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The Health Situation in Norwegian Aquaculture 2020

The cnidarian *Ectopleura larynx* Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

The Health Situation in Norwegian Aquaculture 2020

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Cover photograph: The cnidarian *Ectopleura larynx* attaches and grows on fish farm nets and ropes. If allowed to grow uncontrolled, cleaner fish graze on these fouling organisms rather than on salmon lice. Water circulation may also be reduced resulting in low oxygen levels. The photograph has been colour manipulated.
Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

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Health and welfare, a precondition for growth and expansion

By Edgar Brun

The aquaculture industry is entering a new era with establishment of technically advanced land-based farms and giant offshore constructions. The technical possibilities related to effective, intensive production have led to expectations of significant financial return. Such expectations may not be realised unless the biological requirements of the fish are met.

Once again we see that technology advances faster than biology, and the biological implications of new production technologies are largely unknown. There remain unanswered questions related to the environment, welfare, health and risks of infection, both within the farm and to the surrounding environment. Significant research is required to ensure that the challenges are met in this new generation of farm.

This year's fish health report presents a number of areas in which networks, particular production factors and routines allow spread of infectious diseases between farms along the whole coastline. This situation is widely acknowledged throughout the industry and we see that counter measures introduced at the company level have effect. Prevention is, however, most effective both in terms of costs and practical effect, when the industry as a whole works together towards a common goal.

Biosecurity measures are considered as an investment in other food production systems that result in a predictable, manageable disease situation and in increased profit. Although the fish farming industry must be considered 'young' when compared to terrestrial domestic animal production (to which the Norwegian Veterinary Institute also provides scientific support) the industry should, in our opinion, manage to work together toward common goals to ensure prevention and control of infectious diseases as well as reduced mortality.

Despite the fact that many companies use significant resources on sustainable production, the collective fish mortality within the industry was again in 2020, far too high. Of 300 million smolts transferred to sea, more than 50 million died prior to harvest. Similar proportions die during the hatchery stage and in cleaner-fish populations. Measures introduced to reduce these mortalities do not appear to be working. New solutions are required. If fish are considered as individuals rather than 'biomass' then this may change attitudes. Further, as the regional density and localisation of farms influences transmission of infection, our long coastline should be divided into different regions based on infection status. PD is a good example of how rapidly a disease may establish and spread in the absence of effective mitigation measures. The PD situation also shows that limiting the geographic spread of infection is possible given that the will and ability.

The ongoing work of mortality categorisation is an important contribution to understanding the underlying causes. Increased knowledge should result in targeted interventions to limit the main causes of mortality. The sole focus of the authorities on the salmon louse as a sustainability indicator should be re-considered. Current mechanical delousing regimes represent one of the most important causes of mortality and poor welfare. In the new aquaculture strategy currently being developed by the Industry and Fisheries Department, the Norwegian Veterinary Institute has advised that focus should be shifted towards the collective 'burden' imposed by farming practices and experienced by the fish, and that further expansion of the industry should be based on consolidated statistics for fish-health and welfare.

23 outbreaks of ISA were registered in 2020. This is the highest annual number of ISA outbreaks recorded over the last 30 years. The outbreaks were to a greater degree than previously identified along the whole coastline, and probable sources of infection were identified in fewer outbreaks than in previous years. This was the situation in a year when The Norwegian Food Safety Authority led the work of investigation of alternative strategies for ISA-control. This work is founded on new EU animal health legislation which comes into force in April 2021. The prevalence of ISA in 2020 has several probable

explanations, including continuing knowledge-gaps relating to the mechanisms of emergence of virulent ISA-virus, new production technologies which challenge infection-hygiene principles, legal challenges and varyiable application of infection-preventative practices.

ISA is a societal problem in view of its injurious potential to a major national industry and as a notifiable disease in an international market. In our opinion, control and prevention of ISA should remain a national concern for which the authorities should establish common standards and steering.

For over 30 years antibiotic consumption in the Norwegian aquaculture industry has remained almost insignificant. The Norwegian aquaculture industry has been lucky, but also adept in implementation of vaccination as a prophylactic measure against bacterial diseases. Antibiotic resistance is almost unknown. The situation for the salmon louse illustrates, however, that biological, welfare and economical challenges can emerge when traditional medicines lose their effect.

Disease prevention, early detection and limitation of spread are considered some of the most important measures that the industry can implement to reduce the present infection situation and to limit the effects of future disease and welfare challenges.

This year we can happily say that this year's Fish Health Report has been strengthened. There was the greatest response to date by fish health personnel to our annual questionnaire, a response which is extremely important for dissemination of the everyday challenges met by these practitioners in the field. Their input is central in relation to prioritisation of health and welfare work in aquaculture.

This year's report is also strengthened through extended collaboration between the Norwegian Veterinary Institute, farming companies and private diagnostic laboratories relating to diagnostic statistics for non-notifiable diseases. This collaboration contributes to quality assurance and strengthening of the statistical foundations upon which the report is based. This illustrates how a trust-based collaboration can contribute to better disease surveillance and an increased knowledge base. We hope that 2020 represents a new beginning for further collaboration. Confidential data transfer between different actors will provide both the industry and the authorities with a solid foundation for common knowledge generation and data-driven health and welfare work.

Summary

By Ingunn Sommerset

Mortality is a crude, but measurable, indicator of fish health and fish welfare. 60.3 million Norwegian farmed salmon were lost from production between sea-transfer and harvest, of which 52.1 million were categorised as mortality-related, not far short of the record number registered in 2019 (53.2 million). The high figure in 2019 could be partly explained by losses associated with algal blooms in Nordland and Troms, which alone killed approximately 8 million fish. We have not identified any particular event which could be linked to the high mortality registered in 2020. We see that the increase in mechanical delousing continued again between 2019 and 2020. There are no indications of decreasing prevalence of infectious diseases. On the contrary, an increase is indicated where comparable statistics are available.

Reliable statistics related to mortalities experienced during the juvenile stages of salmon production are lacking, as are mortality rates in cleaner-fish species at work in salmon cages. They way in which these mortalities are registered make analyses of changes over time and identification of the causes challenging.

Notifiable diseases

Until new animal health legislation enters force in 2021, notifiable diseases of fish are divided into list 1 (exotic), list 2 (non-exotic) and list 3 (national) categories. On suspicion or diagnosis of notifiable disease the Norwegian Food Safety Authority must be informed. The Norwegian Veterinary Institute assists the Norwegian Food Safety Authority in maintenance of updated statistics related to diagnosis of notifiable diseases. List 1 diseases, monitored via surveillance programmes and routine diagnostic investigations have never been identified in Norway. A summary of list 2 and 3 diseases and number of diagnoses is shown in the table below.

Two notifiable diseases show a clear increase in prevalence compared to the previous year: Infectious salmon anaemia and furunculosis.

There were 23 new ISA diagnoses in 2020, all in sea-farmed salmon. The disease was identified in a total of seven different production areas (PO), with PO 10-12 (Troms og Finnmark) most heavily affected with 15 outbreaks. The origins of infection (i.e. previous outbreaks) could not be identified for around half of the diagnoses made in 2020 and these appear to represent primary outbreaks. Around a quarter of outbreaks are associated with infected hatcheries and the remainder to

Table 1.1. Summary of list 2- and 3-diseases with number of diagnoses for the years 2013-2020.

	List	2013	2014	2015	2016	2017	2018	2019	2020
Farmed fish: salmonids									
ISA	2	10	10	15	12	14	13	10	23
VHS	2	0	0	0	0	0	0	0	0
PD	3	100	142	137	138	176	163	152	158
Furunculosis	3	0	1	0	0	0	0	0	5
BKD	3	1	0	0	1	1	0	1	1
Systemic *F. psychrophilum* in rainbow trout	3	3	2	3	4	1	4	4	2
Farmed fish: Marine species									
Francisellosis (cod)	3	1	1	0	0	0	0	0	0
VNN, nodavirus	3	1	0	0	0	0	0	0	0
Furunculosis (lumpfish)	3	0	0	1	4	0	0	0	3
Wild salmonids (fresh water)									
Gyrodactylus salaris	3	1	1	0	0	0	0	1	0
Furunculosis	3	0	0	2	1	2	0	2	0

transmission from nearby affected sites.

Furunculosis (caused by *Aeromonas salmonicida* supspecies *salmonicida*) was diagnosed in five marine salmon farms, all geographically linked to the Namsen fjord area (PO 7). Three outbreaks of furunculosis were also diagnosed in lumpfish, of which two cases were in the same farm as affected salmon. Furunculosis, in contrast to 2019, was not identified in wild salmonid fish in 2020. Bacteria isolated from the 2020 outbreaks displayed the same phenotypical marker as the local endemic strain of *A. salmonicida* subsp. *salmonicida* which has been associated with outbreaks in wild salmon in the same area in previous years.

The number of farms affected by pancreas disease (PD) remains at a high level. With 158 new diagnoses identified in 2020 this represents a slight increase from 2019. An increase in the number of outbreaks of PD caused by SAV-3 was registered in PO2 (Ryfylke) and PO4 (Nordhordland to Stadt) while a reduction was registered in PO3 (Karmøy to Sotra). There were no new diagnoses of PD in the surveillance zones in the south (PO1) or the north (PO 7-13), but a previous suspicion of PD in 2019 was confirmed in the late spring of 2020 in PO7 (Nord Trøndelag and Bindal).

For the remaining notifiable diseases the situation remains relatively stable, with none or few diagnoses made in 2020.

Fish health spokesperson Ingunn Sommerset is editor of this report. She is based at the Norwegian Veterinary Institute's research laboratory in Bergen. Photo: Eivind Senneset.

Investigation of a routine sample from Norwegian farmed fish at the Norwegian Veterinary Institute research laboratory in Bergen. Photo: Eivind Senneset

Non-notifiable diseases

This year, for the first time, the Norwegian Veterinary Institute has gained access to data from private diagnostic laboratories for a number of non-notifiable diseases (See chapter 1 'Statistical basis for the report'). This data has been made available at the site level, such that we can be certain that sites awarded with a particular diagnosis are registered only once. Although these agreements cover only 74% of active farming localities, and do not include all diseases, the data available for 2020 represents a more comprehensive data set than has been available for several years.

In the annual survey of fish health personnel and Norwegian Food Safety Authority inspectors, CMS is considered the most important mortality related problem in ongrowing salmon in 2020 (see the red columns in figure 'Top 10 problems in ongrowing salmon' below. Heart and skeletal muscle inflammation (HSMI) is also a serious non-notifiable disease considered less important in terms of mortality. Both CMS and HSMI are viral diseases and clinical outbreaks with increased mortality are often triggered by stress factors. Complex gill disease, as the name suggests, is commonly multifactorial and several agents may be concurrently identified including virus, bacteria and parasites. In addition to causing mortality, reduced welfare and growth, gill disease is considered by respondents to the health survey as one of the diseases with the most increased impact in 2020. All the diseases listed as the 'top 10 problems in ongrowing salmon' will be exacerbated by production procedures involving handling e.g. mechanical delousing.

Based on consolidated data from private laboratories and the Norwegian Veterinary Institute, 154 farms were diagnosed with CMS in 2020 (203 including localities diagnosed by PCR alone) and 161 farms were diagnosed with HSMI (232 including localities diagnosed by PCR alone). Although most CMS outbreaks appear to occur in south- and mid-Norway and most HSMI outbreaks occur in mid- and northern- Norway, both diseases are widespread along the whole coastline.

Of bacterial diseases, skin lesions caused by *Moritella viscosa* (classic winter-ulcer) and *Tenacibaculum* spp. (atypical winter-ulcer) have been important causes of reduced welfare and mortality in the sea-phase of salmon farming. The prevalence of both classic and atypical winter-ulcer are difficult to estimate since the diseases are non-notifiable and relatively easily diagnosed in the field.

The Norwegian Veterinary Institute has reported a concerning increase in the number of outbreaks of pasteurellosis in farmed salmon over the last three years. Consolidated statistics from the Norwegian Veterinary Institute and private laboratories reveal that 57 different localities were diagnosed with pasteurellosis in 2020, which is a significant increase from 2019. The majority of these diagnoses were made in Vestlandet region (PO2-4). This disease results in serious welfare challenges in affected farms.

It has been speculated upon whether the increase in number of pasteurellosis outbreaks in farmed salmon is a result of transmission of infection from cleaner-fish in the same farms. To establish whether this is the case, the Norwegian Veterinary Institute initiated in 2020 a genetic study in which a large collection of *Pasteurella* isolates from salmon and lumpfish were whole-genome sequenced. The study included isolates from both Norway and Scotland. The results show that the lumpfish variant is not associated with disease in salmon. All the Scottish isolates were identified as *Pasteurella skyensis*, a clearly different species from the variant causing the vast majority of outbreaks in Norwegian salmon. In the late autumn of 2020, the situation became slightly more complicated when *P. skyensis* was identified in two salmon ongrowing farms in Norway.

Fish welfare and delousing

In 2020 the salmon louse situation in the country as a whole was similar to the previous year. The average annual production of louse larvae was highest in PO2, PO3, PO4 and PO6 while during the period of outward migration of salmon smolts, larval production was lower or similar to the previous year in all POs, with the exception of PO2 and PO8. Production of louse larvae therefore fell in the most critical production areas during outward migration of salmon, while the annual production statistics show a more variable picture. With a total of 2983 non-medicinal delousing treatments registered in 2020 this represents a collective increase (21%) in the number of weeks in which non-medicinal delousing activities were registered compared with 2019. This increase represents thermal, mechanical and freshwater delousing (53% increase from 2019). Thermal delousing remained the most common form of non-medicinal delousing in 2010. Fish health personnel reported (via the annual questionnaire) increased mortality following thermal and mechanical delousing in particular. This probably represents a considerable contribution to the overall mortality experienced during the sea phase of culture of both salmon and rainbow trout. Injuries resulting from delousing procedures were considered the most important cause of reduced welfare for both salmon and rainbow trout (see 'top 10 problems during ongrowing salmon and appendix B2). This underlines once more the relationship between delousing and fish welfare.

Use of cleaner fish in the fight against salmon lice has been and remains a contentious practice. Statistics from the Directorate for Fisheries show that there was a reduction in the number of cleaner-fish, particularly lumpfish, transferred to sea in 2020. In the survey, as in 2019, emaciation, skin complaints and delousing once more appear to be important welfare related themes for lumpfish held in salmon cages. Over 95% of respondents responsible for cleaner fish health in ongrowing salmon farms considered mortality to be at a similar level in

Figure 'Top 10 problems ongrowing salmon'.
Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with responsibility for fish health in ongrowing salmon farms were asked to indicate the five most important health problems on a list of 28 different problems, based on whether each problem resulted in mortality, reduced growth, reduced welfare or was considered to be on the increase. The number of respondents for mortality and reduced welfare were 78, while 71 responded to reduced growth and increasing prevalence. Abbreviations: Mech.Inj.delous = Mechanical injuries related to delousing, CGD = Complex/multifactorial gill disease, CMS = Cardiomyopathy syndrome, Salmon louse = infection with salmon lice, PD = Pancreas disease, HSMI = heart and skeletal muscle inflammation, Mvisc = infection with *Moritella viscosa* (classical winter-ulcer), Tena = infection with *Tenacibaculum* spp (atypical winter-ulcer), Ulcer = ulceration of the skin and underlying tissues, Past = infection with *Pasteurella* spp. (pasteurellosis).

2020 as in previous years, or that they did not know whether mortality had risen or fallen. The large proportion who answered 'don't know', illustrates the scale of the welfare challenges that cleaner-fish face i.e. that it is difficult to know how many die and when they die. It is therefore difficult to estimate whether mortality is rising or falling or whether measures introduced to reduce mortality are in fact working.

The question on whether these species can adapt to conditions within salmon cages will be central in deciding if and how cleaner fish should be used in the future.

Wild salmon

The Norwegian Veterinary Institute and the Norwegian Food Safety Authority launched a national reporting scheme for registration of diseased and dying wild fish in 2020. The reporting system is part of the health surveillance programme for wild salmon and the main aim is early identification of events of importance for wild fish health in Norway. A number of cases reported under the scheme are presented in Chapter 9 'The health situation in wild fish'. Disease and mortality was once again registered in the river Enningdalselva during the summer of 2020. The condition, which has been termed 'red skin disease' appears shortly after the fish enter freshwater. Similar observations have been registered in several Northern-European countries, but the cause has not yet been identified. Results of investigations performed by the Norwegian Veterinary Institute do not indicate infection agents as the primary cause.

The river Ranaelva (Rana watershed) was declared free from *Gyrodactylus salaris* infection in the autumn of 2020, following extensive eradication and surveillance programmes. The parasite represents a steadily less significant threat to wild salmon in Norway, but several rivers remain untreated. The parasite remains present in Sweden close to the Norwegian border.

Sampling of tissues from the vital organs of a fish in the Bergen laboratory. Photo: Eivind Senneset.

1 Statistical basis for the report

Av Britt Bang Jensen og Ingunn Sommerset

The statistics presented in the current report are mainly obtained from four different sources; official data, data from the Norwegian Veterinary Institute, data submitted by private laboratories and data based on responses to a survey sent out to Fish Health Services and the Norwegian Food Safety Authority.

In each section of the report, the information sources upon which the statistics and the author's evaluation of the situation is based, are clearly indicated.

Official data

According to current legislation, all notifiable diseases must be reported to the Norwegian Food Safety Authority. In addition, legislation states that 'on increased mortality, with the exception of mortality clearly unrelated to disease, health inspection must be carried out without delay to identify the cause. A veterinarian or fish health biologist must perform the health inspection. The Norwegian Food Safety Authority must be immediately notified of unexplained increased mortality in an aquaculture facility or aquaculture area for mollusc farming, or on any reason for suspicion of disease on list 1, 2 or 3 in aquaculture organisms'.

Through surveillance programmes and routine diagnostic work, we know that List 1 diseases do not exist in Norway today. A summary of the numbers of farming localities affected by diseases on Lists 2 and 3 is presented in a table in the 'Summary' of this year's report.

The Norwegian Veterinary Institute receives diagnostic submissions from various fish health services. These are investigated in the Norwegian Veterinary Institute laboratories in Harstad, Trondheim, Bergen and Oslo. Photo: Colourbox

The statistics are based on data from the Norwegian Veterinary Institute, which continually supports the Norwegian Food Safety Authority in maintaining an overview of the prevalence of notifiable diseases.

The Norwegian Food Safety Authority notifies the Norwegian Veterinary Institute of diagnoses made by external laboratories such that these are registered alongside those diagnoses made by the Norwegian Veterinary Institute (see below). As National Reference Laboratory (NRL), the Norwegian Veterinary Institute shall, in principle, confirm all diagnoses of notifiable disease made by external laboratories.

The 'official statistics' in this report relate to the number of new diagnoses/positive sites following fallowing. As some farms may hold fish diagnosed the previous year, the actual number of affected sites may be higher.

Data from the Norwegian Veterinary Institute

The Norwegian Veterinary Institute receives samples for diagnostic investigation from a number of Fish Health Services. These samples are analysed in our laboratories in Harstad, Trondheim, Bergen and Oslo. All information generated from submitted diagnostic samples is stored in the institute's electronic journal system (PJS). Samples sent in for purposes of research, ring tests and surveillance 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

Non-listed diseases are non-notifiable. For this reason, Norwegian Veterinary Institute data alone cannot provide a complete picture of the national situation. In order to provide as complete an overview as possible for the 2020 Fish health report, we have asked private laboratories to contribute data based on their own diagnostic analyses related to twelve important non-notifiable diseases.

1. Heart and skeletal muscle inflammation (HSMI)
2. Cardiomyopathy syndrome (CMS)
3. Infectious pancreatic necrosis (IPN)
4. Yersiniosis
5. Pasteurellosis
6. Infection with '*Ca.* Branchiomonas cysticola'
7. Infection with atypical *Aeromonas salmonicida*
8. Parvicapsulosis
9. Infection with salmon gill poxvirus
10. Infection with lumpfish flavivirus
11. Nephrocalcinosis
12. Haemorrhagic smolt syndrome (HSS)

The data was retrieved from the electronic journal systems of Patogen AS, Fish Vet Group Norway and Pharmaq Analytiq AS. All data was checked and authorised by the respective submitting farming companies before use. The data was filtered such that specific diseases/agents were only registered once for each farming locality.

There was a monthly average of 607 active salmonid farming sites (ongrowing, brood stock, hatcheries and research facilities) in 2020. We have data related to the 12 diseases listed above from 446 farms i.e. 74% of all active farms. The proportion of farms we received data per production area (POs 1 -13) varied between 47-92%.

In some cases, the same disease/agent may have been diagnosed previously in the same batch of fish in 2019, so the statistics do not necessarily describe the number of new cases in 2020. The exception is for notifiable diseases (described above).

Data from the annual survey

As in recent years, the Norwegian Veterinary Institute sent out an electronic survey to obtain the views of Fish Health Services along the whole coast as well as officers of the Norwegian Food Safety Authority. Respondents were asked to rank the importance of different diseases in salmon and rainbow trout, in hatcheries, ongrowing and broodstock farms, as well as diseases affecting cleaner-fish species. Respondents were also asked to comment on the effect of lice treatment and various parameters relating to fish welfare. Space was also provided for free text comments under individual thematic areas.

The survey was sent to 188 fish health professionals working in Fish Health Services or farming companies with in-house health personnel and a response was received from 38 individuals working for private Fish Health

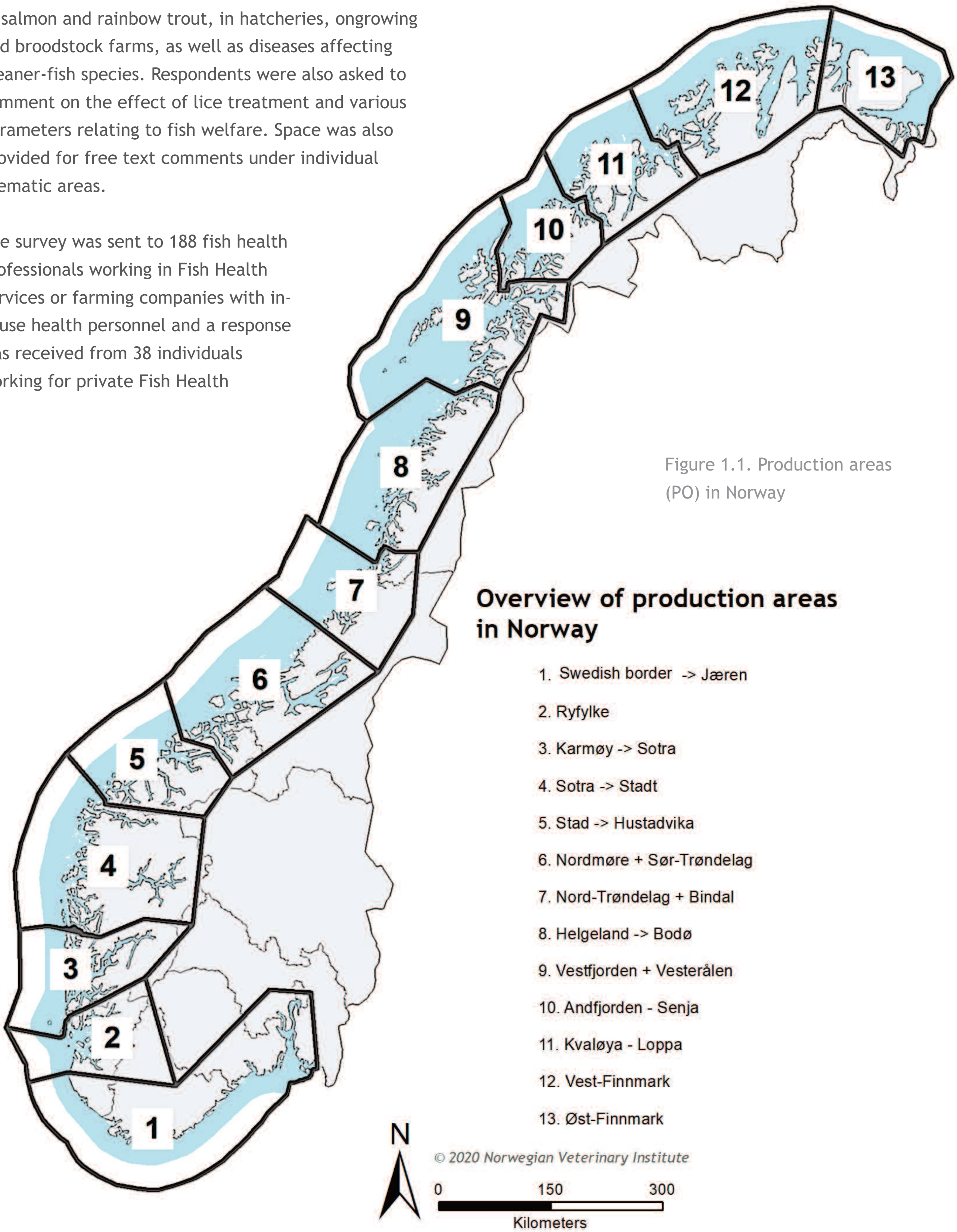


Figure 1.1. Production areas (PO) in Norway

Services and 35 individuals working for farming companies (total response 71 individuals). The survey was also sent to 90 Norwegian Food Safety Authority inspectors and we received responses from 21. All contributors were offered a public acknowledgement and those who accepted are listed by name at the end of this report.

The data received was used in relevant sections throughout the report. A ranking of the various disease and welfare challenges is shown in appendices A-E.

Geographical distribution

In previous editions of the Fish Health Report the number of disease outbreaks per region have been reported. 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 Fish Health Report for 2020 will, with few exceptions, report statistics for production areas rather than regions. The thirteen Production Areas (Norwegian = Produksjonsområde = PO) 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 of the Norwegian Food Safety authority. Photo: Colourbox

2 Changes in infection risk

By Victor H. Silva De Oliveira, Arve Nilsen, Britt Bang Jensen, Ingunn Sommerset, Mona Dverdal Jansen and Edgar Brun

In this section we wish to highlight trends and/or changes that we consider as challenging related to the prevalence and spread of infectious diseases.

