large seasonal variations may occur in the water's content of e.g. metals. Precipitation of iron (ochre) and toxic aluminium compounds on the gills can lead to high and acute mortality.

Bacterial gill disease or infection with the oomycete *Saprolegnia* in salmonid fish in freshwater are commonly considered secondary infections following e.g. episodes of low pH, metal precipitation or infection with single-celled parasites like *Ichthyobodo necator* (Costia) or salmon gill pox virus (see Chapter 4.8 Salmon pox).

In recirculation facilities (RAS), the interaction between technology, water chemistry and biology is particularly demanding and the fish's gills will be particularly susceptible to suboptimal conditions both in terms of the chemistry of the water, the microbial environment and the increase in particles and metals that may occur. It has also been experienced that infectious agents can accumulate in closed systems. For more information on water quality in land-based and sea-based farms, see chapter 8.5 Water Quality.

In marine farms precipitation of aluminium compounds may occur during freshwater AGD or salmon louse treatments.

In spring and summer, there is a sharp bloom of algae and jellyfish in the sea, several of which have the ability to irritate or damage the gills. The same applies to organisms that grow in the fouling of the cage nets and that are released by washing. Hydroids are a type of cnidarian closely related to jellyfish and can dominate net fouling. When washing nets under water with the use of high-pressure jets, hydroids are crushed, cnidarian cells are spread in the water and can cause irritation and damage to the gills. Secondary infections with ubiquitous marine bacteria e.g. *Tenacibaculum* may often follow such events.

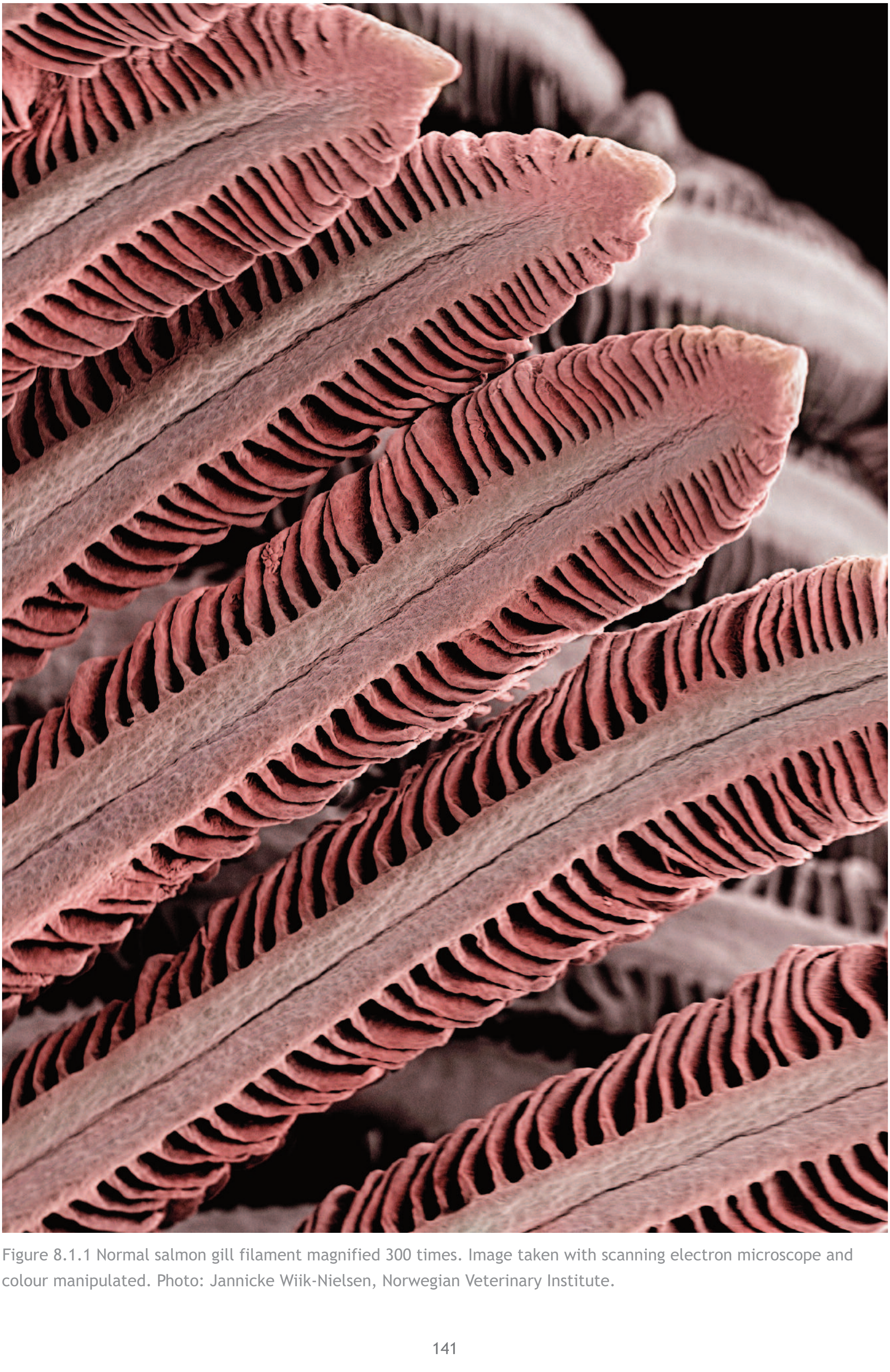


Figure 8.1.1 Normal salmon gill filament magnified 300 times. Image taken with scanning electron microscope and colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

New research has shown that thermal and mechanical delousing can have a negative effect on gill health and an increase in the incidence of the epiteliocystis bacteria *Ca*. Branchiomonas cysticola after thermal lice treatment. Another study suggests that *Ca*. B. cysticola is of great importance for the development of gill disease in salmon in the sea in Norway. For more details on the various microorganisms, see the separate chapters on *Paramoeba perurans* (Chapter 7.4) and SGPV (Chapter 4.8) in the report.

There are good reasons to consider that environmental threats such as plastic pollution, increasing water temperatures and acidification of the oceans as a result of climate change can have consequences for gill health and function. Changes in water parameters will also influence the relative presences of potentially disease-causing agents.

The extent of gill damage necessary to cause negative health effects on the fish remain unknown, but on identification of clinical signs of ill health, tissue damage is advanced and the disease has often progressed to a chronic stage. As gill disease may have several causes, and may manifest in differing ways, diagnosis of a precise cause may be difficult as is choice of treatment. Regular monitoring and checking gill health is therefore very important during the whole life cycle in all fish farming systems.

More tools

An unambiguous nomenclature for characterisation of gill diseases is lacking, but for the occasions in which a number of different types of pathological change and several infectious agents can be involved, the term 'complex gill disease (CGD) is becoming commonly used. In recent years a number of useful diagnostic tools have been developed for identification of the individual agents contributing to gill disease.

To aid diagnostics of gill disease, the Norwegian Veterinary Institute has developed a multiplex PCR (gill package) which can detect four of the microorganisms related to gill disease in the sea: *Paramoeba perurans, Desmozoon lepeophtherii, Ca*. Branchiomonas cysticola and Salmon gill pox virus. Comparison of PCR results with histopathological analysis is recommended to allow identification of the pathogens and extent of the tissue damage. Recent studies based on histopathological methods have increased the possibility of uncovering the dynamics of the development of gill injuries. Special dyes, immunohistochemical methods and in-situ hybridisation (ISH) (RNAScope®) allow the microorganisms to be visualised in affected tissues and thereby provide valuable information on the cause and effect on gill tissues (Figure 8.1.2).

About prevention and treatment

For infectious gill disease, the same basic biosecurity requirements apply as for other infectious diseases. There should be strict requirements for documentation of fish stocks at the facilities, and there must be a focus on water quality for optimal water chemistry and the development of a good microflora. There are indications that smolts may already be infected with gill pathogenic microorganisms at sea-transfer. Disinfection of incoming water is therefore of extreme importance in juvenile production facilities. Disinfection of biofilters in RAS facilities should be considered when recurring gill problems are experienced. In an outbreak of disease due to salmon gill pox virus, feeding should be ceased, stress avoided and adequate oxygen levels maintained. Good generational separation and fallowing of sites is necessary before the transfer of new smolt to the sea. Since some sites have recurrent gill problems, it may also be important to consider the possibility of infection between neighbouring facilities. It is also important to maintain washing procedures for cage nets and semi-enclosed facilities which are designed and carried out in a way that as far as possible shields the fish from being exposed to particle loads and harmful growth organisms. Treatment of *Paramoeba perurans* is discussed in Chapter 7.4 Amoebic gill disease (AGD).

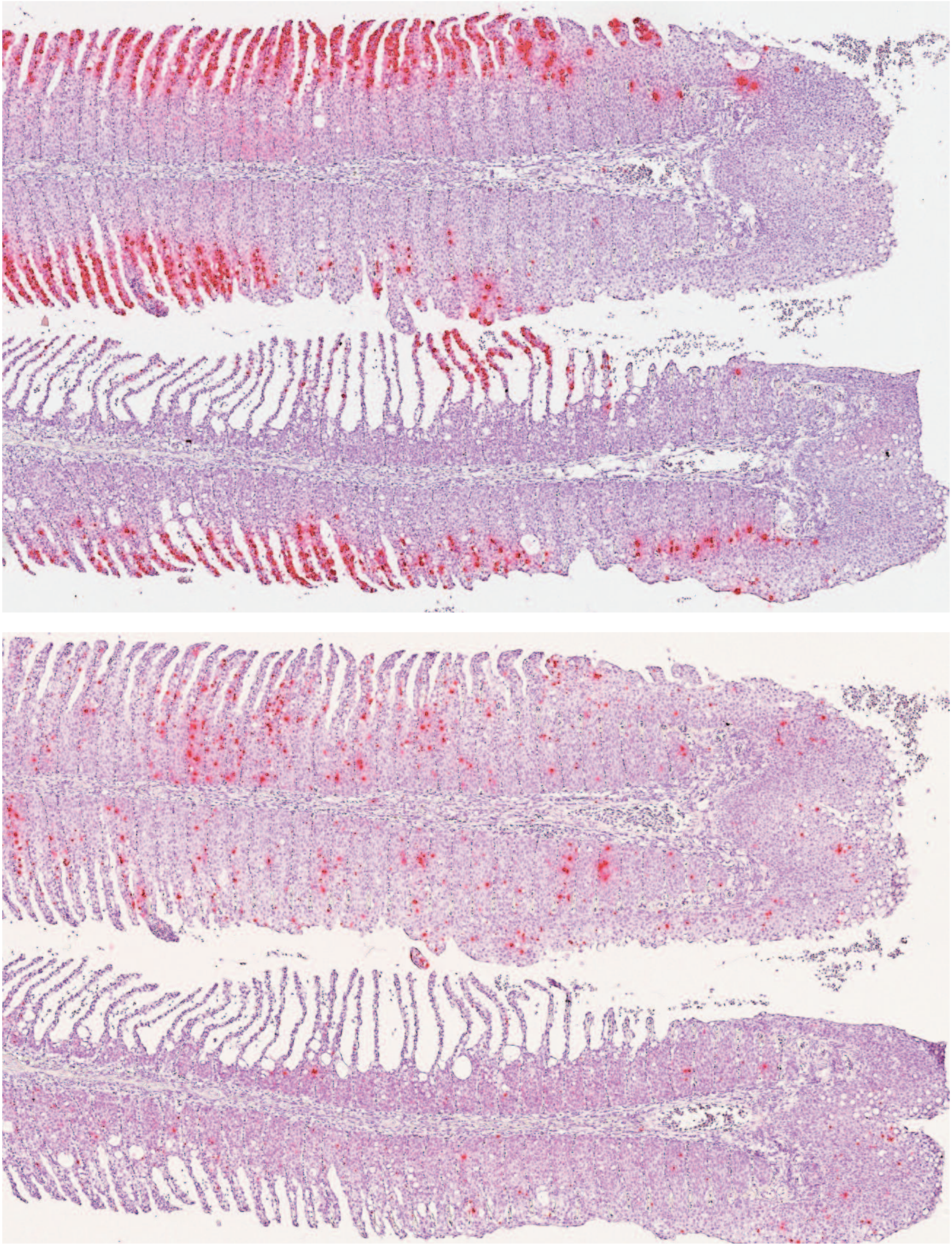


Figure 8.1.2 In-situ hybridisation (ISH) of the same gill filaments from a salmon with a probe (red colour) for the microsporidian *Desmozoon lepeophtherii* (above) and the bacterium *Ca*. Branchiomonas cysticola associated with epitheliocystisis (below). ISH technology can thus show the quantity and distribution of current gill agent along with the changes in gill tissue. ISH can provide better insight into the pathogenesis of complex gill disease in studies of disease progression and can provide important information about gill status in diagnostics.
Photo: Mona Gjessing, Norwegian Veterinary Institute.

The Health Situation in 2021

Gill disorders are not listed and are not reported to the Food Safety Authority. The prevalence of these conditions nationwide cannot therefore, be estimated with any degree of certainty.

Submissions to the Norwegian Veterinary Institute from salmon in fish farms with gill damage as the main or additional diagnosis were received throughout the year last year with a predominance of cases in April to June, compared to each of the other months. Many facilities experience extended periods of disease, lasting several months. Dominant findings were thickened and to varying degrees fused gills without any specific cause being detected. There are reasons to believe that water quality is an important factor in such cases. As in 2020, only few cases were diagnosed in which bacteria, parasites or fungi were involved. Infection of gills with salmon gill pox virus (SGPV) is discussed in Chapter 4.8. There were very few submissions for rainbow trout with gill problems in hatcheries.

In 2021, submissions from salmon in sea facilities with main or additional diagnoses concerning gills were distributed throughout the year with most in the spring-early summer and late autumn, a pattern seen for many years. In some farms the conditions appeared to persist over time. In a number of cases a complex aetiology was suspected. The cases in which epiteliocysts were involved (proven by histopathology) had a similar distribution in incidence throughout the year, with dominance in spring and autumn. In Norway, epitheliocysts on gills are most often caused by the bacterium Ca. Branchiomonas cysticola. There were also some detections of Costia (*Ichthyobodo* sp.) on gills in 2021, most often as part of complex gill disease, and these cases were mostly detected in the spring months. There were only a few submissions to the Norwegian Veterinary Institute for rainbow trout with gill diagnoses in sea facilities.

The Annual Survey

In the survey, fish health personnel and inspectors of the Food Safety Authority were asked to state which health problems they considered the top five in 2021, based on whether they were the cause of mortality, reduced growth, reduced welfare and an increasing problem.

For salmon in the hatchery phase, gill disease scores relatively low as a cause of death and as a cause of reduced growth. Gill disease in the freshwater phase is also low-rated in terms of reduced welfare. For rainbow trout (few respondents), gill disease is judged to have little impact on mortality, and as for salmon gill problems are to a small extent (rainbow trout) or not indicated as an increasing problem.

Complex/multifactorial gill disease is considered one of the main causes of reduced welfare in fish farming. Complex gill disease is also ranked relatively high among current disease problems in terms of reduced growth, increased mortality and as an increasing problem in the food fish phase. For rainbow trout, gill disease is judged to be of moderate importance for mortality, reduced growth, reduced welfare and with regard to an increase in incidence (few respondents). For details regarding ranking of gill health problems in the survey, see Appendix A–C.

Evaluation of the situation

The survey shows that gill disease is still a significant problem for salmon in the sea phase and of great importance both for the welfare of the fish and as a cause of loss. New knowledge, more tools and better monitoring have emerged in recent years, but significant efforts and open information exchange from all actors are still required to gain control.

8.2 Smolt quality and runt syndrome

By Synne Grønbech, Julie Christine Svendsen and Lisa Furnesvik, Norwegian Veterinary Institute.

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 there is then 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. Bacteriological and virological investigations are often negative.

The causes of runt development remain unknown and several possible factors may be involved. During the sea phase, it has been observed that fish having survived IPN, PD and/or parvicapsulosis may be extremely emaciated. 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. 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.

Runts are assumed to incur parasites and disease to a greater extent than healthy fish. Once they become carriers of disease, runts can thus increase the risk of further transmission of agents and contribute to outbreaks of disease. Tapeworm infections are an example of a normal finding in runted fish. 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 2021

Data from the Norwegian Veterinary Institute (NVI)

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 NVE from fish health personnel.

In 2021, the NVI diagnosed emaciation at eight salmon sites, which was about the same as in 2020 and 2019. These included six sea water sites, one hatchery, and one broodstock facility. IPNV was detected at one of these locations. Emaciation was also detected at one site farming trout. There were 35 cases this year where increased mortality was reported after the transfer of salmonids. The submitters of these cases reported HSS, nephrocalcinosis, ulcer problems (both of mechanical and probably bacterial causes) and environmental conditions in hatcheries. Several submitters also reported PRV-positive smolt, and/or clinical signs/possibly findings that may be reminiscent of HSMI. Finally, one submitter reported pseudosmoltification.

The Annual Survey

Approximately half of the respondents believe that mortality for salmon and rainbow trout has remained at approximately the same level as that of last year, both for hatcheries and in the ongrowing phase. The remaining respondents divide their responses between "lower mortality," "higher mortality," or "don't know". The proportion of respondents who answered "higher mortality" is somewhat higher when it comes to salmon recirculation facilities, but as the total number of respondents here is relatively low (33), this is associated with some uncertainty. This should be observed over several years, in order to be able to say something more about any development.

In the annual survey, fish health personnel and inspectors at the Norwegian Food Safety Authority were asked to indicate the five health problems which were most relevant for each of the categories mortality, reduced growth, reduced welfare and increasing prevalence at ongrowing farms and hatcheries.

With regard to smoltification problems in salmon in the hatchery phase, results from the survey ranks this as the fifth most important cause both for mortality and as increasing in prevalence, and in eighth place for reduced welfare. These are similar experiences as in the previous year. Emaciated fish/runts in salmon in the hatchery phase are the second most important cause (after nephrocalcinosis) of reduced growth, and also enters the top 10 list as one of the most important causes of

Salmon fry before smoltification. Photo: Johan Wildhagen.

mortality and reduced welfare (see Table 8.2.1 for ranking the top five problems for hatchery salmon).

There are significantly fewer respondents (probably reflecting fewer facilities with rainbow trout) 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 and deficiencies. Of these answers, smoltification problems appear to cause fewer problems compared to salmon, while runted fish are high on the list for mortality (first place), reduced growth (second place) and reduced welfare (third place).

Other important causes of mortality highlighted in salmonids in the hatchery phase are HSS, ulcers, IPN and nephrocalcinosis, while for welfare and growth, fin erosion, shortened gill covers and deformities are considered to play a greater role. See tables 8.2.1 and 8.2.2 for an overview of the respondents' ranking of the most important diseases/other challenges.

Table 8.2.1: 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)	Nefrocalcinosis	Fin erosion	Nefrocalcinosis
2	Wounds	**Loser fish**	Short operculum	Infection with non-virulent ISA virus
3	Infectious pancreas necrosis (IPN)	Short operculum	Nefrocalcinosis	HSS
4	Nefrocalcinosis	Deformities	HSS	IPN
5	**Problems with smoltification**	HSS	Deformities	**Problems with smoltification**

Table 8.2.2: 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	**Loser fish**	Deformities	Nefrocalcinosis	Deformities
2	IPN	**Loser fish**	Short operculum	Nefrocalcinosis
3	Deformities	Nefrocalcinosis	**Loser fish**	IPN
4	Nefrocalcinosis	Poor water quality	Deformities	Short operculum
5	Poor water quality	Short operculum	Fin erosion	HSMI

After seatransfer, deficient smoltification and runt syndrome are both regarded as relatively less important than in the hatchery phase. However, they are significant problems for salmon and are now re-entering the top 10 list for causes of mortality (places 9 and 10, respectively). For both salmon and rainbow trout, runt syndrome is still highly ranked as a cause for stunted growth.

For more details regarding ranking of smoltification problems and runt syndrome, see appendices A1-2 and B1-2.

Like previous years, respondents of the survey have described issues related to smolt quality and runt syndrome in free text fields. An example for the hatchery phase is the increasingly intensive management, due to inadequate supply of smolt, which leads to higher fish densities and reduced water quality and welfare. Furthermore, it is commented there are production plans with an intended surplus stocking of roe, which leads to a subsequent culling of runted fish. In recirculation facilities it is reported that runted fish develop from unknown reasons, but also as a result of production and investments being prioritised over fish biology. Moreover, protracted chronic gas supersaturation results in reduced growth. Challenges in connection with the production of larger fish in hatcheries were also described. Examples include a higher incidence of nephrocalcinosis and HSS. On a raised level, it was commented that the ambition for producing large smolt might be greater than necessary experience and investment ability.

In the seawater phase the timing of sea transfer is particularly emphasized. Especially the importance of avoiding transfer of small fish when sea temperatures are low, as this often results in ulcer development and weakened fish. A particularly important challenge is to plan for smoltification to coincide with the time point when the sea sites are ready to receive smolt after the appropriate fallowing time. If this fails, premature smoltified fish must wait to be sea transferred to meet the required time of fallowing.

Evaluation of the smolt quality and runt syndrome situation

The use of large smolts continues to increase as part of the strategy to limit infection with salmon louse, and other viral and bacterial diseases. Several RAS facilities are constructed to be able to produce large smolts. Some have established good routines for production of smolts up to 300-600g in weight. Increased biomass leads to even greater challenges with water quality and synchronisation of smoltification. It is reported that pseudosmolt production associated with continuous light and seawater supplement, and de-smoltification, are problematic in RAS facilities. Fluctuations in water temperature in flow-through facilities remain challenging for smoltification, especially in the production of smolt designated for sea transfer in the spring.

In 2021, nephrocalcinosis and HSS are stated to be the two largest challenge in salmon hatcheries with regard to reduced growth and mortality (see Chapters 8.3 and 8.4). It can be assumed that HSS is a contributing factor to the mortality associated with smoltification problems in hatcheries. It is further reported that IPN (see Chapter 4.3) is a somewhat increasing problem. This may possibly be linked to runt development in the sea phase, but whether this is a more important causal factor than others for 2021 is speculative.

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 and difficult to define. 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.

8.3 Nephrocalcinosis

By Anne Berit Olsen and Arve Nilsen

The Disease

Nephrocalcinosis (renal calcification, kidney stones) has been most common in rainbow trout in intensive farming, but is gradually also becoming a common finding in salmon. The disease is considered related to production and is not infectious. Mortality in connection with nephrocalcinosis is generally low, but may be elevated by e.g. handling and sea transfer. Precipitation in the kidney is the result of abnormal physiological conditions in the fish and often such fish have reduced growth.

Nephrocalcinosis is an important welfare indicator in farmed fish as the condition is related to the balance between water usage and volume of fish. Diagnosis of nephrocalcinosis is almost certainly an indicator of several reduced welfare parameters.

Early-stage kidney changes are not visible, but are uncovered by microscopic (histopathological) examination as precipitation of calcareous material in the kidney excretory system where urine production takes place. Precipitation may cause clogging of kidney tubules. The cell lining (epithelial cells) in the inner surfaces of these tubules are often damaged. Consequently, the haemopoietic tissues surrounding the tubules will become fibrinous. In severe cases, the deposits can penetrate the tubuli and lead to inflammatory reaction in surrounding tissues.

Precipitation in the kidney tubules will eventually be visible as longitudinal white stripes (Figure 8.3.1). The kidney can also become enlarged and knotted. The changes may be extensive, such that the function of the kidney may be impaired. Kidney lesions related to nephrocalcinosis may in some cases be extremely similar to those associated with the notifiable bacterial kidney disease (BKD), and should be diagnostically investigated.

Development of kidney stones can probably have various causes, or the causes may also be complex. The precipitation may have different consistency, which may indicate different composition and cause, or there may be different stages of the same precipitation. Based on investigations to date, the composition of the stones may vary somewhat, but they most often contain most calcium phosphate. Often magnesium is also present.

While published work shows that non-optimal mineral content in feed can result in nephrocalcinosis, by far the most commonly attributed cause is high levels of CO_2 in the water, occurring due to intensive water-saving operational routines. Not all studies can document the relationship between high levels of CO_2 and nephrocalcinosis, and it has also been speculated that fluctuations in other water quality parameters may have an influence. The mechanisms are not fully understood, but high CO_2 content in the water changes the composition of blood plasma in the fish, which in turn can cause metabolic challenges. The recommended highest level of CO_2 in salmon farms is 15 mg/L, but recent research has shown that harmful effects of CO2 can also occur at lower values, perhaps especially related to water with a proportion of seawater. Several projects are currently focusing on identification of risk factors for the development of kidney stones.

Nephrocalcinosis is often an additional finding in the disease haemorrhagic smolt syndrome (HSS), see Chapter 8.4. A typical finding in HSS is bleeding in renal tubuli, causing the fish to get bloody urine. Whether the calcious precipitation can be linked to the bleeding has not been clarified, but is being investigated.

Nephrocalcinosis is most commonly found in pre-smolt, smolt and post-smolt. An increased prevalence is associated with seawater supplementation in the post-smolt phase. Nephrocalcinosis can be found in rainbow trout through most of the sea phase. Mild and moderate kidney damage will most often heal eventually without treatment. Pronounced kidney damage will not heal and results in increased mortality.

Disease control

Nephrocalcinosis is considered an environment-related problem. Ensuring good quality intake water, adequate surveillance and optimisation of level and stability of water in cage and tank, including pH and CO_2, together with sufficient flow-through (specifically water consumption), will reduce the risk of nephrocalcinosis development. It is important that monitoring of water parameters and metabolic waste substances such as CO_2 is done systematically and with good equipment and is adapted to the production of vessels and facilities. There may also be grounds to reconsider seawater supplementation during smoltification and the transition to post-smolt.

Nephrocalcinosis has in some contexts been associated with an unbalanced feed. A feed adapted to the needs of fish during different stages of development and environmental conditions may therefore be of importance for the prevention of the disease.

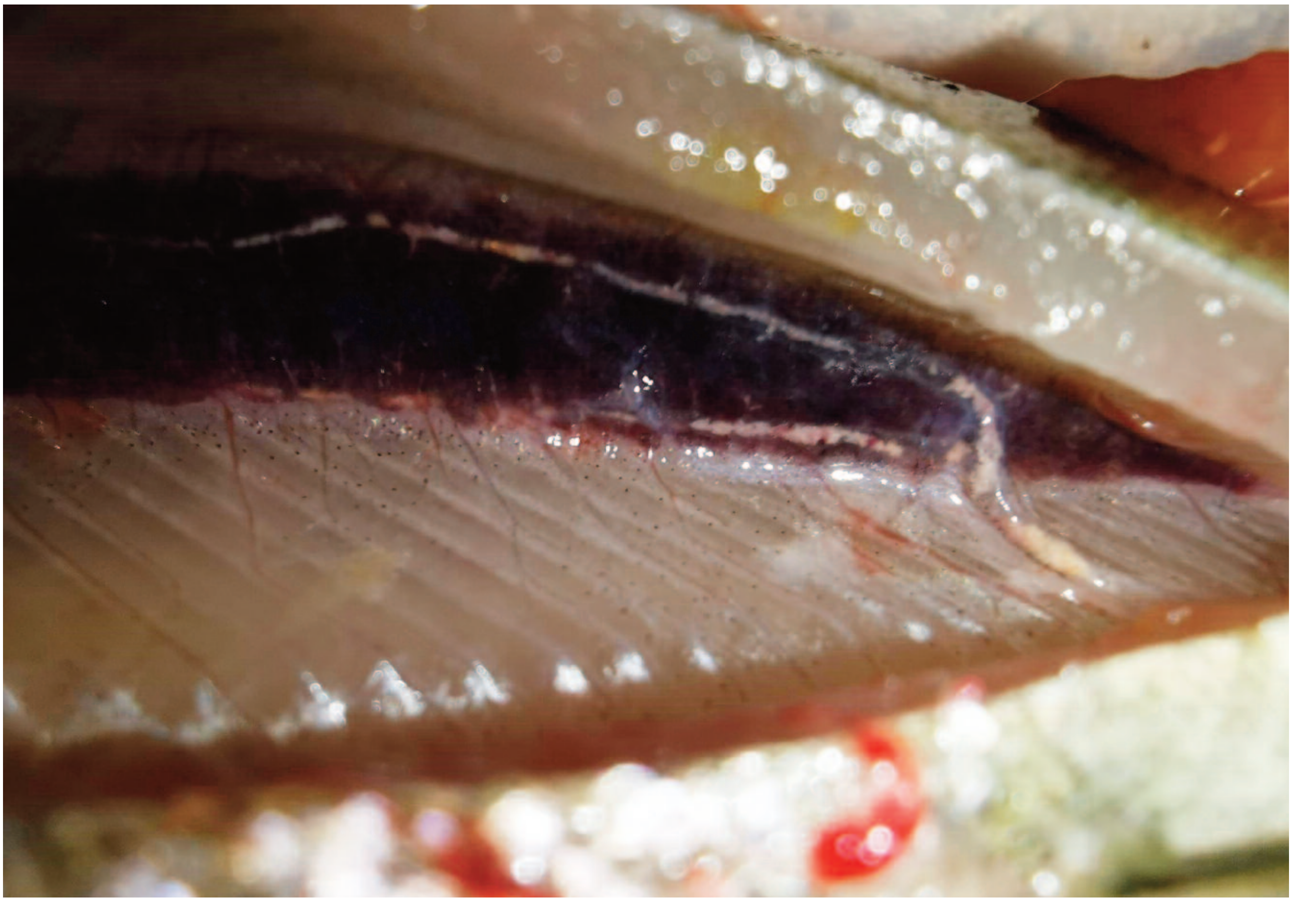


Figure 8.3.1 Nephrocalcinosis in smolt from a hatchery just before sea transfer. There is clear precipitation in the ducts and urinary bladder. In the event of such changes, we also find damage to kidney tissue and kidney function.
Picture: Magnus Kjellstad Lian, STIM AS.

The Health Situation in 2021

It is uncertain how many facilities were detected with nephrocalcinosis in 2021, and laboratory figures for this condition are nevertheless an underestimate. The disease is not listed and diagnoses are often made in the field on the basis of typical visible kidney changes. Nephrocalcinosis diagnosed by histopathology in the laboratory is in many cases a coincidental finding.

The Annual Survey for 2021

For salmon in hatcheries, nephrocalcinosis was crossed off as the main cause of reduced growth and as a growing problem and ended up in third and fourth place respectively for reduced welfare and increased mortality. Overall, and as in 2020, nephrocalcinosis tops the list of the most important health challenges for salmon in the hatchery phase in 2021. For rainbow trout in hatcheries, nephrocalcinosis falls into second place by deformities. In 2020, the disease topped the list for rainbow trout. Nephrocalcinosis was considered to have limited importance for mortality, reduced growth and reduced welfare of salmon in the sea phase, but some respondents cite nephrocalcinosis as a growing problem here as well. When it comes to rainbow trout (few respondents), nephrocalcinosis achieves the highest score for reduced welfare and increasing problem, and also gets some points as the cause of increased mortality and reduced growth. Of the health conditions that were of national importance for rainbow trout in the sea, nephrocalcinosis came in second place in 2021.

The survey gives the opportunity to score water quality in hatcheries for effect on mortality, growth, welfare and as an increasing problem. The overall score for salmon gives it ninth place, which is further down the list than in 2020. For rainbow trout, there were few respondents and water quality end up in fifth place out of ten current health challenges. There are grounds to believe that improvement in water quality may improve the nephrocalcinosis situation. For details, see Chapter 8 Water Quality, and appendices A1-A2 and B1-B2.

Evaluation of the nephrocalcinosis situation

Without official statistics, it is not possible to give a complete annual overview of the real situation of nephrocalcinosis in farmed salmonids. The results of the survey clearly show that nephrocalcinosis is still a common diagnosis and of importance for the health and welfare of both salmon and rainbow trout in hatcheries.

RAS farms are considered at higher risk for the development of nephrocalcinosis, which is probably related to water quality issues. There is a need for more systematic registration of the condition before valid comparisons can be made between flow-through and RAS sites.

In ongrowing facilities, nephrocalcinosis is commonly diagnosed during the first three months following sea-transfer. The fish probably brought this damage with them from the hatchery. In a few sea facilities, high mortality as a result of nephrocalcinosis was recorded relatively shortly after transfer to sea, but in some facilities the incidence of nephrocalcinosis lasted for several months after transfer. The disease was also detected in 2021 in some cases in large fish, from about 1.5 to 3 kg.

8.4 Haemorrhagic smolt syndrome (HSS) / Haemorrhagic diathesis (HD)

By Geir Bornø, Anne Berit Olsen and Toni Erkinharju

The Disease

Haemorrhagic smolt syndrome (HSS), also called haemorrhagic diathesis (HD), is a condition that commonly occurs in salmon late in the hatchery phase or soon after sea-transfer. Affected fish often display haemorrhages in the musculature, peritoneum and inner organs. Haemorrhage in the skeletal musculature, perivisceral fat, kidney and heart are particularly common (Figure 8.4.1).

The cause of this condition is unknown, and there are as of yet, no indications that it is caused by an infectious agent. It is presumed to be related to osmoregulatory problems during smoltification, but there is little literature available on the subject. HSS does not normally result in significant mortality, but occasional incidences are reported of several thousand individuals with the condition, and a relatively high acute mortality. The situation usually normalises within several weeks post sea-transfer.

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 however, extremely important that serious, infectious diseases such as viral haemorrhagic septicaemia (VHS) are considered as differential diagnoses, as this disease results in a similar clinical picture. In case of suspicion of HSS, samples should therefore be secured for histopathological examination and PCR detection of VHS viruses in order to exclude this and/or other infectious diseases that cause similar bleeding.

The Health Situation in 2021

Data from the Veterinary Institute

Based on available consolidated statistics related to diagnosis of HSS, a total of ten unique farms had HSS detected in 2021. Of these, six were hatcheries, three were ongrowing facilities and one was a cultivation plant.

The Annual Survey

In the survey of fish health personnel and inspectors at the Norwegian Food Safety Authority, HSS is cited as one of the five main causes of mortality in salmon in the hatchery phase by 27 out of 47 respondents (57 percent), and is thus ranged at "top" as a cause of death in hatchery salmon (Appendix A1).

As a cause of reduced welfare, 22 out of 51 respondents (43 percent) say that HSS is among the top five. A lower proportion indicated HSS as an important cause of reduced growth or increasing problem (25 percent of respondents) in salmon during the hatchery phase. HSS is considered a minor problem in hatchery raised rainbow trout.

Reports from the field indicate that the condition is on occasion associated with high mortality and is considered a serious problem in some farms.

Evaluation of the HSS situation

In the annual survey for both 2020 and 2021, HSS was considered the most common cause of mortality in hatchery salmon. This condition has been recognised for many years, but the causes remain very poorly understood. One of the aims of a current project investigating this disease (FHF project 901588) under the auspices of the Norwegian Veterinary Institute is to identify risk factors and aetiological relationships. It is perhaps surprising that HSS has had so little previous attention as a health problem in the hatchery phase.

Figure 8.4.1. Salmon from smolt facility with HSS, where you see bleeding in the skeletal muscles and liver. Photo: Lisa Furnesvik, Norwegian Veterinary Institute.

8.5 Water quality

By Kamilla Furseth, Endre Steigum and Åse Åtland, Norwegian Institute for Water Research (NIVA), Aquaculture Section

Knowledge and control of water quality is essential to ensure survival, growth and good fish welfare. The various water quality parameters operates in a complex interaction where one parameter can both reinforce or protect against the toxicity of one or more other parameters. The industry is transforming towards more recycling of water (RAS facilities), whereas flow-through facilities are reusing more of the water and keeping post-smolt longer on land. In the sea, we see the emergence of closed and semi-closed facilities. All new technology and changes in modes of operation entail new challenges to monitor and ensure suitable water quality for the fish.

This is the fourth year with water quality as a separate topic in the Fish Health Report, and we at NIVA see that many of the water quality challenges presented in previous years are still relevant in 2021. Here we will focus on the trends we have observed over the last year in both land-based and sea-based farms. The following review is based both on separate registrations in NIVA, and the results from the survey carried out by the Norwegian Veterinary Institute for the Fish Health Report.

Land-based facilities

In 2021, NIVA registered several incidents of more or less severe water quality in both recirculating and flow-through facilities.

Gas supersaturation/nitrogen supersaturation

In 2021, we have experienced fewer incidents of acute mortality related to gas or nitrogen saturation than in 2020, which is also reflected in the survey. In the 2020 survey, 19 and 27 % of the respondents answered that gas saturation had a negative impact on the fish in flow-through and RAS facilities, respectively. In the 2021 survey, 7 % (flow through) and 13 % (RAS) responded that they had observed a negative impact in the fish due to gas saturation. Since this type of mortality often occurs acutely, it is still a relevant risk factor for the hatcheries. However, we hope the lower numbers represents a lasting trend.

A challenge with gas saturation is that there are currently no clear limits for the negative effects of high gas saturation in the water of Atlantic salmon, but it is a recommendation to keep total gas pressure (TGP) below 100 %. The relationship between TGP and nitrogen saturation, which is a main focus in aquaculture, is well described in the Fish Health Report for 2020.

Total gas pressure is a parameter that must be measured on site and not in a laboratory afterwards. There is a high demand for stable and reliable sensors, and also some uncertainty and confusion about the difference in importance between nitrogen gas saturation and total gas saturation related to gas bubble disease in fish.

In fish with acute gas bubble disease, small air bubbles can be observed around the edges of the fins and the eyes and gills. NIVA registered few individual incidents where such symptoms were described in 2021. Chronic gas saturation over a long period of time may be more difficult to identify and requires well-maintained sensors and good routines for measurement. Some sites report reduced appetite, behavioural changes and fish health challenges as a result of elevated TGP over long periods of time, and this should be followed up further.

Hydrogen sulphide

In 2021, we received some enquiries for analysing hydrogen sulfide (H_2S) in water with fish, but few cases of H_2S were detected and linked to mortality in land-based facilities. NIVA has further developed a well-known method and achieved detection of H_2S down to 1 µg S^{2-}/L. Sensors have also been developed that can measure H_2S continuously in facilities to these low levels. This commitment to method development means that the fish farmers now have far better tools for uncovering risk or explaining any production deviations.

Toxic effects of high levels of H_2S in RAS received a lot of attention in 2018 and 2019. To form H_2S, anoxic (oxygen-free) conditions with the presence of sulfate and low nitrate levels are required. Since seawater contains far higher concentrations of sulfate than freshwater, there is a risk associated with seawater interference in hatcheries and the formation of mixing zones. All together, these conditions give the bacteria what they need to break down organic matter and form H_2S. H_2S formation can occur in biofilm, often this happens in places with stagnant water or low water flow. It has also been shown in experiments that the biofilter can be the starting point for H_2S formation in RAS facilities.

Fewer incidents of H_2S-related mortality were observed in 2020, and this trend continued in 2021.There are several facilities where low concentrations of H_2S are detected; this is due to the low detection limits and analytical methods that have been developed. It is evident that the industry has increased its focus on H_2S and several hatcheries have taken measures to prevent several major mortality incidents like pH regulation, cleaning, better control of feeding and preventing the accumulation of sludge. Removing dead zones and optimising water speed and flow through the facility are important measures. The survey reflects this trend that we see related to H_2S problems; In 2018, 57 % of responders answered that they had experienced H_2S problems that had adversely affected welfare in RAS facilities, while 31 % answered the same in 2019, 10 percent in 2020 and 11 % in 2021 (Figure 8.5.1). We hope that increasing knowledge of the problem has helped in this reduction in the number of H_2S cases.

Aluminium and metals

Metal problems related to intake water and the accumulation of aluminium and copper on the gills are found in freshwater facilities with a large supply of new water, where water sources often show a large seasonal variation.

The survey suggests that negative effects of metals at RAS facilities are increasing, while this appears to be a decreasing trend at flow-through facilities. At NIVA we saw several cases of an increase in metal concentrations in the water related to flood episodes at flow-through

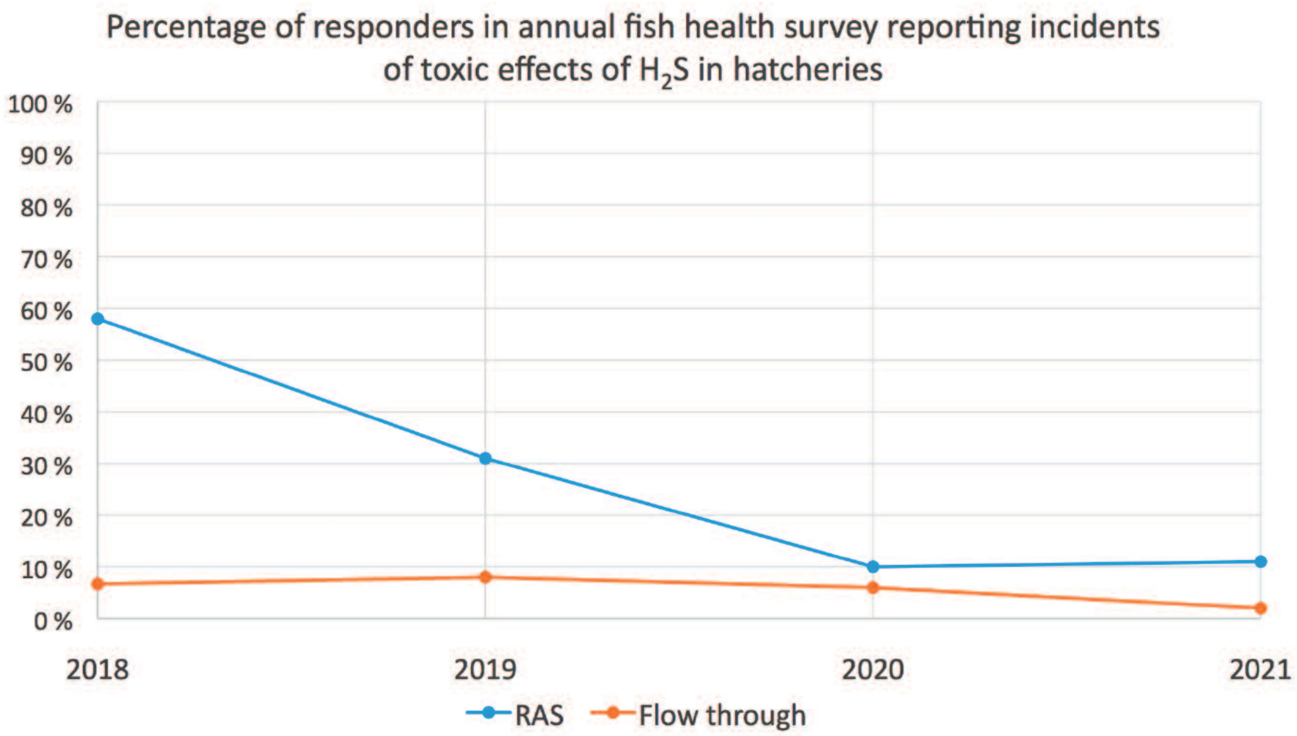


Figure 8.5.1 Results from the survey on the question of whether H_2S problems have been experienced that adversely affected welfare. The number of respondents (N) for RAS in 2018 was (N=21), 2019 (N=26), 2020 (N=30), and 2021 (N=38). The number of respondents from flow-through facilities in 2018 was (N=30), 2019 (N=36), 2020 (N=36) and 2021 (N=42).

facilities, but few cases with large metal accumulation on the gills. This suggests that the facilities have become much better at water treatment measures (mainly silicate dosing) to detoxify aluminium and other metals, and that people are aware of risks related to, for example, mixing zone problems. At RAS facilities, many are concerned with concentrating, for example, copper and other heavy metals in water at a high recycling rate. Awareness among the fish farms to monitor this has increased in recent years.

Inadequate calcium levels

In 2021, we will see some enquiries from broodstock facilities, hatcheries and fry producers who have ion-poor acidic water with low buffer capacity. Several have expressed concern that low calcium levels can cause problems for fish by, for example, ion regulation challenges and poor gill health. Often it is in vulnerable phases of the life cycle where these issues become most relevant. It has long been known from research that calcium in the water has a protective effect on metal toxicity in fish. Nevertheless, no lower recommended limit for calcium has been established in the water. More research is needed on the effect of calcium on fish health, and possibly establishing recommended limit values for salmon in aquaculture.

The main sources of negative fish welfare in RAS and flow-through facilities

The survey states that CO_2, gas saturation and turbidity are considered the main factors that adversely affected fish welfare at RAS facilities in 2021, a change from 2020 where nitrogen compounds (ammonia and nitrite) were one of the main factors. These parameters are often associated with the operating intensity of the facility. At flow-through facilities, CO_2 also comes high on the list together with temperature, similar to 2020. The number of respondents that mentioned the negative impact regarding CO_2 at flow-through facilities has decreased from 2018-2020, but the number increased in 2021 from 42 % in 2020 to 48 % in 2021.

High values of CO_2 expose the fish to respiratory stress, and the long-term effects of CO_2 are increased incidence of nephrocalcinosis, reduced growth and possibly increased mortality. It is evident from the survey that some farmers have experienced cases of elevated CO_2 along with cases of nephrocalcinosis, some link this to excessive density, while others are unsure of the cause. CO_2 also leads to lower pH, which in turn affects chemical compounds that have a pH-dependent state, including aluminium and possibly sulphides. Data from the water quality surveys suggest that salmon smolt may have problems when CO_2 exceeds 13-15 mg/L, but there is also experience from salmon and trout farming that higher CO_2 concentrations can be unproblematic. It seems that a steady increase in CO_2 concentration is less problematic than sudden fluctuations, or when CO_2 occurs together with other stressors.

The survey points out that the main factors that affect the welfare of fish can be linked to increased intensity in the hatcheries, reflecting the need to work with proper dimensioning of facilities, adequate water treatment and water consumption.

Of cases received in 2021, we saw that the fish farmers have better control over nitrogenous waste products, and that this is to a lesser extent linked to mortality and other production deviations. This is probably related to the increased awareness in the last years, more capacity at the facilities to do their own monitoring and a consolidation of water chemical competence in the industry through training in RAS and fish welfare.

Turbidity was a question in the survey, and although there are fewer than in the years before, 23 % still answered that this is a parameter that negatively affects fish welfare in RAS. Turbidity is one of several parameters that say something about the particle load in the water that many people are concerned about, especially in RAS facilities. Turbidity, like TOC and the colour of the water, gives a general picture of particles in the water. Naturally, many RAS facilities want to know more about the size of particles in the water and how they may be concentrated, how they can be removed and how it affects the fish. In recent years, researchers from NIVA have carried out several inspections at RAS facilities and carried out so-called Particle Size Distribution analyses (PSD) to uncover more information about particles that have been dissolved in the water. The feedback from the fish farmers in the survey shows that they want to understand more about particles in RAS, how it relates to feeding, microbiology, fish behaviour, and there is speculation about how this can be linked to fish health, among other things, unspecific gill irritation.

Sea facilities & wellboats

Enquiries from sea facilities in 2021 were much about mortality after sea transfer or mortality after returning fish from wellboat operations during delousing, AGD treatment or transport. We see that the problems may be related to disturbances in ion regulation, metal poisoning and/or gas problems as described above. Research is still needed to precisely address these problems in connection with time-limiting operations in wellboats. It is gratifying to see how FHF is now addressing these issues in newly financed projects.

In connection with freshwater treatment of salmon in the sea, there has been a risk of H_2S formation when freshwater is stored in reservoirs, and in 2021 there were cases where NIVA uncovered the risk of poisoning from H_2S. H_2S can occur when seawater spills into such freshwater depots in bags in the sea. The seawater, which has a higher density than freshwater, will then sink to the bottom of the depot and can form an oxygen-poor seawater layer with H_2S. If this "dead" seawater mixes with the rest of the freshwater layer, H_2S can follow over to the well with fish, and this could create toxic conditions. A risk-reducing measure may be to measure oxygen and salinity at the bottom of the freshwater depot prior to pumping to determine whether a "dead" seawater layer is at the bottom. The farmers should consider whether the practice of keeping freshwater reservoirs in bags in the sea is suitable at all. Our assessment is that this is an unnecessarily high risk.

Summary

The precautionary principle means that most of the farmers are concerned about the classic causes of production deviations in Norwegian hatcheries; metals in the intake water, acidity and buffer capacity, ammonia and CO^2. At the same time, we need to be aware of the "new" issues related to RAS such as particles in the water and H_2S.

The hatcheries seem to be at the forefront of many of the situations that cause major problems previously. This is done through increased preparedness in the form of systematic water analyses, emergency response boxes for sampling at acute events and increased demand for training and a consolidation of internal expertise in water chemistry and measuring equipment at the facilities. We see an even closer collaboration between veterinarians and the fish health services with NIVA to see fish health in light of the quality of the water and changes in this.

Knowledge and control of water quality and the environment of fish is essential to ensure survival, growth and good welfare. Photo: Eivind Senneset.

8.6 Vaccine efficacy/side effects

By Kristoffer Vale Nielsen, Sonal Jayesh Patel and Ingunn Sommerset

Vaccination is an important part of preventive health work in fish farming. The vaccination of salmonids has led to the outbreak of historically important bacterial diseases (such as cold-water vibriosis and furunculosis) being very rare. Vaccination has therefore contributed to lower losses, dramatically reduced antibiotic use and improved fish welfare.

Vaccination of fish is regulated according to the aquaculture legislation (Akvakulturdriftsforskriften, paragraphs 11 and 28) and chapter 13 of the “Trade and Disease in Aquatic Animals” legislation. The legislation describes in general terms the requirement to perform relevant infection prevention measures including vaccination. Mandatory vaccination against PD in the area from Taskneset (Fræna) in the south to Langøya near Kvaløya (Sømna) in the north (corresponding to PO6 and PO7), is currently on hold and postponed until the Ministry decides otherwise.

Fish may be vaccinated by dipping, bath immersion, orally via feed and by injection. In Norway, intraperitoneal injection of multivalent oil-based vaccines is the most common form of vaccination in salmonid fish. At the same time, it is this method that causes the greatest side effects. Single-component vaccines are often used, and these can be with or without oil adjuvant for intraperitoneal disposal (such as inactivated PD and yersiniosis vaccine) or given intramuscularly without oil adjuvant (DNA vaccine against PD).

Farmed salmon in Norway are usually vaccinated against furunculosis, vibriosis, cold water vibriosis, winter ulcer (*M. viscosa*) and IPN. It has been common to vaccinate against PD in Western Norway (endemic area for SAV3), but salmonids is vaccinated against PD also in other areas. In Trøndelag and parts of Western Norway, it is also common to vaccinate against yersiniosis. Vaccination against ISA in Norway was limited until 2020, but an increase was reported in 2021. There is only a limited selection of vaccines for marine fish.