Mortality statistics provide a rough indicator of the health and welfare of farmed fish. The annual mortality statistics thereby reflect the overall health and welfare challenges experienced by the industry in the course of the year at both national and regional levels. By comparison with previous years we can judge how successful industry health and welfare strategies have been that year. The work of categorisation of cause of death continues and allows identification and ranking of the various causes. This is an important task that in the longer term may allow introduction of mitigation measures aimed at the most important causes and thereby contribute to reduced mortality and better fish welfare.

The emergence of novel diseases and re-emergence of 'old' diseases in a different form is not unknown. We have chosen to discuss the new challenges posed by *infectious salmon anaemia*, ISA (see also Chapter 4.2) in terms of infection dynamics and public management. Consumption of pharmaceuticals such as antibacterials, salmon lice and intestinal parasite medicines, together with prescription data provide a basis for evaluation of the status for different types of infectious disease.

Biosecurity is the universal key in all types of prevention and limitation of infection. At the highest level, national guidelines relating to biosecurity, network structures including digitalisation and infrastructural relationships concerning farm localisation, harvesting sites and availability of smolts as well as use of well-boats, will be decisive for the success of this type of work.

The industry is *technology* driven and implementation of new technologies can result in health and welfare challenges as well as changes in the infection situation. It is therefore important that health and welfare aspects are considered at an early stage of technological development, such that the farmed fish can also benefit.

2.1 Mortality and production

Some production statistics

Preliminary harvest statistics for 2020 indicate an increase in production of around 2.7% compared to 2019. This is a smaller increase than in previous years (Table 2.1). Biomass in the sea registered at the end of 2020 has increased by nearly 100,000 tons since 2017, which suggests that the total production in 2021 will increase considerably. Preliminary figures for juvenile production and sea-transferred smolts are similar to those reported in 2019.
Production of rainbow trout has increased in recent years, approaching 100,000 tons harvest weight in 2020.

According to Norwegian Directorate of Fisheries biostatistics, 42.2 million cleaner fish were utilised at sea in 2020. This is a reduction of around 15% from 2019. Mortality amongst cleaner fish is discussed in Chapter 11 'The health situation for cleaner fish'.

Fish losses during the seawater phase of culture

Fish losses occurring between sea transfer and harvest must be reported to the Directorate of Fisheries. Losses are categorised as either mortality, rejected, escapees or 'other'. Mortality covers losses associated with disease or injury etc. Infectious disease is one of the most important causes of biological and economical loss in aquaculture. 'Discard' relates to fish removed during harvest on quality grounds. 'Other' can relate to mortality episodes occurring in association with e.g. lice treatment or other management procedure, but also fish destroyed as part of a disease control procedure. Mortality is a general indicator of poor fish welfare and fish health. In this chapter, we focus on mortality, but also report on losses attributed to the other loss categories.

Calculation of losses included data for all salmon and rainbow trout transferred to sea, including production fish, brood stock as well as fish in research and development farms etc. The total loss of Norwegian farmed salmon in 2020 was 60.3 million salmon, categorised as 86.5% dead fish, 5.8% 'rejected', 7.7% 'other' and 0.01% escapees (See http://apps.vetinst.no/Laksetap). The distribution between the various categories was similar to previous years.

The total number of salmon dying during 2020 was 52.1 million, very close to the 53.2 million reported in 2019 (Table 2.1). One explanation for the high mortality registered in 2019 was the algal bloom which killed approximately 8 million fish in Nordland and Troms during the late spring of that year. While such events were not reported in 2020, mortality increased by 11% compared to 2018, while production increased by 8.7 % in the same period.

Eleven farms reported losses due to escape to 'Havbruksdata' in 2020. The total number of fish reported as escaped was 6215 and all were salmon. The Norwegian Directorate of Fisheries provides an annual report relating to escapes registered in their 'escape' register and in 2020, 48 such episodes involving salmon were reported. The estimated total of escaped salmon in this system was 31498. There is therefore a considerable discrepancy between the two reporting systems. As most reported episodes describe fewer than 100 escaped fish, the largest proportion are related to relatively few, but large escapes. More information on escapes may be found on the Directorate for Fisheries web-page https://www.fiskeridir.no/Akvakultur/Tall-og-analyse/Roemmingsstatistikk.

Table 2.1 Production of farmed fish, figures from the Directorate for Fisheries as of February 2021.

	2016	2017	2018	2019	2020*
Number of farms					
Salmonid. Concessions. Juvenile production	220	220	217	221	227
Salmonid. active sites. sea	978	986	1015	966	986
Marine fish. number of sites. sea	66	58	42	64	36
Biomass at end of year. tons					
Salmon	740 000	797 000	814 000	811 958	896 961
Rainbow trout	31 500	35 700	40 400	47 094	40 625
Harvested. Tons round weight					
Salmon	1 180 000	1 237 000	1 279 000	1 361 747	1 400 117
Rainbow trout	80 700	61 600	66 700	79 600	92 793
Marine species (halibut. char. cod. other)	2 473	2 683	2872	3230	
Juvenile fish transferred to sea. millions					
Salmon	292	299	304	288	290
Rainbow trout	14.9	17.1	20.0	20.8	17.5
Cleaner-fish	37.4	54.6	48.9	49.1	42.2
Post sea-transfer mortality. millions					
Salmon	44.8	45.8	46.3	53.2	52.1
Rainbow trout	2.4	2.4	2.8	3.1	2.8
Mortality in percent**					
Salmon	16.2	15.5	14.7	16.1	14.8
Rainbow trout	19.2	17.5	16.5	16.3	16.0

* Preliminary estimate, Directorate for Fisheries, January 2021

** Calculation based on monthly mortality rates, see calculation method in text.

The total losses of rainbow trout between 2016 and 2019 has varied between 2.8 and 3.8 million. The total loss of rainbow trout in 2020 is reported as 3.4 million, distributed between 81.2% mortality, 9.7% discard, 9.1% other and 0% escape (See http://apps.vetinst.no/Laksetap). This is a similar level as reported in previous years and may be interpreted as positive, given that the volume of rainbow trout harvested has risen by 14% from 2019 to 2020.

In Table 2.1 mortalities for salmon and rainbow trout for the last five years are shown. These figures do not include losses attributed to discard, escape or 'other'. The figures are based on calculation of 'rates' which allows the total number of fish which can die, to change from month to month. In contrast to percent values, rates may be summed and thereafter converted to a percent, which describes the probability that a salmon dies in the course of a given period. Firstly, monthly mortality rates for each locality are calculated, which then allows the average monthly rate to be calculated. This average value is finally summed and converted to 'percent dead fish' per year.

In table 2.2 the percent wise mortalities are provided for each production area (PO). The results show that there remain very different geographical differences in mortality. This table reports only % dead fish, not other causes of loss. Of the positive changes it can be seen that there is a negative trend in PO's 6 and 8, as well as an average mortality of less than 7% in PO 13. The high mortality recorded in PO 9 and PO 10 in 2019, due largely to algal related deaths, returned to previous levels in 2020. At the opposite end of the scale, mortality in PO 4 went up from 19.4% to 27.2% and in PO 11 from 10.7% to 15.7% between 2019 and 2020. The cause/s of these increases are not known, but it is worth noting that Po 4 has experienced a marked increase in the number of PD-diagnoses in 2020 (see chapter 4.1). The large number of ISA-cases in Troms and Finnmark were not particularly related to PO 11 (one case). Thus the increase in mortality in this area cannot be directly attributed to ISA (see chapter 4.2). The figures for the remaining areas have been reasonably stable for 2019 and 2020. For rainbow trout there was a registered reduction from 19.7% to 15% in PO 2 and PO 3, while there were increases in PO 5, PO 6, PO 7, PO 9 and PO 10 (Table 2.2). The statistics for rainbow trout will naturally vary from year to year as there are relatively few farms farming this species.

One may also choose to consider mortality on a

Table 2.2 Mortality (%) amongst salmon and rainbow trout for the period 2018-2020 per production area. For calculation method see text. For region-wise distribution of mortality or comparison with earlier years use the interactive link at http://apps.vetinst.no/Laksetap/.

Salmon				Rainbow trout			
Production-area	2018 % Mortality	2019 % Mortality	2020 % Mortality	Production-area	2018 % Mortality	2019 % Mortality	2020 % Mortality
1	6.0	10.8	11.3	-	-	-	-
2	16.3	15.7	14.4	2 & 3	21.3	19.7	15.0
3	20.8	19.1	19.9				
4	18.0	19.4	27.2	4	17.0	17.2	17.1
5	13.7	15.0	15.2	5	15.6	8.8	10.4
6	16.4	12.1	13.5	6 & 7	8.9	18.2	20.0
7	8.2	7.9	10.5				
8	13.3	10.2	9.7	-	-	-	-
9	12.9	28.8	9.6	9 & 10	9.7	8.1	9.9
10	8.4	23.0	10.2				
11	9.6	10.7	15.7	-	-	-	-
12	11.6	8.2	11.1	-	-	-	-
13	9.4	16.1	6.7	-	-	-	-

*Production areas with fewer than 5 farming localities have been generation or production cycle basis. Calculated mortality for production cycles, which are completed each year, are based on reports from commercial ongrowing sites. Broodstock, fish from research and development concessions, teaching concessions etc. are not included.

We have calculated the total mortality for farms completely harvested during the year in question and only included production cycles completed in sites which had fish present for at least 12 months previous to harvest. For production cycles completed in 2020, the median mortality was 17.9%, while 50% of the mortality scores lay between 10.8 and 26.9 % (Table 2.3). Thus, there is considerable variation between individual production cycles.

The Norwegian Veterinary Institute has developed an interactive web-page allowing losses and mortality in different regions or production areas between 2015-2020 to be compared: http://apps.vetinst.no/Laksetap.

The probable cause of 'mortality' is not presently reported to the Directorate of Fisheries, but the large regional differences can indicate differing regional disease/ infection situations, which are discussed throughout the report.

Mortality and loss during the juvenile stage of production

In Norway there has been less focus on mortality levels during the juvenile stage of salmon and rainbow trout production compared to ongrowing at sea. As for ongrowing, juvenile losses are reported in Altinn, but in contrast to the marine phase only mortality is reported and the different causes are not registered. In addition to mortality, the number of fish held and average weights are reported.

The Norwegian Veterinary Institute in cooperation with the Norwegian Animal Protection Alliance has investigated mortalities registered between 20011 until 2019. Generally there has been an increase in the number of fatalities between 2012 and 2019. The total mortality has increased from 24.9 million in 2012 to 61.0 million in 2018. Our analyses also revealed differences in mortality between different weight classes of fish. In fish 40-80 g there was a 5 x increase in the number of dead fish between 2012 and 2018. As the total number of fish in each weight class remains unknown, it is not possible to identify changes in the proportion of fish affected. Fish >3 g represent 44% of all mortalities.

The data is unfortunately of lower quality than is desired. Double registrations are common and registration of mortality levels in excess of the total population size occur. Good analysis is dependent on increased quality of the data registered. More information and proposed improvements in reporting are available here:
https://www.vetinst.no/rapporter-og-publikasjoner/rapporter/2019/dyrevelferd-i-settefiskproduksjonen-smafiskvel

Table 2.3 Median mortality (%) for completed production cycles. Annual mortality data for 2016-2019 are different from previous reports because production cycles shorter than 12 months have been excluded in the recalculation. For calculation method see text.

	2016	2017	2018	2019	2020
Median mortality in percent for all sea-transferred salmon production cycles completed per year	16.9	17.3	17.5	15.0	17.9
1.- 3. quartile (50% of mortality % lies within this interval	11-26.9	11-26.4	10.9-25.4	9.6-25.1	10.8-26.9

2.3 Infectious salmon anaemia (ISA) - new challenges

Results from the annual survey of fish health personnel and inspectors of the Norwegian Food Safety Authority reveal that ISA is considered to be an increasing problem in salmon farming, both during the juvenile and sea-phases of production.
In the marine phase, ISA is ranked equal 1st with the salmon louse, up six places compared with the 2019 survey. For juvenile fish, ISA has moved up nine places to fifth place (see appendices A1 and B1). This, in a year in which 23 ISA diagnoses were registered, with a further five non-confirmed cases suspected. Between 1993 and 2019 between one (1994, 2011) and 20 (2001) cases were registered annually, with an annual average of 10 cases. Last year's total represent therefore the largest number of ISA cases since 1992, a statistic which the Norwegian Veterinary Institute considers a matter of concern.

It is generally accepted that the pathogenic variant of ISA-virus (ISAV-HPRdel) develops from a non-pathogenic variant (ISAV-HPR0). Such changes may explain those cases that cannot be traced back to a probable known source of infection. Phylogenetic analyses show that seven of the ISAV-HPRdel associated outbreaks in 2020 were probably related to ISAV-HPR0 infections diagnosed in the juvenile production facilities supplying smolts to these localities.

A national overview of the ISAV-HPR0 situation does not currently exist for either freshwater or marine sites. This lack of documentation makes generation of knowledge related to the significance of ISAV-HPR0 infection for further development of ISA difficult.

The Norwegian Food Safety Authority has since 2019, conducted a surveillance programme for ISAV-HPR0 in Norwegian juvenile production facilities for salmon, in which around 50% of all facilities are screened annually. In 2019, around 7% of tested juvenile production farms tested positive, while testing performed in 2020 revealed a prevalence of around 14%. Recirculation based sites (RAS) appear to be over represented amongst ISAV-HPR0 infected sites. Surveillance programmes performed in ISA control zones and surveillance performed in ISA-free zones and segments, together with diagnostic investigations performed by the Norwegian Veterinary Institute, identified a total of 40 ISAV-HPR0 infected marine sites in 2020. 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 juvenile production facilities and marine farms positive for ISAV-HPR0 infection during the course of any year. The World Animal Health Authority (OIE) has listed both ISAV-HPRdel and ISAV-HPR0, and both are therefore notifiable infections in OIE member countries.

The EU introduced new legislation regarding control of infectious animal diseases on March 31. 2016. As a result of the EEA-agreement the new legislation will come into force in Norway on April 21. 2021. In this legislation, ISA is characterised as a disease which may be controlled on a voluntary basis. Continuation of current ISA control practices in Norway is therefore dependent on design of a control strategy with clear targets regarding achievement of a disease-free (part or whole) Norwegian aquaculture industry, and that the control strategy must be approved by ESA and accepted by the EU member states and the EU commission.

The Norwegian Food Safety Authority distributed in December 2020, a document for consultation regarding future management of ISA. In the document the Norwegian Food Safety Authority recommend a strategy based on public authority regulated control of ISA. One of the three alternative strategies was based on voluntary control alone. The Norwegian Veterinary Institute considers that ISA, as one of the most significant viral diseases in Norwegian salmon farming, must remain controlled by a public authority based control strategy. Previous ISA epidemics in Norway, the Faeroe Isles and Chile show how serious the situation can become when ISA cannot be controlled.

2.3. Bacterial infections – antibiotic consumption

Consumption figures for antibiotics are a good indicator of the prevalence of bacterial diseases. Ever since vaccines against coldwater vibriosis and furunculosis became available at the end of the eighties and early nineties, consumption of antibiotics in Norway has been low. From 1996 onwards, annual consumption has lain between ½ and 1½ tonnes active substance, despite continually increasing numbers of fish farmed during this time. In 2015 and 2016, antibiotic consumption lay between 200-300kg (table 2.5). In 2017, antibiotics prescribed for farmed fish increased to just over 600kg and in 2018, a further increase to over 900kg was registered. Antibiotic use in that two-year period was related to treatment of a few outbreaks of yersiniosis in large sea-farmed salmon. In 2019 and in 2020, the total antibiotic consumption reduced again to 2015 and 2016 levels, with 223 kg prescribed (Table 2.4)

Seventeen antibiotic treatments involving sea-farmed salmon were reported in 2020 (ongrowing fish and brood stock). In juvenile production, eleven treatments were reported, which is an increase from the previous two years (Table 2.5). Of the seventeen marine treatments, 10 were prescribed for brood stock and 7 for ongrowing fish. Three of the treatments involving sea-farmed salmon involved winter-ulcer and *Moritella viscosa* infection, while no specific bacterial agent was reported for the remaining prescriptions.

Cleaner-fish have been overrepresented in prescription statistics for the past five years. There was however a marked reduction during 2020 with 25 treatments performed in cleaner fish compared to 79 in 2019. The situation can be partly explained by the reduction in number of cleaner fish transferred to sea in 2020 compared to previous years (more on cleaner fish in Chapter 10). Since the peak year in 2016 there has been a steady decrease in the number of prescriptions related to antibiotic treatment of cleaner fish.

Table 2.4 Pharmaceutical products prescribed for farmed fish (in kg active substance with the exception of hydrogen peroxide figures in tons). Figures from the Norwegian Institute for Public Health. For the antibacterial substances oxytetracycline, enrofloxacin and amoxicillin (less than 1 kg) the amounts are calculated based on statistics from the Veterinary Medicines Register (VetReg) as of January 2021.

Antibacterial substance	2015	2016	2017	2018	2019	2020
Florfenicol	194	138	270	858	147	117
Oxolinic acid	82	74	346	55	66	112
Oxytetracycline	(25)	0	10	20	0	0.72
Enrofloxacin					0.26	0.04
Amoxicillin					-	0.09
Total antibiotics	276	212	626	933	213	230
Anti-salmon lice medication						
Azamethiphos	3904	1269	204	160	154	286
Deltamethrin	115	43	14	10	10	8
Diflubenzuron	5896	4824	1803	622	1296	1000
Teflubenzuron	2509	4209	293	144	183	1603
Emamectin	259	232	128	87	114	117
Hydrogen peroxide (tonn)*	43246	26597	9277	6735	4523	5084
Anti-tapeworm medication						
Praziquantel	942	518	380	171	50	123

* Total consumption of hydrogen peroxide, includes both treatment against salmon lice and amoebic gill disease (AGD).

Table 2.5 Number of prescriptions per year for antibiotic treatment for different categories of farmed fish. Preliminary figures January 2021 from the Veterinary Medicines Register (VetReg).

Category farmed fish	2015	2016	2017	2018	2019	2020
Salmon, ongrowing and brood stock	8	11	6	13	13	17
Salmon, juvenile fish	24	21	28	9	5	11
Rainbow trout	0	1	1	3	2	3
Halibut	29	30	28	18	28	18
Cleaner-fish	108	126	115	91	79*	25*
Sum	169	189	178	134	127	74

*With the exception of a single treatment involving Ballan wrasse, all prescriptions were prescribed for lumpfish.

2.4 Spread of infection by transport of live fish, use of well-boats and work boats.

Biosecurity and introduction of infection

Transport of live animals is considered to represent one of the most significant risk factors for spread of disease between farms, regions and countries. This is also true for fish farming where transport of fish occurs on a large scale. In this chapter we describe the situation primarily for farmed salmon, but the same risk factors apply to other farmed species.

The Food and Agriculture Organisation of the United Nations (FAO) defines biosecurity as 'A strategic and integrated tool for analysis and risk management related to food hygiene, plant and animal health and biological safety'. With increased globalisation, increased transport of animals, food and humans across borders and between continents, biosecurity is important for human health, animal health, plant health and food safety. Biosecurity is a holistic concept of importance for sustainability, including protection of the environment and biodiversity. We will here focus on infection risk.
Risk factors for introduction of infection may be divided into fish, water and other channels for which the probability of introduction of infection may be estimated (Figure 2.4). Contact with other farmed fish, use of non-disinfected water and use of well-boats are considered the most serious. Of other operations, net washing is considered a significant threat, while introduction of infection via workboats is considered a medium risk and divers as a low risk. In the figure we have included use of boats as a risk factor in the lower row, based on biosecurity plans developed by the industry in the geographical area covered by PO's 4-7 (www.biosikkerhet.no).

Infection associated with transport of live fish

That brood stock spend a considerable part of their life cycle in 'normal' marine sites represents an element of uncertainty in terms of biosecurity, as the fish may be exposed to several agents associated with seawater, which may then be transmitted vertically (via sexual products). Brood stock are subject to strict health surveillance and eggs must be disinfected prior to sale, but the risk of vertical transmission cannot be completely avoided. Farming of juvenile salmon is performed in freshwater, under conditions of relatively good biosecurity. It is known however, that juvenile production farms may be infected with 'house strains' of particular pathogens which may result in outbreak of disease following sea-transfer e.g. *Yersinia ruckeri*, IPNV and salmon gill pox virus. Fresh water farms may also have problems with ectoparasites (ciliates and flagellates), but these agents are dependent on freshwater and do not represent a disease risk in seawater. Many sea farms express a desire for larger and larger smolts, which can be transferred to sea throughout the year. For this reason

Fish	Disinfected roe	Fry	Smolt	Wild fish -marine -salmonids	Farmed fish
Water	Disinfected freshwater Groundwater	Freshwater without anadromous fish	Recirculated freshwater	Freshwater with anadromous fish Disinfected seawater	Seawater
Vectors	Employees Visitors Craftsmen	Divers Feed delivery boats	Fish health personnel Work boats	Net washing	Well boats
Use of boat *	Sites without fish	Mooring work	Towing and other assignments outside cages or in empty cages	Work in cages with fish: net washing, diving	Handling of fish: delousing, sorting, transportation

Figure 2.4. The most important sources of introduction of infection in fish farms. From Lillehaug et al. 2105 and * from biosecurity plans described by www.biosikkerhet.no (downloaded 07.02.2021).

more and more juvenile production farms utilise brackish water or full strength seawater following smoltification on land.

Post-smolts farmed in disinfected seawater can be sold as a 'normal' smolts. Sale of fish farmed in non-disinfected seawater is subject to limitations. Following sea transfer the fish will be exposed to many different marine pathogens and the risk of transmission of infection on transport of such fish will always be high. See also the Norwegian Food Safety Authority guidelines for transport of salmonid fish between farms (Mattilsynet 2019 04 03)

A basic requirement for good biosecurity is that all groups of fish shall have regular health inspections and that screening for important pathogens is performed prior to transport. The transport process itself should also be subjected to a risk evaluation; covering the vehicle or boat, transport water and transport route. In addition to knowledge of current diseases it should also be considered that new or unknown diseases may appear. The precautionary principle should therefore always apply to transport of live animals. For IHN, VHS, PD and ISA there exist national surveillance programmes. For the serious diseases ISA and PD, strict limitations are imposed on transport of fish following a diagnosis. For all outbreaks of ISA and for all outbreaks of PD outside the endemic zone or caused by a genotype not normally found within the endemic zone, control zones and surveillance zones are established. Transport of fish is also regulated under aquaculture legislation and in PD-legislation. For yersiniosis, pasteurellosis and infection with SAV-3 the industry itself has introduced biosecurity related limitations on transport of fish and boat traffic.

Although an increasing proportion of the cleaner fish used in salmon farming are of farmed origin, there remains considerable transport of wild-caught wrasse species into salmon cages, both ongrowing and brood stock populations. This represents a considerable risk of introduction of infection. Increased availability of cleaner-fish of documented infection status is therefore highly desirable in terms of biosecurity.

Measures that will improve biosecurity are: 1) limit transport distances for fish supplied from land-based farms, with a requirement for risk evaluation prior to transport of fish from land-based farms using brackish water or seawater, 2) screening for important infectious agents prior to transport, 3) minimise transport of fish in the sea.

Boats and risk of infecti5on

Licensing of well-boats and cleaning and disinfection routines are regulated by transport legislation. Transport of smolts following other types of transport requires inspection and attestation by a veterinarian or fish health biologist and can only occur following a 48 hour post-attestation quarantine period.

The compulsory attestation represents a quality assurance of the boats hygiene programme and the quarantine period should contribute to a reduction in infection risk and limit the number of changes between different types of transport. Boats leaving a PD-zone are subject to the same requirements, although the Norwegian Food Safety Authority may permit dispensation from these requirements in certain cases.

The industry has established a number of biosecurity protocols that describe standards for hygiene control between different types of transport (www.biosikkerhet.no). For several years it has been argued that biosecurity could be improved by limiting individual well-boat activity to specific geographic areas and that smolt transporters should as far as possible avoid other types of work. However, well-boat companies sell their services along the entire coastline, some also internationally, and for small farming companies the opportunities to enter long-term contracts are minimal. The most important tools in terms of biosecurity are, therefore, the equipment and the routines performed by each boat in relation to cleaning and disinfection, the expertise of the personnel and time available for completion of these routines in hectic working conditions and under all types of weather. Although well-boats have become ever more complicated and greater in size, development of automated cleaning systems and integrated disinfection systems or use of ozone have also provided the possibility of satisfactory disinfection between jobs. However, it is the view of the Norwegian Veterinary Institute that there remain significant hygienic challenges related to well-boat transport: 1) Busy schedules allow too little time to allow thorough cleaning between jobs and that in this way the boats become too dirty for normal subsequent cleaning to be effective, 2) Too many ‘risky’ changes in type of transport are performed due to insufficient well-boat availability at certain times of the year e.g. between harvest or delousing contracts and smolt delivery, and 3) Too much faith is placed on the automated systems, despite the fact that certain areas within the well-boat still require manual cleaning.

Both mechanical and thermal delousing treatments are currently performed on/in well-boats and using equipment mounted on purpose built barges. Delousing barges have been developed concurrently with the change from medicinal to non-medicinal delousing methodologies. The biosecurity risks associated with movement of such barges from one locality to another make thorough cleaning and disinfection essential. Where the industry has developed specific biosecurity protocols for delousing barges, extended quarantine periods between deployment in different localities are demanded.

Use of well-boats for transport of cleaner-fish has increased in recent years. Commonly, smaller, older boats are used in this shuttle traffic, transporting smaller numbers of fish, often across zone-borders, which then

Transport of live animals represents one of the most important risk factors for spread of infectious disease between farms, regions and countries. Photo Arve Nilsen

require a large number of hygiene inspections. While transport of farmed cleaner-fish is covered by transport legislation transport of wild-caught cleaner fish is not. We are not aware of any study or report describing delousing barges, cleaner-fish well-boats or similar vessels, their equipment or biosecurity routines.