Recognised vaccine side-effects following injection vaccination utilising oil adjuvants in salmonid fish normally consist of growth of connective tissues

Figure 8.6.1 Minor adhesions and melanin deposition around the injection site. Photo: Kristoffer Vale Nielsen, Norwegian Veterinary Institute.

between the inner organs and between the inner organs and the peritoneal walls, melanin deposition, reduced appetite and reduced growth (Figure 8.6.1). Spinal deformities are registered as vaccine induced side effects, with a particular 'cross-stitch vertebrae' deformity associated with oil-adjuvanted PD-vaccination.

The various vaccine side-effects are presumably painful for the fish and the degree of side effects will vary with vaccine type and various parameters such as fish size at vaccination, degree of misplaced vaccination, injection pressure, water temperature, hygiene etc. Given the extensive use of vaccination in Norwegian aquaculture and negative welfare aspects of vaccination, it is important that a focus be maintained on reduction of vaccine related side effects. There is still more to be done in relation to the risk of undesirable side effects when using current oil-based types of vaccination. The vaccination process itself should be performed under optimal conditions on healthy fish under continual monitoring.

More recently, there has been an increased focus on pathogens mutating and forming new types or variants. In the aquaculture industry, there are indications that a new variant of *M. viscosa* is of increased importance. It has also been feared that a new variant of the IPN virus may be on the rise. In such situations, it is important to clarify whether the vaccines used also provide protection against the new types of agents. The relationship between the efficacy and side effect of vaccines is also important to consider. For example, using a vaccine that provides limited protection and at the same time has obvious side effects will be ethically difficult to defend. The degree of protection a vaccine provides must therefore always be seen in the light of the degree of side effects.

The Annual Survey for 2021

Fish health personnel and inspectors at the Food Safety Authority were asked about the efficiency and side-effects of current vaccines used in salmonid fish. 58 out of 99 respondents (58.6 %) replied that they had experience with vaccination of salmonid fish, side-effects or degree of protection following vaccination. The results of the survey give an impression of the opinions of professionals in the industry on the topic of vaccination, and results (numbers) must therefore be interpreted on this background.

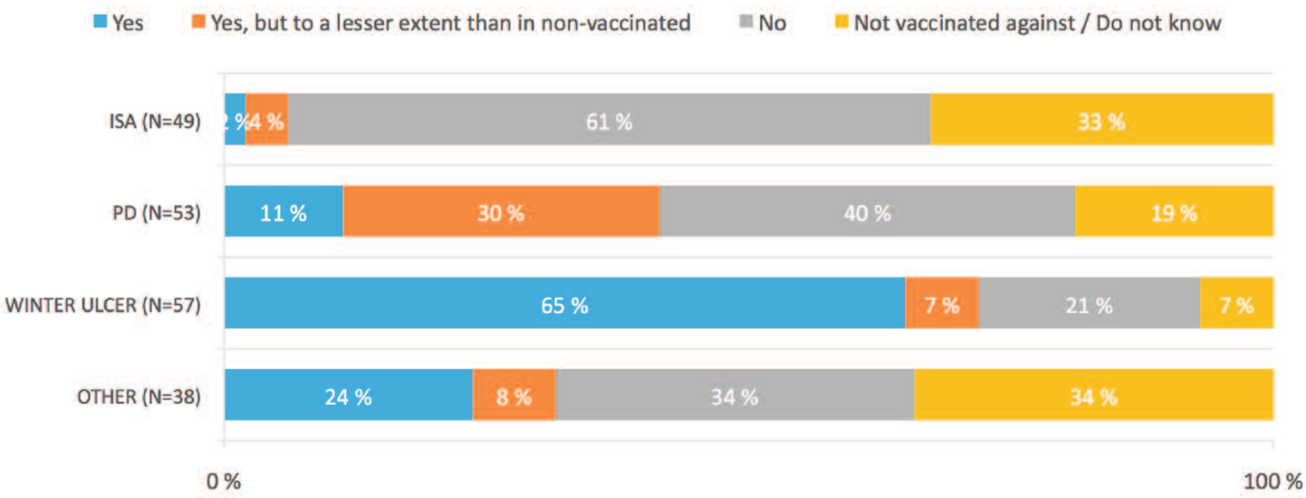


Figure 8.6.2 Summarised answers to the question: Have you experienced clinical outbreaks of the following disorders despite the fact that the fish are vaccinated against these diseases? N is equal to the number of respondents who answered the question for each of the diseases ISA, PD, Winter Ulcer (*M. viscosa*) and Other.

The first question read: Have you experienced clinical outbreaks of the following disorders despite the fact that the fish were vaccinated against these diseases? The diseases ISA, PD, Winter Ulcer and Other were asked specifically. There were four answer options for each disease: 1) "Yes", 2) "Yes, but to a lesser extent than in non-vaccinated", 3) "No" and 4) "Not vaccinated against / Do not know". The results show (summarised in Figure 8.6.2) that there are generally few outbreaks of ISA in ISA-vaccinated fish (3 out of 33 responses). In the case of PD-vaccinated fish, there are several outbreaks (22 out of 43 responses), but here several (16 out of 22) report that outbreaks had less impact than in non-vaccinated fish. Outbreaks of winter ulcer occur relatively often despite vaccination; 41 out of 53 respondents have experienced this, and of these only four reported recuded clinical impact as a result of vaccination. Twelve out of 25 have experienced outbreaks of “Other” diseases despite vaccination to combat them. In the follow-up question to questions about lack of vaccine efficacy, one could in free text elaborate on the specific cases. Of the 29 responses, 14 dealt with winter ulcer, eight PD, six IPN, two ISAs, one furunculosis, one vibriosis (rainbow trout) and one atypical furunculosis (lumpfish).

Acute side-effects are often associated with intraperitoneal vaccination in the hatchery phase. These events are perhaps more related to the handeling of fish and processes surrounding vaccination rather than the vaccines themselves. Acute side-effects of vaccination will often manifest as reduced appetite or increased mortality over a short period. Other undesirable events may occur in association with vaccination, which may influence vaccine success. Vaccine leakage through the infection channel may result in fish receiving a lower vaccine dose than planned. Misplaced injections or deposition of the vaccine can result in increased severity of the side effects or reduced efficacy, and contamination of vaccination equipment may result in infection and mortality in fish shortly after vaccination.

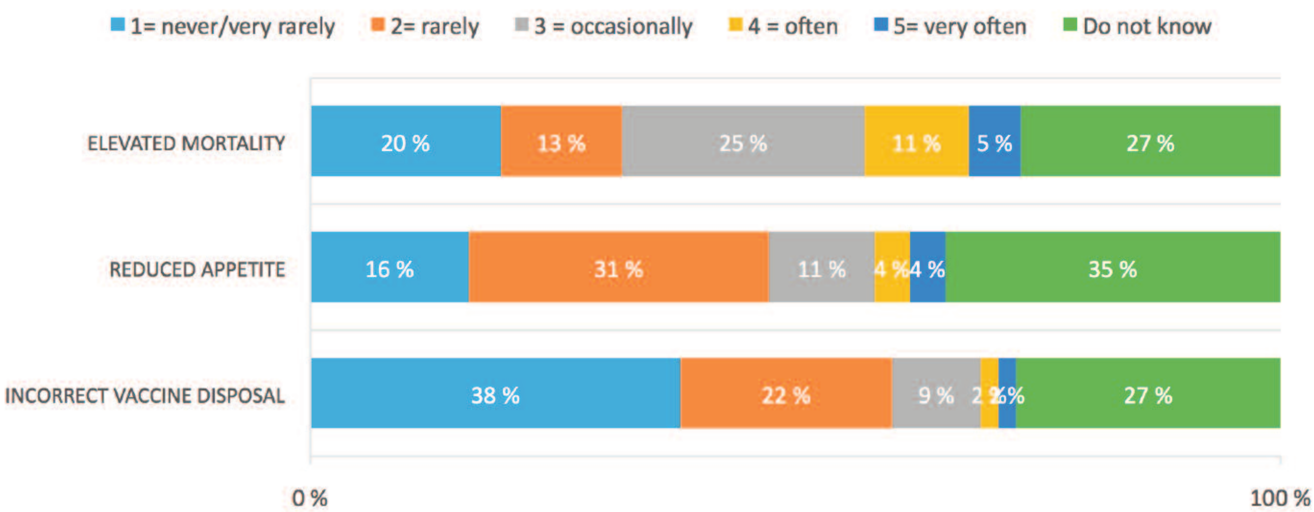


Figure 8.6.3 Summarised answers to the question: How often do you experience the following acute side effects of vaccine and vaccination process in hatcheries? Elevated mortality after vaccination (N=56); reduced appetite beyond 7 days duration (N=55); deposition in more than 5 % of the vaccinated fish (N=55). Replies were ranked on a scale of 1-5, where 1 = ‘very rarely/never’, 5 = ‘very common’ and another response option ‘don’t know’. The columns for each acute side effect indicate, as a percentage, the number of respondents who have given the different answer options and N is the number of respondents who have answered the question.

We asked "How often do you experience the following acute side effects of vaccine and vaccination process in fish farms", and the responses were indicated on a scale of 1 to 5, where 1 corresponds to "very rarely/never" and 5 corresponds "very often". The results (Figure 8.6.3) show that many of the respondents believe that acute side effects and undesirable events occur "very rarely/never" or "rarely". Elevated mortality after vaccination is a more common finding, and more respondents indicate that it occurs "often" or "very often". The spread of the responses reflects the fact that there is room for improvement of vaccination methods and fish handling at some facilities. The follow-up question "Do you have other/in-depth comments regarding acute side effects of vaccine and vaccination process (e.g. vaccine leakage, sea-transfer before the recommended number of degree days for immunity)?" was answered by 14 respondents. Six responses dealt with sea transfer before the recommended number of degree days, five responses dealt with vaccination technology or handling and one response to post-vaccination mortality.

We also asked "How often do you experience the following long-term side effects of vaccine in ongrowing sites/ harvest facilities", where the sub-questions dealt with spinal deformities, reduced growth, melanin in fillets and the degree of adhesions between organs in the abdominal cavity (Speilberg score). Replies were ranked on a scale of 1 – 5, where 1 = 'rarely/never' and 5 = 'very common'. The results (Figure 8.6.4) show that most respondents believe that long-term side effects over a certain extent occur relatively rarely. The variable responses do indicate, however, that there is still room for improvement concerning risk of long-term vaccine side effects. The follow-up question "Do you have other/in-depth comments regarding long-term vaccine side effects?" was answered only by five respondents. This reinforces the impression that long-term side effects of vaccine are not considered to be a major problem.

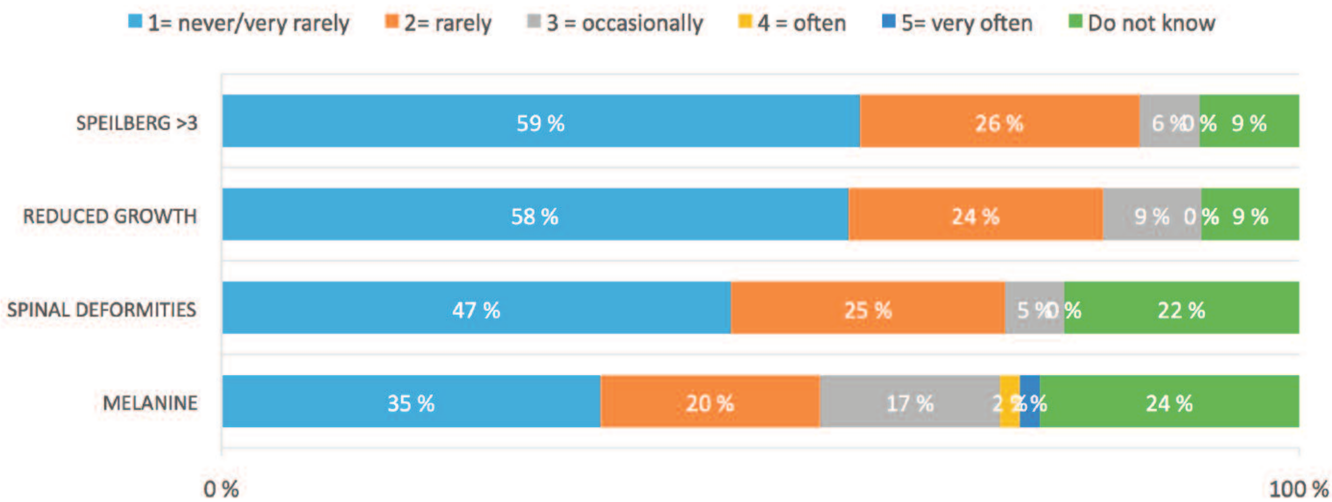


Figure 8.6.4 Summarised answers to the question: How often do you experience the following long-term side effects of vaccine in ongrowing sites/ harvest facilities?": Speilberg score grade 3 or above, in more than 10 % of examined fish (N = 54); suspicion of reduced growth in the fish group due to vaccine side effects (N= 55); suspicion of vaccine-induced spinal deformities in more than 5 % of fish (N=55); suspicion of vaccine-induced melanin stains in musculature (N=54). The answers were entered 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, as a percentage, the number of respondents who have given the different answer options, and N is the number of respondents who have answered the question.

Table 8.6.1. Number of persons for number of responses (N) within different categories of salmonids farming that indicate that vaccine side effects are among the 5 most important problems related to mortality, growth, welfare or as an increasing problem.

	Mortality	Poor growth	Reduced welfare	Increasing problem
Hatchery salmon	2 of 47	5 of 35	8 of 51	1 of 39
Hatchery rainbow trout	0 of 9	0 of 7	0 of 9	0 of 3
Ongrowing salmon	2 of 88	2 of 73	6 of 87	2 of 69
Ongrowing rainbow trout	0 of 12	0 of 9	0 of 13	0 of 7

In the overall welfare issues in the survey, where a wide range of disease and welfare problems are compared, vaccine injuries do not appear high on the list of the major welfare problems in salmon and rainbow trout farming. Nevertheless, some respondents ticked off welfare problems related to vaccination as one of their "top five" in salmon farming, both at hatchery and ongrowing facilities (see Table 8.6.1). On the other hand, no one believes that vaccine side effects are a major problem in the breeding of rainbow trout. There are also extremely few that consider vaccine side-effects to be an increasing problem in salmon and rainbow trout farming.

Vaccination is an important part of preventive health work in fish farming. Photo: MSD Animal Health Norway.

9 The health situation in wild Fish

By Åse Helen Garseth, Toni Erkinharju, Lisa Furnesvik, Siri K. Gåsnes, Haakon Hansen, Roar Sandodden, Julie Svendsen and Brit Tørud

9.1 Introduction

Norway represents a significant proportion of the natural range and gene pool for wild Atlantic salmon. Accordingly, Norway has a special responsibility to safeguard and protect the species. This is reflected in measures such as the National Salmon Rivers and Salmon Fjords, The Quality Norm for Wild Atlantic Salmon and the Traffic Light System. Despite these and other national programmes, the Atlantic salmon was listed as a Norwegian Red List Species for the first time in 2021, in the category near-threatened.

Management of wild stocks requires knowledge of the many factors that affect them. Disease is one of these factors, but without a clear understanding of the causes behind disease and mortality, interaction with other factors and tolerance limits, there is a risk of making management decisions on the wrong basis. With the exception of the parasites *Gyrodactylus salaris* and the salmon louse (*Lepeophtheirus salmonis*), the health of wild fish has only been studied to a limited extent.

In 2020, the Norwegian Veterinary Institute (NVI) launched a national reporting system for registration of disease and mortality in wild fish in collaboration with the Norwegian Food Safety Authority (NFSA). The reporting system (also called the wild fish health portal) is an integral part of health monitoring in wild fish and the main purpose is early detection of serious incidents related to fish health in Norway. The system also provides a general insight into the health of wild fish. The reporting system applies both to fish in freshwater and in the marine environment (Chapter 9.2).

In the summer of 2021, disease and mortality due to red skin disease was not recorded in wild salmon in the river Enningdalselva in the Municipality of Halden. Red skin disease is characterised by rash-like bleedings and changes in the skin. Similar signs of disease have been observed in several countries in Northern Europe. The cause of the disease is still unknown. The Nordic Council

Figure 9.1.1 The alien species pink salmon has an increasing incidence in Norway. The photo shows a male fish from River Skallelv. Photo: Åse Helen Garseth, Veterinary Institute.

Snorkling the river to assess the spawning stock after re-establishing the salmon stock in River Rauma. Photo: Shane Colvin.

of Ministers is now funding a joint Nordic project that, among other things, is studying this condition (see Chapter 9.3).

The interest for traditional inland aquaculture (char, brown trout and rainbow trout) and land-based aquaculture of salmon is increasing. The need for knowledge on how inland aquaculture affects wild fish is therefore increasing in pace with this interest. In connection with health monitoring of wild salmonids in 2021, wild and hatchery reared brown trout (for stock enhancement) as well as rainbow trout and brown trout from inland farms (commercial aquaculture) were examined for the virus piscine orthoreovirus-3 (See Chapter 9.4).

Norway has declared its intention to eradicate the parasite *G. salaris* from all affected rivers. Following the declaration of freedom from infection in treated rivers, the parasite represents a decreasing threat to Norwegian wild salmon. In 2021, large-scale testing of chlorine treatment has been carried out. This is one of several relevant eradication methods in the remaining infected watercourses (Chapter 9.5).

The salmon louse is a significant threat to wild salmon, sea trout and sea-run Arctic char. The red traffic light was turned on for the first time in February of 2020, and in November 2021 the Expert group delivered a new evaluation of the probability of salmon louse induced mortality in wild salmon postsmolts (Chapter 9.6).

The gene bank for wild Atlantic salmon was established in 1986 by the Directorate for Nature Management (Now the Norwegian Environment Agency) to preserve endangered strains of salmon. The gene bank comprises a sperm bank and live gene banks, i.e. farms stocked with the offspring of wild Atlantic salmon broodstock. Results from the mandatory health control of wild-caught broodstock are presented in Chapter 9.7.

Introduction of alien species and climate change are among the greatest threats to the diversity of nature. The number of pink salmon in Norwegian rivers has increased dramatically in the period 2015 to 2021, and there is considerable concern about the ecological and economic consequences. The Norwegian Veterinary Institute has examined pink salmon from several rivers, but has not detected any of the serious listed infectious agents. Furunculosis and proliferative kidney disease are two of the diseases that are expected to have greater significance in warmer climates (Chapter 9.8).

9.2 Reporting system for diseased wild fish

According to the Norwegian Food Act, anyone who suspects the presence of infectious animal disease that may have serious societal consequences is obliged by law to report it to the Norwegian Food Safety Authority (NFSA). The duty to notify also applies when disease and mortality is observed in wild fish. In 2020, the Norwegian Veterinary Institute (NVI) and the NFSA therefore launched the Wild fish health portal, a national reporting system to register disease and mortality in wild fish. The reporting system is a part of the health monitoring of wild fish, and its main aim is early detection of serious incidents related to fish health in Norway. The system also provides insight into the health of wild fish generally. The system can be used to report observations on wild fish both in freshwater and in the sea. Pathologists continuously assess registered cases, and everyone who reports a case receives a response from the NVI.

The system is not restricted to serious infectious diseases. The more the system is used, the more knowledge will be generated on the health of wild fish. As a result, NVI will be able to provide a better scientific service. It is therefore better to report a disease once too often rather than not at all.

The number of cases reported increased from 44 unique cases in 2020 to 89 in 2021.The increase in the number of cases is probably because the system has become better known. In addition, all river owner associations, relevant research institutions, authorities and agencies were informed about the existence of the reporting system in 2021.

In 2021, reported cases involved disease in Atlantic salmon, trout, Arctic char, pink salmon, pike, cod, perch, halibut, mackerel, cuckoo wrasse, lumpfish and thornback ray. Cases were reported from all over the country, but with predominance of cases from coastal areas (Figure 9.2.1). The reports involved parasites, bacteria, fungal- and viral diseases, tumours, mechanical injuries and predator injuries. The majority of the cases concerned skin changes (23 cases), parasites (21 cases), fungi (12 cases) and mechanical injuries (8 cases). Here,

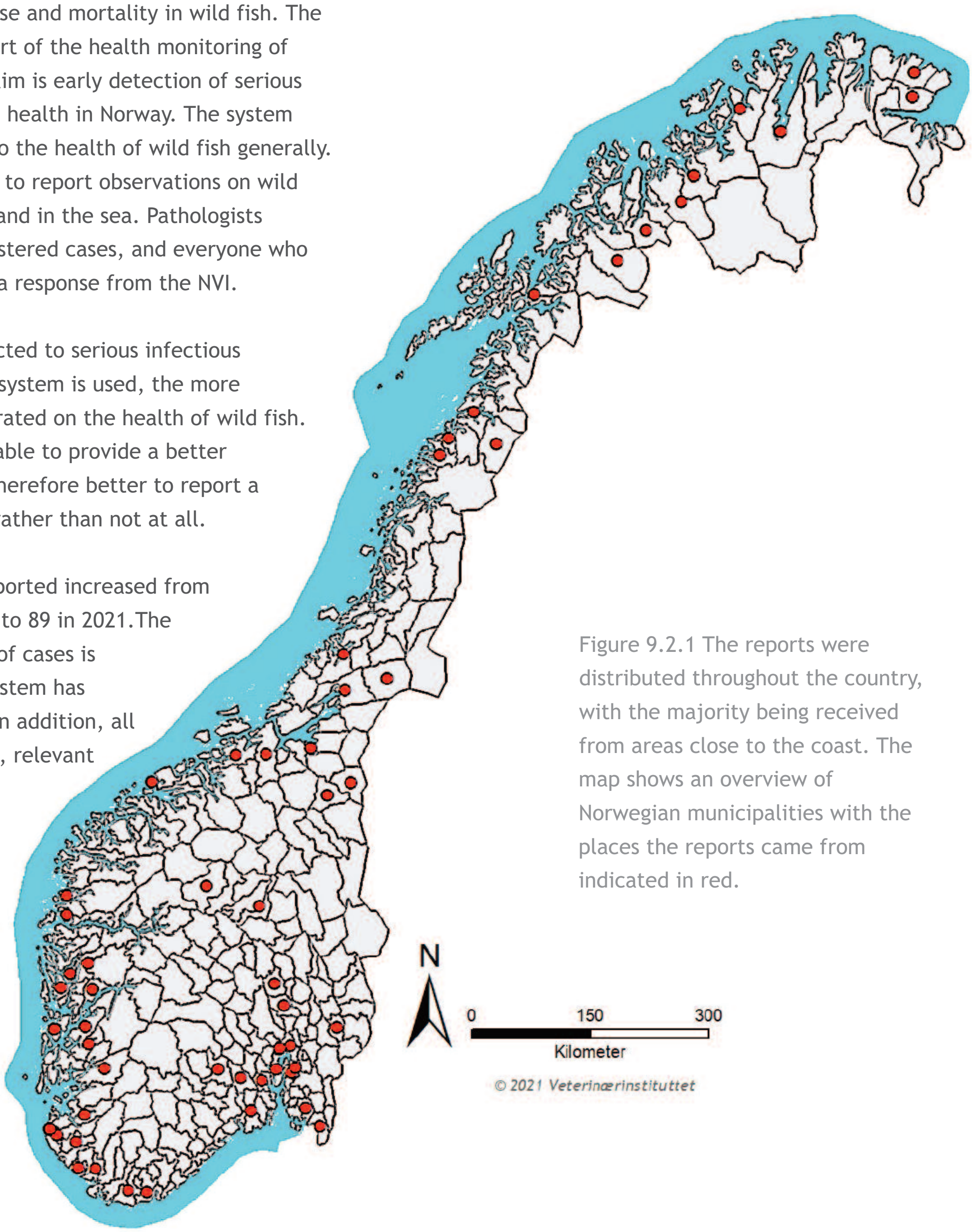


Figure 9.2.1 The reports were distributed throughout the country, with the majority being received from areas close to the coast. The map shows an overview of Norwegian municipalities with the places the reports came from indicated in red.

we present a summary of the reported cases for 2021, and some additional cases identified by other means.

In 2021, the river owners' associations were encouraged to be particularly vigilant and report suspected cases of red skin disease and furunculosis. This has probably contributed to more reports of cases with symptoms resembling these diseases. In 2021, as in 2020, tapeworm and saprolegniosis have been among the most frequently reported diagnoses.

Other relevant systems for reporting and notification

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 website called the “Marine Citizen Science” page, 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.

Skin changes

European plaice with neoplastic skin formations (tumours)

In early March 2021 a European plaice (Pleuronectes platessa) was reported from Vinjefjorden in the Municipality of Heim in Trøndelag, with several raised, tumour-like skin growths, which in particular were associated to red spots in the skin (Figure 9.2.2). The fish was a sexually mature male with a lot of milt and otherwise seemed to be in good health. Based on the location and morphology of the skin growths, it is suspected that the changes could be skin tumours. One possible explanation for the changes may be lymphocystis, a benign iridovirus infection known in flatfish and many other types of marine and freshwater fish. The virus infects cells in the skin that proliferate/enlarge greatly, leading to the formation of nodular growths on the skin and fins. The disease is usually self-limiting and the skin changes may regress over time. Among other possible reasons, pigment cell

Figure 9.2.2 Plaice from Vinjefjorden with several skin growths. The recessed images show higher magnification of multiple growths (top) and simple growth (bottom) in the skin. Photo: Tommy Tølche.

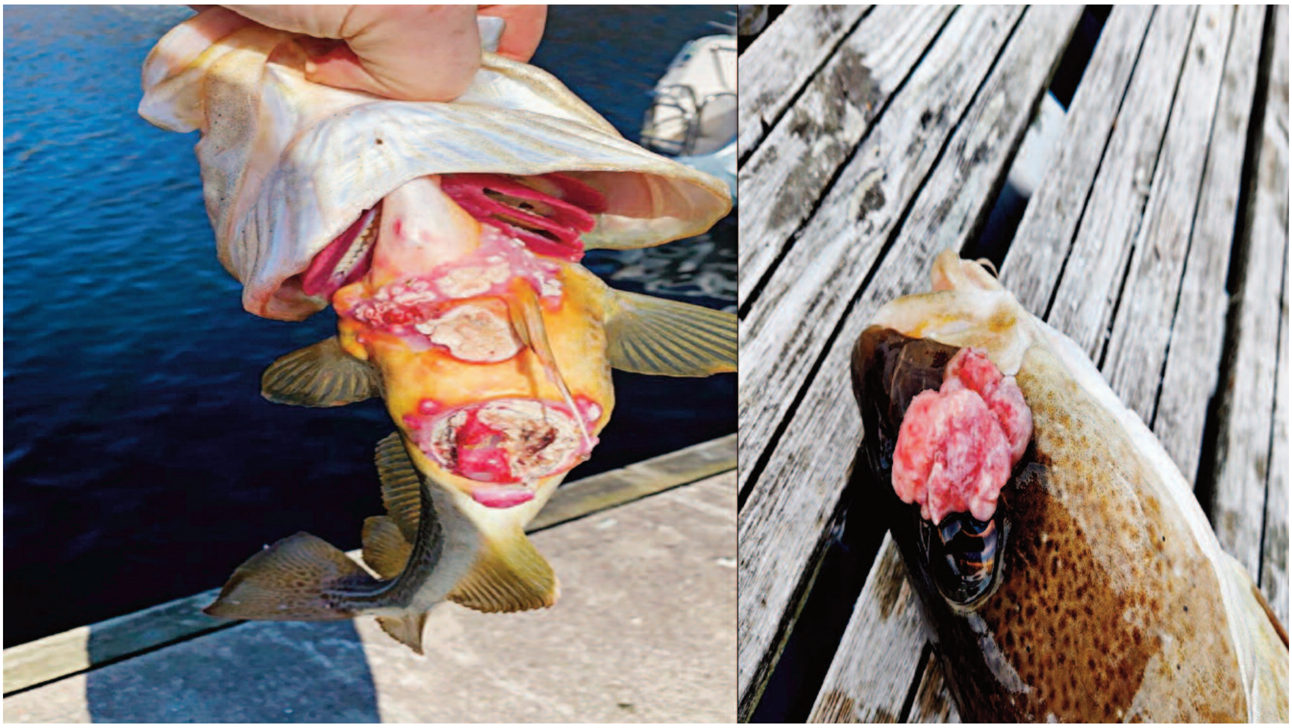


Figure 9.2.3 Cod from Abelnes with several large skin processes on the underside of the body (left). Photo: Christian S. Thompson. Cod from Nordarnøya with tumour-like growth on the head (right). Photo: Lasse Hernes.

tumours have also been discussed, as red (erythrophores) and/or yellow (xanthofors) pigment cells seem to be involved in the changes. Based on the reproductive status of the fish, it has also been speculated whether the skin changes may be due to natural changes in connection with spawning and the development of secondary sexual characteristics. The fish was released back into the wild and was not available for sampling at the NVI.

Skin changes in cod

Some of the reports involved skin changes in cod (*Gadus morhua*). In early April, for example, a 1.5 kg cod , was discovered in Abelnes in the Municipality of Flekkefjord, with very prominent and pale, partly reddish skin processes located on the ventral side of the fish, where there also appeared to be perforations into the coelomic cavity (Figure 9.2.3). Possible explanations include neoplasms or so-called granulomatous inflammation, a form of chronic inflammation that occurs frequently in cod, where disease-causing agents (such as bacteria, fungi etc.) are encapsulated by the fish's own immune system with the formation of larger or smaller inflammatory nodes (granulomas). The fish was euthanised, but not submitted to the Veterinary Institute for sampling.

One cod (about 1 kg) was discovered in mid-July at Nordarnøya in the Municipality of Gildeskål, with a large tumour-like skin growth on the right side of the head close to the eye. The location of the changes is interesting. Cod and related species can develop a form of so-called 'X-cell tumour', where mainly the pseudobranchia are infected by a type of single-celled parasite (Perkinsus-like) that can lead to the formation of large, growing tissue masses. The disease state is also described as a form of pseudo-tumour. Such changes can also lead to skin ulcerations with subsequent secondary infections, or grow into nearby gill tissue and thus lead to severe respiratory difficulties for the host. However, whether it was the actual cause of the changes in this described case is unknown, as the fish was not available for sampling at the NVI.

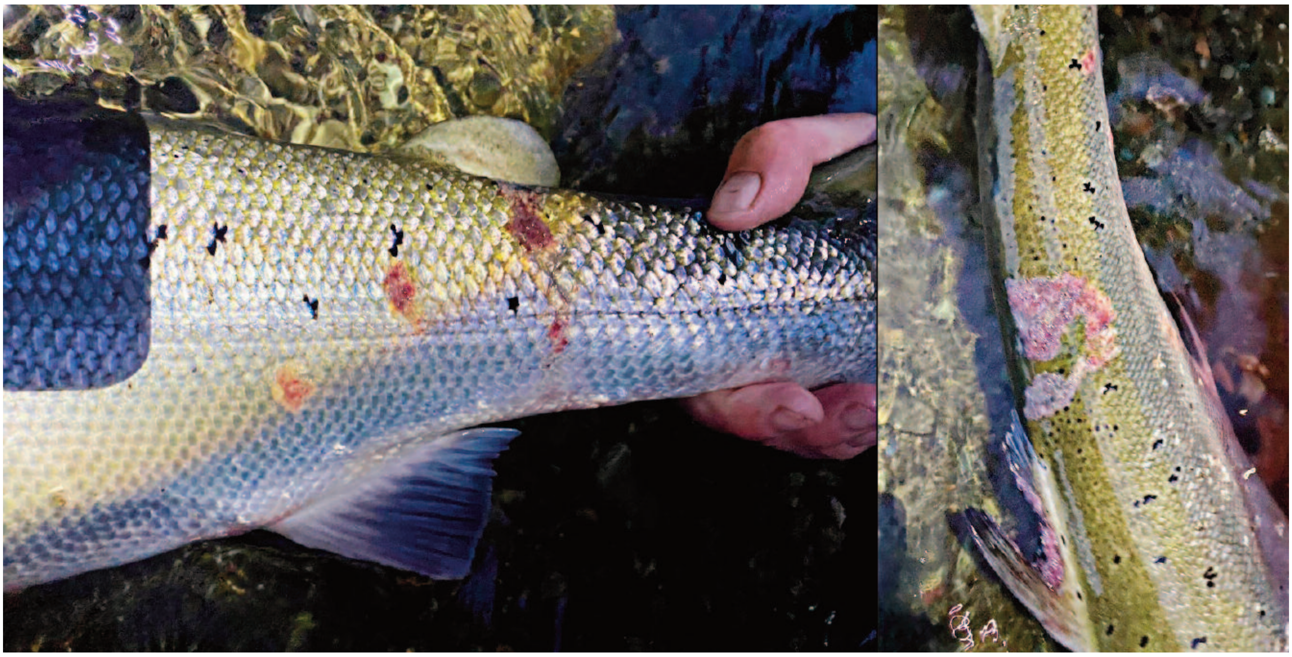


Figure 9.2.4 Salmon from Vesle Orkla with wart-like growths and fin erosion (right), and minor ulcers/growths on the body (left). Photo: Tor Roar Hjellebråten.

Skin changes in salmon

In early July, a large (about 9 kg) male salmon was reported from the Vesle Orkla river in the Municipality of Orkland in Trøndelag, with several rough, greyish and somewhat red-coloured skin thickenings in several places on the body, as well as minor ulcers, skin haemorrhages and fin erosions (Figure 9.2.4). In this case, it was suspected that the changes could be due to papillomatosis (warts), a benign skin disorder most likely caused by a herpes virus and described from several fish species. The disorder will eventually pass, as the growths fall off and possibly leave scars in the skin. No samples of this fish were submitted to the NVI. Papillomatosis was also described in the **Fish Health Report for 2018.**

At the end of November a female salmon (about 2 kg) was reported from the Olderfjordelva river in the Municipality of Kvænangen in Finnmark, with a focal, red-coloured/bloody boil-like skin swelling on the dorsal side, located in front of the adipose fin (Figure 9.2.5). The skin process itself was cut off and submitted for examination at the NVI to check for possible causes, and to rule out the possibility of the fish being affected with furunculosis (a notifiable bacterial disease). The histopathological examination showed a growing cellular process, which appeared to originate from the dermis and displace surrounding skin tissue and scales. However, the sample material was also affected with post mortem changes, which made further histological description impossible. As such, it is uncertain what the causal (etiological) origin was of the tumour change. Neither furunculosis nor other known fish pathogenic bacteria were detected during bacteriological examinations.

Complex health conditions

In wild fish, disease conditions are often complex and composed of several different afflictions with different aetiology. The immune system of spawning fish is often impaired. In addition, they use much of their energy reserves to produce milt and roe, and for activities related to spawning. Damage to the skin and gills can create a gateway for disease-causing organisms (agents). Weakened salmonids in the rivers can be infected by both primary and secondary (i.e. subsequent) agents. The fish may also have other underlying disorders. The complexity of disease conditions often increases with the age of the fish.

A typical salmon of this kind was sent in from the Reisavassdraget watercourse in Finnmark. The salmon measured 106 cm, was found dead in the river and sent to the NVI. The fish was subject to a post-mortem examination and a selection of diagnostic examinations were carried out. The post-mortem examination found parasites in the gills (gill lice, probably *Salmincola* sp.) and herring worm (*Anisakis*) in the abdominal cavity. The histopathological examination (microscopic examinations of stained tissue sections) revealed bacteria in several

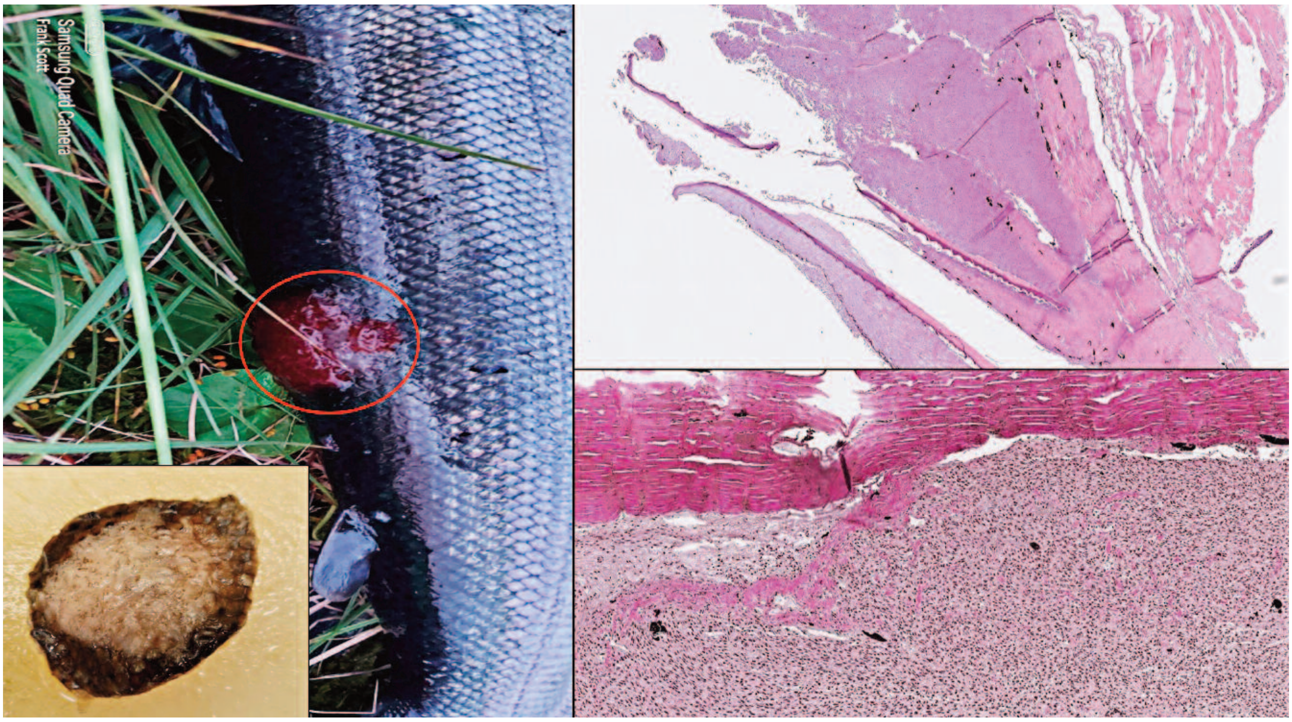


Figure 9.2.5 Salmon from the Olderfjord river with local, bloody boil-like swellings on the back (red circle) (left). Photo: Frank Scott. Recessed image: Skin biopsy sample submitted from salmon for examination at the Veterinary Institute. Photo: Anette Hansen, Norwegian Veterinary Institute. HE-stained histological image showing a cell-like, proliferating process in the dermis (right, above). Photo: Toni Erkinharju, Veterinary Institute. Van Gieson-stained histological image showing the process (brown) displacing surrounding dermis tissue (red) (right, below). Some pigmentation can also be seen (dark colour).

organs, indicating a bacterial infection. In addition to bacteria, several fungal-like structures were also detected, which are probably oomycota in the genus *Saprolegnia* that are common in freshwater. In bacteriological cultivation of samples collected from the kidney and spleen, *Aeromonas hydrophila* was found. This is a common bacterium found in freshwater and brackish water. It is not considered to be a primary disease-causing bacterium in salmonids, but it is plausible that it might have been a secondary infection in this case. Since the fish appeared to be anaemic judged by the appearance of the gills, and since the submitter suspected that this could be an escaped farmed salmon, infection with infectious salmon anaemia virus (ISAV) was ruled out by a negative ISAV specific real-time RT-PCR analysis. Analysis of scale samples, including both visual and genetic analyses, led to the further conclusion that it was a wild salmon. It had probably spent four years in the river before smolt outward migration, then four winters at sea. It had also spawned earlier (kelt).

Figure 9.2.6 Sexually mature wild female salmon measuring 106 cm. Sent in from the Reisavassdraget watercourse. The gills were characterised by anaemia, *Salmincola* sp and a fungal/bacterial coating. Photo: Truls Bergmo.

Figure 9.2.7 Shows a sea trout with saprolegniosis from Songdalselva river, Kristiansand 2021. Photo: Espen Halvorsen.

Fungal infection (Saprolegniosis)

Saprolegniosis is caused by the oomycete *Saprolegnia* sp. and is the most commonly found fungal disease of wild fish. This fungus is found in freshwater and mainly causes disease in fish with a damaged mucus layer, damaged skin or a fish which is subjected to stress (See also chapter 6 Fungal Diseases in Salmonids). In wild fish the disease is most commonly seen in spawning fish, in fish that have been handled (catch and release) or under particularly unfavourable environmental conditions. The fungus infects the skin and starts most commonly in scale-less areas like the head, back 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. 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 2021, the species *Saprolegnia parasitica* was detected in several rivers. This is the most disease-causing species. In Songdalselva river in Agder, saprolegniosis was observed in spawning salmon, stationary trout and juvenile fish, and the mortality rate passed 300 fish. If mortality occurs before spawning, the spawning stock numbers can also be affected (Figure 9.2.7).

Parasites

White spot disease (Ichthyophthirius multifiliis)

The single-celled parasite *Ichthyophthirius multifiliis* (Ciliophora) causes white spot disease in fish and is one of the most pathogenic/disease-causing fish parasites found. White spots observed on fish are a clear indication of white spot disease, and microscopic examination will show a characteristic horseshoe-shaped cell nucleus. *Ichthyophthirius multifiliis* is reported from all areas where fish are farmed and it causes significant losses in aquaculture worldwide. The parasite is also found in wild populations on most continents and much of its spread is due to fish movements for instance in connection with fish farming. In Norway, the parasite has been detected in several different species of wild fish in Eastern Norway, from hatcheries in Western Norway (reported in the Fish Health Report for 2014) and from the Alta River and the Tana River in Troms and Finnmark. *Ichthyophthirius multifiliis* does not appear to be host-specific, and can probably infect all fish species. Outbreak depends on temperature and host density, and in Finland, it has been shown that temperatures above 14 degrees are necessary for larger disease outbreaks. Since the life cycle is completed faster at warmer temperatures, white spot disease can become more problematic in Norway with rising temperatures as a result of climate change.

Fig. 9.2.8. Trout from Ferga river, Trøndelag, with white spot disease caused by the ciliate *Ichthyophthirius multifiliis*. Photo: Eva Marita Ulvan, Norwegian Institute for Nature Research (NINA).

Fish lice – Argulus

Fish lice in the genus Argulus are parasitic crustaceans that have caused problems in fish-farming since the 18th century. They can cause mortality both in farmed and in wild fish. There are many species in the genus and most are parasites on fish in freshwater. In Norway, we are familiar with the large fish lice (*Argulus coregoni*), which is a common parasite on salmonids such as trout (*Salmo trutta*) and common whitefish (*Coregonus lavaretus*). Small fish lice (*A. foliaceus*) infest a wide variety of fish species including perch (*Perca fluviatilis*), trout (*Salmo trutta*), pike (*Esox lucius*) and three-spined stickleback (*Gasterosteus aculeatus*). The picture shows fish lice and injuries to the head of a trout as a result of fish lice (Figure 9.2.9).

Fish lice are mobile on the fish; they jump on and off and between hosts to eat and lay eggs. They can also survive several days outside the host. Fish lice have a round and flat shape and are characterised in part by the fact that

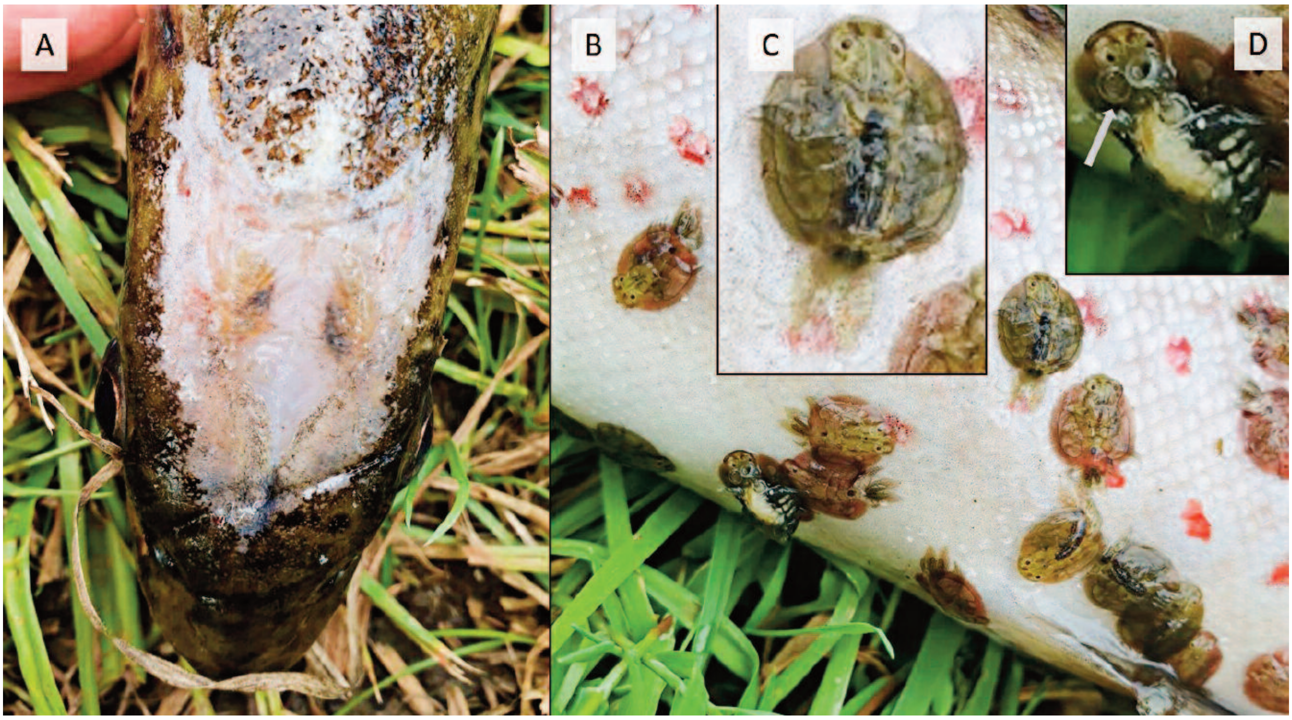


Fig. 9.2.9 Infection with large fish lice (*Argulus coregoni*) from trout in Snåsavassdraget watercourse, Trøndelag County. A: damage to the head caused by fish lice, B: a variety of fish lice on the abdomen, C: enlarged trout photo of the one parasite showing the morphology more in detail, and D: enlarged fish lice seen from underneath showing the most characteristic morphological character, the suction cup-shaped first maxillae (arrow) used to attach to the fish. Photo: Kjersti Hansen, County Governor for Trøndelag.

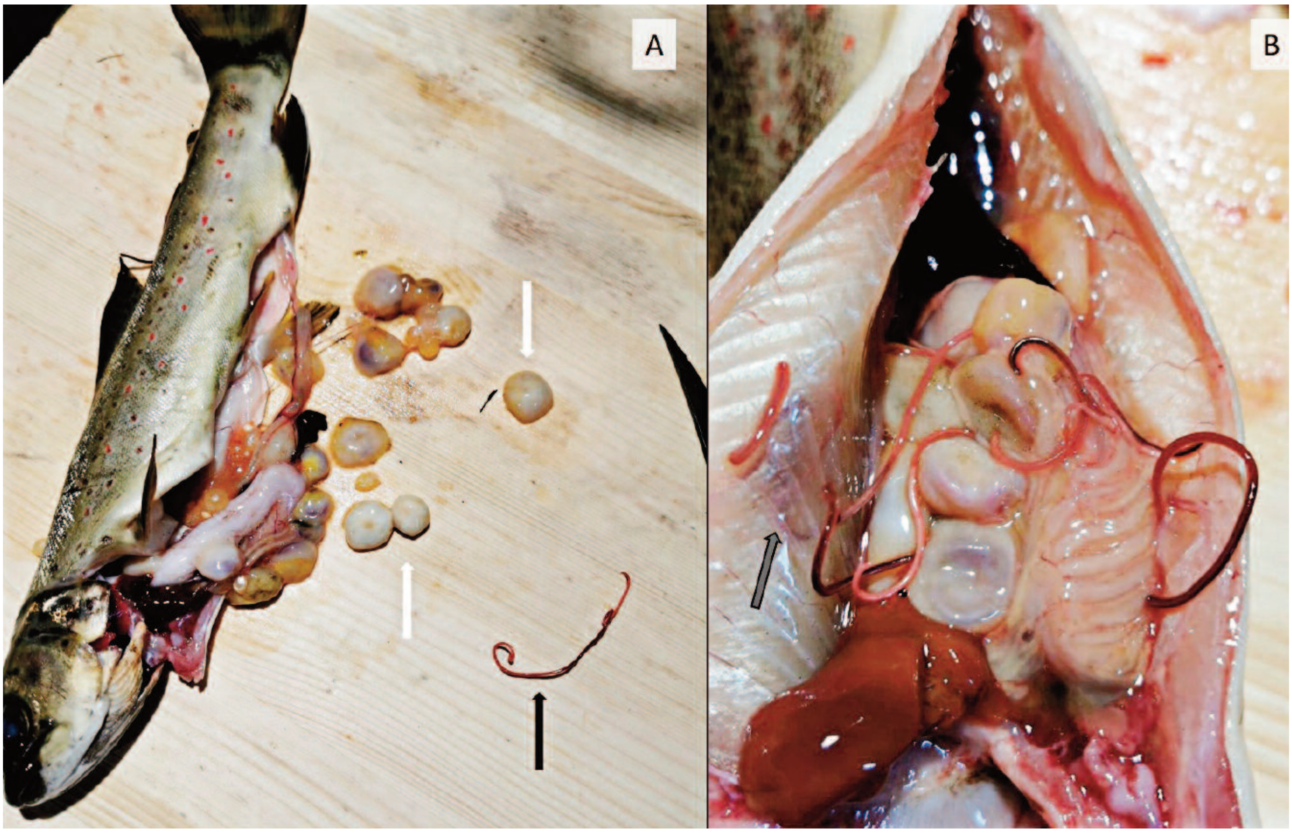


Fig. 9.2.10 Trout from the Eksingedalsvassdraget, Vestland County, infected with the roundworm *Eustrongylides* spp. A: shows gutted trout with capsules containing the parasite (white arrow) and a detached parasite (black arrow), and B: free and encapsulated parasites on the intestines and parasites in the muscle (grey arrow). Photo: Geir Lasse Kaldestad.

the first pair of maxillae (mouth parts) is modified and act as suction cups (Figure 9.2.9). *Argulus* does not have eggs in extruded egg strings, as we know from salmon lice, but has the eggs in the ovaries (ovarium) and lays the eggs in rows on a suitable substrate. Eggs laid in late summer hatch during autumn (September), while eggs laid later in autumn can overwinter and hatch in the spring. In this way, one can have two generations per year, but the population density of fish lice is often highest in autumn. Fish can be infected by fish lice without seemingly causing problems, and in order for them to kill the fish they must be present in high numbers. However, often only a few lice are observed on the fish because the parasites often jump off the host when they are captured.