Measures that can increase biosecurity include: 1) That companies enter contracts related to use of specific well-boats and limit the number of high-risk changes in use prior to transport of smolts, 2) limit the geographic operating area for individual boats, 3) registration of deviations identified during hygiene inspections and use of these registrations in planning of improved cleaning and disinfection routines, and 4) Documentation of biosecurity related to cleaner-fish well-boat transport.

Infection risks related to transport routes and transport water

From January 1. 2021 all well-boats must utilise approved purification and disinfection technology for treatment of both influent and affluent water. Transport legislation requires that with the exception of 'waiting' cages, influent water must be treated prior to transport of fish to aquaculture localities. Water taken aboard from the locality delivering the fish is not subject to this requirement. On transport of fish to a marine site, the transport water is released at the site. On transport to a harvest facility, transport water must be treated before release. Collected slurry shall be treated as a by-product and dead fish must be delivered to the receiving locality for approved disposal.

Boats equipped with approved water treatment technology can therefore travel with open valves during transport. In the absence of approved water treatment equipment, transport water can be taken aboard at the receiving site and transport shall be performed with closed valves. Specific rules apply for fish infected with list 2 diseases in the PD zone and in control and surveillance zones for PD or ISA. In some production areas there is also a general requirement from the industry that all smolt transports shall be performed with closed valves even if the boat is equipped with approved water treatment technology.

Specific ‘bleeding’ boats are available for transport of harvested fish. These boats euthanize and bleed the fish at the farm site and thereafter transport the fish in ice-slurry to the processing plant. This can provide greater biosecurity in that extended transport of live fish is avoided and improved welfare due to immediate euthanization of the fish on removal from the cage.

All well-boats are linked to an automatic identification system (AIS) that reports their position continually in real-time to the Directorate of Fisheries. This data is logged and can be subsequently used to track the boats movements. AIS data can also show when the boat is within a certain radius of any particular farming locality, but does not register any contact between the boat and the farming site. The Norwegian Veterinary Institute has established an infection-contact model that shows potential infection spread as a result of (well-) boat traffic connecting farms along the coastline in a network.

The model revealed that for PD (infection with SAV), well-boat traffic represents a considerable contributor to spread of infection. Given access to good high resolution data, such models could be valuable tools for infection tracing and identification of ‘risk behaviour’ and in that way contribute to reducing the probability of transmission of infection via contact networks.

New marine farming technologies

New marine production systems are under development and a number of new principles are under planning or testing. The government will, in the course of spring 2021, propose a new aquaculture strategy and has indicated that it wishes to encourage such developments. The developments are taking two different directions; either offshore farms designed for exposed localities or different forms of semi-enclosed facilities for more protected sites. Existing semi-enclosed farms normally utilise untreated influent seawater, while offshore farms are open cage-based. In both cases, with one exception, biosecurity must be considered just as important as in open cage based aquaculture. The exception to this rule is semi-enclosed farms in which all influent water is pumped up from 20-25 m deep. Such farms have been shown to be effective in prevention of salmon louse infestation. Submersible cages, snorkel cages and cages with skirts of various depth have documented as awarding differing degrees of protection against lice and there appears to be a vertical gradient; increasing separation of the salmon from surface water layers resulting in better protection against louse infestation. It is claimed that semi-enclosed farming will result in a lower risk of fish escape, but as these farms vary considerably in design, it is not possible to arrive at a general conclusion in this regard.

The Norwegian Veterinary Institute has found that common viral infections like PRV and IPNV as well as multifactorial conditions such as ulcers and complex gill disease can also be found in semi-enclosed farms. The infectious agents may be found in the fish, the water inside the farm and in the environment up to 1 km from the farm. Concurrently, following stocking of fish into a semi-enclosed farm, a clear change in the microbiological community can be identified in seawater at up to 1 km from the farm. This shows how stocking of a large number of fish into a cage at a particular site leads to significant changes in the microbial community at the site and that this will probably also be true for open-cage based farms or other cage-based technologies.

Two large offshore-based projects in exposed localities have been under testing as part of the ‘development farming concession’ programme. There is limited biological data available, but in both cases louse infestations requiring treatment have been reported. Other infectious agents have also been reported prior to harvest. Some operational challenges have been reported related to delousing in large units exposed to wind and waves.

Offshore cages have until now been established in proximity of other active farms, but are expected in the long term to be sited more remotely. This may change the infection situation both for salmon lice and other infectious agents which may travel via the water column. Offshore farms may provide better protection from infection due to the physical distances between active farms, but open cage based systems will always be exposed to a certain waterborne infection pressure. These farms are also large and require stocking with large numbers of fish. High densities of fish may be negative following introduction of infection. Water exchange and maintenance of sufficient oxygen levels may be challenging. Some farms intend to use large propellers (thrusters) to increase water exchange and thus ensure good water quality in the cage as a whole. Offshore farms are dependent on supply of large post-smolts from farms closer to the coast, which also poses a risk of introduction of infection. SINTEF have 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 microbial load around such farms on wild fish as well as eventual escapes should be evaluated before they start operating.

The environment, health and fish welfare will pose important challenges in new technology projects, and it will remain necessary to have measures in place to reduce the environmental footprint and ensure good fish welfare. Large numbers of fish in a single unit will also pose a considerable challenge on eventual outbreak of disease.

The Norwegian Veterinary Institute has established an infection-contact model that reveals the potential for spread of infection by (well-) boat traffic connecting farms along the coast into a network. Photo: Colourbox.

3 Fish welfare

By Kristine Gismervik, Siri Kristine Gåsnes, Kristoffer Vale Nielsen and Cecilie M. Mejdell

Animal welfare legislation demands that farmed fish shall have an environment and care that ensures good welfare throughout the whole farming cycle. The law applies equally to all farmed fish species, including lumpfish and wrasse used as cleaner-fish in removal of salmon-lice. There remains considerable work to be done before farmed fish are treated as individuals with individual welfare requirements.

Animal welfare relates to the animals quality of life and may be defined in several ways. Three normal interpretations of the term are based on: 1) The animal's biological function, with good health and normal development, 2) The animal's own experience, with regard to feelings such as fear and pain, or 3) a most natural life. Animal welfare may be defined as the individual's mental and physical condition resulting from its attempt to control its environment, or the quality of life experienced 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. Individual diseases (discussed in specific chapters in this report) have a negative impact on welfare, but the degree of impact will vary between different diseases and the organs and functions affected. Both intensity and duration of pain and discomfort are important animal welfare parameters. A disease with a chronic course may affect welfare to a greater degree than a disease with an acute course with similar or even higher levels of mortality. 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. Evaluation of fish welfare is therefore complex.

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. A systematic comparison of the public legislative framework for animal health and animal welfare of farmed salmon and poultry revealed that generally less positive wording was used relating to welfare in farmed salmon. Legislation related to welfare of farmed salmon included potentially contradictory text related to economic aims and fish welfare, while similar legislation related to poultry husbandry focussed on welfare alone. Such differences may affect how legislation is interpreted. Animal welfare regulative § 3 states that animals have their own value independent of their usefulness for 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.

In this year's welfare chapter we focus on how welfare can be measured. Further, we describe how sharing of data can contribute to a better knowledge base, allowing risk factors to be be more easily identified. This is particularly important in relation to introduction of new technologies or improved methodologies. Improvements to regulations and public management are described in separate sections. Geographical differences in welfare and disease status are good examples illustrating the complexity of public management issues. As previously we use particular risk factors related to particular forms of production and novel technological solutions. For large smolt production we refer the reader to the Fish Health report for 2019, as a new survey was not performed for the 2020 report. We continue our focus on juvenile production and cleaner-fish, and share the experiences of over 90 fish health personnel along the whole coast.

3.1 Welfare indicators

There are many occasions when one may need to measure animal welfare. For fish, we use welfare indicators. Welfare indicators are often categorised as environmentally based (e.g. water quality), individual-based (e.g. scoring of external injuries) or population-based (e.g. mortality or schooling behaviour). Good welfare indicators should be simple to measure and easily interpreted. Part of the challenge regarding use of welfare indicators is possession of enough knowledge of biological variation, threshold values, indicators that should be prioritised during evaluation and indicators that are useful for identifying when the fish experience their welfare as good. To measure welfare at the upper end of the scale, more knowledge of positive welfare indicators indicating thriving and the fish's preferences are required. On review of the available evidence it can be difficult to identify the indicators that should be weighted most and whether some should indicate poor welfare while others indicate good 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 evaluation of how the fish experience their situation.

The project 'Fishwell' collected knowledge of welfare indicators relevant for farmed salmon and how these can be used. In 2020 an equivalent book for rainbow trout was published entitled ' Welfare indicators for farmed rainbow trout: evaluation and documentation of fish welfare'. These books represent a good start point for further systematic development of welfare indicators and a compilation of pragmatic welfare protocols for different situations and fish species. The project 'Laksvel' (FHF-901554) develops further and evaluates methods for practical welfare surveillance in Norwegian salmon farms.

Before one can conclude on which welfare indicators are most suitable for welfare control, it is necessary to systematically collate and evaluate data on a suitably large scale. Development of good methods and technologies for monitoring fish behaviour, health and welfare will contribute to rapid identification of discrepancies and introduction of mitigation measures. It is important to remember that animal welfare is equal to the individuals experienced life quality.

Average values for a farming site or individual cage or tank must be used with caution to avoid camouflaging the effects on individual fish. Description and registration of the variation within the group is important as are inclusion of 'runted' fish i.e those individuals with the poorest welfare within the system. Variation between farms in e.g. mortality during the hatchery phase, reveals potential areas for improvement.

Dead fish represent the most reported welfare associated indicator (See chapter 2). However, without additional information, this indicator provides little information on fish welfare or the possibility for repeated incidences of mortality. Mortality categorisation is a way to identify

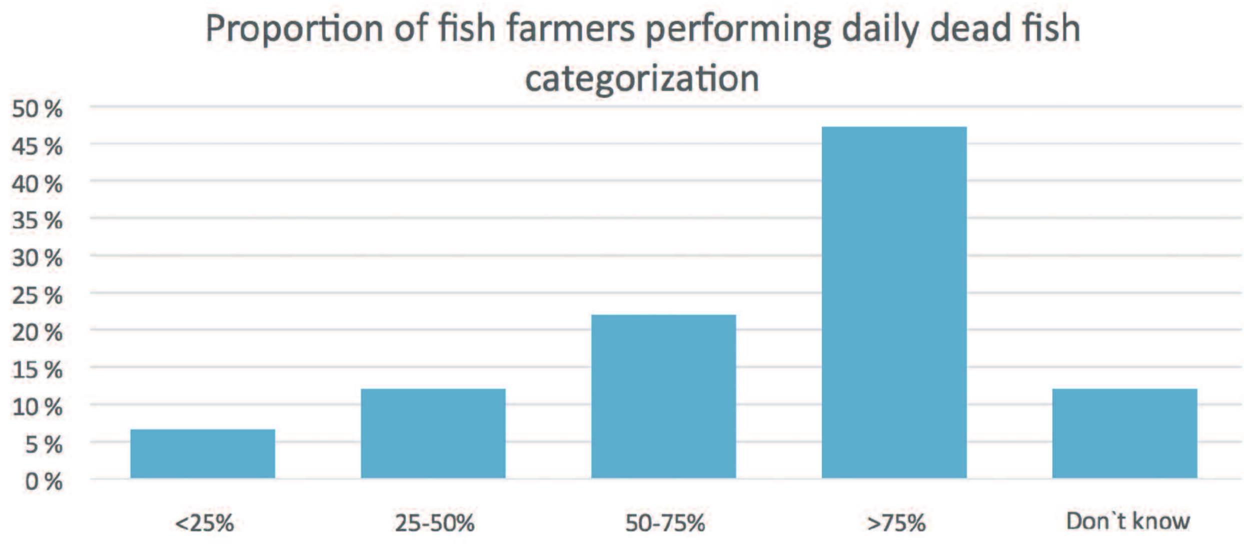


Figure 3.1.1. Respondents (N=91) were asked to state the number of farms (X-axis) that, based on their own experiences, performed daily mortality-categorisation in 2020. N= number of respondents, who in this survey were mainly veterinarians and fish health biologists.

probable cause of death. The categories can include disease, mechanical injury, environment-related, smoltification-related, production-related, predators, and other known and unknown causes. In this year's survey, fish health personnel were asked how many farmers performed daily categorisation of dead fish. Nearly half reported that more than 75% of farmers performed such routines in 2020 (Figure 3.1.1). Fish health personnel were also asked to share their experiences on the degree to which dead fish categorisation accurately described the situation on the farm. A total of 91 respondents replied to this question using a scale from 1 (extremely poorly) to 5 (extremely well). No respondents gave a reply of 1, 4% replied 2, 25% replied 3, 46% replied 4 and 10% replied 5, while 14% replied 'don't know'.

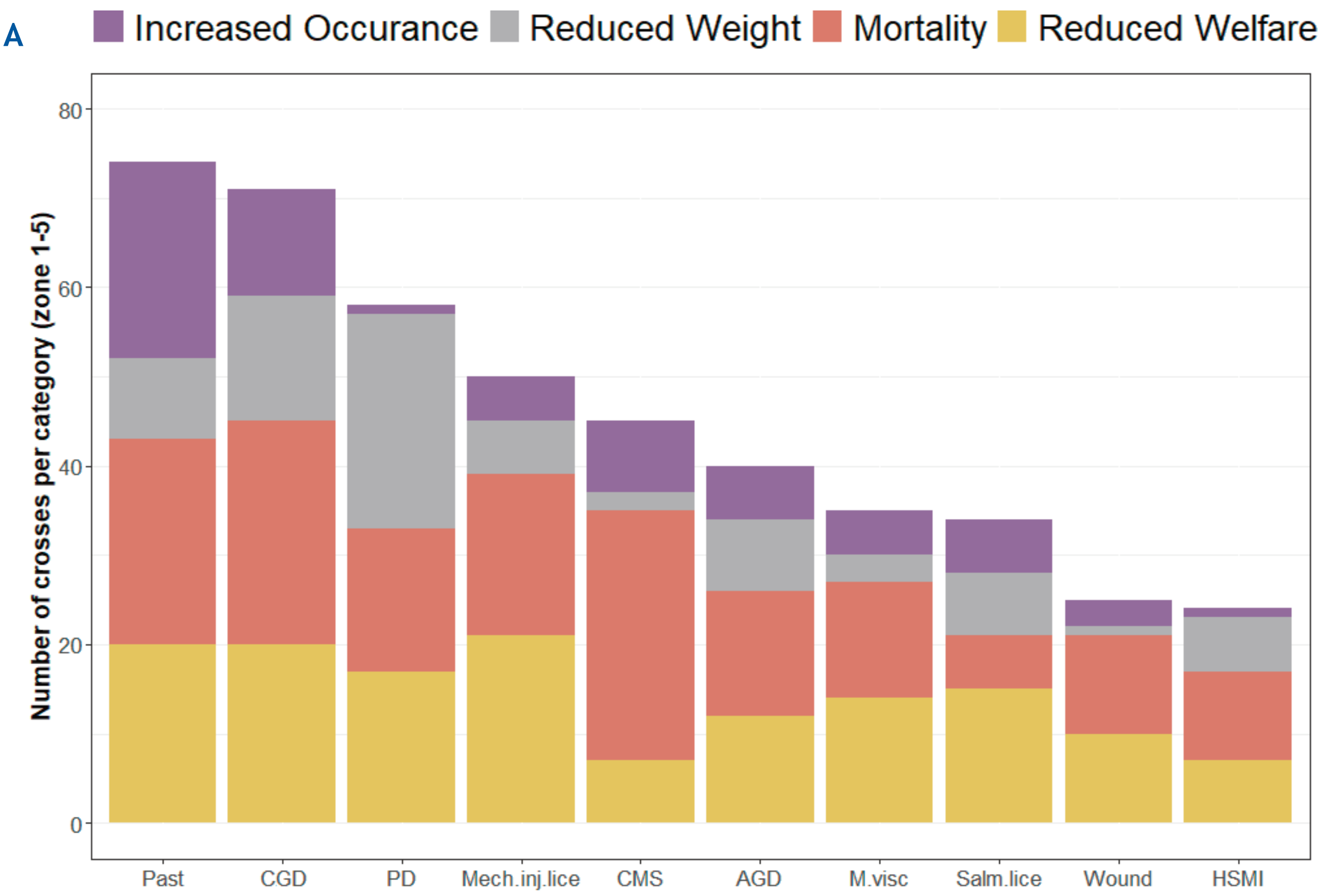
Many respondents comment that mortality categorisation may be improved if national standards were established. Improved education, mentoring by fish health personnel and system simplicity were noted by respondents.

Further it was mentioned that it is important that senior staff within the farming companies recognise the importance of this practice and that staff are allowed sufficient time to perform this task in a systematic fashion.

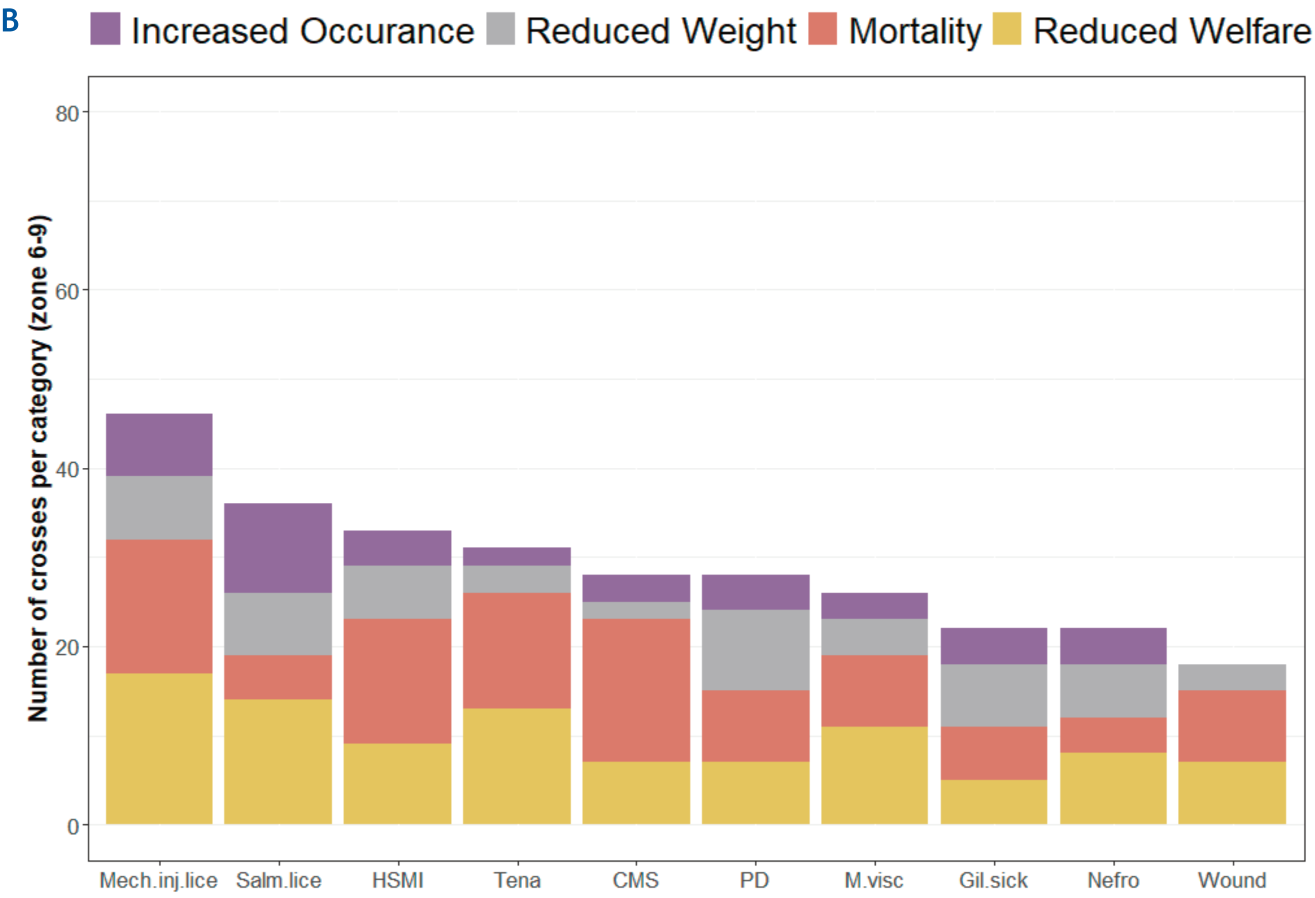
3.2. Fish welfare and health in legislation and public management of a long coastline

It is important that legislation and public management of fish welfare and health are fit for purpose and enable extraction of relevant statistics related to the welfare and health of farmed fish. There is room for improvement in legislation, industry reporting to the public authorities and organisation within the public authorities. For details see the Fish Health Report 2019. In addition to an improved statistical basis related to welfare and data that makes it possible to follow fish groups from egg to harvest, there is also need for a real time update regarding significant changes in production routines and technology in the industry. In this way, data

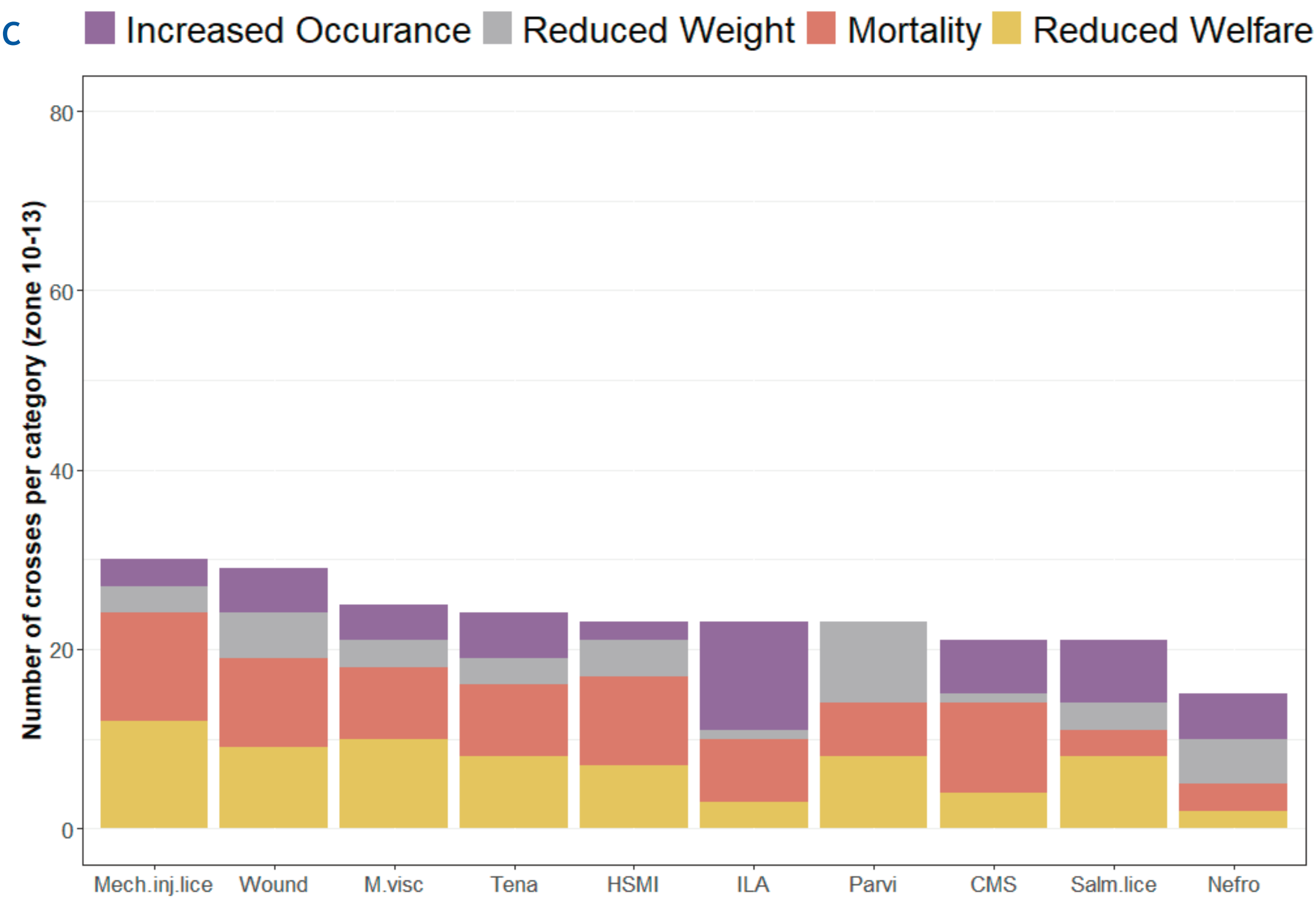
Figure 3.2.1. The 10 diseases or welfare problems receiving most crosses per collective production area group, respectively A) PO 1-5 (N=34), B) PO 6-9 (N=24) and C) PO 10-13 (N=14). N= number of respondents, mainly fish health personnel. For explanation of abbreviations see Appendix B2.



B


Increased Occurance
Reduced Weight
Mortality
Reduced Welfare
Number of crosses per category (zone 6-9)
0
20
40
60
80
Mech.inj.lice
Salm.lice
HSMI
Tena
CMS
PD
M.visc
Gil.sick
Nefro
Wound

C


Increased Occurance
Reduced Weight
Mortality
Reduced Welfare
Number of crosses per category (zone 10-13)
0
20
40
60
80
Mech.inj.lice
Wound
M.visc
Tena
HSMI
ILA
Parvi
CMS
Salm.lice
Nefro

can be compared over time and trends identified. In the long term this will provide an improved 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 and identify trends at both national and regional levels. 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, by fish health personnel (number of crosses per disease; A) PO 1-5, B) PO 6-9 and C) PO 10-13 (se geographical description of PO in chapter 1, Figure 1.1). The trends shown here must be interpreted with caution, due to the fact that some respondents' replies had to be excluded as it was not possible to geographically place them. All the same, 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 and PD in southern areas, while in the middle of the country mechanical injuries related to delousing, salmon lice, and HSM were considered most significant.