Eustrongylides

Roundworms (nematodes) in the genus *Eustrongylides* sp. infect fish in their life cycle and commonly occur in many areas of Norway, perhaps especially the south and west of Norway. Since there are many species in the genus and it is generally difficult to determine the species, they are often referred to as *Eustrongylides* sp. The parasite has a complicated life cycle with aquatic oligochaeta as the first intermediate host. Different fish species are the second intermediate host and the vast majority of the species in the genus are sexually mature in fish-eating birds, among which it is often reported from cormorants (*Phalacrocorax carbo*). Some fish are only transport hosts, i.e. hosts where the parasite does not develop, and in these, the parasites can wander out into the musculature and cause inflammatory reactions. In fish, the parasite is either found freely in the abdominal cavity or encapsulated in muscles and on internal organs as the photo of the trout shows. The parasite causes mortality in birds of the heron family (Ardeidae) and in other waders. The parasites can be zoonotic (infect humans) when ingested raw or in poorly cooked fish.

Figure 9.2.11 Net-caught salmon from Vestre Jakobselv, Finnmark. The white edge of the wound suggests that the repair process has begun, indicating that it is an injury that is not completely new. Photo: Vidar Isaksen.

Figure 9.2.12 Cuckoo wrasse with distinctly dilated swimming bladder. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

Mechanical injuries and predation

A proportion of the cases registered in the reporting system are various forms of traumatic lesion. These encompass mechanical injuries, caused by e.g. fishing gear and power turbines, or injuries caused by predators such as birds, seals and otters.

One example is a case from river Vestre Jakobselv in Finnmark, where the submitter reported that almost all the upstream-migrating Atlantic salmon from about 2.5 kg upwards, over a period of several weeks, had injuries that had probably occurred at sea.

Miscellaneous

Cuckoo wrasse with excess pressure in the swimming bladder

The picture (Figure 9.2.12) shows a cuckoo wrasse (*Labrus mixtus*), with part of the air-filled swim-bladder protruding out of the vent. Wrasse lack a connection between the swim-bladder and the alimentary canal (physoclisti, closed swim-bladder). Removal of gas from the swim-bladder occurs through a specialised organ called the ovale and it takes a long time to equilibrate pressure differences. In the event of rapid ascent, as often occurs in connection with fishing, the decreased pressure from the water column will result in a rapid and significant increase in air volume in the bladder. Thus, this is not a morbid condition, but a result of abnormally rapid ascent.

9.3 Red skin disease

About red skin disease

Red skin disease is the term used for a disease with unknown etiology that has been observed in freshly run wild salmon . Different degrees of redness of the skin are observed, from a light rash to burn-like injuries, especially on the abdomen, fins and head. Affected salmon have impaired sentience and can be easy to catch. In Norway, this disease is only registered with certainty in the river Enningdalselva in the Municipality of Halden, in 2019 and 2020, but the NVI receives reports of individual fish with similar changes also from other rivers in Norway. Internationally, similar signs of disease have also been observed, but criteria for diagnosis are not established, and the cause is unknown – thus, it remains uncertain whether it is the same disease. Read more about NVI's work to clarify the disease in the fish health reports for 2019, 2020 and the Red Skin Disease fact sheet.
https://www.vetinst.no/sykdom-og-agens/red-skin-disease-hos-vill-laks-en-ny-tilstand.

Red Skin Disease Status in 2021

During 2021, red skin disease and associated mortality was not observed in the river Enningdalselva. The conditions in the river were different from the previous two seasons, the temperature was lower and the water level higher than is usual for Enningdalselva. There were also fewer reports of disease and mortality in Swedish rivers during the 2021 season.

In the river Numedalslågen, an unusual number of dead salmon were observed in the summer of 2021. These were observed at the bottom of the river below the Holmfoss waterfall in the County of Vestfold and Telemark. Four salmon, were examined by the NVI, but the cause of disease and mortality was not identified.

Nordic cooperation for salmon health

The Nordic cooperation for salmon health is a collaborative project in which the Nordic Council of Ministers finances workshops, knowledge sharing and sampling of fish. The Council of Ministers funds scale and mucus investigations, gene expression studies and the development of non-lethal techniques for sample extraction. It has not yet been clarified which analyses will be carried out.

The Council has coordinated sampling and analyses for some time in Sweden, Finland, Norway, Denmark, the Faroe Islands and Iceland. The project started in 2021 and is due to be completed in 2023. The Norwegian Institute for Nature Research (NINA) is the Norwegian representative in this research project, and the NVI assists NINA by examining tissue samples. For this project, samples from 15 salmon were taken in Enningdalselva in the period 24 to 28 May 2021. None of these had characteristic signs of red skin disease, as observed in previous seasons, but some had bleeding in the skin that might have been an early sign of illness. At the end of May-June 2021, samples were also taken from 17 salmon from the river Drammenselva as controls in the Norwegian contribution to the Nordic cooperation. At the end of the project, results of the completed analyses will be published as a report.

9.4 Health monitoring in wild salmonids

The Norwegian Food Safety Authority's health monitoring programme aims to investigate the source and occurrence of disease-causing agents in wild salmonids (salmon, sea trout and Arctic char).

In Norway, rainbow trout (*Oncorhynchus mykiss*) are farmed along the coast, including open net cages in the sea, and in completely freshwater-based traditional small-scale inland farms. Traditional inland farming also includes farming of char and brown trout. Knowledge of the fish health status in inland farming is limited as is knowledge of how production affects the health of wild fish in the surrounding environment. To remedy this situation, the health monitoring programme for 2021 was expanded to include both wild fish and inland farming.

Piscine orthoreovirus-3 (PRV-3) in rainbow trout causes a disease similar to heart and skeletal muscle inflammation (HSMI) in salmon. In the past, the Food Safety Authority's monitoring programme has shown that PRV-3 is present in all stages of marine rainbow trout production and that the virus is common in wild sea trout (anadromous brown trout, *Salmo trutta*). The occurrence and importance of this virus in inland farming of rainbow trout and brown trout in Norway has not been investigated, but from continental Europe, findings of PRV-3 are reported in inland farming of both rainbow trout and brown trout. Inland farming of rainbow trout and brown trout takes place adjacent to important populations of wild brown trout. It is therefore necessary to investigate the presence of PRV-3 in rainbow trout and brown trout in inland farming, and in wild brown trout in Norway.

The health monitoring program in 2021 consisted of a PCR-based screening of kidney samples from 209 wild brown trout (seven sites), 179 rainbow trout from six commercial inland fish farms, 60 brown trout from two commercial inland fish farms, and in addition 90 brown trout from three stock enhancement hatcheries. The latter facilities produce brown trout that are offspring of wild brown trout and are released to enhance or restore wild populations. The monitoring programme did not find PRV-3 in rainbow trout and brown trout in commercial inland farming. However, the virus was detected in one of the three examined stock enhancement hatcheries for brown trout, and here all 30 samples were PCR positive for the virus. Furthermore, PRV-3 was detected in a total of five brown trout from the two lakes that receive fish from the virus-positive hatchery, one brown trout from a lake near these lakes and in two brown trout from Selbusjøen. (Read more in the report published later in **2022 Health Monitoring in Wild Salmonids** *)

Divers from the Norwegian Veterinary Institute counting Atlantic salmon spawners. Photo: Shane Colvin.

9.5 *Gyrodactylus salaris*

Gyrodactylus salaris was introduced to Norway in the 1970s and has so far been detected in 51 Norwegian rivers. The parasite has caused catastrophic decline in the salmon populations in affected rivers and the environmental authorities management target is to eradicate the parasite from Norway/infected rivers. The Norwegian Veterinary Institute (NVI) is the national centre of expertise in regard to 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 2021

The NVI coordinated three surveillance programmes in 2021 for *G. salaris* under contract from the Norwegian Food Safety Authority; The surveillance programme for *Gyrodactylus salaris* in Atlantic salmon and rainbow trout in Norway (OK programme), the post-treatment surveillance programme for *Gyrodactylus salaris* (FM programme) and the surveillance programme to document absence of Atlantic salmon (Salmo salar) and *G. salaris* in the River Drammenselva upstream of Hellefossen following closure of the salmon ladder there in 2019. See the reports from the various programmes published here: **https://www.vetinst.no/overvaking.**

In the surveillance programme for *Gyrodactylus salaris* in Atlantic salmon and rainbow trout in Norway, 3010 salmon and rainbow trout from 89 facilities and 2412 salmon from 72 rivers were examined in 2021. *Gyrodactylus salaris* was not detected in any of the samples.

As part of the post-treatment surveillance programme for *Gyrodactylus salaris* in Norway in 2021, 596 salmon juveniles and 25 Arctic char from four watercourses were examined in 2021. In addition, fins from 510 Arctic char from the lakes Fustvatnet, Mjåvatnet and Ømmervatnet in Fustavassdraget watercourse (Nordland county) were examined. *G. salaris* was not detected in any of the examined samples.

Infection status and threat situation

Of the original 51 infected watercourses, there were only eight rivers in Norway with recorded *G. salaris* at the end of 2021 (Figure 9.5.1). These are the rivers Drammenselva and Lierelva in Viken county, Sandeelva river (Vesleelva) and the Selvikvassdraget watercourse in Vestfold and Telemark county, and Driva, Usma, Litledalselva and Batnfjordselva rivers in Møre og Romsdal county. Four watercourses have been treated and are undergoing recovery; Fustavassdraget in Nordland county, and Skibotnelva, Signaldalselva and Kitdalselva in Troms and Finnmark county.

Eradication measures 2021

In 2021, no eradication measures were initiated against *G. salaris*. However, conservation of salmonids, studies and mapping have been carried out in both Driva and the Drammen region as well as large-scale test dosing with chlorine in Driva.

Skibotn infection area

In the Skibotn region in Troms and Finnmark, restoration of stocks is still taking place for salmon, sea trout and char after treatments were carried out in 2015 and 2016.

Driva infection area

G. salaris was detected in the river Driva in Møre og Romsdal for the first time in 1980. The affected area includes the rivers Driva, Litledalselva, Usma and Batnfjordelva. Driva is a long river with many inaccessible places along the salmon-migratory route. To limit the extent of the treatment area and thereby increase the chances of success, a migratory barrier (preventing upwards migration alone) was built at Snøvasmelan, approximately 25 km from the river mouth. Salmon above the migratory barrier will eventually migrate downstream of the barrier and within six years no salmon or *G. salaris* will be present above the barrier. The barrier was completed in 2017 and chemical treatment is planned for 2022 and 2023. A full-scale test dose of chlorine was carried out in 2021. The entire watercourse with tributaries from the salmon barrier at Snøvasmælan down to the fjord was treated.

In 2021, the hydrological survey, aimed at drawing up detailed treatment maps, was almost completed. On 8

February 2022, the Food Safety Authority issued a notification of a decision regarding chemical treatment against *G. salaris* in the Driva region. Chemical treatment is planned to be carried out in the latter half of August 2022.

To conserve the sea trout population in the Driva watercourse, all sea trout stopped by the fish barrier are transported over the barrier following genetic testing and saltwater treatment. Since 2020, sea trout have also been brought in downstream of the barrier for relocation. The salmon in the watercourse are collected for live and frozen gene banks. While the material presently held in the gene bank has aged over the years, new families were added in 2018 and 2021. The conservation of salmon in the river Batnsfjordelva has followed a similar plan. In 2020, collection of material for the gene bank from the Driva region was extended to include sea trout from the Batnfjordselva and Litledalselva rivers, and salmon and sea trout from Usma. The work in 2021 followed the same course as in 2020. The eradication and preservation project coordination group is led by the County Governor for Møre og Romsdal and includes representatives from the Food Safety Authority, the Environmental Agency and the NVI, 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*.

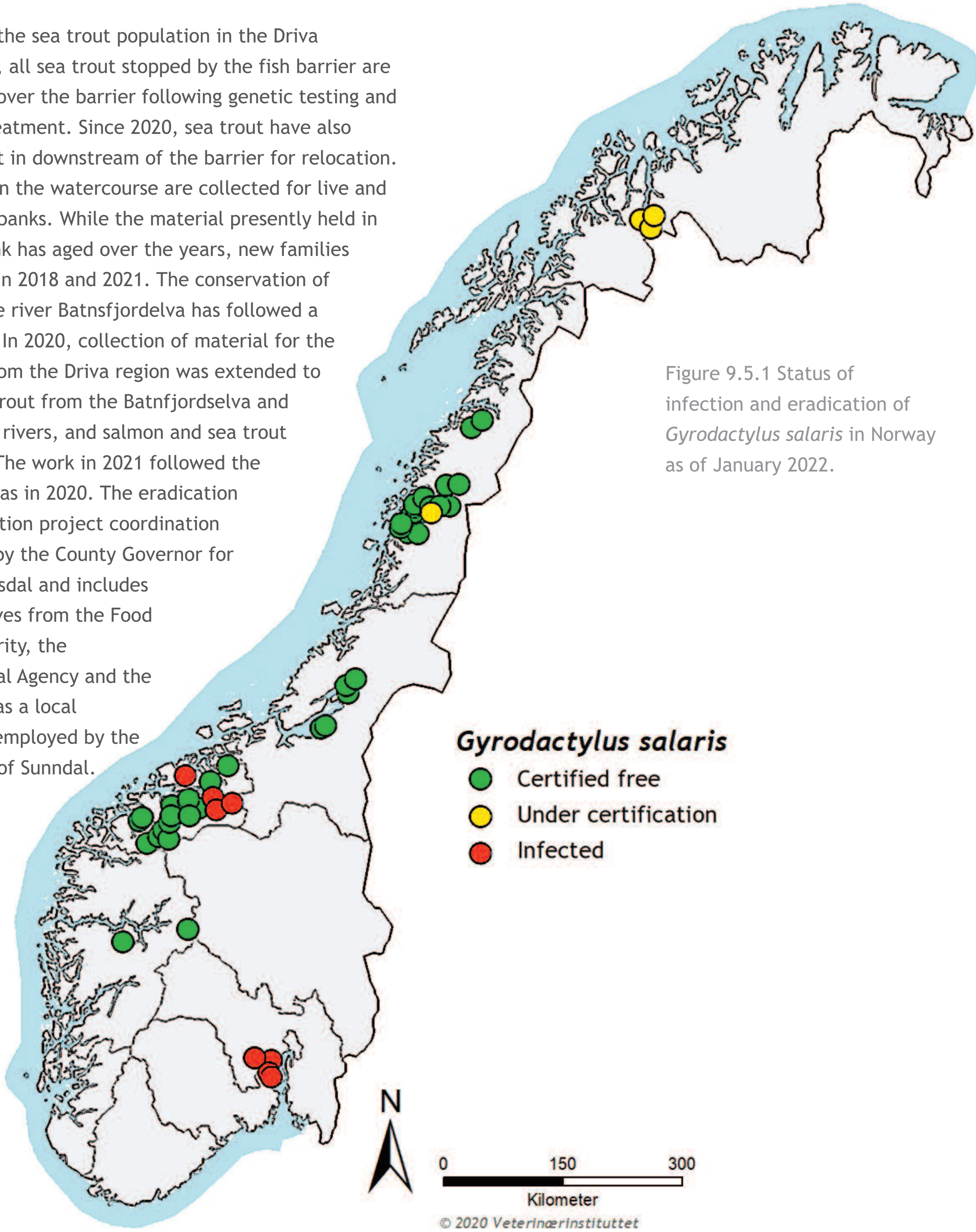


Figure 9.5.1 Status of infection and eradication of *Gyrodactylus salaris* in Norway as of January 2022.

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 is considered that the rotenone method is likely to provide the best chance of success. At the same time, the rotenone method has significant disadvantages for the fish communities. As of today, there is not sufficient experience for utilising the chlorine method, but the method is under development in Driva. Experience from Driva may provide answers as to whether chlorine should be used in the Drammen region. In preparation for future treatment, hydrological surveys of the river Lierelva were carried out during 2021.

Since 2016, the NVI has collected wild salmon from the Lierelva and the 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 the 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 salt water treatment. This is to prevent the movement of hybrids and to remove any parasites. The fish ladder at Hellefossen waterfalls has been closed for salmon since 2018, 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 and Viken and includes representatives from the Food Safety Authority, the Environmental Agency and the NVI.

Gyrodactylus salaris feeding on Atlantic salmon skin. The parasites are magnified 800 times. Image taken with scanning electron microscope and colour manipulated. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

9.6 Salmon louse and sustainability

A Traffic Light System has been established to ensure that expansion of the aquaculture industry is done in a sustainable way. As of today, mortality attributable to salmon lice infestation in outward migrating wild salmon smolt is the only sustainability indicator 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.

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, the advice of the steering group and an assessment of socio-economic consequences are important. Results may thus differ from the advice given by the steering group and the expert group. The main rule of the Traffic Light System then, 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.

In the most recent assessment published in December 2021, PO3 and PO4 from Karmøy to Stadt are in the high risk (red) category. PO5 and PO7 are in the moderate risk category (yellow), while the remaining nine areas are considered to have a low risk of mortality (green). Assessment from 2020 and 2021 form the scientific basis for colour assignments in 2022. Table 9.6.1 shows the expert group's conclusions for the 13 production areas (PO) in the period 2016-2021.

Extensive exemptions

The production is mainly regulated by the colour of the traffic light. However, paragraph 12 of the Production Area Regulations, allows fish farmers to apply for increased production or exemption from capacity reduction, regardless of the environmental status (colour) in the production area. This is called exemption growth and is granted on condition that not more than one medicinal delousing treatment has been performed on a particular farm during the previous production

Table 9.6.1 The expert group's evaluation in the period 2016-2021. 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 area	2016	2017	2018	2019	2020	2021
1. Swedish border - Jæren	Low	Low	Low	Low	Low	Low
2. Ryfylke	Mod	Low	Mod	Low	High	Low
3. Area Karmøy to Sotra	High	High	High	Mod	High	High
4. North Hordaland to Stadt	Mod	High	Mod	High	Mod	High
5. Stadt to Hustadvika	Mod	Mod	Mod	High	Low	Mod
6 Nordmøre - Sør-Trøndelag	Mod	Low	Low	Low	Low	Low
7 Nord-Trøndelag with Bindal	Mod	Low	Mod	Low	Mod	Mod
8 Helgeland - Bodø	Low	Low	Low	Low	Low	Low
9 Vestfjorden and Vesterålen	Low	Low	Low	Low	Low	Low
10 Andøya - Senja	Low	Low	Low	Mod	Low	Low
11 Kvaløya - Loppa	Low	Low	Low	Low	Low	Low
12 West Finnmark	Low	Low	Low	Low	Low	Low
13 East Finnmark	Low	Low	Low	Low	Low	Low

As of today, mortality in outward migrating wild salmon smolt as a result of salmon lice infection is the only sustainability indicator in the Traffic Light System. Photo: Ketil Skår, Norwegian Veterinary Institute.

cycle, and that the number of lice has been held under a defined level for a defined period. The exemptions have several unfortunate aspects. They are drivers of frequent use of non-medicinal delousing methods for the purpose of avoiding production reduction or to gain production increases. Furthermore, the exemptions undermine the intentions of the traffic light system, that is to avoid exceeding a sustainable level of salmon lice hosts in the area.

When the number of salmon lice hosts in a red production area do not decrease as intended, the possibility of having an effect in the form of reduced salmon lice-induced mortality in wild salmon smolt cannot be accomplished. In addition, even a low average lice count will represent a large louse population when the number of farmed fish in the population is high. The other unfortunate aspect of the exemption provisions is the effect on farmed fish that have to undergo frequent non-medicinal delousing. All non-medicinal delousing methods create welfare challenges for farmed fish (Chapter 3 Fish Welfare). The high mortality rate of farmed fish in red production areas is an important signal that the area's tolerance limit has been exceeded.

Over time, it is important that the Traffic Light System is evaluated. There is a need to assess how the system safeguards wild salmon stocks, but also to what extent it safeguards the health and welfare of farmed fish.

Unilateral use of one indicator is unfortunate, and there is a need to establish a set of indicators or measures that ensure that the environment, wild fish and farmed fish are safeguarded, and that offsets the unintended effects of the individual indicator.

Increased spread of infectious agents after handling-intensive operations?

There are many infectious diseases that affect farmed fish, and several infections often occur simultaneously in the same population and in the same fish. It is a known phenomenon that infections can be activated or worsened when individuals are exposed to stress. This is one reason for using so-called latent carrier tests (based on cortisol treatment and high temperature) to reveal latent carriers of furunculosis. A key question is therefore whether stressful handling-intensive operations, such as non-medicinal delousing, affect the transmission of infection.

The Norwegian Veterinary Institute conducted studies in 2021 showing that symptom-free carriers of *Yersinia ruckeri* increased bacterial shedding during thermal delousing. Initial studies with Pasteurellosis infection also show shedding in treatment water. Based on this, there is reason to believe that farmed populations that carry various infections, and are exposed to frequent and intensive handling, increase infection pressure in the sea.

9.7 The health situation in the Gene Bank for wild salmon

The Gene Bank for wild Atlantic salmon was established in 1986 by the Directorate for Nature Management (now the Norwegian Environment Agency) to preserve endangered salmon stocks. The Gene Bank comprises a sperm bank and five live gene banks, i.e. farms stocked with offspring of wild-caught salmon. The Norwegian Veterinary Institute (NVI) is the national centre of expertise for the country's gene bank program and coordinates activities under contract from the Norwegian Environment Agency.

The aim of the Gene Bank's biosecurity strategy is prevention of proliferation and spread of infectious disease during restoration of salmon stocks. The biosecurity programme also aim at securing good fish health within the gene bank stations to avoid disease, mortality and thus loss of or directional selection in important genetic stocks.

Health control of wild-caught broodstock

Health controls are carried out on all candidate broodstock collected for the gene bank for wild salmon. In addition, all fish entering the gene bank are subjected to scale analysis by the NVI and genetically characterised by NINA to ensure that only offspring of wild salmon are included in the gene bank programme. The health control is based on post-mortem examination and testing of relevant target tissues for a list of pathogenic agents, using PCR. Current legislation requires testing for at least *Renibacterium salmoninarum* (causative agent of bacterial kidney disease), but also any other relevant disease dependent on the health status of the fish being tested and the geographical area in which the fish was caught.

In 2021, all broodstock collected for the wild salmon gene bank were tested for infectious pancreatic necrosis virus (IPNV), *Renibacterium salmoninarum* (causing BKD) and infectious salmon anaemia virus HPR0 (ISAV HPR0). In addition, salmon were tested for piscine orthoreovirus-1 (PRV-1) and sea trout were tested for piscine orthoreovirus-3 (PRV-3).
The two latter analyses were conducted as part of research to identify possible vertical transmission in salmonids, i.e. transmission of infection from parent to offspring via the roe and milt. In 2021, all fish collected for the gene bank for wild salmon were also tested for the bacterium that causes furunculosis (*Aeromonas salmonicida*, subsp. *salmonicida*) by bacterial cultivation from the kidney.

In 2021, 453 salmon and 202 sea trout were examined. One sea trout tested positive for IPNV on PCR. *R. salmoninarum* was not detected, while PRV-1 was found in several salmon and PRV-3 was found in several sea trout (see Table 9.7.1).

Table 9.7.1 Results after 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. From the Trøndelag region, two stock enhancement plants are included and these have only been tested for IPNV and BKD.

Production area	Salmon	Sea trout	Comment
Helgeland Region (PO8)	70		5 salmon positive for PRV-1
Trøndelag Region (PO6)	41		
Driva and Sunnmøre region (PO5 and 6)	172	74	14 salmon positive for PRV-1, 24 sea trout positive for PRV-3
Hardanger region (PO3)	106	60	36 of 104 salmon positive for PRV-1, 10 sea trout positive for PRV-3
Drammen Region (PO1)	63	68	61 salmon tested for PRV-1, 16 sea trout positive for PRV-3
Total	452	202	

9.8 Recent developments

Pink salmon

The pink salmon is an alien species in Norway, but has established self-producing populations in Norwegian rivers following translocation and release in the White sea in Russia. According to Statistics Norway, a total of 111 657 pink salmon (191 tons) captured in rivers and 38 900 pink salmon (72 tons) captured in the sea were registered in 2021. The species was registered along the entire coast, including Norway's most south-easternmost river, Enningdalselva. As much as 98 percent of the river catches were registered in the north, in the County of Troms og Finnmark.

There is a great need for knowledge about the ecological and economic effects of the pink salmon invasions, including whether they can contribute to introduction or spread of infectious agents. Through the Sea Health Project (Havets helse) organized by the NVI, samples from pink salmon from the rivers Karpelv and Skallelv on the south and north sides of Varangerfjord, respectively, as well as the rivers Skibotnelva and Signaldalselva at Lyngenfjorden in Troms og Finnmark were collected. The NVI also received frozen pink salmon from other rivers and from the sea along the coast through a cooperation with the Norwegian Institute for Nature Research (NINA), master's student Tora Paulsen at the University of Tromsø and local river owners' association and stock enhancement hatcheries.

The NVI has examined samples from a total of 181 pink salmon using PCR. The material has been entered into the Food Safety Authority's monitoring programme for surveillance of two viral diseases – viral haemorrhagic septicemia (VHS) and infectious haemorrhagic necrosis (IHN). Samples were also tested for infectious salmon anaemia virus (ISAV), *Renibacterium salmoninarum* (which causes BKD) and piscine orthoreovirus-1 (PRV-1). No infectious agents associated with listed diseases (VHSV, IHNV, ISAV or *R. salmoninarum*) were detected. On the other hand, PRV-1 was again detected in eight individuals: five in the Skibotnelva, one in Skallelv and two from the Ferseth watercourse system in Vega. PRV-1 was first detected in pink salmon in Norway through the Food Safety Authority's health monitoring programme for wild salmonids in 2019. Sequencing and phylogenetic analyses conducted by the Veterinary Institute in 2019 showed that viruses from pink salmon belonged to the PRV-1b genotype, which is the variant that causes heart and skeletal muscle inflammation (HSMI) in Atlantic salmon.

Aeromonas septicemia in pink salmon

In mid-August, a pink salmon with signs of disease resembling furunculosis was found dead in River Gjersjøelva in the Municipality of Nordre Follo in Viken. The Follo hunting and fishing association notified the Food Safety Authority, which delivered the pink salmon frozen for examination at the NVI. The bacterium *Aeromonas hydrophila* grew from both muscles and kidneys. The suspicion of furunculosis, which is caused by the bacterium *Aeromonas salmonicida* subsp. *salmonicida*, was thus disproven, but the finding is nevertheless interesting. *A. hydrophila* is found naturally in water, but under certain conditions can cause disease

Table 9.8.1 Norwegian Veterinary Institute health monitoring of pink salmon did not detect serious fish diseases. The PRV-1 virus that causes heart and skeletal muscle inflammation in Atlantic salmon was found in pink salmon from three rivers.

River	Number examined	PRV-1 positive	CT value
Skallelv	62	1	37.25
Karpelv	60	0	
Skibotnelva	31	5	25.8-36.6
Signaldalselva	3	0	
Fersethvassdraget	10	2	37-37.6
Gjersjøelva	1	0	
Sandvikselva	10	0	
Ranelva	5	0	

in fish, and a wide range of animal species including humans. In fish, the bacterium causes a systemic infection (septicemia), while in humans it can cause wound infections, but also gastrointestinal infections. Infections with *A. hydrophila* mainly, but not exclusively, occur in warmer regions.

Furunculosis is not very prevalent in wild populations

In 2020 and 2021, an increased incidence of classic furunculosis (*Aeromonas salmonicida* ssp. *salmonicida* infection, hereinafter referred to *A. salm*) has been recorded. The prerequisite for such detections is that reservoirs of the bacterium exist. A plausible question is

Figure 9.8.1 Pink salmon from Gjersjøelva river in the Municipality of Follo had signs of disease that triggered suspicion of furunculosis. Photo: Sander Engeland.

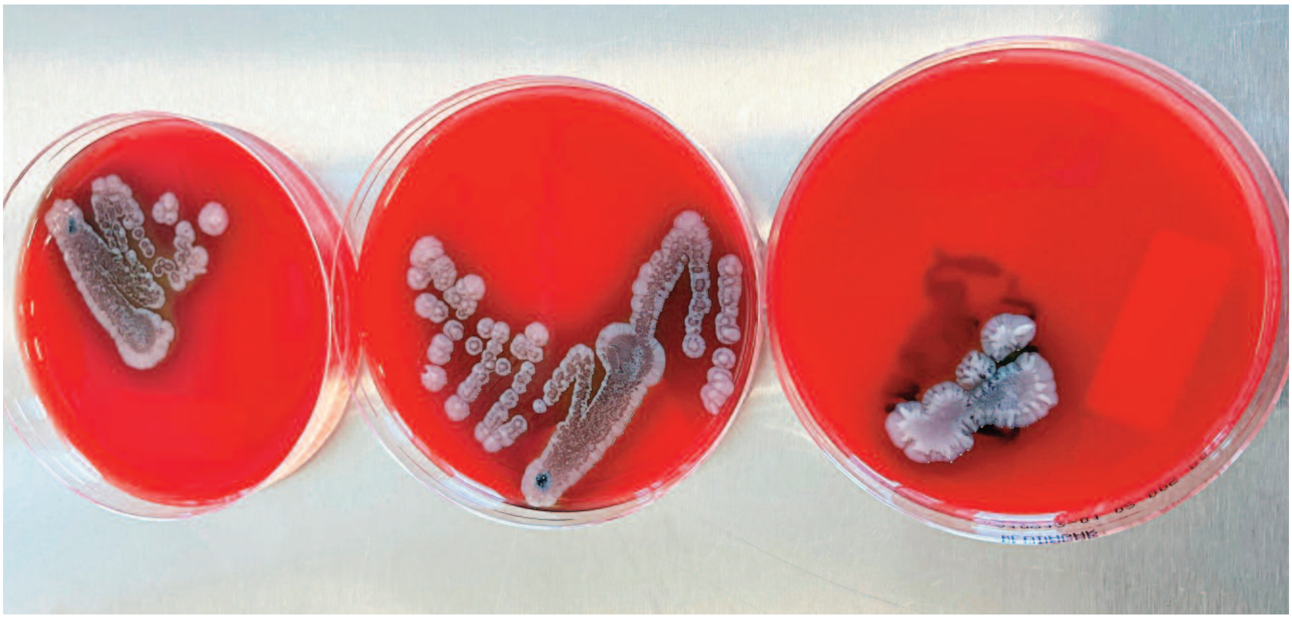


Figure 9.8.2 The bacterium *Aeromonas hydrophila* was detected in cultivations from the kidney and muscle of pink salmon from Gjersjø river. Photo: Duncan Colquhoun, Norwegian Veterinary Institute.

therefore how common is furunculosis in wild salmonids today?
A. salm was first introduced to Norway with rainbow trout from Denmark (1964) and later with salmon smolt from Scotland into fish farms in Nord-Trøndelag (1985). After its introduction in 1985, the infection spread within the aquaculture industry and to wild salmonids in several areas along the coast. The use of oil-based vaccines in farmed fish was crucial to gain control of the furunculosis situation in the aquaculture industry, and probably also contributed to the decline observed in incidences in wild fish.

The NVI has reviewed available data to describe the occurrence of furunculosis in wild salmonids. The review showed that the disease has been linked to a few watercourses in the period after the year 2000. In the Namdal region of Trøndelag, furunculosis was detected in Aursunda (2001), Bogna (2000, 2003, 2015-2018), Ferga i the Ågårdsvassdraget watercourse (2000, 2001, 2003, 2006, 2008, 2017-2019) and in Namsen (Sandøla) (2007, 2008, 2015, 2018, 2019). In the Spilder watercourse in Nordland, furunculosis was detected in trout fry in the Spilderdalen hatchery (stock enhancement hatchery) in 2004, and in a wild trout in the Spilderelva river in 2006. The Norwegian Veterinary Institute did not detect furunculosis in wild salmonids in 2020 or 2021.

In the period 2005-2015, a total of 4005 salmon, 606 sea trout and 76 char were examined by the health services for stock enhancement hatcheries in their health control of wild-caught broodstock. The testing included a limited number of rivers (about 30), but these are distributed throughout the country. In the described material, A.salm was only detected in one fish, a PCR-positive salmon from Nordmøre. The detection was made in 2010 using a non-accredited PCR method, the sample material itself did not pass the laboratory's quality control, and the result was not verified by other methodologies. The stock enhancement facility has since maintained testing for A. salm without any further detections. The results thus indicate that *A. salm* is not common in wild salmonids returning to the rivers to spawn.

Both in farmed and wild fish, asymptomatic (covert) carriers of furunculosis are difficult to detect, but are probably more easily detected in wild-caught spawning fish than otherwise. Spawning fish generally have impaired immune systems and experience both stress and reduced health status in connection with fish handling during captivity before stripping. These are factors that can activate latent *A.salm* infection, ref. stress tests that the aquaculture industry used to detect latent infection before sea transfer. Since 2015, furunculosis has been detected in lumpfish in fish farms in the Namdal area.

Figure 9.8.3 Wild salmon with furunculosis. Photo: Anton Rikstad.

Here, furunculosis is still recorded in wild salmonids 35 years after the original introduction. This shows that established reservoirs of *A. salm* may have long-lasting consequences for wild fish, but also for farmed fish. One observation that supports this conclusion is that furunculosis in lumpfish has only been detected at fish farming sites in the Namdal area, even though the species is used as cleaner fish along most of the coast.

Proliferative kidney disease (PKD)

Proliferative kidney disease (PKD) is expected to have an increased impact in warmer climates. The disease is caused by infection with the multicellular parasite *Tetracapsuloides bryosalmonae* in the group myxozoa (Myxozoa), subclass Malacosporea. The parasite lives in freshwater and has bryozoa as its final host. In bryozoa, sexual reproduction takes place with the production of spores that are scattered with the water masses. The parasite infects fish by penetrating the mucus layer of the skin and then spreads with the blood circulation to most internal organs. In the kidneys, the parasite reproduces asexually with the production of the spores infecting the bryozoa. These are excreted into the water via the urinary tract.

After outbreaks of PKD in wild salmon and trout fry in the Åbjøra and the Jølstravassdraget watercourse in 2006, NINA and the Veterinary Institute mapped the incidence of the parasite in Norwegian rivers. The parasite was found in 15 of 18 examined rivers distributed between southern Nordland and Rogaland. On behalf of the Nord Trøndelag Energiverk (NTE), the Norwegian Veterinary Institute investigated fry of brown trout and salmon in the Åbjøra river in Trøndelag in the period after this 2006 outbreak and detected PKD in 2010, 2011, 2013, 2014, 2016-2019 and 2021. In connection with these investigations, several other parasites were also observed in some individuals, such as gastrointestinal coccidians, nematodes (roundworms) in the coelomic cavity and eye flukes.

Salmonids can be infected with *T. bryosalmonae* without developing the disease. The disease primarily affects salmonids in watercourses, stock enhancement hatcheries and hatcheries, and preferably when water temperatures are above 15 °C for 14 days. The problems can be exacerbated in regulated watercourses with low water flow and high temperature. In PKD-infected fish, swollen kidneys and pale gills are often seen. The parasite can be detected using histopathological examinations in which *T. bryosalmonae* (PKX-cells) can be seen in tissue sections, especially in the kidney and spleen. The parasite can also be detected using molecular biological methods. Read more in the NVI's fact sheet: **Proliferative kidney disease (PKD) (vetinst.no)**

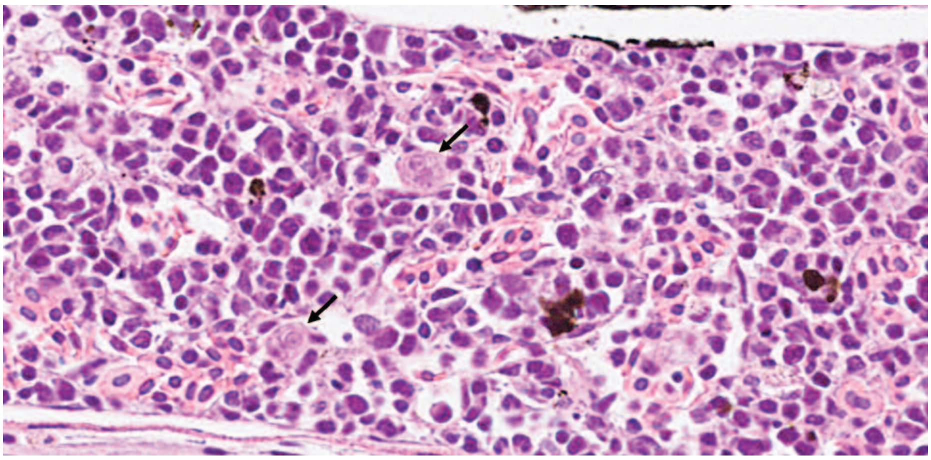


Figure 9.8.4 Kidney tissue containing *T. bryosalmonae*, so-called PKX-cells (black arrow). Photo: Lisa Furnesvik, Norwegian Veterinary Institute.

10 The health situation in cleaner fish

By Toni Erkinharju, Snorre Gulla, Synne Grønbech, Julie Christine Svendsen, Geir Bornø 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 17.02.2022) a total of 40.6 million cleaner fish were transferred to sea in Norway in 2021. This is lower than the updated figures for 2020 (biomass data updated on 01.07.2021) with transfer of 42.4 million cleaner fish to the sea. According to the same register, 21.8 million lumpfish were transferred to sea in 2021 compared to 22.7 million lumpfish in 2020. 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 (Figure 10.1) 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. Last year, 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 2021 as in 2020, especially in PO3-5.

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 (Figure 10.2 A). '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 (see Chapter 5.2).

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* 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 (see Chapter 5.5). The Norwegian Veterinary Institute (NVI) has recently proposed the 'working name' of *Pasteurella 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 10.1 Lumpfish in Atlantic salmon cage. Photo: Rudolf Svendsen, UW Photo

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 (Figure 10.2 B) 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 (see Chapter 5.4).

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.

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.

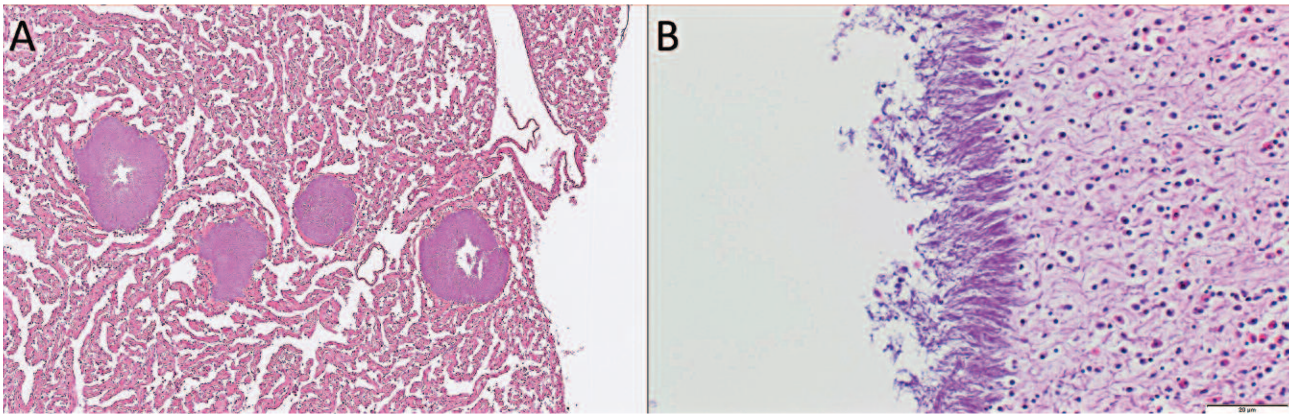


Figure 10.2 Bacterial infections of cleaner fish. A: Microcolonies of short rod-shaped bacteria in the heart of lumpfish suffering atypical furunculosis. B: Skin ulcers in lumpfish, associated with various types of filamentous rod-shaped bacteria (probably *Tenacibaculum* spp.). Photo: Toni Erkinharju, Norwegian Veterinary Institute

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 cross-species 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 under-diagnosed 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.

The myxosporidian *Kudoa* sp., probably *K. islandica*, is sometimes detected in skeletal muscles in lumpfish. This species has been described from wild-caught lumpfish and wolffish in Iceland and was not considered to cause high mortality, but was associated with reduced swimming capability and welfare in affected fish.

Infection with the ectoparasite *C. 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 *Caligus elongatus*. Due to its low host specificity, this parasite can also transmit to salmon.

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.

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 (diarrhoea-like 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 wild-caught 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 held together 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 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 2021

Data from the Norwegian Veterinary Institute and other laboratories

Bacteria

In 2021, the NVI has detected atypical furunculosis/atypical *Aeromonas salmonicida* in lumpfish at 36 sites and in wrasse at 24 sites. At five of these sites, disease/agents were detected in both lumpfish and wrasse. This is lower compared to last year, where the corresponding figures was 51 sites for lumpfish and 29 for wrasse. However, figures from 2020 are not directly comparable, as the detections for this year included data from both the NVI and other laboratories (the latter is not available for atypical *A. salmonicida* this year). Furunculosis and/or typical *A. salmonicida (A. salmonicida* subsp. *salmonicida*) was not detected in cleaner fish in 2021.

The NVI and other laboratories detected *Pasteurella* sp. (*P. atlantica* gv. *cyclopteri*) in lumpfish at eight sites in 2021. This is much lower than the reported figures for last year with a total of 36 detections. Infection with a closely related variant of the bacterium (*P. atlantica* gv. *salmonicida*) was also detected in several salmon sites in 2021 (see Chapter 5.5).

In 2021, *Pseudomonas anguilliseptica* was detected in lumpfish at 15 sites; slightly lower than last year's “record” of 18 affected sites. In addition, *P. anguilliseptica* was also (for the first time since 2017) detected in ballan wrasse from one of the sites in 2021.

Vibrio anguillarum serotype O2 was detected in lumpfish at one sea site in 2021. There were no detections in wrasse in 2021.

In 2021, *Vibrio ordalii-l*ike bacteria were detected in lumpfish at one site in Northern Norway. There have generally been few detections in lumpfish in recent years.

A broad array of vibrio species (*V. splendidus, V. logei, V. tapetis, V. wodanis, V. alginolyticus, Vibrio* sp.), as well as *Tenacibaculum* spp. and *Moritella viscosa*, were also isolated from cleaner fish in 2021, often in mixed culture. *M. viscosa* was detected by the Veterinary Institute and other laboratories in lumpfish at 26 sites and in wrasse at 3 sites. *Tenacibaculum* spp. was detected by the Veterinary Institute and other laboratories in lumpfish at 33 sites and in wrasse at 6 sites. Where species affiliation was determined, *T. finnmarkense* gv. *finnmarkense* was found in lumpfish at 8 sites. *T. finnmarkense* gv. *ulcerans* was detected in lumpfish at 6 sites and in wrasse at 1 site. *T. dicentrarchi* was detected in lumpfish at 1 site and in wrasse at 1 sites. *T. maritimum* was detected in lumpfish at 3 sites and in wrasse at 1 site. Additionally, during 2021 there have also been several sites with detections of *M. viscosa* and *Tenacibaculum* spp. in connection with development of severe skin ulcers and outbreaks of winter ulcer in salmon (see Chapter 5.4).

Fungi

In 2021, systemic mycosis (unknown species) was detected in lumpfish at one sea site in Southern Norway. There were no detections of specific types of fungal infections or superficial/systemic mycosis in wrasse.

Virus

No virus was detected in diagnostic cleaner fish material submitted to the Veterinary Institute in 2021. Figures from private laboratories show a total of 21 sites with detections of cyclopterus lumpus virus (CLuV) or lumpfish flavivirus virus in 2021. The corresponding figure for last year was a total of 30 sites with detections of the virus.

Parasites

In 2021, the NVI and other laboratories detected AGD in lumpfish at eight sites and in wrasse at five sites. *Nucleospora cyclopteri* was not detected in lumpfish by the NVI in 2021. As previously mentioned, it is likely that *N. cyclopteri* may be underdiagnosed, as the parasite is often difficult to detect by routine histological examination.

Coccidiosis was detected in lumpfish at two sea sites in 2021.

Infection with myxozoa parasites (*Kudoa* sp.) in skeletal muscles was detected in lumpfish at two sea sites in 2021. At three sites, varying degrees of parasite infestations (most likely myxozoa) were detected in parts of the kidney (excretory tissue) in lumpfish.

In 2021, sporadic incidences of ciliates (*Trichodina* sp.) were detected in the gills of lumpfish at several sites, but this was not related to significant health problems in the fish.

Trematodes were found in organ samples (gills and gastrointestinal tract) from lumpfish at a few farms. Live and encapsulated roundworms (nematodes) were also found in the coelomic cavity of lumpfish at two sea sites.

Other diseases and health problems

Figures from the NVI show nine lumpfish sites and one ballan wrasse site where nephrocalcinosis was detected in 2021. Regarding lumpfish, varying degrees of emaciation have also been recorded in individual fish from several sites.

The annual survey

When asked whether the mortality rate for cleaner fish has changed, only a smaller proportion (<10 percent) of respondents report an increase or decrease from last year, while >80 % answered that the level is unchanged or that they do not know. This applies to both lumpfish and wrasse. However, these figures must be seen in light of the fact that many submitters over several years have stated in the free text field in the survey that there is almost total mortality of cleaner fish in salmon cages.

For the hatchery phase, production disorders such as fin erosion and suboptimal care are highlighted as particularly problematic for both lumpfish and wrasse (Appendices D1 and E1). Of the specific infectious diseases, crater disease (“2nd place” for lumpfish) and AGD (“2nd place” for wrasse) are identified as the most problematic during this phase, while the other diseases follow in slightly different order.

After transfer to sea in salmon cages, production-related disorders are still ranked high for both cleaner fish groups (Appendices D2 and E2). At the top are problems related to non-medicinal delousing, emaciation, ulcers, fish handling, suboptimal care and fin erosion. However, two specific infectious diseases are important, namely crater disease (“2nd place” for lumpfish) and atypical *A. salmonicida* (“1st and 6th” place for wrasse and lumpfish, respectively).

Approximately half of the respondents answered “NO” to questions whether stunning and euthanising of cleaner fish at harvest facilities provided satisfactory fish welfare, while just under 20 % answered “YES” (the remaining did not know). In the free text section of this question, 10 out of 11 respondents mentioned that this works poorly in practice. Common for most of the respondents appear to be that they experience a lack of effective and/or approved methods for sorting of fish and stunning, which in turn leads to many cleaner fish in harvest facilities eventually dying in an unacceptable manner.

Among the 36 free-text comments on the general health situation of cleaner fish, approximately 80 % of the respondents are to varying degrees critical to aspects of current practice. Among the others, only one respondent said that the cleaner fish are in good health and have low mortality, while the rest are neutral or state that cleaner fish are only to a limited extent used in their areas. About half of all respondents make highly critical statements, i.e. that mortality is almost total and/or that cleaner fish health is far too poorly safeguarded. A quarter of the respondents mentions that the current use of cleaner fish on the whole, can hardly be justified from a health and welfare perspective. The challenge highlighted by most of the respondents is a lack of methods for efficient/gentle collection of fish prior to delousing. Several people found that the health and welfare of cleaner fish suffer from a general lack of adapted methods for care and tending to the fish, and/or that attitudes towards this need to be improved. Problems with infectious diseases and lack of effective vaccines also recur among several of the answers.

It is also worth mentioning the summary part of the survey, where comments and improvement proposals were requested related to the general health and welfare of Norwegian farmed fish, regardless of species: Among 47 received responses, 11 highlighted specific challenges related to cleaner fish, of which 6 believe that the use of wrasse and/or lumpfish should be discontinued altogether.

It is worth mentioning replies to the survey is not differentiated geographically, and therefore represents views of the country as a whole. Nevertheless, there may be fairly large regional/geographical differences related to how the cleaner fish situation is perceived.

Evaluation of the cleaner fish situation

Fish health personnel reported that a lot of cleaner fish are still dying in the fish farms, and although exact mortality data is 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.

Production-related disorders, and in particular the lack of good methods for fish collection prior to delousing, create major problems. There are also reports of a lack of efficient and suitable methods for sedation, stunning and/or euthanisation of cleaner fish in harvest facilitiess. Bacterial agents still rank highest on the list of infectious diseases, both according to the NVI's own diagnostics and reporting from fish health personnel. There is still a need for new and/or improved vaccines and vaccination programmes.

Many fish farmers undoubtedly strive for an improvement in the health and welfare of cleaner fish. Nevertheless, it seems that necessary technology and suitable solutions are still lacking to enable sustainable use based on acceptable welfare conditions. Knowledge of the distinctive biology and nutritional needs of the cleaner fish species is also inadequate.

The welfare of cleaner fish is further discussed in Chapter 3 Fish Welfare.

A total of 40.6 million cleaner fish were transferred to sea in Norway in 2021. Photo: Rudolf Svendsen, UWphoto

11 The health situation in farmed marine species

By Hanne Nilsen, Toni Erkinharju, Lisa Furnesvik, Geir Bornø and Hilde Sindre

Marine species in aquaculture

Farming of marine fish species is done at land-based farms and in sea cages. Halibut is bred in specially adapted onshore facilities, and interest in halibut farming is increasing. Turbot thrive best in warm water and is produced in onshore facilities where water can be better controlled. Turbot fry, which must be imported, have been a limiting factor.

Commercial wolffish farming is only in the starting phase. This species has high survival rates between fry stage and harvest. Producers aim to produce harvest-ready fish within a three-year period. Wolffish are bottom dwellers and require sufficient tank floor area to thrive.

There is now an increasing interest in cod farming in Norway.. Through 5-7 generations, ongoing breeding work has bred cod that is calmer and has good growth in captivity. Farmed cod has its fry phase on land and fry production has started at recirculation facilities (RAS). The fry phase is followed by production in sea cages.

Diseases of farmed marine fish species

In Norway, nodavirus infections have caused losses in marine fish farming since the middle of the 1990s. In cod, the disease was first detected in Norway in 2006. In halibut, the disease was last detected in 2012.

In halibut fry, aquatic halibut reovirus (AHRV) is associated with mortality, and infectious pancreatic necrosis virus (IPNV) has been found capable of inducing mortality in infection trials.