In the most northerly areas, skin disease associated with *Moritella viscosa* infection, skin disease in general and *Tenacibaculum* infections have worried most fish health personnel in 2020 after delousing related mechanical injuries, which can lead to ulcer development at low water temperatures.

3.3. Welfare challenges and new technology

Technology aimed at optimization of production and handling of fish is under rapid development. All new technologies must by law, be demonstrated as providing acceptable animal welfare before being taken into use. This legislation has been in place for a number of years and is repeated in a number of different regulations applicable to aquaculture species. The legislation is, however, only variably adhered to in practice. For this reason the Norwegian Food Safety Authority published a revised 'Guidelines for fish welfare on development and use of new methods, equipment, technologies etc. in aquaculture' in 2020. The aim of these revised guidelines is to contribute to establishment of a common understanding of relevant legislation and in this way improve fish welfare.

On development of new technologies in the aquaculture industry it is important that the steps of development, from idea to commercial product are carried out in the correct order (Figure 3.3.1). Following initial idea conception, a risk evaluation of the method in relation to fish welfare must be performed. Technologists and fish welfare specialists must work closely together on this risk evaluation and relevant literature and other sources of information should be considered. An important goal here is avoidance of making the same mistakes as others have made previously. When the prototype is ready for testing on fish, scientifically based welfare protocols must be developed and it must be established whether the planned testing requires approval according to experimental animal legislation. The '3R principles' upon which experimental animal legislation is based relate to: Replace, Reduce and Refine, must be followed. It is, however, important that 'The fourth R' i.e. Rejection, is included as a possible conclusion. At each step of the process it should be considered whether the idea or technology is fit for further testing or whether it should be rejected on fish welfare grounds.

On commercialisation of new technologies/methods, both the farmer and the seller have a responsibility to update and make available guidelines and optimised 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.

Much of recent technology development has in recent years focussed on delousing technologies or technologies that prevent contact between fish and the lice. Significant development projects are also related to farming in exposed marine sites.

3.4 Welfare challenges during juvenile production

There has been increased focus on welfare and causes of mortality during the juvenile stages of production in recent years. It is increasingly recognised that a good start in life is important for later development. Some hatchery operators have, in consequence, changed operating procedures and reduced production intensity during early production stages.

In trials performed between 1997 and 2003, eggs and fry were held at different water temperatures. For salmon eggs an important temperature limit was identified. If eggs are held below 8°C, development of deformities

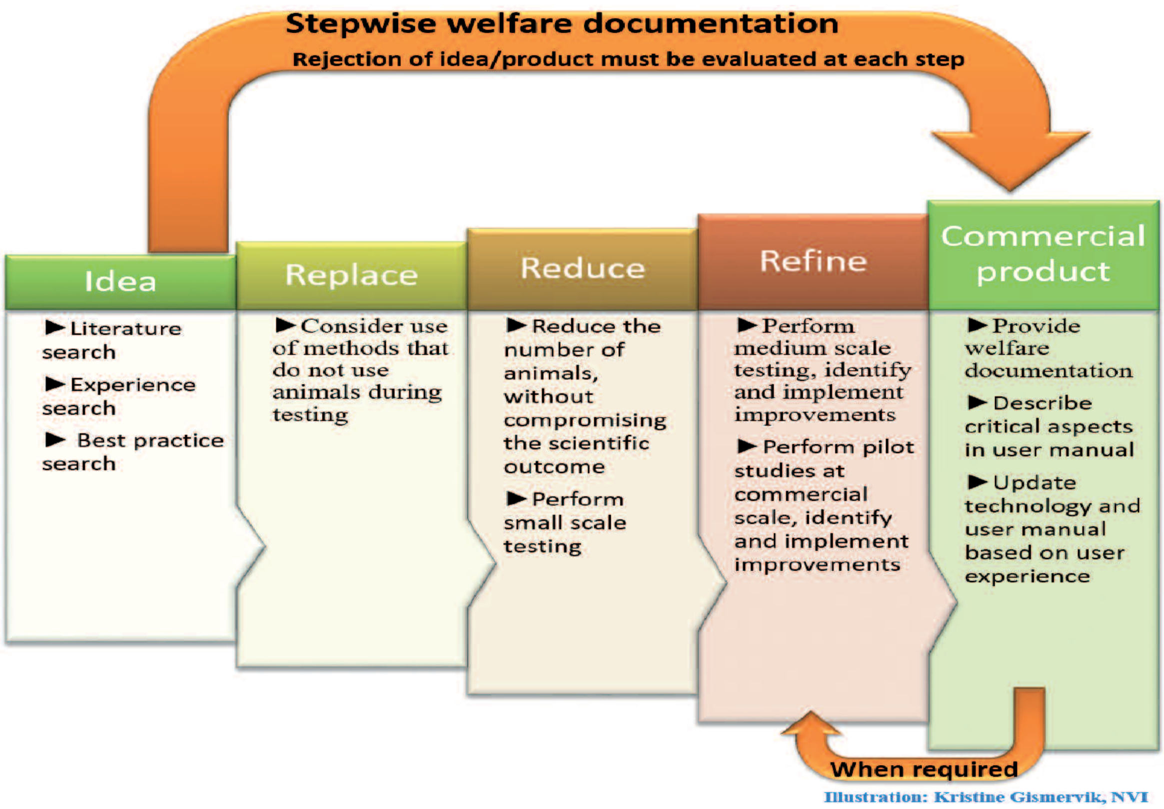


Figure 3.3.1. Stepwise documentation from idea to commercial product implementing the '3 R's' (Replace, Reduce, Refine). A fourth 'R'- Reject, is also included. At each step the technology must be evaluated as to its suitability for further development and whether it should be rejected on welfare grounds. Established methods may also be rejected as new knowledge or alternative methods become available. Before new technologies are placed on the market it is important that they are tested and found satisfactory in terms of fish welfare. Illustration by Kristine Gismervik, Norwegian Veterinary Institute.

involving the heart, operculum and skeleton can be avoided.

Good, stable water quality is one of the basic requirements for good fish welfare independent of farm type. Poor water quality will always stress fish and make fish more susceptible to disease. Salmon fry and parr prefer water temperatures of 10-14°C with 100% oxygen saturation. Wild salmon will to a significant degree choose resting places according to other environmental parameters such as current speed, temperature and salinity. In cold-blooded animals, production increases with water temperature, but the chances of abnormal growth also increase with temperature. In a farming situation, where fastest possible growth is desirable, this desire should be balanced against the risks of development of deformities. In practice, a compromise between an optimal environment for the fish and high productivity is the norm.

Under farming conditions of limited water exchange, oxygen levels can be regulated but waste products such as CO_2 and nitrogenous substances will accumulate to levels at which they will negatively influence fish welfare unless mitigation measures are introduced e.g. CO_2 removal. Different types of farm technologies have different types of water quality challenges (See chapter 8.5 'Water quality').

In the annual survey, fish health personnel were asked their opinion on the welfare related effects of various water parameters. In through-flow farms, the total quantity of water available is considered a limiting factor of relevance for welfare. In RAS facilities, over-production in relation to the water treatment capability is a challenge. Respondents to the survey consider CO_2 to be the waste product that has the most significantly negative effect on fish welfare in both through-flow and RAS facilities. Temperature and oxygen are considered problematical in through-flow farms while turbidity (particle density) is considered a problem in RAS farms (See chapter 8.5 'Water quality' Figure 8.5.1 and Figure 8.5.2).

Table 3.4.1 Number of welfare related incidents in production of juvenile salmonids reported to the Norwegian Food Safety Authority electronic reporting system (MATS) 2018-2020.

Welfare related incidents			
Cause	2018	2019	2020
Other	26 (45%)	46 (47%)	71 (49%)
Unexplained mortality	27 (47%)	46 (47%)	47 (33%)
Pumping	1 (2%)	2 (2%)	13 (9%)
Vaccination	2 (3%)	3 (3%)	10 (7%)
Natural forces - storm	1 (2%)	-	3 (2%)
Fire	-	1 (1%)	-
Counting	1 (2%)	-	-
Total	58	98	144

In this year's survey there was a trend towards reporting of better water quality compared to 2019. This year's report also indicates a reduction in gas supersaturation and H2S toxicity in RAS farms, although any conclusion on this should be arrived at with caution.

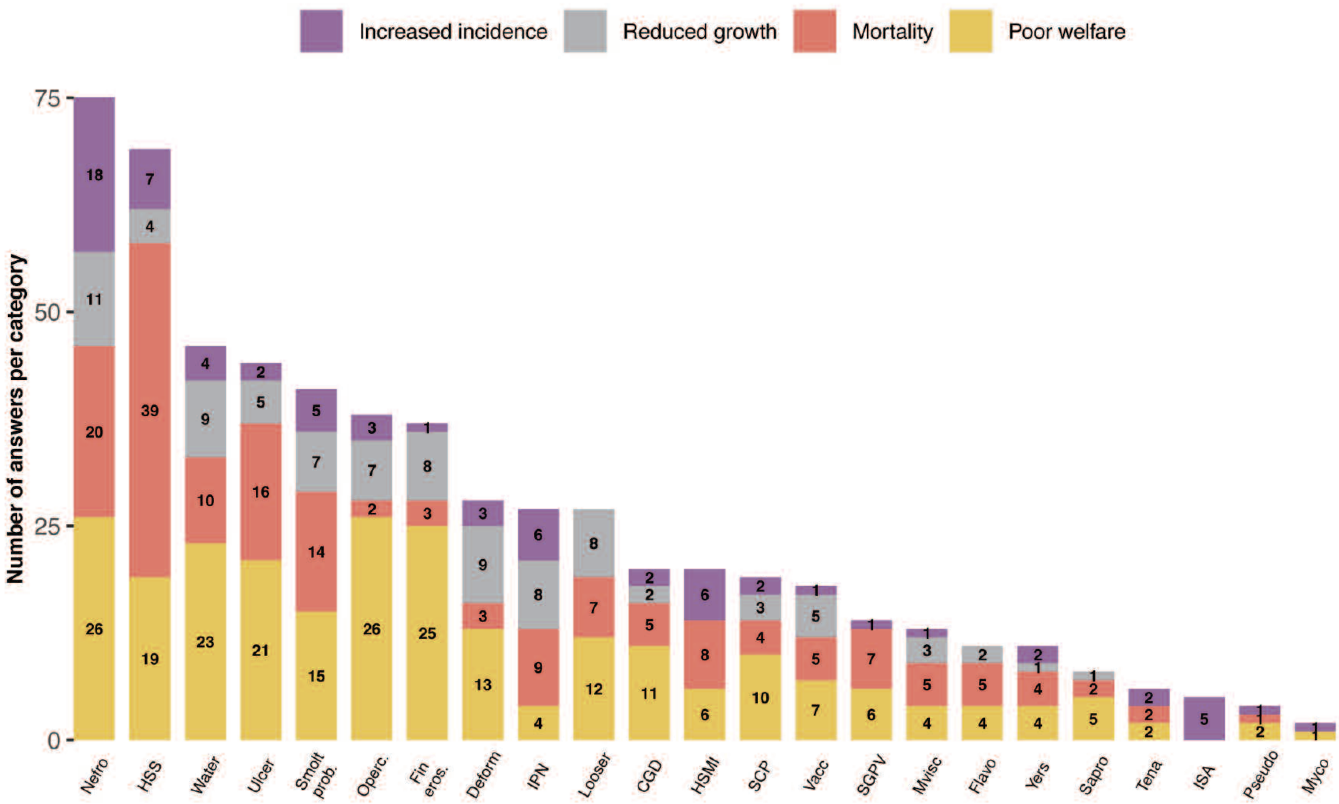


Figure 3.4.1. Fish Health Personnel ranking of the five most important causes of mortality (N=45), growth (N=32) and welfare (N=51) and whether an increasing prevalence was registered (N=31) in juvenile salmon production. See also appendix A1 for explanation of abbreviations for the various diseases/problems on the x-axis. N= number of replies.

Fish health personnel also report challenges related to smoltification at uneven temperatures. In through-flow farms, lower levels of water quality monitoring represent a risk factor for development of poor water quality. Monitoring of water quality is even more important in RAS farms. Problems related to the precision of water quality monitoring equipment are reported. The survey also shows that temperatures resulting in too rapid growth are utilised. This probably leads to premature smoltification and higher than optimal fish densities.

When asked whether the mortality situation had changed in salmon reared in through-flow hatcheries in relation to previous years, more than half (54%) replied that this was at a similar level to previous years, 30% replied that they did not know, while 9 and 7 replied that mortality was respectively higher or lower (N=46). For RAS –based salmon farms, 42% replied that mortality was around the same level in 2020 as in previous years, while 12% considered mortality to be higher, 3 % lower and 44% replied 'don't know' (N=41).

The number of welfare related incidents in juvenile production facilities reported to the Norwegian Food Safety Authority has risen over the last three years (see table 3.4.1).

Whether this marked increase in reported incidents in recent years is caused by an actual increase in incident frequency, improved reporting routines in hatcheries, a general increase in production of juvenile fish or other reason, is unclear.

In the survey, fish health personnel were asked to indicate (by means of a cross) the five conditions which in their opinion resulted in the most significant reduction in welfare, increase in mortality and reduced growth in 2020, and whether their prevalence/frequency is increasing. While the categories poor growth, mortality and welfare were considered independently, poor growth can indicate poor welfare and before a fish dies it will commonly experience poor welfare. Nephrocalcinosis, hemmorhagic smolt syndrome (HSS) and poor water quality represent the three most significant challenges for salmon during the juvenile stage of production. In relation to reduced welfare, nephrocalcinosis, opercular deformities, fin erosion and water quality are considered the most significant challenges for salmon during the juvenile stage of production (See Figure 3.4.1 and responses for rainbow trout juvenile production in Appendix 2). There are only small changes from responses to the 2019 survey.

3.5 Welfare challenges related to water quality during the marine phase of farming

Variable or reduced water quality in open cage farming can be a challenge for fish resulting in poor welfare. Low oxygen levels as a result of e.g. low water exchange, are the most common cause of poor water quality. In this year's survey, respondents were asked 'How often do you consider poor water exchange to result in poor welfare in open marine cages?' The reply alternatives were on a scale from 1-5, where 1 represents 'extremely rarely/never' and 5 represents 'extremely often'. Of 81 respondents, 31% replied 1, 37% replied 2, 15% replied 3, 3% replied 4, 0% replied 5 and 15% replied 'don't know'. In combination with reports of poor water quality, this can indicate that reduced water quality in open sea-cages is observed rarely. All the same, several respondents consider skirts deployed around cages, particularly during periods of high water temperature in the summer and autumn to represent a risk factor for reduced water quality. Should the fish additionally suffer from reduced gill health and/or toxic algae or jellyfish are present in the water, the welfare of the fish will be further reduced.

Regulation of oxygen levels in open cage based aquaculture systems is challenging. Such cages can be large and deep and current speed and direction vary with time and depth and the fish themselves also impact water quality. The number and placement of sensors is important. Collected data must also be controlled and processed, the systems must also be maintained. Norwegian Standard NS 9417 'salmon and rainbow trout –

unified terminology and methods for documentation of production' is currently under revision. One of the aims of this revision is inclusion of important terminology and standards related to health, welfare and environment. Standards for monitoring of oxygen content in the water are proposed. Should such standards be taken into use, it will enable comparison and generate knowledge around the relationship between water quality and fish welfare. The reader is also referred to the chapters on water quality (Chapter 8.5) and algae (Chapter 8.7).

3.6 Welfare challenges related to salmon lice, particularly thermal and mechanical delousing

Prevention of high levels of louse production within the aquaculture industry is important to limit infection pressure towards wild salmon. The welfare of farmed salmon is also a concern and the high louse numbers experienced in some farms during 2016 should be avoided. If the louse burden is held below the maximum treatment threshold, there is little direct impact on the welfare of farmed fish. Mechanical lice treatments have, however, been identified to represent a considerable challenge to fish welfare, particularly if the fish are already weakened by disease. Special consideration must also be given to the welfare of cleaner-fish species during lice treatment. If ignored, these fish commonly die during lice-treatment. 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 3.10 welfare challenges for cleaner-fish).

Salmon lice display, to an increasing degree, significantly reduced susceptibility to most available chemical treatments. This has led to rapid expansion of novel non-medicinal treatments. In 2020, we have seen further increases in use of such methods (Table 3.6.1). For further details, see chapter 7.1 (the salmon louse).

Non-medicinal delousing methods are, in the main, based on three different principles: thermal, mechanical (water jets and/or brushing) and use of freshwater. Use of freshwater has increased considerably in 2020 compared to 2019 (see Table 3.6.1), although thermal treatment clearly dominated followed by mechanical treatments. In addition combinations of different treatments have begun to be tested. Table 3.6.1 shows combinations reported for the same farm in the same week. All do not represent true combinations e.g. one may have deloused one cage using thermal treatment and another cage using mechanical delousing in the same week. Thermal treatment requires transfer of fish from a cage to a

Table 3.6.1. Number of weeks with non-medicinal delousing reported to the Norwegian Food Safety Authority as of 24.01. 2021*. Treatment methods are categorised as thermal (warm water), mechanical (different forms of water based removal) and freshwater. The first combination category indicates use of both thermal and mechanical delousing in the same farm in the same week. The second combination category relates to use of freshwater together with thermal and/or mechanical treatment. The category 'other' relates to those reports that cannot be categorised based on free text included in the reporting form.

Type non-medicinal delousing	2012	2013	2014	2015	2016	2017	2018	2019*	2020
Thermal	0	0	3	36	684	1247	1355	1463	1736
Mechanical	4	2	38	34	312	236	428	673	816
Freshwater	0	1	1	28	73	75	87	150	238
Thermal + Mechanical	0	0	0	0	12	42	38	58	57
Therm./Mech. + Freshwater	0	0	0	0	23	22	25	34	43
Other	132	108	136	103	75	51	69	87	93
Total, sum weeks	**136**	**111**	**178**	**201**	**1179**	**1673**	**2002**	**2465**	**2983**

*Differences in statistics for the 2019 report are caused by new category combinations, updated routines for identification of treatment types based on text in the reporting form and delayed reporting.

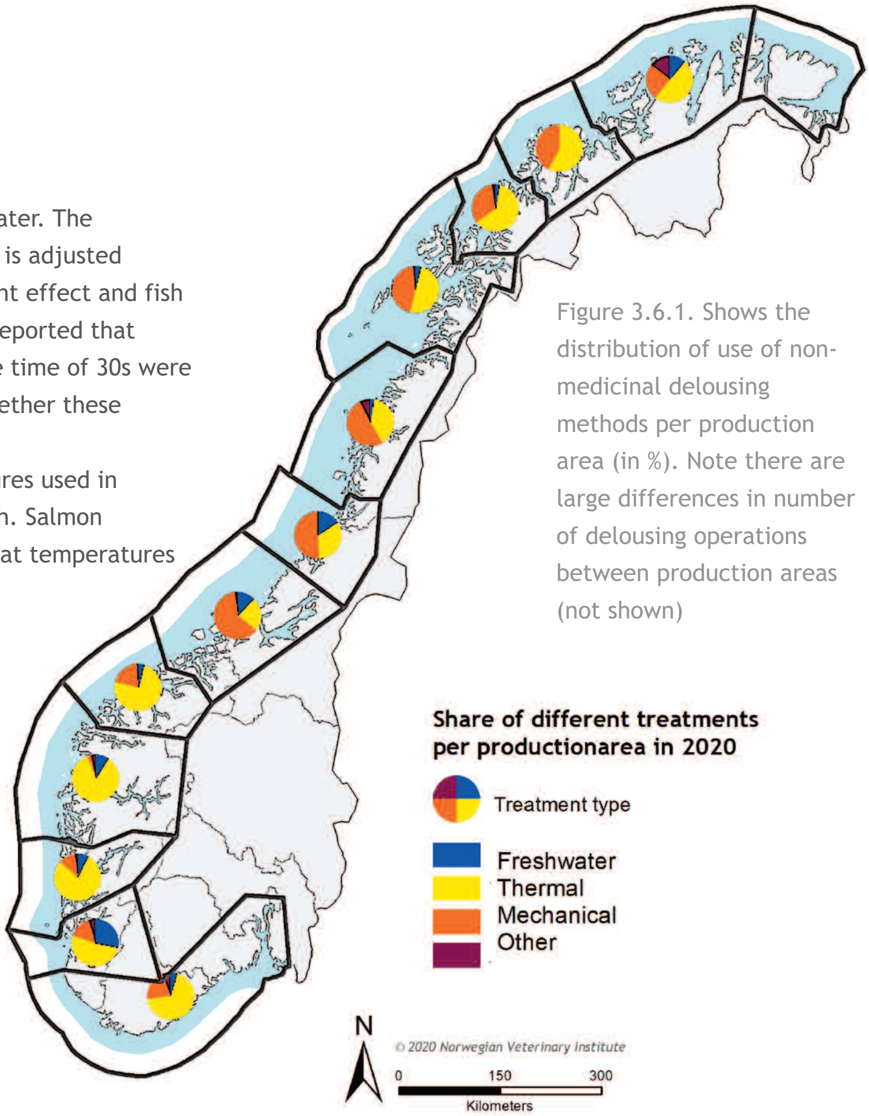


Figure 3.6.1. Shows the distribution of use of non-medicinal delousing methods per production area (in %). Note there are large differences in number of delousing operations between production areas (not shown)

treatment chamber containing warm water. The temperature in the treatment chamber is adjusted according to sea temperature, treatment effect and fish welfare. In 2018 fish health personnel reported that temperatures of 29-30ºC at an exposure time of 30s were most commonly used. It is not clear whether these parameters still apply in 2020.
Research has shown that the temperatures used in thermal delousing are painful to the fish. Salmon displayed discomfort and pain reaction at temperatures above 28ºC in studies performed and published by the Institute of Marine research and the Norwegian Veterinary Institute in 2019. Increased swimming speed, collision with tank walls, jumping, cramp-like symptoms and head shaking were observed. Head shaking was also observed at lower temperatures. Available literature describes death in salmon parr and smolts within 10 minutes on exposure to water temperatures of 30-33ºC. The trial, published in 2019, confirmed that salmon ceased swimming and lost equilibrium (and were euthanised) after only a few minutes when exposed to such temperatures. Death of wild salmon occurring at high water temperatures (approximately 29.5ºC) was identified as early as the 1940's. In 2020 the Institute of Marine research and the Norwegian Veterinary Institute published research that showed that tissue injuries definitely related to exposure to water temperatures of 34ºC for 30s could not be identified. Fin injuries were, however, identified in the treated group and the treated fish displayed a strong behavioural response despite deep sedation. The salmon utilised in this research weighed just over 1 kg.

The Norwegian Food Safety Authority declared in 2019 that thermal delousing at temperatures in excess of 34ºC is forbidden, as welfare documentation at higher temperatures has never been presented. The Norwegian Food Safety Authority has further declared that thermal delousing at temperatures of 28oC and above will be phased out over the next two years if no new documentation can be presented indicating that such treatment may be used in a welfare-acceptable way (www.mattilsynet.no, updated 15.10.19). Table 3.6.1 shows that thermal delousing remains widespread in 2020 and that an increase in its use was in fact observed. The distribution of the various methodologies within production areas is illustrated in Figure 3.6.1. As can be seen in the map, some areas use thermal delousing almost exclusively e.g. in PO4, 85% of all delousing is thermal based, while PO6 reports 62% mechanical treatment weeks. Other areas e.g. PO9 appears to have a 50/50 distribution amongst treatment principles.

Mechanical delousing is based on various forms of flushing with seawater in order to remove the salmon lice from the fish. Three different methods have dominated in recent years, one based on flushing alone, another based on turbulent water treatment and the third based on a combination of flushing and brushing. In 2020 there appear to be a number of new suppliers and varying combinations of treatments involving post-treatment (non-flushing based) flushing. Delousing technologies are under continual development. There is still limited documentation of their effect on the fish (e.g. mortality, injury, strass and discomfort). The importance of the impact of frequent delousing on skin and mucosal surfaces including the gills remains poorly documented.

One common element of all non-medicinal delousing technologies is that the fish must be crowded prior to pumping into the delousing system. Crowding in itself has been identified as a significant welfare risk. Thermal, mechanical and freshwater delousing treatments include extensive handling and a series of situations with a significant risk of stress, mechanical damage to the gills, fins, eyes, skin etc. in addition to injurious changes in water quality e.g. fall in oxygen levels or gas supersaturation.

In the annual survey, 'Mechanical injury related to delousing' was ranked as the most important cause of reduced welfare in ongrowing salmon and rainbow trout (see appendices B1 and B2). Delousing injuries are also considered the second most important cause of mortality in salmon and the most important cause of mortality in ongrowing rainbow trout. In the free text comments it was registered that delousing also results in welfare problems in broodstock fish. More information on broodstock will be collected for next year's report. For delousing related injuries in lumpfish and wrasse spp. see 3.10 (Welfare challenges in cleaner-fish).

The Norwegian Food Safety Authority received 1559 reports of welfare related incidents in ongrowing/broodstock farms in 2020. This is an increase from the 1487 reports received in 2019. Of those received in 2020, 843 (54%) were related to non-medicinal delousing and associated handling (see Table 3.6.2).

Whether the reduction in reported welfare incidents related to non-medical delousing from 2019 to 2020 is real, is unclear. The seriousness and extent of registered incidents varies, different companies can have different thresholds for reporting, and some reports do not identify the fish species involved. When importing the data from the Norwegian food Safety Authority, data related to 2019 was adjusted due to the availability of reports unavailable when the 2019 report went to press. The number of late reports for 2019 was higher than in previous years.
In 2020 the practice of having a 'bleeding boat' on standby during delousing in case of high levels of morbidity during/following delousing was registered. In an effort to find out how common this practice is, respondents to this year's survey were asked how often they had observed 'bleeding boats' on standby and how often they had experienced that such boats had been used during delousing in 2020. The alternative replies were 1 = extremely rarely/never to 5 = extremely often. Of 70 respondents, 49% answered 1, 9% answered 2, 17% answered 3, 11% answered 4 and 7% answered 5, i.e. extremely often. 6% replied 'don't know'. It appears that the frequency of use of 'bleeding boats' varies with geography as all respondents who replied with alternatives 3-5 are based in production areas 1-7.