Francisellosis, a bacterial disease, was first detected in adult cod in Rogaland/Hordaland in 2004/2005. In the following years, the disease was found in cod of all age groups as far north as Nordland, and profitability in Norwegian cod farming decreased dramatically. Atypical *Aeromonas salmonicida* (i.e. all species of *Aeromonas salmonicida* except subsp *salmonicida*) is associated with mortality in marine species. *Vibrio anguillarum* causes disease in cod and Vibrio species such as *Vibrio (Allivibrio) logei*, *Vibrio splendidus* and *Vibrio tapetis* are often isolated from weak or dead fish. Abundant incidences of *Vibrio logei* have been associated with elevated mortality in halibut fry without any other findings.

Tenacibaculum maritimum is, in addition to regular discoveries in lumpfish (discussed in Chapter 10), previously detected in turbot in connection with skin lesions in Norway. This Tenacibaculum species is an important pathogen in marine species in farming in warmer climates. Species within the genus *Tenacibaculum* are also commonly found in marine fish species and are mainly associated with external lesions of the skin and/or eyes.

Of parasite diseases, "Costia" (*Ichtyobodo* sp.) is not an uncommon finding in the skin and gills of halibut and cod. Changes consistent with *Kudoa* sp. infection have previously been detected in wolffish, and the parasite is considered an unusual finding. Cod can become infected with sea lice, Caligus elongatus and cod lice.

Disease control

Viral nervous necrosis (VNN)/Viral encephalo-retinopathy (VER), caused by nodavirus infections are notifiable List 3 viral diseases in Norway. Francisellosis (*Francisella* sp.) is a notifiable List 3 bacterial disease in Norway. No commercial vaccines are available against these diseases.

See the Norwegian Veterinary Institute's fact sheets for more information:

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

https://www.vetinst.no/sykdom-og-agens/nodavirus-hos-marin-fisk-vnn-ver

The Health Situation in 2021

Official data

Infection with Nodavirus was detected in halibut in Norway in 2021. Francisellosis, caused by *Francisella noatunensis* subsp. *noatunensis*, was not detected in cod in 2021.

Data from the Norwegian Veterinary Institute

Halibut and turbot

In 2021, a total of 11 submissions were received to the Veterinary Institute from halibut and turbot. This is somewhat fewer than in 2020. In halibut with nodavirus infection, typical findings such as viral nervous necrosis/viral encephalopathy and retinopathy were found and VNN/VER was verified in the affected population. Sequencing of the viruses showed nodaviruses similar to known halibut varieties. As before, atypical *Aeromonas salmonocida* and Vibrio species have been detected in connection with disease in halibut. *Carnobacterium maltoaromaticum* was found in broodstock with inflammation in the abdomen, pericardium and gonads. In turbot, increasing mortality from gill disease has been seen.

Cod

In 2021, cod material was received from five sites. *Vibrio anguillarum* O2 has been detected at two cod sites; adult cod with signs of bacterial spread and from a hatchery at one facility with increased mortality. *Moritella viscosa* has been detected in cod at one site.

Gill inflammation with findings of epiteliocysts, *Trichodina* sp. and *Gyrodactylus* sp., has been detected in submitted material. Tissue reactions from parasites and granulomas are a common finding in cod. Parasites (probable myxozoa) have been detected in the excretory system in the kidneys of adult cod, as well as calcification in the kidneys.

Spotted wolffish

In 2021, two submissions of wolffish material were received. There have been reports of ulceration without increased mortality.

The Annual Survey

Eye injuries and sunburn have been reported as problems in halibut farming. It has been reported that Atlantic halibut reovirus (AHRV) has presented challenges. In wild-caught cod, emaciation and trapping injuries developing into damaged eyes or ulcers have been reported. At facilities with cod farming, volvulus (twisted intestines), runted fish, eroded skin and ulcers have been reported.

Evaluation of the health situation in farmed marine species

With increasing farming of both halibut and cod, it will be important to learn from previous experience and keep watch for nodavirus. Nodavirus will typically develop persistent infections that are asymptomatic in larger fish,but infective viruses may be activated upon stressful handling such as spawning. With increasing cod farming, it is important to be vigilant for new detections of francisellosis.

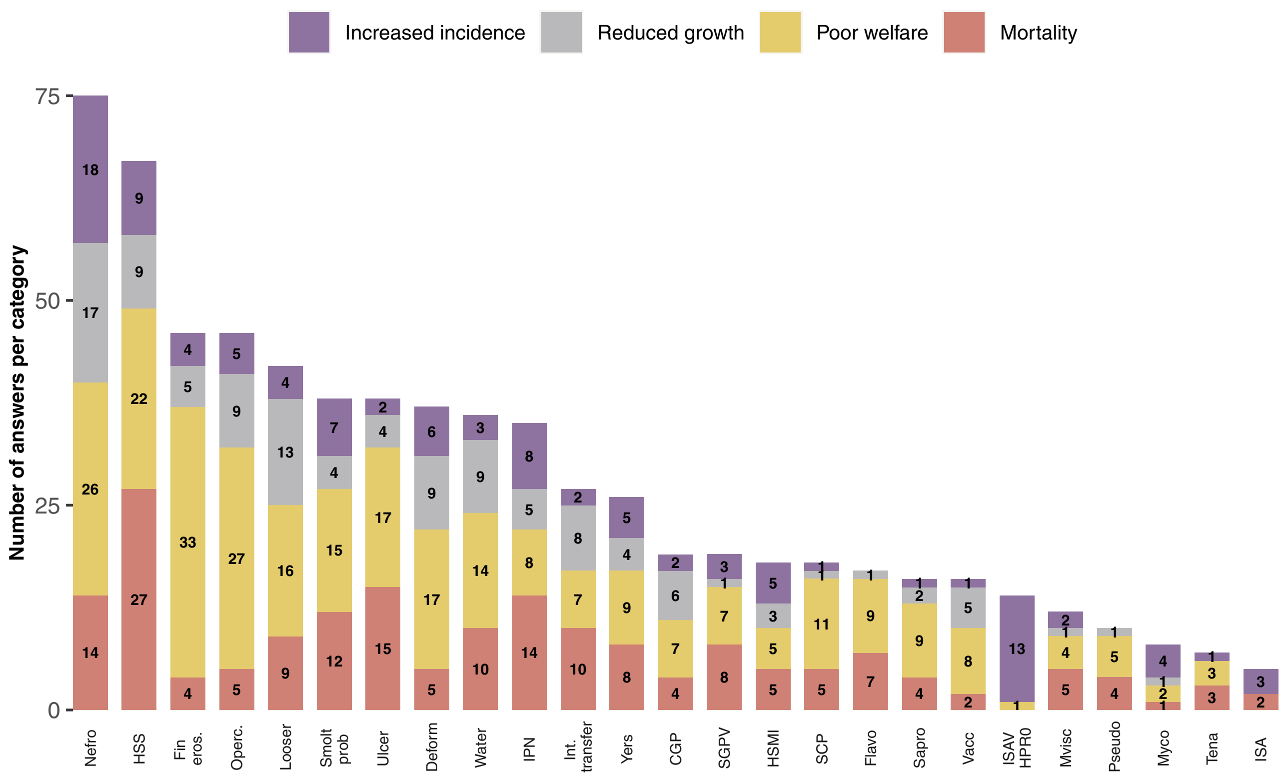
Appendix A1:

Health problems in juvenile salmon production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in salmon hatcheries were asked to cross off the five most important of 26 possible problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), reduced growth (grey bars) or were considered to be an increasing problem/ increased incidence (violet bars).There were N=47 respondents who responded on mortality, N=51 on reduced welfare, N=35 on reduced growth and N=39 on increased incidence.

The following abbreviations for the various problems the respondents were asked to express an opinion on were:

Nefro = nephrocalcinosis
HSS = haemorrhagic smolt syndrome
Fin eros. = fin erosion
Operc. = shortened gill covers
Looser = runted fish, runt syndrome, emaciation
Deform = deformities
Smoltprob = smoltification problems
Ulcer = skin ulcers and underlying tissues, unspecified cause
Deform = deformities
Water = poor water quality
IPN = infectious pancreas necrosis
Int.transfer = moving fish between operational departments with different water qualities (e.g. RAS to flow-through)
Yers = infection with *Yersinia ruckeri* (yersinosis)
CGP = gill disease complex/multifactoral
SGPV = salmon gill pox virus (disease due to SGPV)
HSMI = heart and skeletal muscle inflammation
SPC = single-celled parasites on gills/skin (e.g *Ichthyobodo* spp., *Trichodina* spp.)
Flavo = *Flavobacterium psychrophilum* infections
Sapro = infection with *Saprolegnia* spp.
Vacc = vaccine side effects
ILAV HPR0 = infection with non-virulent ISAV (ISAV HPR0)
Mvisc = infection with *Moritella viscosa* (classic winter ulcer)
Pseudo = infection with *Pseudomonas* spp.
Myco = infection with Mycobacteria
Tena = infection with *Tenacibaculum* spp (non-classic winter ulcer)
ISA = Infectious salmon anaemia (infection with ISAV HPR-deleted)



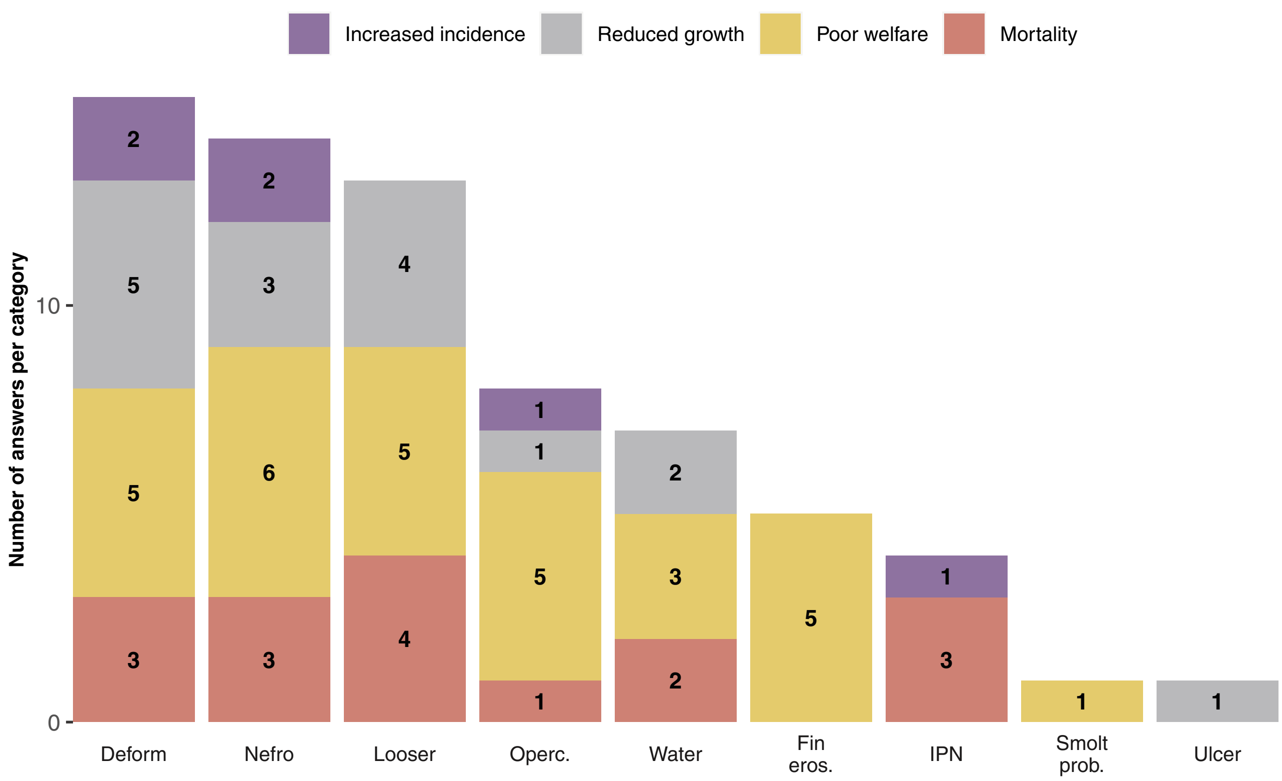
Appendix A2:

Health problems in juvenile rainbow trout production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in rainbow trout hatcheries were asked to cross off the five most important of 24 possible problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), reduced growth (grey bars) or were considered to be an increasing problem/ increased incidence (violet bars).For each problem category there were N=9 respondents who responded on mortality, N=9 on reduced welfare, N=7 on reduced growth and N=3 on increased incidence.

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
Nefro	=	nephrocalcinosis
Looser	=	runted fish, runt syndrome, emaciation
Operc.	=	shortened gill covers
Water	=	poor water quality
Fin eros.	=	fin erosion
IPN	=	infectious pancreas necrosis
Smolt prob.	=	smoltification problems
Ulcer	=	skin ulcers and underlying tissues,



Appendix B1:

Health problems during ongrowing salmon

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in salmon ongrowing facilities were asked to cross off the five most important of 32 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), reduced growth (grey bars) or were considered to be an increasing problem/ increased incidence (violet bars). The results are divided into two charts, so the figures for the lowest ranked diseases become visible. For each problem category there were N=88 respondents who responded on mortality, N=87 on reduced welfare, N=73 on reduced growth and N=69 on increased incidence.

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):

Mech.injury delouse	= mechanical harm related to delousing
Mvisc	= infection with *Moritella viscosa* (classic winter ulcer)
CMS	= cardiomyopathy syndrome
Tena	= infection with *Tenacibaculum* spp (non-classic winter ulcer)
CGD	= gill disease complex/multifactoral
HSMI	= heart and skeletal muscle inflammation
Salmon louse	= salmon lice (grazing injuries following infection with *Lepeoptheirus salmonis*)
Past	= infection with *Pasteurella* sp. (pasteurellosis)
Looser	= runted fish, runt syndrome, emaciation
ISA	= Infectious salmon anaemia (infection with ISAV HPR-deleted)
PD	= pancreas disease
AGD	= amoebic gill disease
Nefro	= nephrocalcinosis
LOS	= lack of smoltification
IPN	= infectious pancreas necrosis
Sexual mat.	= sexual maturation
Ulcer	= skin ulcers and underlying tissues, unspecified cause
Deform	= deformities
Mech.injury	= mechanical harm not related to delousing, e.g. after manual handling, transport
Parvi	= infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Caligus	= Caligus elongatus (grazing injuries following infestation with *Caligus elongatus*)
Fin eros.	= fin erosion
Collision	= jumping injuries, collision with equipment in cage
ISAV HPR0	= infection with non-virulent ISAV (ISAV HPR0)
Vacc	= vaccine side effects
Tapew.	= tapeworm
Furunc	= furunculosis (infection with *Aeromonas salmonicida* subsp *salmonicida*)
Myco	= infection with Mycobacteria
Yers	= infection with *Yersinia ruckeri* (yersinosis)
Algae	= algae
Jellyfish	= jellyfish
SGPV	= salmon gill pox virus (salmon pox disease)

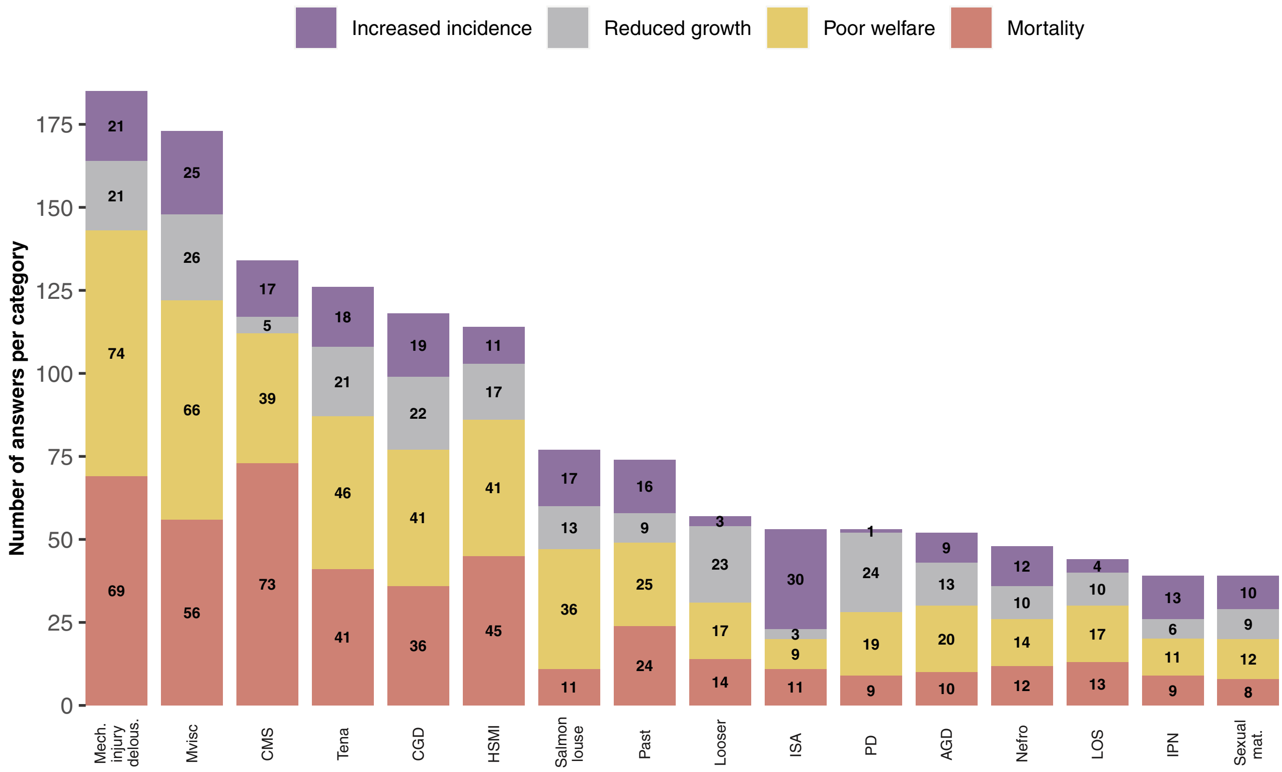


Chart part 1. The 16 highest ranked health problems in salmon at ongrowing facilities.

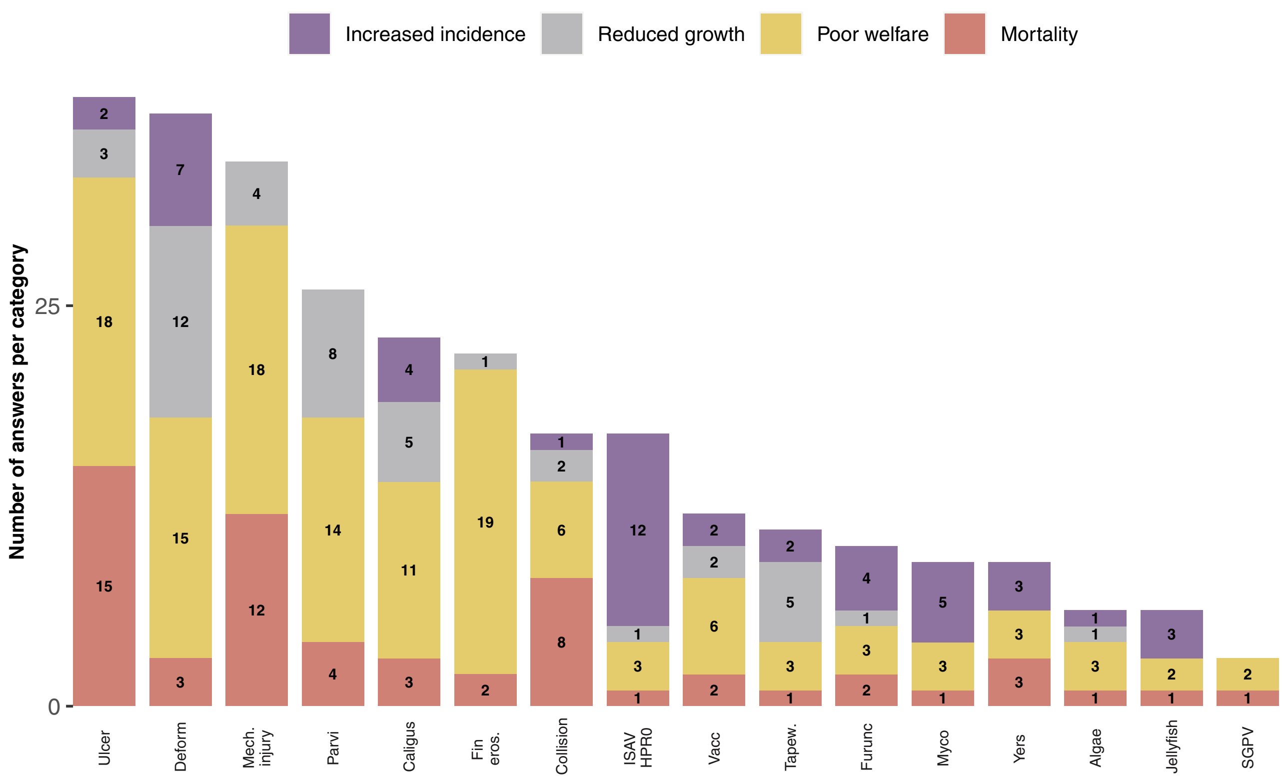


Chart part 2. Ranking of health problems 17 to 32 in salmon at ongrowing facilities.

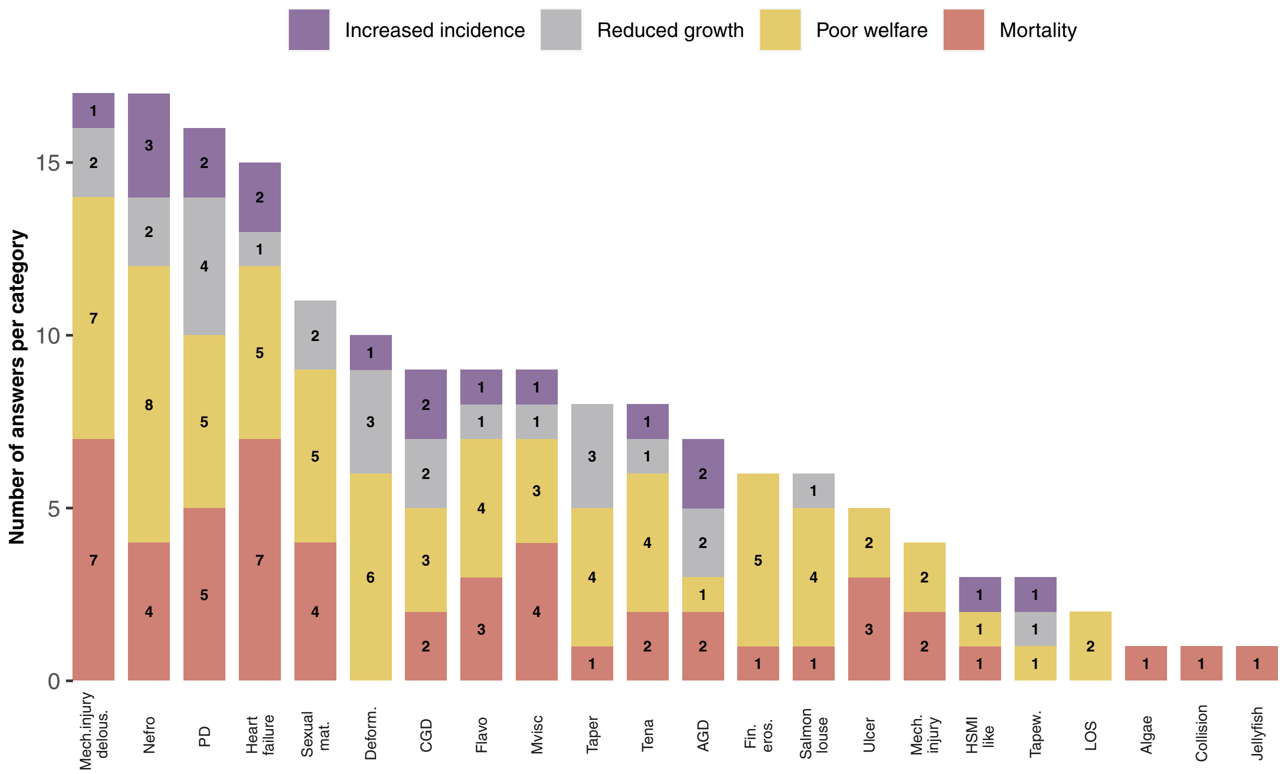
Appendix B2:

Health problems during ongrowing rainbow trout production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in ongrowing rainbow trout were asked to cross off the five most important of 29 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), reduced growth (grey bars) or were considered to be an increasing problem/ increased incidence (violet bars). For each problem category there were N=12 respondents who responded on mortality, N=13 on reduced welfare, N=9 on reduced growth and N=7 on increased incidence.