In 2020 there has been a general reduction in in prescription of medicinal delousing substances compared to 2019 (see chapter 7 'The salmon louse', Table 7.1.1). Use of non-medicinal methods has increased and re-infestation following thermal and mechanical treatments continues to be reported, which leads to increasingly frequent delousing. There is a lack of knowledge on how the number of treatments or handling in general and the intervals between these treatments affect the fish. There are grounds to believe however, that the total impact increases with increasing use of non-medicinal methods.

Table 3.6.2. Shows the distribution of various types of welfare incident reported to the Norwegian Food Safety Authority (ongrowing fish). Data from the Norwegian Food Safety Authority as reported to their electronic reporting system (MATS).

Number reported welfare incidents Incidents ongrowers/broodstock	2018	2019*	2020
Non-medicinal delousing including handling	629 (61%)	905 (61%)	843 (54%)
Unexplained mortality	196 (19%)	251 (17%)	269 (17%)
Other	112 (11%)	178 (12%)	294 (19%)
Handling	40 (3.9%)	60 (4.0%)	77 (5.0%)
Medicinal delousing including handling	40 (3.9%)	54 (3.6%)	19 (1.2%)
Grading/pumping	7 (0.7%)	18 (1.2%)	16 (1.0%)
Natural forces (2019 og 2020)/ Reduced fitness (2018)	1 (0.1%)	9 (0.6%)	23 (1.5%)
Medicinal delousing including handling	9 (0.9%)	9 (0.6%)	6 (0.4%)
Non-medicinal delousing/preventative without handling	3 (0.3%)	3 (0.2%)	9 (0.6%)
Jellyfish			3 (0.2%)
Total	1037	1487	1559

*Fewer reports in the Fish Health report 2019 caused by delayed reporting (statistics now updated).

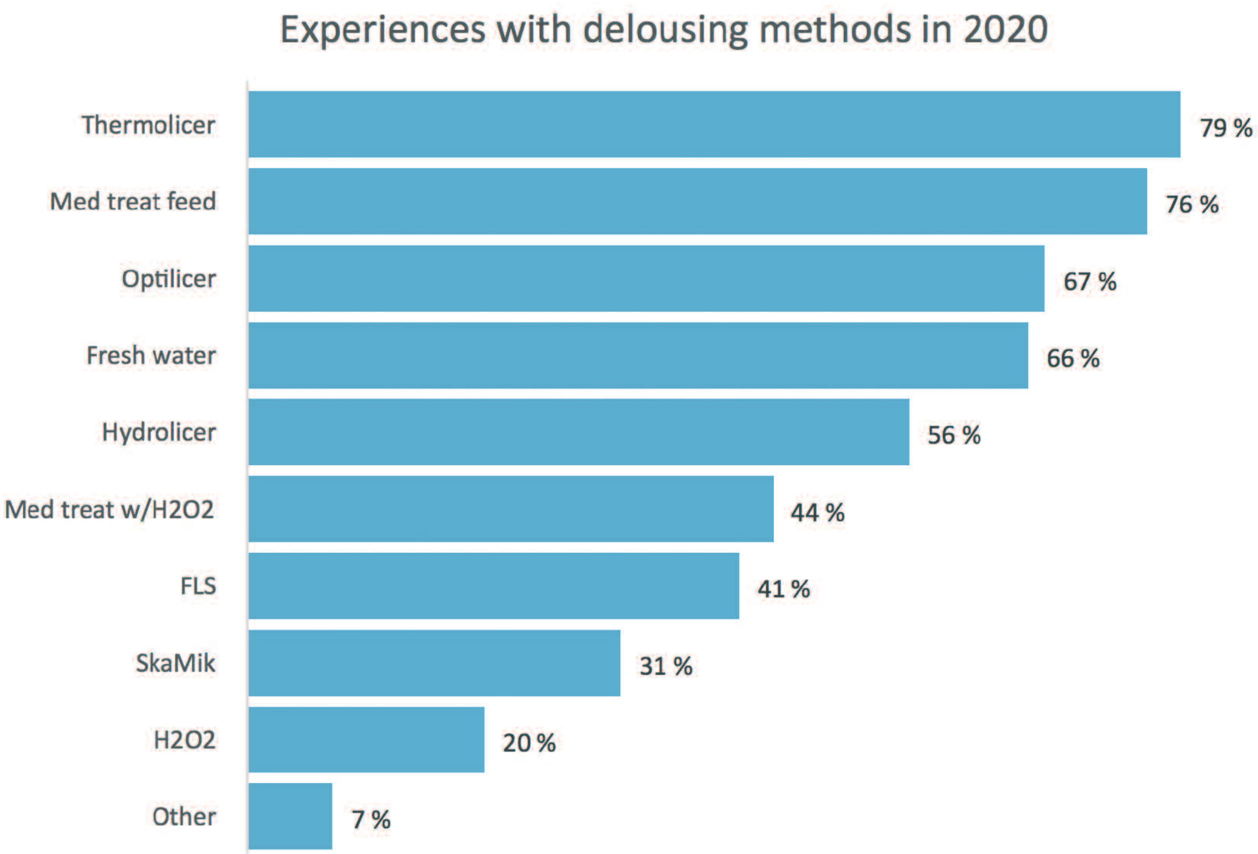


Figure 3.6.2. Summary of the various delousing methodologies for which respondents to this year's survey had experience in 2020 (N=70)

A total of 70 respondents shared their experiences related to welfare and delousing in this year's report. A summary of the delousing methods for which respondents had experience of in 2020 are shown in Figure 3.6.2. In comparison to 2019, it seems that fewer respondents had experience with the optilicer system and more had experience with freshwater treatment in 2020.

The effectiveness of non-medicinal delousing can depend on many factors e.g. treatment principle, pressure, temperature, treatment time, crowding. In this year's survey, respondents were asked whether they had observed changes in effect of non-medicinal treatments. Several respondents mentioned that the effect of thermal delousing had fallen, particularly in the autumn. It is considered likely that this is related to use of lower ΔT i.e. the difference in temperature between the sea and treatment water. The reason for this is the ban on use of temperatures above 34 °C and that a lower ΔT is desirable in relation to fish welfare. Some respondents inform that increased temperatures were required to achieve the desired effect. For mechanical delousing it is reported that flushing pressures had to be increased to achieve satisfactory levels of delousing. It was also noted that frequent delousing (every 2 – 3. week) is injurious for the skin and mucosal organs and that re-infestation is rapid. Several respondents wrote that the effect of treatment remains unchanged compared to earlier years (both thermal and mechanical)

When asked on the highest temperatures used during thermal delousing in 2020, one respondent reported 34.2 °C at a sea temperature of 13.6 °C. Seventy four percent of the 54 respondents informed that the highest temperature used was 34 °C (from 33.5 – 34.0 °C), 6% reported approximately 33 °C, 6% reported 31 °C or lower. When asked the normal temperature difference between sea- and treatment- water, over 50% of respondents answered 22-23 °C, which is a similar figure to that reported the previous year (Figure 3.6.3). The proportion

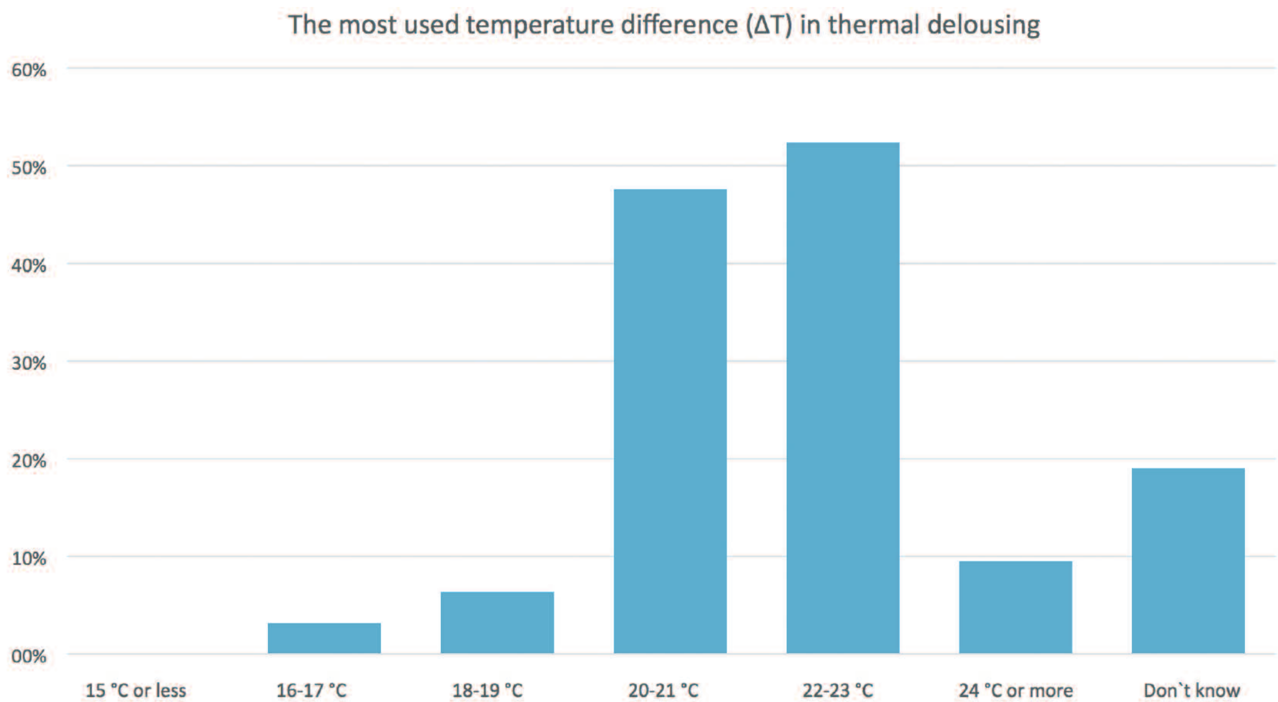


Figure 3.6.3. The most normal temperature differences (ΔT) between sea- and treatment-water during thermal delousing in 2020 (N=54).

who answered 20-21 ºC appears to have increased in 2020 compared with 2019. In the survey, respondents were asked on the frequency of injuries or mortality occurring in relation to various delousing technologies (see Figure 3.6.4). The trends related to type of injury registered appear similar to the previous year. For mechanical delousing, scale loss is most commonly registered while acute mortality is most commonly associated with thermal delousing. A number of respondents replied 'don't know' in regard to brain bleeding and skeletal fractures, indicating that these types of injury are less frequently examined for than others. The figures must be interpreted with caution and only as trends. In the survey, respondents also asked whether they had observed a change in the degree of seriousness of external injuries in association with non-medicinal delousing in 2020, compared to 2019. 42 percent replied that no change had occurred while 4% concluded that there had been a worsening of the situation. 33 percent answered 'don't know' (N= 69).

Several respondents commented that the welfare of treated fish is dependent on the general health status of the fish prior to delousing, crowding or pumping. It was also commented that the threshold definition of increased mortality following delousing of 0.2% means that very many treatments are associated with increased mortality. Others are concerned at the pain, panic reactions and external injuries to eyes, scale loss, abdominal 'scraping', brain bleeding and skeletal fractures in relation to welfare. It also becomes apparent from several respondents that thermal delousing appears to result in delayed mortality (hours – days) with no other obvious cause, and that in such cases it is not possible to

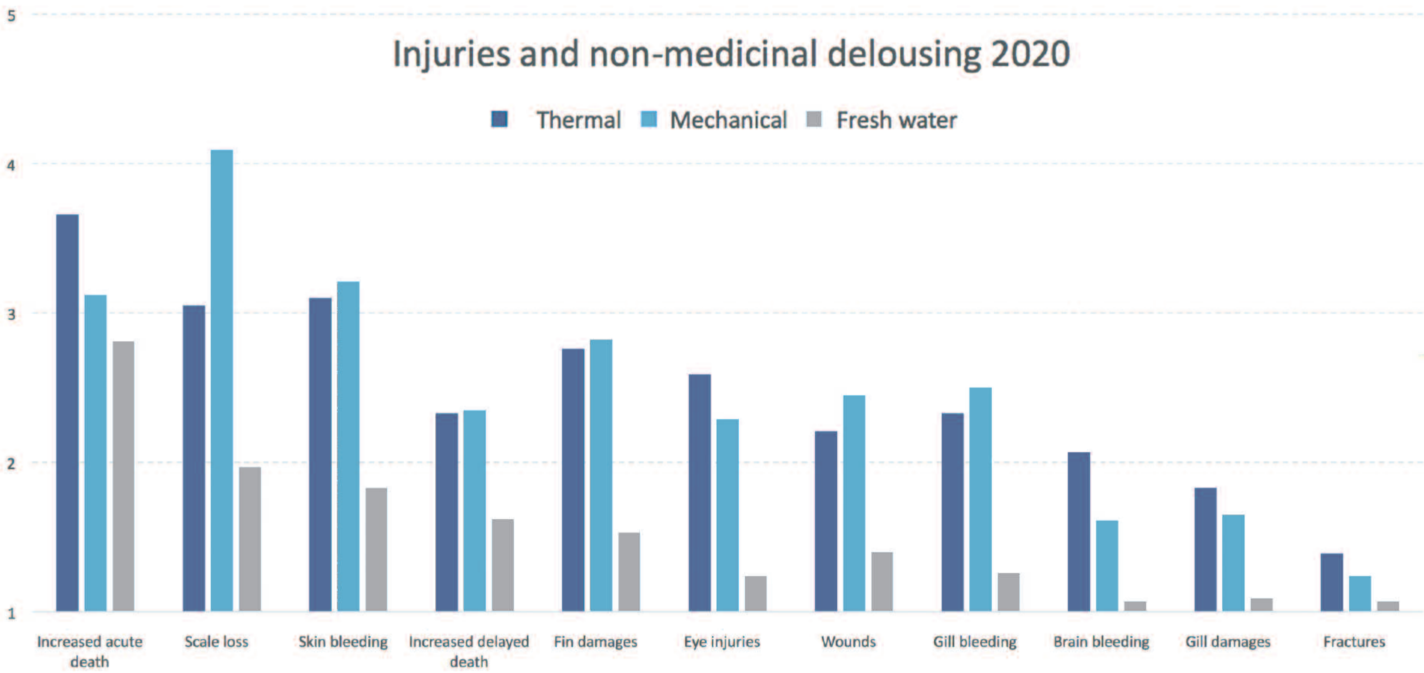


Figure 3.6.4. Shows the average frequency of injury or mortality experienced by fish health personnel in association with various delousing technologies in 2020, on a scale from 1 = never or very infrequently observed to 5 = nearly always occurring. For the two questions related to mortality 5 = nearly all delousing. 'don't know' as a reply is not presented here. The number (N) of respondents = 60 for thermal, 54 for mechanical and 42 for freshwater. Increased mortality - >0.2% during the first 3 days post-delousing. Increased delayed mortality – up to 2 weeks post-treatment.

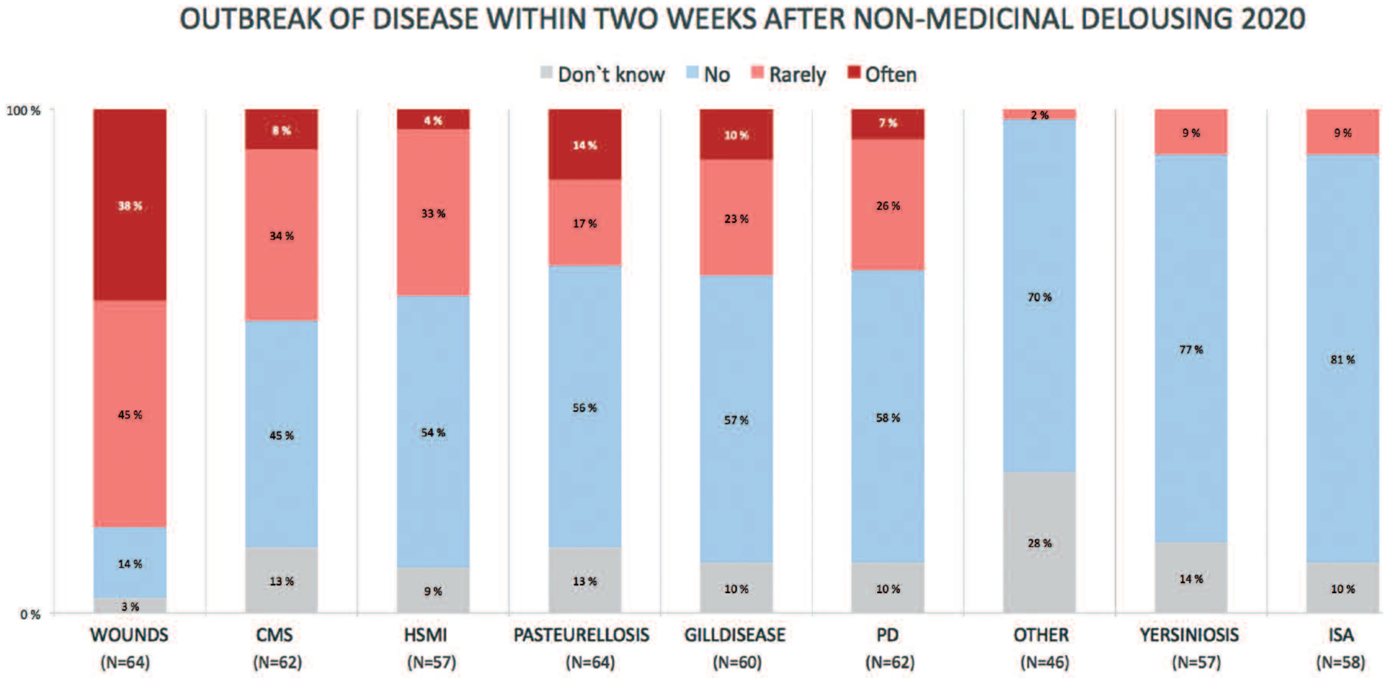


Figure 3.6.5. Fish Health personnel replied to the annual survey on whether they had experienced outbreak of various diseases within the first two weeks post non-medicinal delousing.

suspend treatment. Fish with circulatory disturbances and poor gill health are considered to poorly tolerate thermal delousing. Scale-loss associated with flushing results in skin lesions that do not heal at low water temperatures and is considered particularly worrying.

Underlying or active diseases e.g. CMS, HSMI, PD AGD or poor gill health are reported to result in significant mortalities in association with non-medicinal delousing. In the survey, 'skin lesions' were the most commonly reported disease problem following non-medicinal delousing (see Figure 3.6.5). Water temperature is often decisive as to whether skin lesions develop post-treatment.

In 2020 the Norwegian Veterinary Institute received 11 diagnostic submissions related to increased mortality following thermal delousing (10 from salmon, one from rainbow trout). Thirty-two such cases were submitted in 2019.

3.7 Welfare challenges associated with transport

Farmed fish are transported as smolts, harvest-ready fish or as brood stock. These are operations involving a number of workers, large boats and advanced technologies. There exists little knowledge of how these operations impact fish welfare.

It is important that the chosen transport method is as gentle as possible and is performed such that the fish under transport do not become infected and/or do not transmit infection to other populations during transport. Smolts that are unnecessarily stressed or injured during transport will perform poorly and become more susceptible to infectious disease compared to less stressed fish. In a similar fashion, fish stressed under transport to harvest facilities may result in reduced quality of the final product, particularly if the fish are not allowed to recover before processing.

During all routines involving handling there is a risk of physical injury. During transport this may occur e.g. during crowding or pumping. Control of water quality in well-boats is important. The Norwegian Food Safety Authority received 14 welfare related reports in association with transport of fish in 2020 compared to 24 in 2019 and 5 in 2018. Of the 14 reports received in 2020, seven involved transport related injuries, 3 involved water quality problems and the remainder were classified as 'other'.
Transport of cleaner-fish can also be particularly challenging. More on this can be read in Chapter 3.10.

3.8 Welfare challenges associated with harvesting

All harvesting processes involve a risk of suffering and all fish must be sedated prior to bleeding. The risk of injury, pain and stress is directly related to the degree of efficiency of the sedation process and any handling performed in advance of sedation. Crowding, pumping, chilling, time out of water and collision with harvesting furniture all pose a risk of poor welfare.

Some sedation methods such as 'swim in' tanks followed by a blow to the head are dependent on the fish's own motivation to swim towards the sedation mechanism. This requires fish that are not exhausted or injured. Stunning via electric shock or a physical blow are the permitted forms of sedation for salmonid fish. The aim of sedation is to render the fish unconscious and thereby unable to experience discomfort during bleeding. Each fish must remain sedated until it dies of blood loss.

In the 2020 survey, 20 respondents replied that they had responsibility for a total of 28 harvest facilities, compared with 28 respondents and 49 facilities in 2019.

Most (14 of 20) were responsible for a single facility. Physical stunning and electrical stunning appear to be equally utilised.

Earlier research has shown that these methods are equally satisfactory in regard to fish welfare as long as the system is used and maintained properly. For physical stunning it is important that the fish is dealt a blow of sufficient force in the correct place i.e. on the skull, just behind the eyes, such that the fish immediately becomes unconscious. Effective stunning in automated physical stunning machines is dependent on fish having approximately the same head size and shape. It is also important for both physical and electrical stunning that

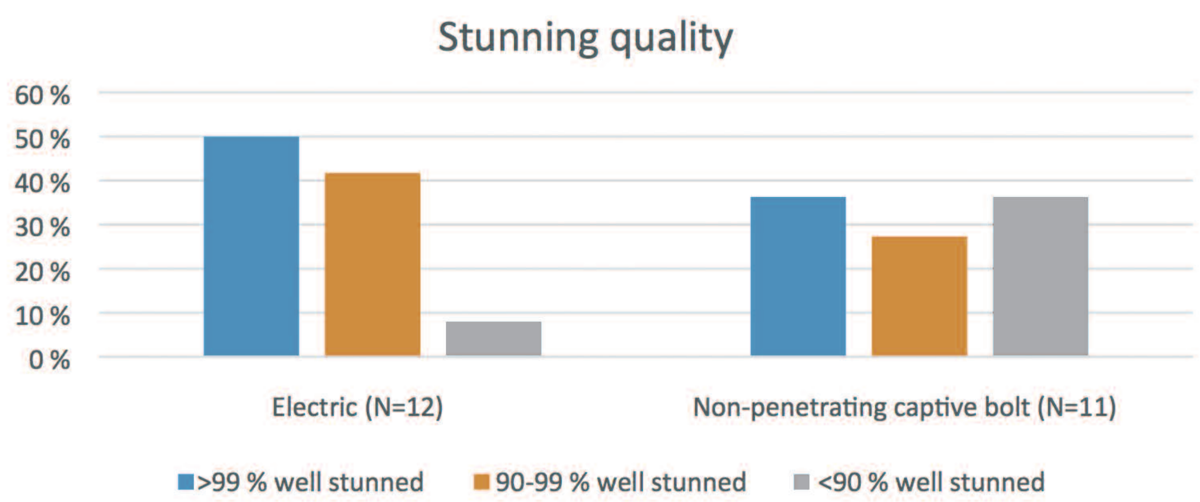


Figure 3.8.1. Respondent evaluation of the proportion of fish adequately sedated following sedation utilising a physical blow or electricity. The number of respondents, for electrical N=12, for physical blow N=11.

the fish are correctly orientated prior to stunning. When electricity is used, the shock to the brain shall be of sufficient strength to cause immediate unconsciousness. On use of an insufficiently strong current, the fish may take too long to enter unconsciousness or that the musculature may be paralysed and the fish rendered immobile yet still conscious. Electrical shocks affecting other areas of the body in advance of unconsciousness are painful.

Respondents were asked their opinion on the quality of sedation provided by both methods (See Figure 3.8.1)

Although the statistical basis for comparison is weak due to the small number of respondents, it is particularly concerning that physical stunning appears to be poorly effective. The suggested causes are that the fish enter the system the wrong way round and that the blow is misplaced due to variable fish size.

Correctly performed physical stunning results in loss of consciousness due to concussion, which often leads to death in advance of bleeding. Electrical stunning leads to normally short-term loss of consciousness and requires rapid bleeding following sedation. Cutting a single gill-arch results in a slower bleed than cutting both gill arches.

Sixteen respondents stated that they had experience with automated bleeding systems, of which 19% considered these systems to work very well, 62% considered them satisfactory and 19% considered that they were often faulty. Automatic bleeding is poorly effective if the fish are not positioned correctly or are not motionless. Some harvest facilities have abandoned automatic bleeding due to a high frequency of misplaced cutting. Misplaced gill cutting on conscious fish is unacceptable in terms of fish welfare and also results in production losses.

All automated systems require manual surveillance and back-up systems. Nineteen respondents supplied their views on whether back-up systems in harvest facilities performed satisfactorily. Nine replied ‘don’t know’, eight replied ‘yes’ and two replied ‘no’.

Product quality and fish welfare are often linked in harvest facilities. Fish that are stressed prior to euthanisation enter and develop a stronger rigor-mortis faster than less stressed fish. This reduces the possibility for pre-rigor filleting and the final fillet pH is higher, which reduces the shelf-life of the fresh product.

To reduce stress levels and increase welfare for the fish to be harvested, cage-side harvesting is preferred as long as sedation and euthanisation is otherwise performed satisfactorily. The collective welfare consequences of pumping into a well boat, transport to the harvest facility and eventual waiting period in a cage at the facility are relatively significant. This is particularly the case for fish already in generally poor health. Cage-side harvesting, where the fish are pumped directly on board the boat, sedated and bled on board, then transported to land for final processing is now common.

‘Emergency’ cage-side harvesting of sick/moribund fish appears to be becoming more common. It is important that the availability of these services does not increase willingness to take risks in relation to delousing and that the numbers of fish harvested in this manner are registered. Such registrations are important for evaluation of delousing in relation to fish welfare and delousing related mortality will be underestimated in their absence.

Measures introduced to improve fish welfare in harvesting facilities should also cover fish not destined for market, including cleaner-fish, coalfish and salmonids discarded for one reason or another. These fish have the same welfare rights as those with commercial value. Several respondents report that facilities suitable for handling cleaner-fish do not exist. Whether these fish experience satisfactory welfare during harvesting is therefore uncertain.

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. Knowledge of the nutritional requirements of new species to aquaculture may be particularly challenging. Changes in feed composition due to changes in the cost of ingredients 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 shorter and longer terms.

Method of feeding and the amount of food provided directly influences fish welfare via altered fish behaviour. An example is increased competition between fish leading to aggression. This may result in injury and under-nourishment in some fish. Fasting, a commonly used procedure prior to transport or handling, performed to empty the intestine of waste and reduce the fishes metabolism, results in a higher tolerance in the fish for the stresses involved during these procedures. It is also performed prior to harvest to maintain quality and reduce contamination of the finished product. There is currently very little available information on how fasting affects fish welfare and how the desired effect of fasting can best be achieved with the minimum impact on fish welfare.

3.10 Welfare challenges in cleaner-fish use

The term 'cleaner-fish' is used collectively for the various wrasse spp. and lumpfish used in control of salmon lice in Norwegian farms. That the various species of cleaner-fish have different needs and life-strategies very different from that of the salmon is challenging in relation to welfare. Many farmers consider cleaner-fish to represent a valuable tool in the fight against the salmon louse, but scientific documentation remains lacking. Disease problems and uncertainty regarding their delousing efficiency may be responsible for the lower number of cleaner-fish transferred to sea farms in 2020 compared to the previous year (see chapter 10 for more details on number and distribution per species).

Presently, most of the wrasse used as cleaner fish are wild-caught. The most important wrasse species are goldsinny-, ballan- and corkwing- wrasse. These fish may be caught in the proximity of the farm in which they will be used or they may be caught and transported long distances. There are significant welfare challenges associated with their capture, storage, transport and biosecurity. The question has been raised as to the effect on wild populations due to removal of wrasse and the effect on the ecosystem from which they have been removed. Similar questions are equally relevant 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 should they escape. Unfortunately several respondents to this year's survey consider the effects of vaccination of cleaner-fish to be less than satisfactory.

Lumpfish are the dominant cleaner-fish presently farmed and have become one of the most numerously farmed fish species in Norway. The advantages of using farmed cleaner-fish compared to wild-caught include a lower risk of transmission of infectious disease, stable quality, stable availability and reduced ecological impact. Not least, the ability to vaccinate farmed fish against the most important bacterial diseases should result in lower mortality and better welfare.

There can be significant differences between the natural environments and the cage environments to which cleaner-fish are exposed. Lumpfish swim poorly, so exposed sites with strong currents are challenging for this species. Lumpfish do not tolerate high water temperatures well, such that summer water temperatures in southern Norway represent an additional challenge.

Disease is a real problem for all species of cleaner-fish. This is described and discussed in chapter 10 of this report 'The health situation for cleaner-fish'. In the annual survey, fin-erosion and non-optimal husbandry during the juvenile phase of production were once more highlighted as particular welfare challenges (see figure 3.10.1).

Knowledge and focus on the welfare related needs of cleaner-fish has increased in recent years. Examples of welfare related production changes include increased attention to their nutritional needs and feeding strategies, increased availability of cover in the cages and vaccination. Despite the increased attention and willpower to adapt the farming environment to the needs of the cleaner-fish, it is apparent that these species adapt to the farming environment with great difficulty. A new study has revealed that ballan wrasse are also poor swimmers and do not thrive in moderate to strong currents. These fish also have low activity at 5-10oC (Yuen, 2019). Another study found that skeletal deformities are common in farmed ballan wrasse, which is presumed to affect both fish welfare and their delousing ability (Fjeldal, 2020).

Figure 3.10.1. The most important problems related to mortality (N=19), growth (N=10), welfare (N=21), and whether these problems are increasing (N=6) in relation to lumpfish in the hatchery phase. See appendix D1 for explanation of the abbreviations.

Replies to the annual survey indicate that emaciation, skin ulcers and non-medicinal delousing were among the major welfare concerns related to lumpfish stocked in salmon cages in 2020 (see figure 3.10.2). The situation was the same in 2019.

The surveillance campaign carried out by the Norwegian Food Safety Authority in 2019 found that mortality in cleaner-fish in the Norwegian aquaculture industry is high. In this year's survey, respondents were asked whether there has been any change in post 'sea transfer' cleaner-fish mortality. For lumpfish, 53% of respondents replied that mortality was more or less at the same level as previously, 5% considered mortality to be lower, 7% higher and 36% replied 'don't know'. For the wrasse species, 38% of respondents replied that mortality was more or less at the same level as previously, 1.5% replied higher while 59% replied 'don't know'. The high percentage of 'don't know' replies illustrates the fact that it is extremely difficult to evaluate the welfare of cleaner fish due to the fact that 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. In the free text area of the survey it becomes apparent that fish health personnel are concerned about the high mortality and poor health status of cleaner-fish. It is also apparent that removal of cleaner-fish prior to delousing of salmon held in the same cage and that introduction of measures aimed at in-cage improvement of cleaner-fish welfare are difficult. There is also increasing concern over the possibility of transmission of disease between cleaner-fish and salmon. Several farming companies have phased out use of cleaner-fish as they consider it too difficult to maintain them in an acceptable fashion. It is also considered by many that cleaner-fish represent an important tool in the fight against the salmon louse. When asked on whether the sedation and euthanisation routines for cleaner-fish during harvesting result in satisfactory welfare 5% replied 'yes', 55% replied 'no' and 40% 'don't know' (N=20).

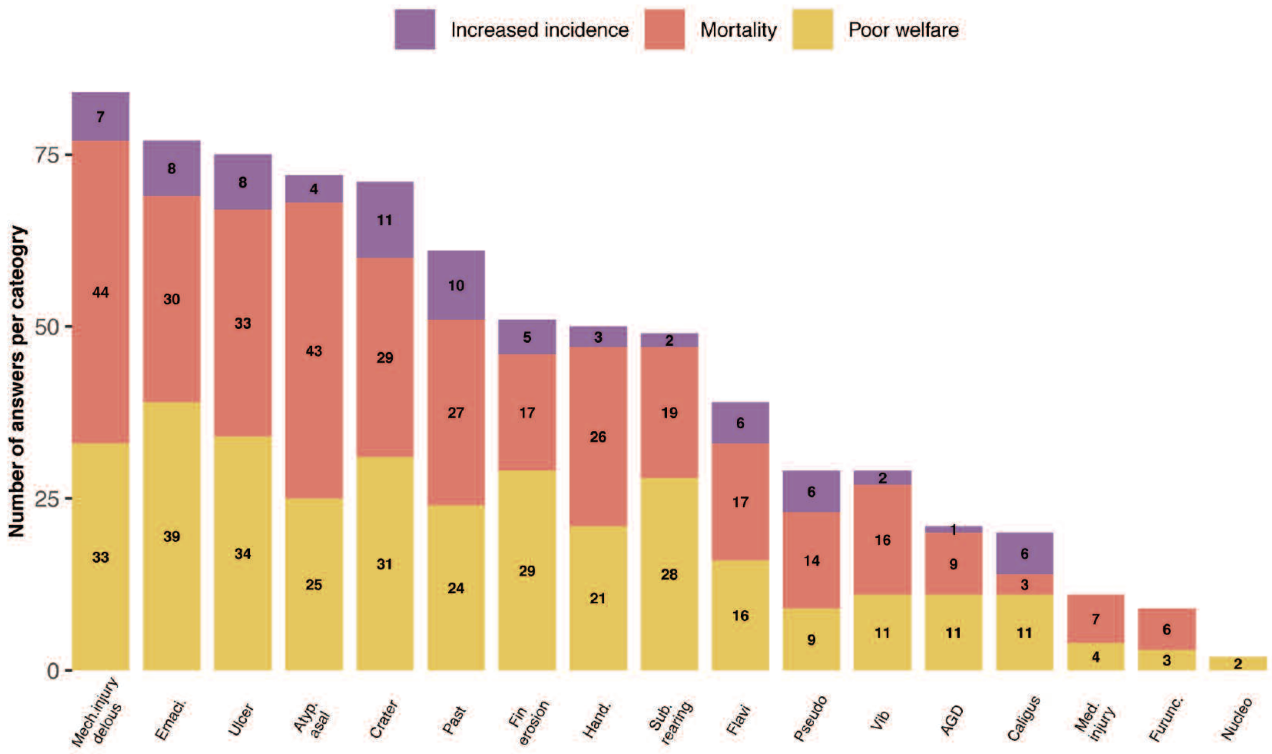


Figure 3.10.2. Respondent scoring for the three most important problems related to welfare (N=68), mortality (N=64) and whether their frequency is increasing (N=28) in lumpfish held together with salmon. See appendix D2 for explanation of the abbreviations.

In the annual survey carried out in association with this report, fish health personnel were asked whether they agreed or disagreed with the statement ‘It is ethically difficult to defend cleaner-fish use’ on a scale of 1 – 5. The proportion of respondents who agreed (wholly or partly) with this statement (5 and 6) was 67% see figure 3.12.1.

For lumpfish and wrasse species utilised as cleaner-fish, the health situation and lack of control of cage-related mortality represent significant welfare challenges. It is also registered that new cleaner –fish are on occasion stocked into cages in which there is ongoing disease in cleaner-fish already held in the cage. This is an illegal practice. Current legislation states that it is illegal to stock a farm already affected by clinical disease if there are grounds to believe that the fish being stocked may also become sick. All fish species farmed in Norway are

Figure 3.10.3 Lumpfish on the autopsy table. Photo: Siri Gåsnes, Norwegian Veterinary Institute

equally protected by welfare legislation. It is therefore paradoxical that cleaner-fish used to improve the welfare of farmed salmon are themselves subject to extremely high mortality rates and a series of health and welfare related challenges. Whether it is at all possible for these species of fish to adapt to conditions within a salmon cage is a central question, which must be addressed if cleaner-fish shall continue to be used.

3.11 Welfare challenges associated with leisure fishing.

In the 2019 report, the welfare and ethical challenges associated with 'catch and release' were discussed. In this year's report we present and discuss the welfare challenges associated with capture of wild fish for food by angling.

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. As far as protests against this practice are concerned, most have been directed at the unnecessary death of non-piscine bycatch such as whales, seals and seabirds that drown in fishing nets. The fate of the fish themselves has only recently arisen as a theme. In Norway the Council for Animal Ethics produced a report

Figure 3.11.1. A blow to the brain which lies just behind the eyes, sedates the fish prior to bleeding. A blunt object, such as a pipe or club is recommended. Photo: Colourbox.

on this theme in 2014 and there have been some R+D projects on this topic. If fish captured on a large scale e.g. in a net or trawl, shall be euthanised rather than allowed to die, industrial solutions similar to those used for sedation and euthanisation of farmed fish are required. On use of fixed nets, a variable number of the fish caught will be dead, dependent on how long the net has fished. 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 improvement of methodology.

Many of the same capture principles are used in both commercial and leisure based fishing e.g. line-capture and net-based principles. We will focus here on capture of fish removed live from the water. What does the fisherman do with them?

During leisure fishing, the catches are normally of such a magnitude that the fish can be treated as individuals. The angler can easily euthanise individual fish if they desire. However, we observe time after time, on TV programmes and in real-life that caught fish are allowed to flap around in a bucket or the bottom of the boat until they die due to lack of oxygen. It is probable that the angler does not reflect over the suffering experienced by the fish, despite the fact that it is well documented that fish feel pain and display panic reactions.

Despite the fact that animal welfare legislation applies equally to fish as well as dogs and sheep, this knowledge does not appear to have reached the 'person on the street'. In the relatively comparable hunting situation, ensuring a rapid and humane death for the game hunted is a priority for all hunters. It is therefore worth making an effort to minimise suffering in fish by raising the consciousness and changing the attitudes of the people involved. Efficient euthanisation may be achieved simply by striking the fish on the head, just behind the eyes with a heavy, blunt object. A hard physical blow above the brain knocks the fish unconscious and it loses the ability to feel pain or fear. The fish should thereafter be bled by cutting over the gill arches allowing it to bleed out. This prevents the fish regaining consciousness should the blow to the head have been insufficient to kill the fish directly. Besides shortening the fish's death-associated stress, bleeding will improve the quality of the final product.

Figure 3.12.1. Distribution of opinions related to various statements on welfare in the 2020 survey. The number of respondents = 82. Replies were ranked on the scale of 1-5, where 1 = totally disagree, 3 = neither agree og disagree, 5= totally agree, as well as "Don't know"

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. Veterinarians and Fish Health Biologists have a particular responsibility to contribute to good fish welfare. Societies views 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 2020. The results are shown in figure 3.12.1.

3.13 Overall evaluation of fish welfare in 2019

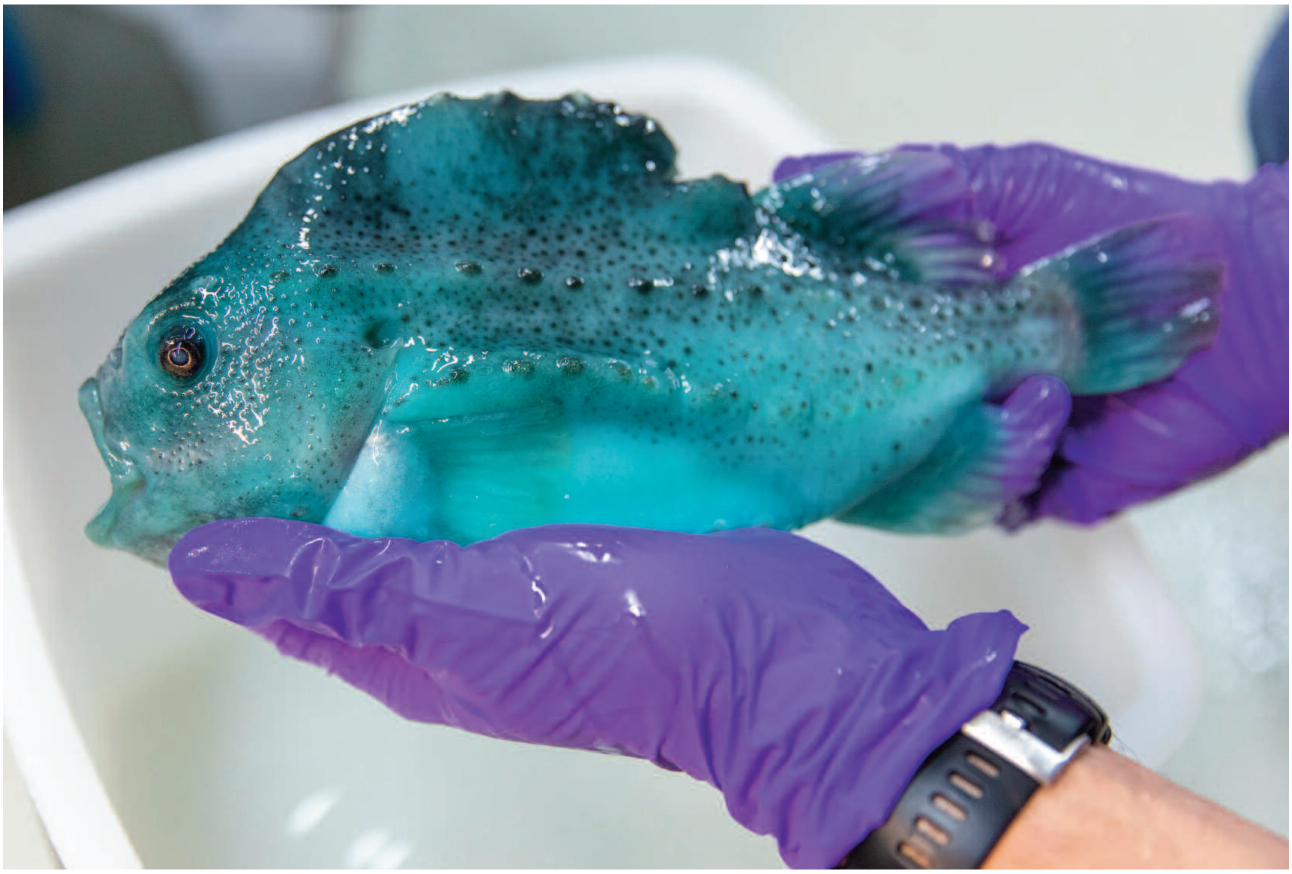
Fish welfare, mortality and the causes of mortality in production of juvenile salmonid fish have received much attention in recent years. We must consider the whole life-cycle of the farmed fish and stop thinking that the life of the farmed salmon begins once it is transported to sea. No changes have been made regarding the requirements for registering dead fish to the Norwegian Food Safety Authority, a topic discussed in 2019's Fish Health Report. It is desirable that groups of fish are followed 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 again in 2020, 'outgrowing' the farm. Fish health personnel describe again in 2020, as in 2019, challenges associated with water quality. Although some farms may have improved, it is reported that CO_2 levels affect welfare during juvenile production in both throughflow and RAS facilities. Nephrocalcinosis, operculum deformities, fin erosion, HSS, smoltification and water supply problems are also reported as challenging. The marked increase in welfare related reports from juvenile production farms continues. In 2020 the Norwegian Food Safety Authority received 144 such reports compared with 98 in 2019. The reasons behind this increase remains unknown.

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 cleaner-fish present. Handling and crowding are in themselves stressful for the fish, and occur as often as every 2-3 weeks in some areas. There is still a lack of knowledge on the tolerance limits related to repeated treatment and restitution time. The number of weeks registered for non-medicinal delousing increased by approximately 20% in 2020 compared to the previous year. Thermal delousing, which incurs exposing the fish to abnormally high water temperatures can result in pain and panic reactions. Experiences indicate that fish in poor health i.e. due to poor gill health, tolerate such treatment extremely poorly.

In this year's survey, unexpectedly high mortalities in the hours or days following thermal delousing were reported. For those systems utilising water-based flushing technologies, scale loss is commonly reported leading to increased susceptibility to winter-ulcer at low water temperatures. Ulcer diseases may be extended and result in serious welfare incidents. The Norwegian Food Safety Authority received in 2020, 1559 welfare reports from ongrowing/broodstock farms, an increase from the 1487 received in 2019. While the proportion of reports related to non-medicinal delousing, including handling, appear to be slightly fewer than in 2019, the data is uncertain due to the recent trend in later reporting. In 2020 there appeared to be an increasing practice of having a harvest boat available during delousing to allow rapid harvesting 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.

For lumpfish and wrasse species used as cleaner-fish, there are significant welfare challenges related to health, delousing and lack of control of in-cage mortality. This statement is consistent with a welfare evaluation carried out by the Institute for Marine Research (https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2021-8). Although much work has been done to improve the situation for these fish, very few fish health personnel consider the situation to have been improved in 2020 compared to previous years. Indeed, 67% of respondents were completely or partly in agreement with the statement that 'It is ethically difficult to defend use of cleaner-fish'. Whether it is at all possible for these species of fish to adapt to conditions within a salmon cage is a central question, which must be addressed if cleaner-fish shall continue to be used.

The industry is in need of concrete drivers that will promote production development in the direction of fish welfare and health rather than quantity. This applies equally to cleaner-fish. The focus on welfare has nevertheless increased over the last year. Fish health personnel are strongly committed in the fight for improved fish welfare, health and general biosecurity and face different problems in the various production areas. Improvement of the situation will require introduction of concrete measures in 2021 and future years. The situation could be improved by introduction of improved reporting to the authorities allowing quantification of the various problems and allow better management. There remain gaps between current animal welfare legislation principles and the actual welfare presently experienced by farmed fish.



Veterinarians and other fish health personnel have a particular responsibility regarding fish welfare. The societal view of fish welfare and thereby that of the public authorities and legislation are also reflected in individual attitudes. The lumpfish in this photo is anesthetized. Photo: Eivind Senneset

4 Viral diseases of farmed salmonids

By Ingunn Sommerset

In 2020, 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). It is however, infectious salmon anaemia (ISA) that has received most attention in 2020. The reason is the marked increase in number of cases compared with annual averages for the last fifteen years.

For the notifiable diseases ISA (list 2) and PD (list 3), where all diagnoses are reported to the Norwegian Veterinary Institute, there were 23 confirmed ISA outbreaks and 158 cases of PD. For ISA this is a considerable increase from the previous year, while for PD this is a similar situation to previous years (Table 4.1).

New for the 2020 report is that the Norwegian Veterinary Institute has, with permission from several farming companies, received data related to identification of the non-notifiable diseases/agents CMS, HSMI, IPN and salmon gill pox virus by private laboratories for inclusion in the report. The data was provided at the farming site level, such that a single site diagnosed with a particular disease will be counted only once (See chapter 1 'Statistical basis'). Although the available data does not cover all farms in the country, we have a much better statistical basis for these diseases than for several years.

Based on available data, 154 localities were diagnosed with CMS in 2020 (including PCR-detection alone = 203 localities) and 161 were diagnosed with HSMI (including PCR detection alone = 232). Although the main area affected by CMS appears to be south – and mid- Norway and that for HSMI mid- and northern- Norway, both diseases are widespread along the whole coast.

As a cause of mortality in farmed salmon, CMS is ranked the most important of all problems in the ongrowing phase, while HSMI lies in fourth place (after CMS, delousing and complex gill disease). In comparison, PD is ranked in eighth place as a cause of mortality in ongrowing salmon, but is ranked first in relation to reduced growth.

For the viral diseases infectious pancreatic necrosis (IPN) and salmon pox (salmon gill pox virus, SGPV) the situation appears to be relatively stable compared to previous years.

Table 4.1 Number of farming localities (salmonid fish) diagnosed with viral diseases for the period 2010-2020. For ISA and PD new diagnosed localities are shown, for other diseases, diagnoses made the same calendar year are shown. For the period 2010-2019 the number of positive localities is based on cases submitted to the Norwegian Veterinary Institute. For 2020, data made avaiable from private laboratories is included* (see Chapter 1).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ISA	7	1	2	10	10	15	12	14	13	10	23
PD	88	89	137	99	142	137	138	176	163	152	158
CMS	49	74	89	100	107	105	90	100	101	82	154*
HSMI	131	162	142	134	181	135	101	93	104	79	161*
IPN	198	154	119	56	48	30	27	23	19	23	22*

Infectious salmon anaemia (ISA) has received most attention in 2020. The reason being the marked increase in number of annual outbreaks compared with the last fifteen years. Photo: Rudolf Svensen

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 PD epidemics underway in Norway. Subtype SAV3 has been widespread in western Norway since its introduction from the Bergen area in 2003-4. Following introduction of a new sub-type, marine SAV2 in 2010, PD caused by this sub-type has spread rapidly in mid-Norway. Most cases of SAV3 PD occur south of Stadt, while nearly all SAV2 cases are registered north of Hustadvika in Møre og Romsdal.

SAV3 associated mortality generally varies from low to moderate, but individual cases of high mortality can occur. While almost all SAV2 infections are associated with low levels of mortality, again high episodes of mortality may be experienced in individual cages. SAV infections lead to low feed conversion and runt development. PD commonly leads to extended production times due to persistent reduced appetite, and losses due to reduced market quality are commonly experienced.

Control of PD

PD is a notifiable disease in Norway (national list 3). Since 2014, infections with salmonid alphavirus (SAV) have been listed on the World Organisation for Animal Health (OIE) list of infectious fish diseases. This means that countries that can document freedom of this disease can refuse to import salmonid fish from SAV-affected areas in Norway.

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

The largest reservoir of infection is infected farmed fish. Intensive compulsory health surveillance forms the basis for early identification and prevention of spread of the disease. According to legislation, monthly samples must be taken from 20 fish from all marine sites holding salmonid fish and other sites utilising untreated seawater. All samples must be RT-PCR screened for SAV and the results reported to the Norwegian Veterinary Institute and the Norwegian Food Safety Authority. Focus on diverse parameters associated with transport of smolts and harvest-ready fish, combined with re-stocking of large fallowed areas, are important disease reducing factors. Rapid harvesting/removal of infected stocks within surveillance zones is favourable both in economic terms and for prevention of spread of PD.

Commercial vaccines against PD are available, and vaccination is standard practice in western-Norway (PO2-PO5). Vaccination has been less widely used in Trøndelag, but from July 2020 compulsory vaccination of all salmon and rainbow trout transferred to ongrowing and broodstock farms in the area between Taskneset and Langøya (production area 6 and 7; §7 in PD-legislation). The effect of vaccination is debatable and protection is undoubtedly lower than for equivalent vaccines against most bacterial agents. It has been shown, however, that vaccination against PD does reduce the number of outbreaks and can lower overall mortality. The vaccine also results in reduced viral shedding from infected fish.

New DNA-based vaccines against PD have recently been released. Field reports suggest that all vaccines now available may have a better effect than previously available vaccines, although this has not yet been documented.

The Norwegian Veterinary Institute is both national and international reference laboratory for SAV. The Norwegian Veterinary Institute collaborates with the Norwegian Food Safety Authority to produce a daily update (map) and monthly reports of PD-diagnoses, which are published on https://www.vetinst.no/

For more information on PD, see factsheet: https://www.vetinst.no/sykdom-og-agens/pankreassykdom-pd

The health situation in 2020

Official data

A total of 158 new cases of PD were diagnosed in 2020, a slight increase from 152 in 2019. This was caused mainly by an increase in cases of SAV3 infection in PO2 and PO4. There was a considerable reduction in number of PD cases in PO3. Two mixed infections involving both SAV2 and SAV3 were also identified in 2020, both in PO2. SAV was not identified in the three most northerly regions in 2020.

Due to an outbreak of PD within the surveillance zone north of Skjemta in Flatanger (Nord-Trøndelag), a control zone was established in 2017 to prevent and control PD in the council areas of Nærøy, Vikna, Leka, Bindal, Brønnøy and Sømna in Trøndelag and Nordland. This control zone was extended in December 2017 to include the council areas of Flatanger, Fosnes and Namsos in Trøndelag. Following a new PD outbreak in September 2019 within the surveillance zone, legislation was again revised to include a control zone around the outbreak. This control zone was repealed in November 2020 and the area included in the surveillance zone.