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):

Mech.injury delouse	=	mechanical harm related to delousing
Nefro	=	nephrocalcinosis
PD	=	pancreas disease
Heart failure	=	heart failure, not related to known infectious disease
Sexual mat.	=	sexual maturation
Deform.	=	deformities
CGD	=	gill disease complex/multifactoral
Flavo	=	infection with Flavobacterium psychrophilum
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Taper	=	runted fish, runt syndrome, emaciation
Tena	=	infection with *Tenacibaculum* spp (Non-classic winter ulcer)
AGD	=	amoebic gill disease
Fin eros.	=	fin erosion
Salmon louse	=	salmon lice (grazing injuries following infection with *Lepeoptheirus salmonis*)
Ulcer	=	skin ulcers and underlying tissues, unspecified cause
Mech.injury	=	mechanical harm not related to delousing, e.g. after manual handling, transport
HSMI-like	=	PRV3/HSMI like disease
Tapew.	=	tapeworm
LOS	=	lack of smoltification
Algae	=	algae
Collision	=	jumping injuries, collision with equipment in cage
Jellyfish	=	jellyfish



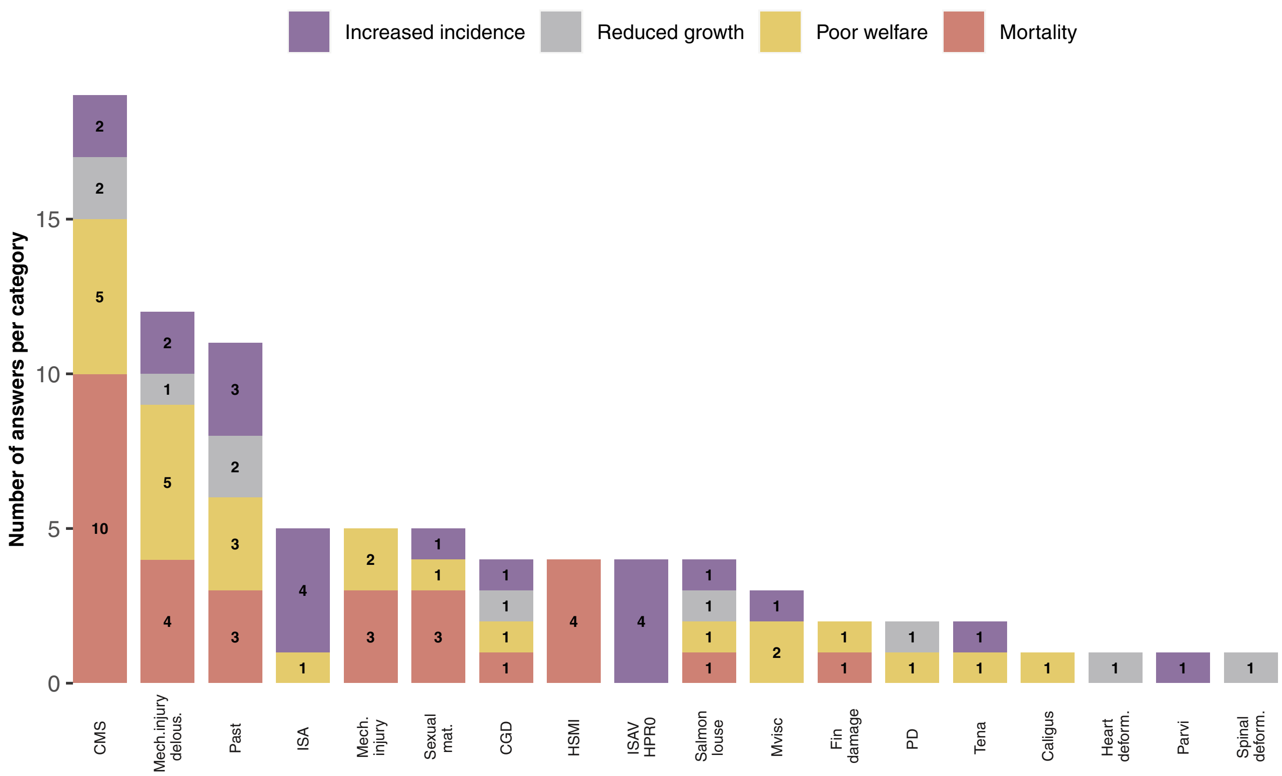
Appendix C1:

Health problems in broodstock salmon production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in broodstock salmon were asked to cross off the five most important of 28 possible problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), reduced growth (grey bars) or were considered to be an increasing problem/ increased incidence (violet bars). For each problem category there were N=12 respondents who responded on mortality, N=9 on reduced welfare, N=4 on reduced growth and N=8 on increased incidence.

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):

CMS	=	cardiomyopathy syndrome
Mech.injury delouse	=	mechanical harm related to delousing
Past	=	infection with *Pasteurella* sp. (pasteurellosis)
ISA	=	Infectious salmon anaemia (infection with ISAV HPR-deleted)
Mech.injury	=	mechanical harm not related to delousing, e.g. after manual handling, transport
Sexual mat.	=	sexual maturation
CGD	=	gill disease complex/multifactoral
HSMI	=	heart and skeletal muscle inflammation
ILAV HPR0	=	infection with non-virulent ISAV (ISAV HPR0)
Salmon louse	=	salmon lice (grazing injuries following infestation with *Lepeoptheirus salmonis*)
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Fin damage	=	fin injuries
PD	=	pancreas disease
Tena	=	infection with *Tenacibaculum* spp (Non-classic winter ulcer)
Caligus	=	infestation with Caligus elongatus
Heart deform	=	cardiac deformities
Parvi	=	infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Spinal deform	=	spinal deformities



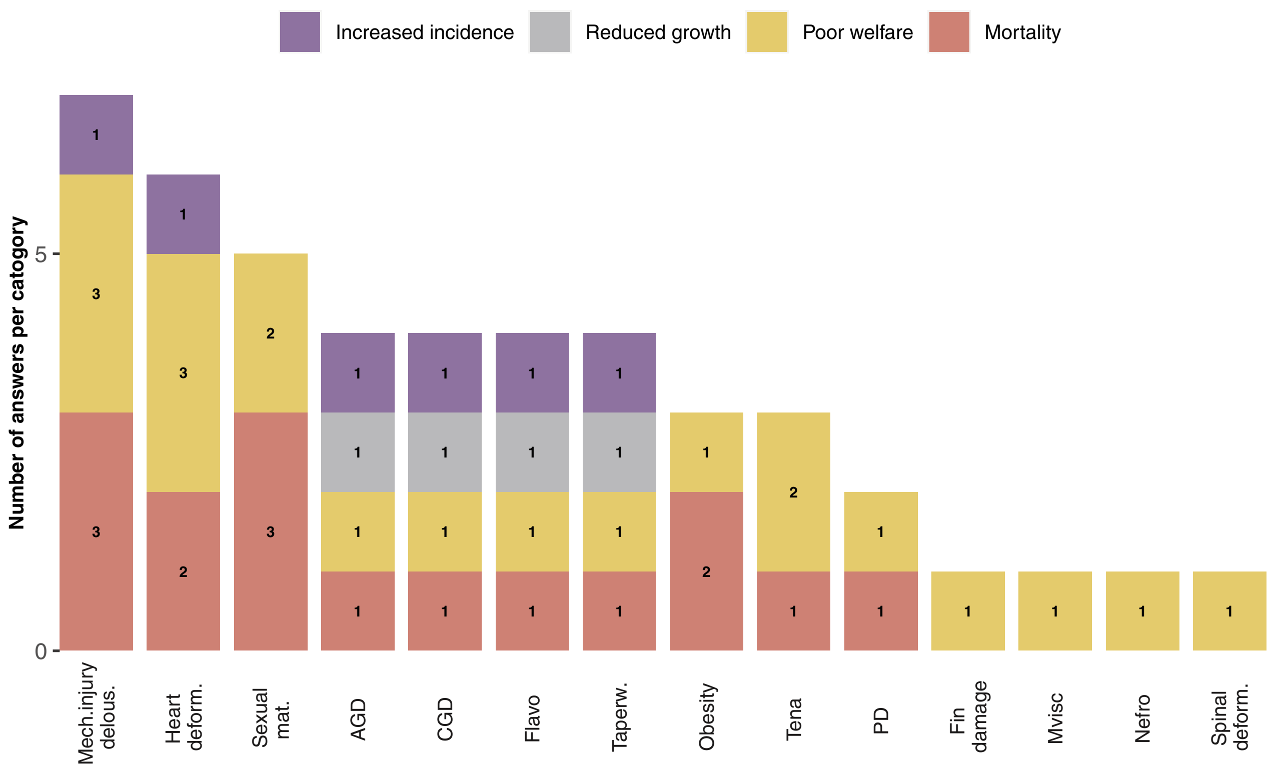
Appendix C2:

Health problems in broodstock rainbow trout production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in rainbow trout broodstock were asked to cross off the five most important of 24 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), reduced growth (grey bars) or were considered to be an increasing problem/ increased incidence (violet bars). For each problem category there were N=3 respondents who responded on mortality, N=5 on reduced welfare, N=1 on reduced growth and N=2 on increased incidence.

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):

Mech.injury delouse	=	mechanical harm related to delousing
Heart deform	=	cardiac deformities
Sexual mat.	=	sexual maturation
AGD	=	amoebic gill disease
CGD	=	gill disease complex/multifactoral
Flavo	=	infection with *Flavobacterium psychrophilum*
Tapew.	=	tapeworm
Obesity	=	obesity
Tena	=	infection with *Tenacibaculum* spp (Non-classic winter ulcer)
PD	=	pancreas disease
Fin damage	=	fin injuries
Mvisc	=	infection with *Moritella viscosa* (classic winter ulcer)
Nefro	=	nephrocalcinosis
Spinal deform	=	spinal deformities



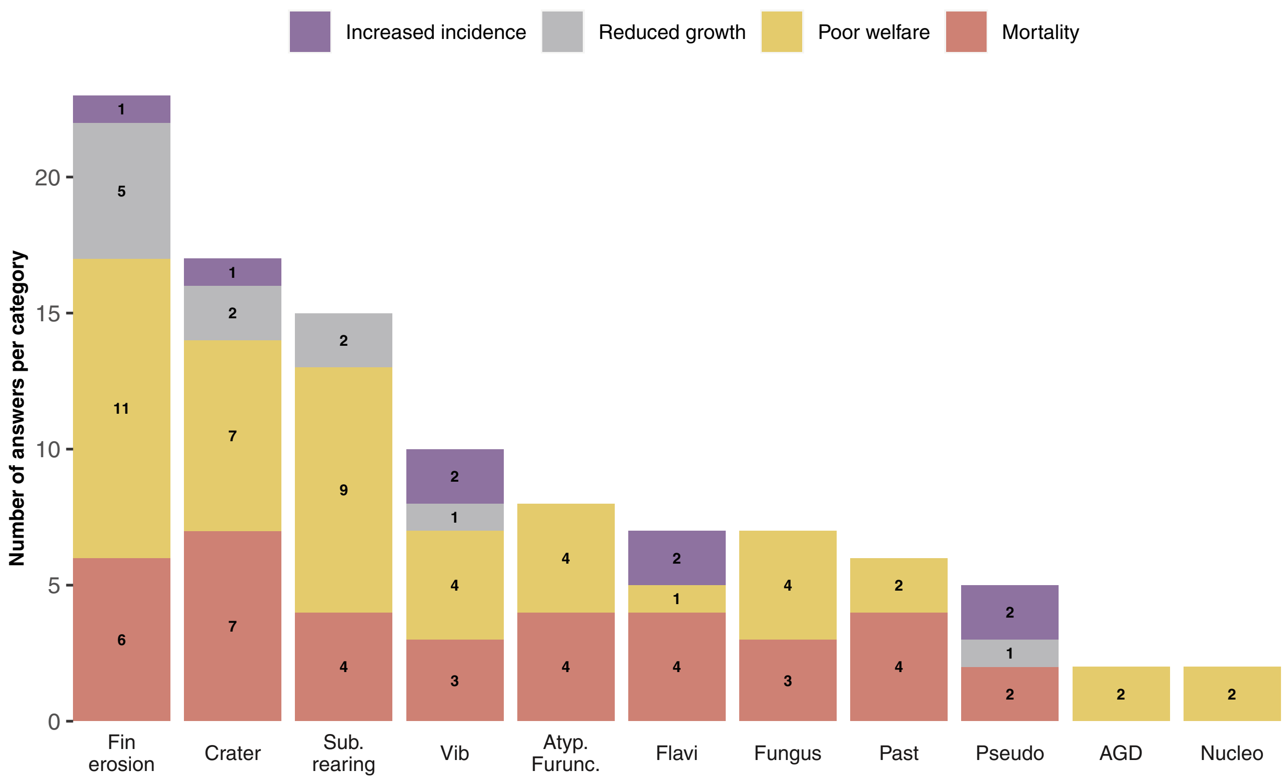
Appendix D1:

Health problems in juvenile lumpfish production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in lumpfish broodstock were asked to cross off the five most important of 12 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), poor growth (grey bars), or were considered to be an increasing problem/increased incidence (violet bars). For each problem category there were N=14 respondents who responded on mortality, N=14 on reduced welfare, N=9 on reduced growth and N=6 on increased incidence.

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):

Fin erosion = fin erosion/rot
Crater = crater disease (infection with *Tenacibaculosis* spp.)
Sub.rearing = suboptimal care
Vib = vibriosis (Infection with *Vibrio* spp.)
Atyp.furunc = atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Flavi = lumpfish flavivirus
Fungus = fungal infection
Past = infection with *Pasteurella* sp.
Pseudo = infection with *Pseudomonas anguilliseptica*
AGD = amoebic gill disease
Nucleo = infection with *Nucleospora cyclopteri*



Appendix D2:

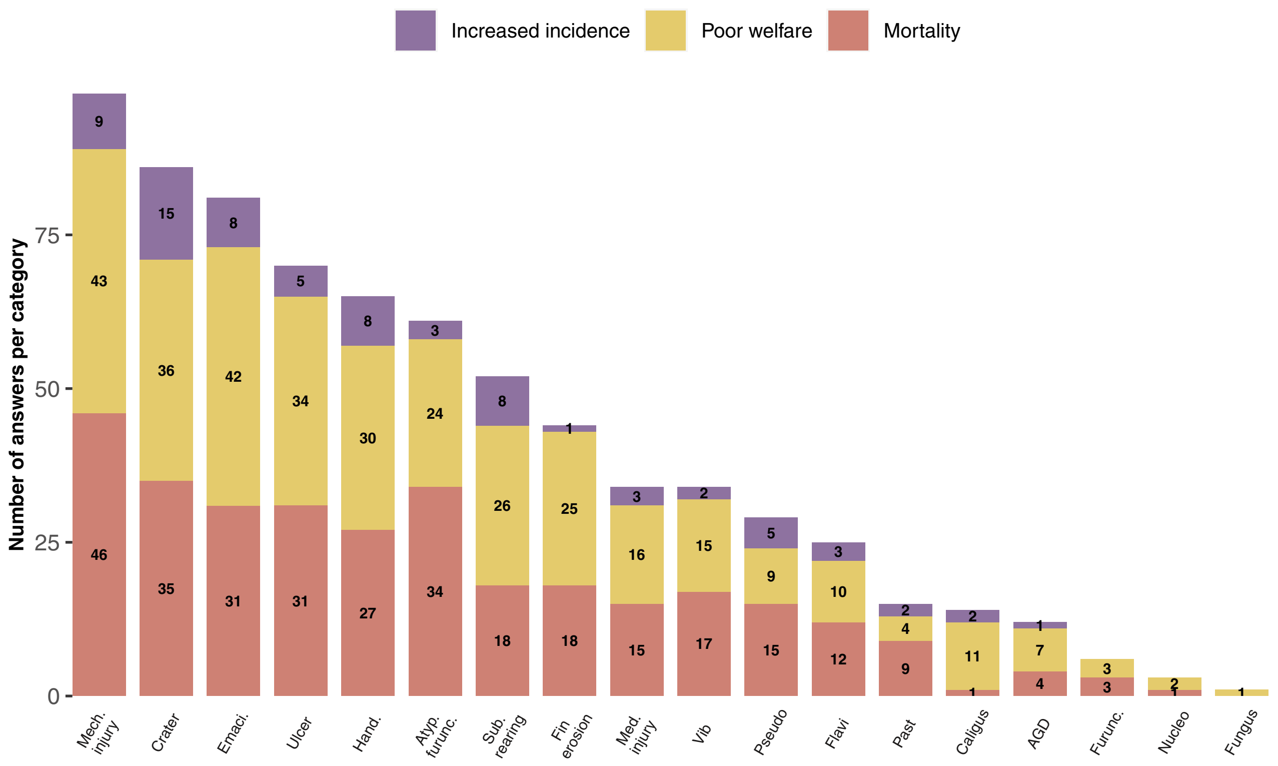
Health problems in lumpfish held with ongrowing salmon

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in lumpfish in ongrowing facilities were asked to cross off the five most important of 19 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), poor growth (grey bars), or were considered to be an increasing problem/increased incidence (violet bars). For each problem category there were N=68 respondents who responded on mortality, N=66 on reduced welfare, N=32 on increasing incidence.

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):

Mech.injury	= injuries/mortality as a consequence of non-medicinal delousing
Crater	= crater disease (infection with *Tenacibaculosis* spp.)
Emaci.	= emaciation, malnutrition
Ulcer	= skin ulcers and any underlying tissues,
Hand	= mortality rate as a consequence of handling
Atyp.furunc.	= atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Sub.rearing	= suboptimal care
Fin erosion	= fin erosion/rot
Med.injury	= injuries/mortality as a consequence of medicinal delousing

Vib	= vibriosis (Infection with *Vibrio* spp.)
Pseudo	= infection with *Pseudomonas anguilliseptica*
Flavi	= lumpfish flavivirus
Past	= infection with *Pasteurella* sp.
Caligus	= infestation with Caligus elongatus
AGD	= amoebic gill disease
Furunc.	= furunculosis (infection with *Aeromonas salmonicida* subsp *salmonicida*)
Nucleo.	= infection with *Nucleospora cyclopteri*
Fungus	= fungal infection



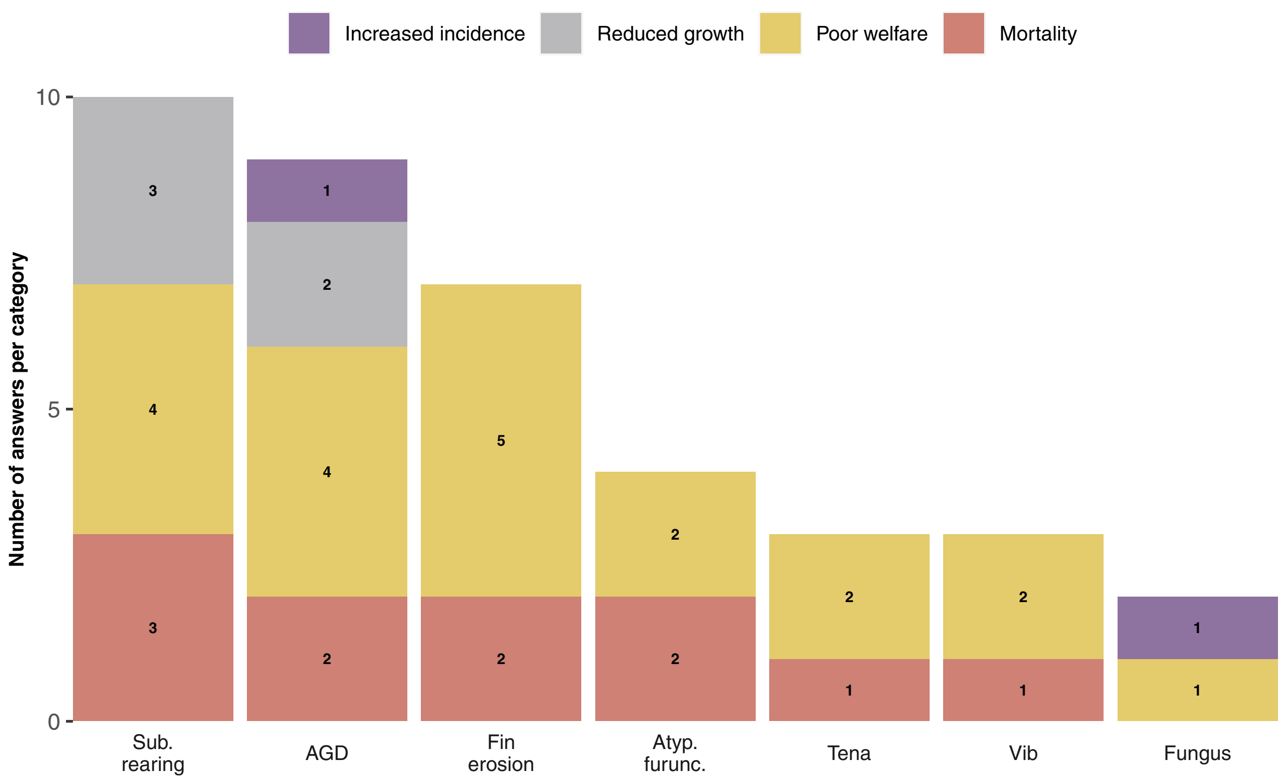
Appendix E1:

Health problems in juvenile wrasse production

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in wrasse in hatcheries were asked to cross off the five most important of 8 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), poor growth (grey bars), or were considered to be an increasing problem/increased incidence (violet bars). For each problem category there were N=8 respondents who responded on mortality, N=8 on reduced welfare, N=5 on reduced growth and N=2 on increased incidence.

The following abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are

Sub.rearing	=	suboptimal care
AGD	=	amoebic gill disease
Fin erosion	=	fin erosion/rot
Atyp.furunc.	=	atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Tena	=	infection with *Tenacibaculum* spp
Vib	=	vibriosis (Infection with *Vibrio* spp.)
Fungus	=	fungal infection



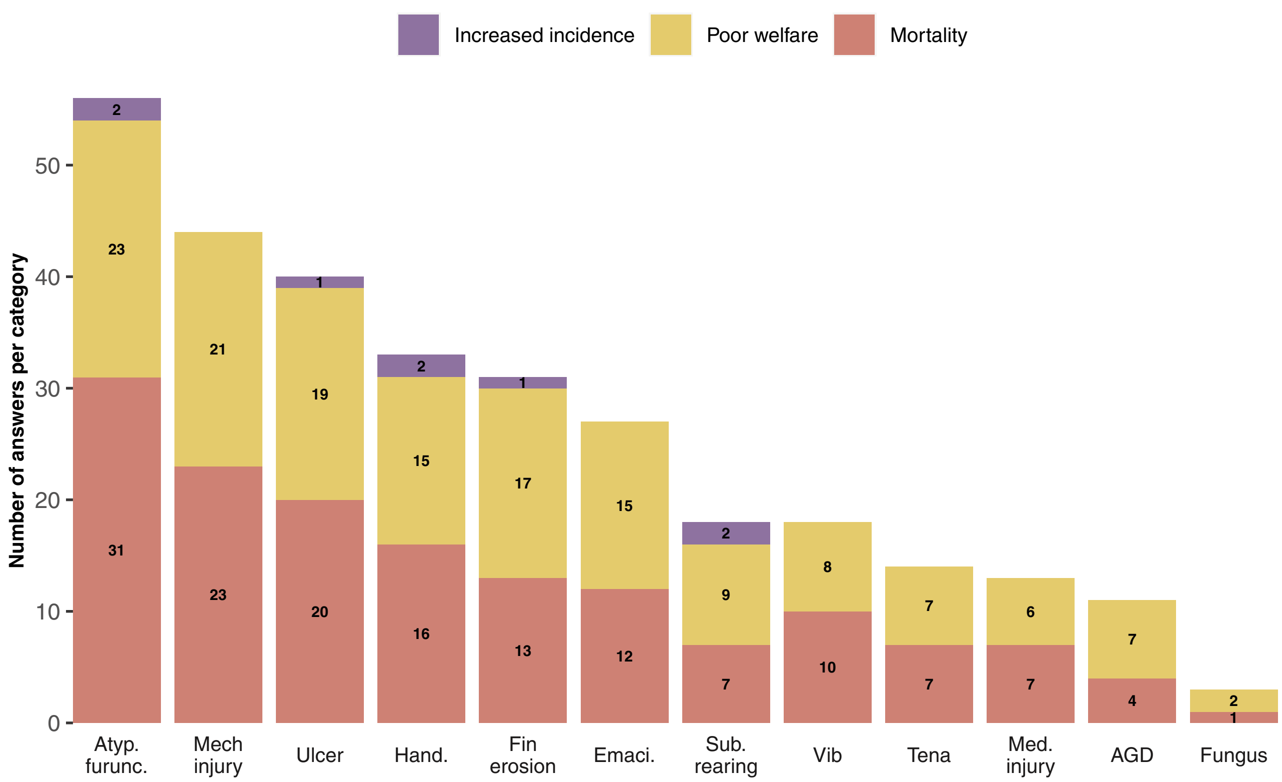
Appendix E2:

Health problems in wrasse held with ongrowing salmon

Results from the survey of fish health personnel and inspectors at the Food Safety Authority as part of the Norwegian Fish Health Report for 2021: Respondents with experience in wrasse in ongrowing facilities were asked to cross off the five most important of 14 possible health problems based on whether they contributed to mortality (red bars), reduced welfare (yellow bars), poor growth (grey bars), or were considered to be an increasing problem/increased incidence (violet bars). For each problem category there were N=38 respondents who responded on mortality, N=37 on reduced welfare, N=7 on increased incidence.

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):

Atyp.furunc. = atypical furunculosis (infection with atypical *Aeromonas salmonicida*)
Mech.injury = injuries/mortality as a consequence of non-medicinal delousing
Ulcer = skin ulcers and any underlying tissues
Hand = injuries/mortality as a consequence of handling
Fin erosion = fin erosion/rot
Emaci. = emaciation, malnutrition
Sub.rearing = suboptimal care
Vib = vibriosis (Infection with *Vibrio* spp.)
Tena = infection with *Tenacibaculum* spp.
Med.injury = injuries/mortality as a consequence of medicinal delousing
AGD = amoebic gill disease
Fungus = fungal infection



A good start in life is essential for salmon fry that will become robust and healthy farmed salmon.
Photo: Eivind Senneset.

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