Due to detection of PD-virus belonging to SAV3 in a site in Smøla council area in Møre og Romsdal and Trøndelag, a control zone was established in April 2019 to prevent, limit and control PD within the Smøla, Aure, Heim and Hitra council areas. This control zone was repealed in June 2020 and the area included in the surveillance zone.

Following outbreak of PD-SAV2 in Tysvær (Rogaland), a control zone was established in December 2019 incorporating the council areas of Tysvær, Vindafjord, Suldal, Stavanger and Hjelmeland. Following detection of SAV2 a control zone was established to prevent, limit and eradicate SAV2 in the council areas of Gulen, Høyanger, Hyllestad and Solund (Vestland region) and similarly in February 2020 a control zone was established to prevent, limit and eradicate SAV2 in the council areas of Stad, Kinn og Bremanger (Vestland region).

Statistics and diagnosis

The statistics presented here relate to the number of new positively diagnosed farms or new diagnoses 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.

Pancreas disease is here defined as 1) histopathological findings consistent with PD and detection of PD-virus in organs from the same fish (diagnosis PD) or 2) histopathological findings consistent with PD, where organ material is unavailable for analysis or detection of SAV in the absence of histopathological findings in the same fish (suspicion of PD). In some cases, a farm may have been diagnosed with PD or SAV following introduction of fish with a SAV/PD diagnosis. The statistic presented here represent a total of both diagnoses and suspected (few in 2020) cases.

SAV3

SAV3 PD occurs mainly in PO's 2, 3 and 4, Ryfylke to Stadt i.e. the southernmost area of the PD-zone. There was an increase in the number of cases of SAV-3 infection from 98 in 2019 to 110 in 2020. Typically the number of outbreaks peaks in the early summer (June-July), but in 2020 the highest number of diagnoses were made in April, of which around half were situated in PO4 (Figure 4.1.1). In PO2, PD was first registered in 2004. While no SAV3 outbreaks were identified in this zone in 2019, 18 cases were identified in 2020. In 2019, SAV3 cases were evenly distributed between PO3 and 4, but in 2020 almost half of all reported outbreaks occurred in PO4 (Nordhordland to Stadt), while there was a reduction in number of cases in PO3. The number of cases diagnosed in PO5 (Stadt to Hustadvika) in 2020 was similar to the 2019 situation. As in 2019, SAV3 was not identified in PO6-13 (Nordmøre to Øst-Finnmark). On two occasions in 2020, both SAV2 and SAV3 were identified in the same farm in PO2.

SAV2

The number of new registrations of SAV2 fell from 56 in 2019 to 50 in 2020. Most SAV2 detections were made in PO6 (Nordmøre and Sør-Trøndelag), where there was an increase from 35 in 2019 to 44 in 2020. In PO5 there was a reduction from 9 cases in 2019 to 2 in 2020. In PO7-13 SAV2 was not identified in 2020. Following the first detection of SAV2 in PO2 in 2019, three new cases of SAV3 were identified early in 2020. As mentioned previously, there is a control zone around SAV2 affected localities both in PO2 and in PO4. This is related to identification of SAV2 south of the endemic area.

Annual survey

As in previous years, the Norwegian Veterinary Institute has carried out a survey amongst fish health personnel and officers of the Norwegian Food Safety Authority. The current survey indicates that respondents still consider

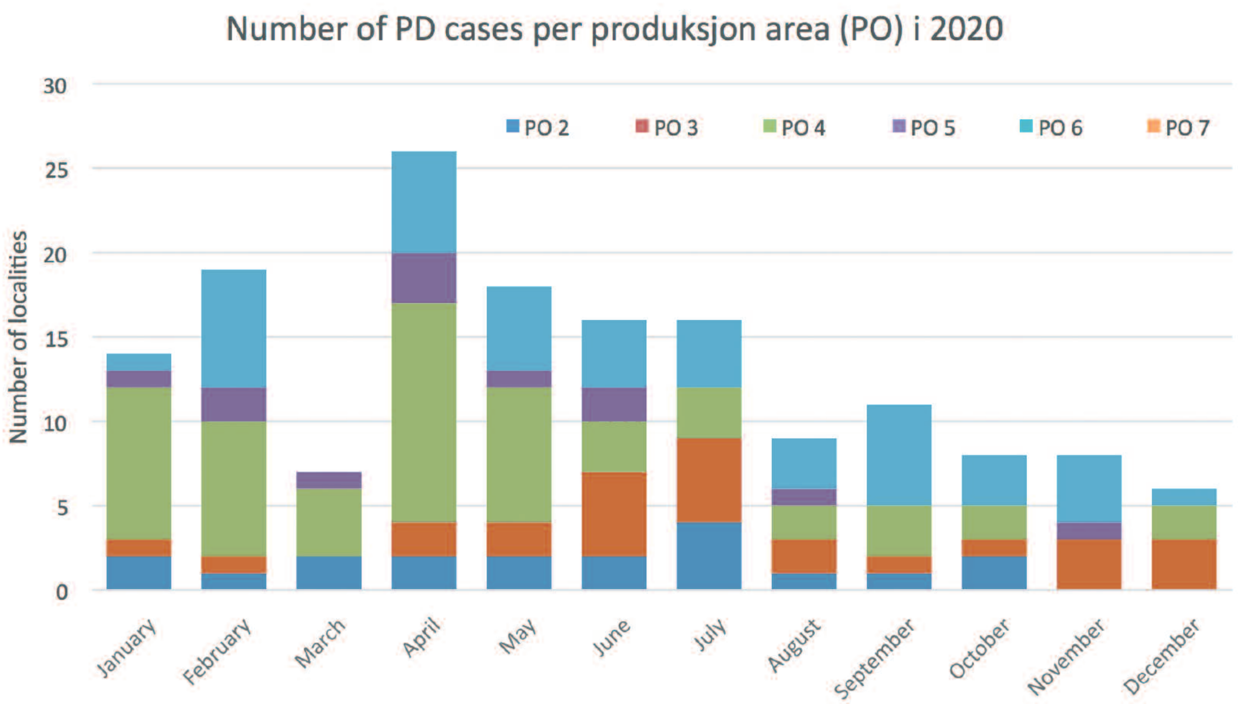


Figure 4.1.1. Map of new localities with pancreas disease (PD) in Norway in 2020 per production area and month.

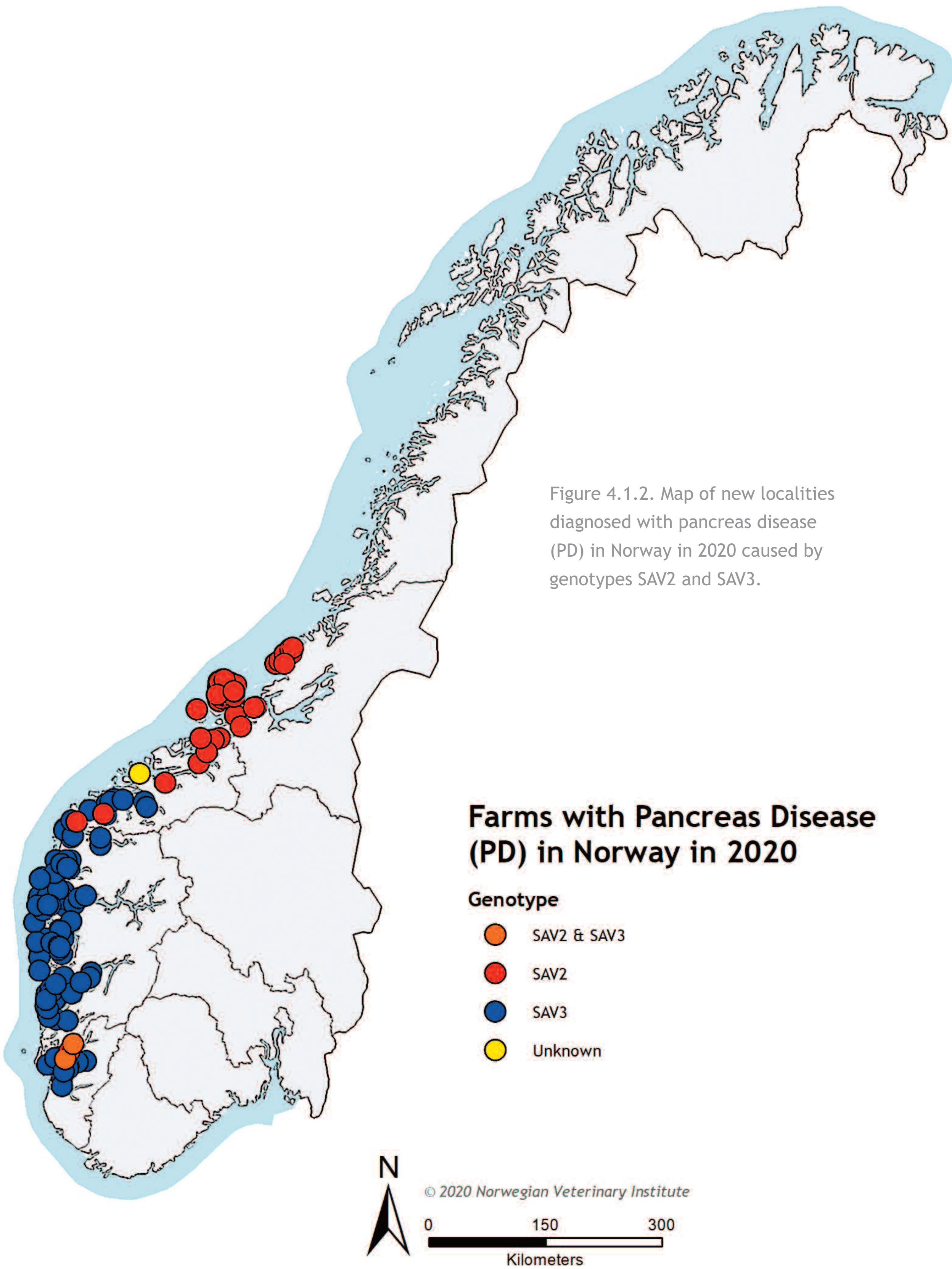


Figure 4.1.2. Map of new localities diagnosed with pancreas disease (PD) in Norway in 2020 caused by genotypes SAV2 and SAV3.

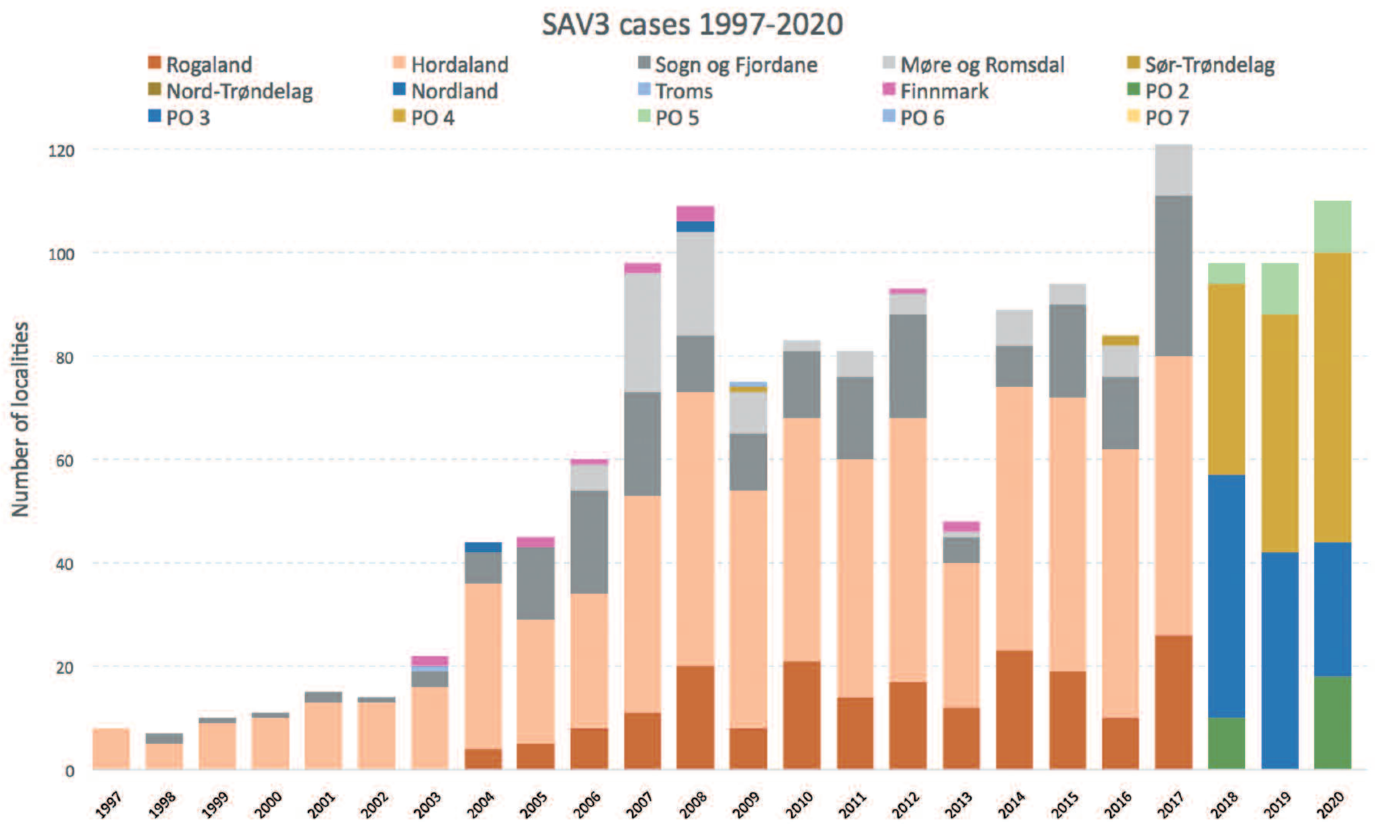


Figure 4.1.3. Geographical distribution (per county 1997-2017, per production area 2018-2020) of new PD cases, genotype SAV3.

PD to be one of the most important viral diseases affecting salmon and rainbow trout farmed in the sea, both ongrowing and broodstock. PD is also associated with reduced growth, reduced welfare and increased mortality (for details see Appendix B and C).

Most respondents with experience of PD vaccinated fish indicate that the degree of protection is moderately good: On a scale from 1 = poor to 5 = good, 40% of respondents replied 3-4, while 37% replied 'don't know'. For views on possible side-effects related to PD vaccination, see chapter 8.6 'Vaccine side-effects'.

Regarding the question of effect of QTL stocks, 31% (13 of 42 respondents) replied that QTL stocks were used, while 60% (26 of 42) did not know. Four respondents had experienced disease despite use of PD-QTL stocks.

Evaluation of the PD situation

The high frequency of outbreak of PD is a challenge to the industry and has serious economic consequences (Norwegian Veterinary Institute, report series 2015 nr. 5, Pancreas disease in salmonids- a review with focus on prevention, control and eradication, ISSN 1890-3290. In Norwegian).

Affected fish may be infected for a long time before displaying clinical signs. Frequent screening is therefore important for early detection of the virus. A locality may, however, be infected despite negative screening results.

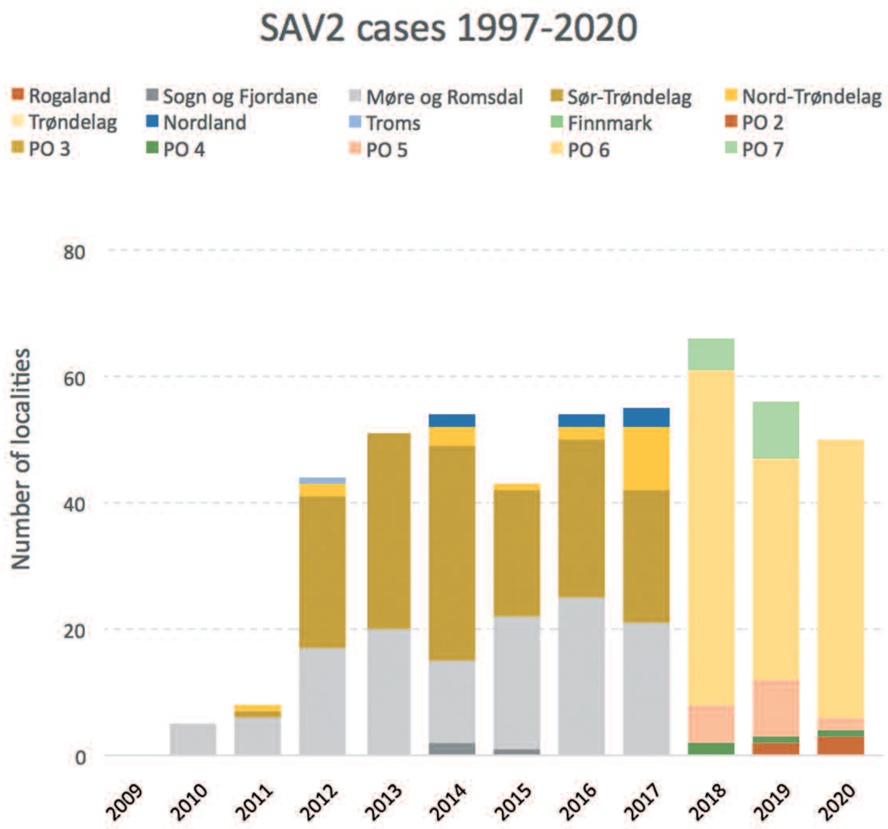


Figure 4.1.4. Geographical distribution (per county 1997-2017, per production area 2018-2020) of new PD cases, genotype SAV3.

The infection spreads in the sea through transport of infected populations between localities. PD is a typical stress related disease. Sub-clinical infections can develop into serious outbreaks following e.g. handling during delousing.

The number of new diagnoses increased dramatically following implementation of new legislation requiring monthly screening for SAV in 2017. Without this screening, a number of sub-clinical cases would undoubtedly have gone undetected

Since movement of the northern limit of the PD-zone, six cases of PD have been identified in an area (near Buholmråsa) that was previously free of PD. No new cases have been identified in this area in 2020. This is considered a positive development in the fight against northerly spread of the disease.

4.2 Infectious salmon anaemia (ISA)

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

The disease

Infectious salmon anaemia (ISA) is a serious and infectious viral disease of 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 (figures 4.2.5 and 4.2.6).

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 outbreak of clinical disease. In such cases, it may be extremely difficult to identify the virus. Commonly only a small proportion of the fish in an affected population may be infected. During the early stages of an outbreak, PCR testing may require analysis of large numbers of fish to identify the infection. Daily mortality in cages with sick fish is often low, typically 0.05-0.1%.

ISA virus can be differentiated into either non-virulent ISAV (ISAV HPR0) or virulent ISAV (ISAV HPR-del). These variants are distinguished by amino acid sequence differences within the hyper-variable region (HPR) of the gene encoding the hemagglutinin esterase protein. HPR-del ISAV originates from HPR0 ISAV and HPR0 ISAV is now widespread in farmed salmon with transient infections normal in hatcheries and in ongrowing and broodstock populations in the sea. Knowledge of the risk of development of HPR-del from HPR0 is, however lacking, particularly in terms of how often it happens and what drives this change. Available epidemiological data, suggests however, that transformation of HPR0 to HPR-del is an infrequent event. Development of ISAV HPR-del from ISAV HPRo may be one explanation for epidemiologically isolated outbreaks, and one such development in the field is described in a publication from the Faroe Isles. The Norwegian Veterinary Institute published an article in 2018 which supports the contention that isolated ISA outbreaks can be related to poor biosecurity routines and stress.

Control

ISA is a notifiable disease in Norway (list 2), in the EU and in the World Organisation for Animal Health (OIE) systems. Outbreaks of ISA are combatted by implementation of strict counter measures. As a rule, a control area consisting of eradication and observation zones is established around the affected site. As the EU is introducing new animal health legislation in April 2021, a new Norwegian public management plan is under development.

See the Norwegian Veterinary Institute Fact sheet on ISA for more information: https://www.vetinst.no/sykdom-og-agens/infeksios-lakseanemi-ila

The health situation i 2020

Official data

In 2020 ISA was diagnosed in a total of 23 localities, of which 2 were in PO2 (Ryfylke, Rogaland), 2 in PO3 (Karmøy to Sotra, Vestland), 3 in PO5 (Stadt to Hustadvika, Møre og Romsdal), 1 in PO8 (Helgeland to Bodø, Nordland), 4 in PO10 (Andøya to Senja, Troms og Finnmark), 1 in PO11 (Kvaløya to Loppa, Troms og Finnmark) and 10 in PO12 (West-Finnmark, Troms og Finnmark). In addition, at the end of the year, there were five non-confirmed ISA cases based on detection of virulent ISA-virus. These were distributed between PO8 (Helgeland to Bodø, Nordland), PO10 (Andøya to Senja, Troms og Finnmark) and PO12 (West-Finnmark, Troms og Finnmark).

The annual survey

Results from this year's survey show that ISA is now considered as one of the diseases most increasing as a problem in salmon farming, both in juvenile production and ongrowing fish. In ongrowing fish ISA is considered alongside the salmon louse, as the most important increasing problem (see appendix B1), while it is ranked after nephrocalcinosis, haemorrhagic smolt syndrome, HSMI and IPN in juvenile farms (see appendix A1). Both were ranked higher in 2020 than in 2019.

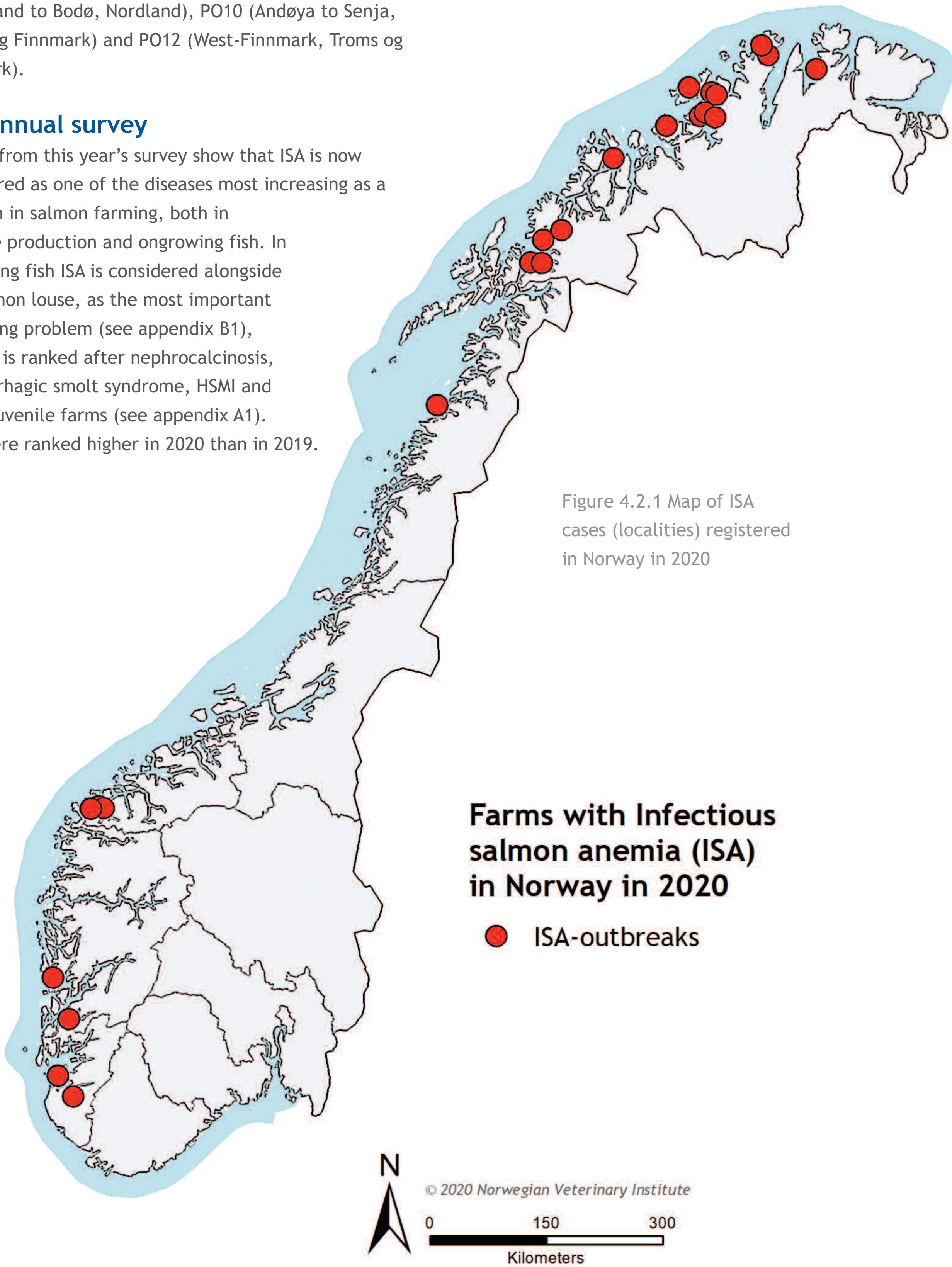


Figure 4.2.1 Map of ISA cases (localities) registered in Norway in 2020

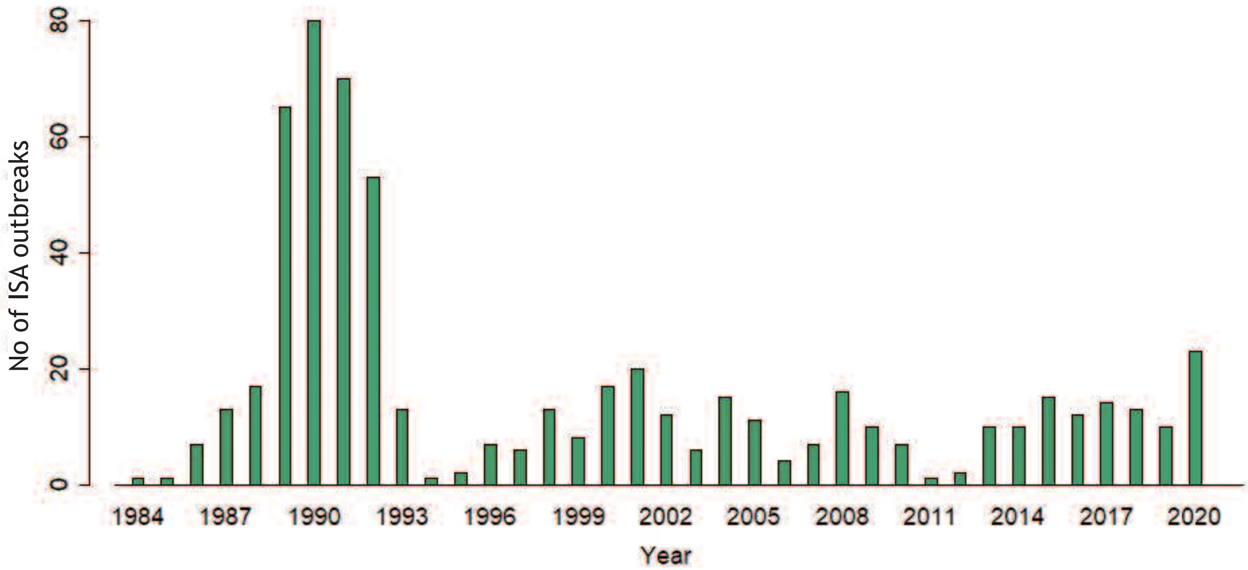


Figure 4.2.2 Summary of outbreaks of ISA registered annually in Norway for the period 1984 - 2020

Evaluation of the ISA situation

The 23 outbreaks in 2020 were distributed between seven different PO's, from PO2 (Ryfylke, Rogaland) in the south to PO12 (West-Finnmark, Troms og Finnmark) in the north (Figure 4.2.1). All 23 affected localities held sea-farmed ongrowing fish, three of which were stocked with triploid salmon. Seven sites were located within existing ISA surveillance zones. Between 1993 and 2019, ISA was diagnosed in one (1994, 2011) to 20 (2001) farms annually, with an average of 10 cases each year. The number of cases diagnosed in 2020 is thereby the highest recorded since 1992 (Figure 4.2.2). Over the last few years the disease has manifested as both local epidemics involving closely related strains of the virus over a relatively limited geographic area and isolated cases widely spread along the coastline. The geographic distribution of diagnosed ISA cases between 2017 and 2020 is shown in Figure 4.2.3.

Phylogenetic analyses revealed that the three outbreaks in PO5 involved a closely related group of viral isolates and that the infection has probably spread horizontally between the farms involved. The original source of the infection has not been identified. Further, two outbreaks in March in PO12 are probably related to an outbreak on a nearby farm in December 2019. The virus identified in relation to the outbreak in PO8 is highly related to the ISAV HPRo strain that had been isolated on repeated occasions from the hatchery that had supplied smolts to the affected sea site. Further the virus identified from two outbreaks in PO10 was very closely related to virulent virus detected in a sea site in the same area in 2019 and ISAV HpR0 detected in the hatchery that had supplied smolts to all three affected sea sites. Due to the geographical distances involved and lack of identified contact between these sea sites it is considered more likely that the hatchery represents the source of all three outbreaks rather than horizontal transmission between the sea sites. In the affected site in PO10, in which the fish were suspected of clinical ISA in the run up to harvest, a virus was detected that was extremely closely related to virus detected on a close neighbour site in the autumn of 2019, and it is considered likely that horizontal transmission occurred in this case.

Four of the outbreaks in PO12 were caused by closely related virus. The sites are owned by the same company and had received smolts from the same hatchery in which ISAV HPR0 had been detected in the autumn of 2019. It cannot be discounted that horizontal transmission occurred between some sea sites, but it is considered more likely that several of the sea outbreaks occurred as a result of transmission from the hatchery. In one of the PO12 outbreaks the virus detected was found to be closely related to virus identified from an outbreak in PO8 in 2019. An epidemiological link between these outbreaks has not been identified.

ISA-virus detected during one outbreak in PO2 was related to virus detected in several sea sites with clinical ISA in Vestland region the previous year and in a Vestland hatchery in the autumn of 2020. Various factors including timespan, geographical distance and varying smolt supplier make identification of any possible epidemiological link between these outbreaks difficult. One possible explanation may be that a particular ISAV-HPR0 variant is circulating in the area and represents the source of virulent ISAV-HPR-del. Virus detected in the remaining outbreaks in 2020 are sufficiently different from previously detected virus that no firm conclusions can be made regarding source of infection.

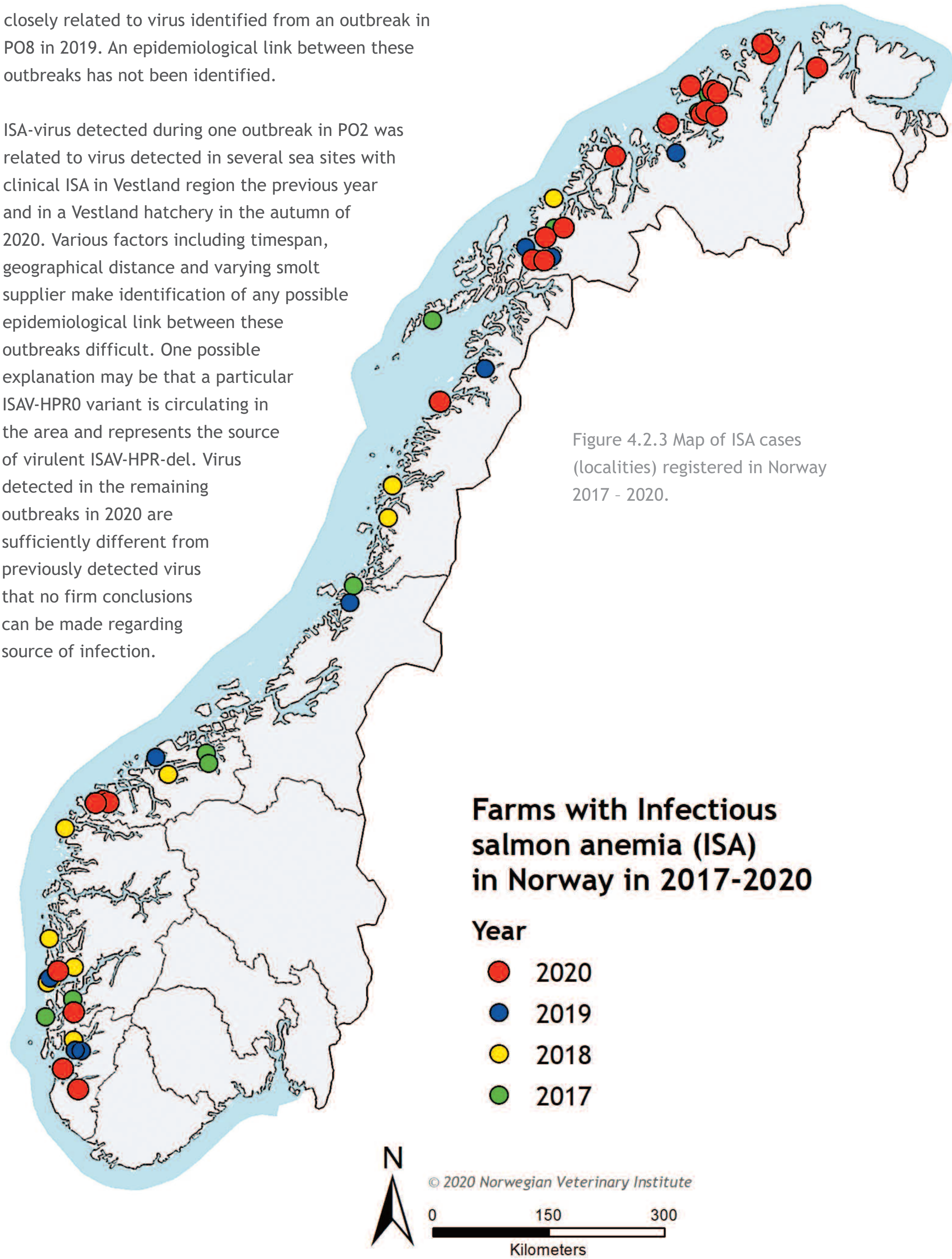


Figure 4.2.3 Map of ISA cases (localities) registered in Norway 2017 – 2020.

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 on GenBank. Sequence designations are based on the geographical origin and year as well as the Norwegian Veterinary Institute journal number. Other information deposited includes the locality name, date of sampling and fish species.

A surveillance program for the presence of HPR0 in Norwegian juvenile salmon production was introduced in 2019 and around half of all Norwegian juvenile production facilities are tested for ISAV-HPR0 (single samplings) every second year. In 2019, five of 74 tested sites tested positive for ISAV HPR0 and in 2020 six of 42 sites tested positive. As HPR0 results in a short-lived infection, and as the sites were only tested once in the course of the year and only a proportion of the fish groups on any one farm were tested, the prevalence identified is almost certainly an underestimate of the number of affected farms. The final statistics and evaluation of the results will be reported in the 2020 surveillance program for ISAV HPR0 in Norwegian juvenile salmon production.

There is no official surveillance program for ISAV HPR0 in marine farms and the Norwegian Veterinary Institute does

Figure 4.2.5 ISA-fish with circulatory failure and blood vessel damage; pale gills, patchy liver, haemorrhage in fatty tissues between pylorus and bloody ascites. Photo: Jan A Holm, Fishguard.

not compile statistics regarding detection of ISAV HPR0 in Norwegian sea-farms. From data generated by the surveillance program for ISAV HPRdel within control zones and ISA-free compartments and routine diagnostic investigations performed by the Norwegian Veterinary Institute, ISAV HPRdel was detected in 40 sea-farms in 2020. The forty affected sites included three sites that had been diagnosed with clinical ISA in 2020 and in one site with suspected ISA the same year. As for freshwater farms, the statistics for marine sites are considered to represent a considerable underestimate of the true prevalence of ISAV HPRo.

Successful control of ISA is based on prevention of spread through early diagnosis and rapid removal of diseased fish from the affected farm. The industry, Fish Health Services and the Norwegian Food Safety Authority have, since 2015, worked together on systematic surveillance within ISA control zones. Surveillance includes monthly inspections and sampling for ISA in order to identify new infections at an early stage. Identification of ISAV in samples taken from fresh fish exported from Norway to China underlines the importance of effective counter measures against ISA in Norway.

Figure 4.2.6. Skin haemorrhages are common in fish with ISA. Such changes may also be observed with other serious infections which cause circulatory disturbances e.g. IHN. Labora AS.

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. Mortality varies between negligible and 90% dependent on virus strain, fish genetics and other environmental or production related parameters.

Control

There is no publically organised control program for IPN in Norway and the disease is not notifiable. Within the industry, avoidance of infection during the hatchery phase is important. A genetic marker (QTL) for resistance to IPN makes possible selective breeding of salmon and rainbow trout with a high degree of IPN resistance. This type of stock is now widespread in Norway. Eradication of 'house strains' of IPN virus has also contributed to the favourable IPN situation. Although a large proportion of Norwegian salmon are vaccinated against IPN-virus, the protective effect is uncertain.

See the fact sheet for more information on IPN: https://www.vetinst.no/sykdom-og-agens/infeksiøs-pankreasnekrose-ipn

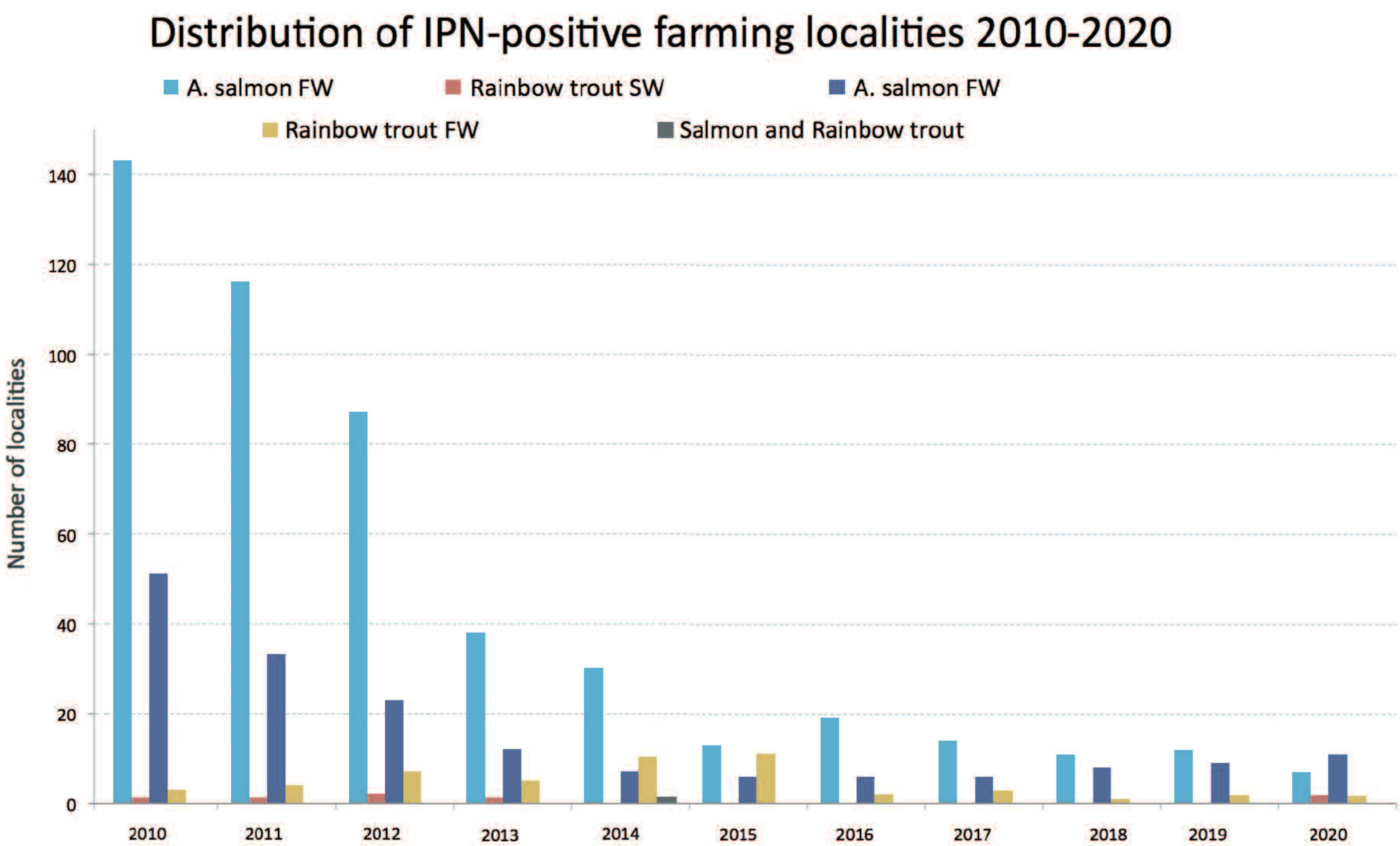


Figure 4.3.1: Number of registered IPN-outbreaks 2010-2020

The health situation in 2020

Data from the Norwegian Veterinary Institute

In 2020, IPN or IPN-virus was identified in 22 farming localities (see 'statistical basis' in chapter 1), of which 18 held Atlantic salmon; 11 juvenile production units and 7 marine ongrowing sites. IPN was also diagnosed in two juvenile and two ongrowing rainbow trout sites. While the total number of outbreaks is similar to that observed in recent years (Figure 4.3.1), one significant change in 2020 was that IPN was diagnosed in ongrowing rainbow trout. Such outbreaks were last observed in 2013. IPN is diagnosed along large areas of the coastline, and the geographical distribution in 2020 was as follows (number of sites affected in parenthesis): PO2 (1), PO3 (5), PO4 (5), PO5 (2), PO7 (3), PO8 (2), PO9 (2) and PO10 (2).

The IPN- virus protein VP2 was sequenced by the Norwegian Veterinary Institute in virus detected in three outbreaks. Comparative analyses show that these IPNV-VP2 sequences are almost identical and further, nearly identical to isolates from outbreaks in the period 2018-2019, but extremely different from outbreaks between 2005 and 2006 i.e. prior to introduction of QTL-fish. The significance of these findings are currently unclear.

Survey

QTL stocks are widely used for both Atlantic salmon and rainbow trout and almost all fish are vaccinated against IPN. Respondents to our survey generally considered IPN to be relatively unimportant, although some consider it to be an increasing problem. In hatcheries, IPN is reported to be on the increase resulting in increased mortality, reduced growth and reduced welfare. In ongrowing salmon sites it is mainly associated with reduced growth and welfare and some mortality. For rainbow trout, reduced growth seems to be the only problem. For further details from the survey see Appendix A1-2 (hatcheries) and B1-2 (ongrowing).

Evaluation of the IPN situation

It is concerning that outbreaks are registered amongst IPN QTL-fish. It remains positive however that the number of registered outbreaks remains at a relatively low level.

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

By Maria K. Dahle and Anne Berit Olsen

The disease

Heart and skeletal muscle inflammation (HSMI) is a very common infection in Norwegian farmed salmon. HSMI was first diagnosed in Norwegian salmon in 1999. The disease is primarily identified during the first year in seawater, but outbreaks may also occur in hatcheries. On histological investigation, sparse to gradually more advanced levels of inflammation may be observed in the heart prior to clinical outbreak of disease, which may last several weeks. Inflammation of the red skeletal musculature (4.4.3), and is also a relatively common finding (Figure 4.4.4). HSMI may result in a variable degree of mortality, and losses are often associated with stressful management routines. Salmon dying with HSMI often display signs of circulatory failure.

An HSMI-like disease was identified in Norwegian rainbow trout in 2013. These outbreaks were identified in freshwater and in fish transferred to sea from infected freshwater farms. While affected rainbow trout commonly display anaemia, this is not common in salmon.

Piscine orthoreovirus (PRV) was identified in HSMI-affected salmon in 2010 (PRV1). Another type of this virus was identified in rainbow trout suffering a clinically similar disease in 2015 (PRV3, also called virus Y or PRVOm). PRV1 from salmon and PRV3 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 PRV1 and HSMI in salmon and PRV3 and HSMI-like disease in rainbow trout was confirmed following experimental challenge experiments performed in 2017 and 2019 respectively.

While PRV1 is widespread and has been identified in wild and farmed salmon, infected salmon do not necessarily develop HSMI. In recent years many genetically different PRV1 strains have been identified and it has been shown that some strains are more pathogenic than others. Variants identified previous to the first known outbreaks of HSMI belong to a genetic group presumed to be of low virulence, while isolates from clinical HSMI outbreaks in recent years, which have also resulted in clinical HSMI in laboratory trials, represent a virulent group of PRV1. The condition and susceptibility of the infected fish will also contribute to the outcome of infection and that stress will also increase mortality levels. PRV3 is less widespread in Norwegian rainbow trout aquaculture following outbreaks in 2013-2015, but has been identified in wild sea-trout.

All known subtypes of PRV infect red blood cells and may be found in most blood-filled organs from early in the course of disease to long after disappearance of clinical disease and commonly until harvest. In contrast, rainbow trout appear to rid themselves of PRV3 often 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. The inflammation observed in the heart and musculature is caused by the immune response of the fish.

Control

There is no official control programme for HSMI in Norway and the disease has not been notifiable since 2014. This situation is due to the widespread presence of the virus in Atlantic salmon, which in most cases cannot be associated with clinical disease. PRV3 in rainbow trout is less widespread in Norway, is also associated with non-clinical infections and is non-notifiable.

There are no 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 is reported to have some effect and HSMI QTL strains of salmon are now available.

Losses to HSMI may be reduced through avoidance of management routines resulting in stress in fish with a high viral load. Experimental studies have shown that salmon with HSMI are sensitive to stress in combination with reduced levels of oxygen saturation in the water. Such conditions may develop during crowding of fish, transport and delousing. 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 are identified in seawater and it would appear that the most important reservoir of infection is infected marine farmed salmon. 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 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 detergent based cleaning routines. A number of farmers have initiated an eradication campaign against PRV in infected 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 untreated seawater to freshwater facilities represents a risk of infection of PRV1.

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

The health situation in 2020

Data from the Norwegian Veterinary Institute and other laboratories

In 2020, HSMI was diagnosed in 161 salmon farms, see distribution per production area in Figure 4.4.1. This statistic represents consolidated data from the Norwegian Veterinary Institute and private laboratories (see Chapter 1 'statistical basis'). The majority of these diagnoses were made in marine ongrowing sites. The Norwegian Veterinary Institute diagnoses included seven hatcheries and 1 broodstock farm. HSMI was diagnosed throughout the year. PRV1 virus was identified in a further 89 localities in the absence of clinical HSMI.

While HSMI was not diagnosed in rainbow trout by the Norwegian Veterinary Institute in 2020, replies to the annual survey indicate that it is considered a challenge in ongrowing rainbow trout.

Annual survey

In the annual survey, respondents were asked to cross off the five most important health problems associated with mortality, poor growth, poor welfare or on the increase. Juvenile production facilities, ongrowing sites and broodstock sites for salmon and rainbow trout were surveyed.

For juvenile salmon HSMI was considered amongst the 10 most important causes of mortality. HSMI was also considered by some respondents to represent an increasing problem, however HSMI does not appear to be associated with reduced growth or welfare. In ongrowing farms, HSMI appears to be strongly associated with mortality and of the viral diseases, only CMS is considered more serious than HSMI on a national basis. HSMI is also considered by some respondents to cause reduced growth and welfare, but that this does not appear to be an increasing problem. A similar picture is observed in broodstock.

For hatchery reared rainbow trout or broodstock, PRV3 was not reported to be a significant cause of mortality, reduced growth or welfare in 2020. In ongrowing rainbow trout a few respondents were of the opinion

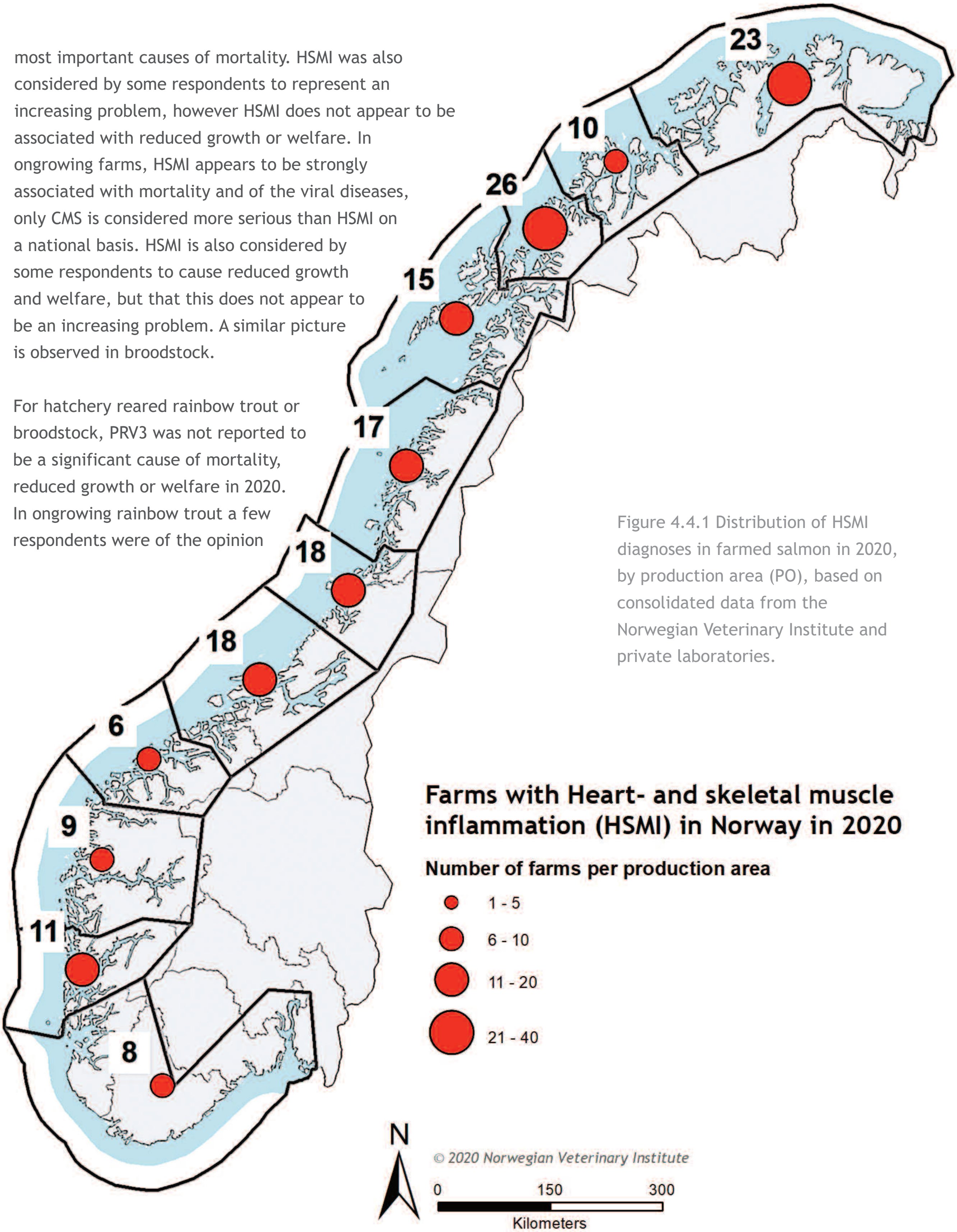


Figure 4.4.1 Distribution of HSMI diagnoses in farmed salmon in 2020, by production area (PO), based on consolidated data from the Norwegian Veterinary Institute and private laboratories.

that HSMI-like disease/PRV3 caused mortality and reduced welfare. Noone reported HSMI-like disease to be on the increase in rainbow trout.

For further details on the considered importance of various health problems in the survey for salmon and rainbow trout, see Appendices A-C.

Evaluation of the HSMI situation

Replies to the annual survey indicate that the HSMI situation in ongrowing salmon remains at a similar level to that observed in 2019. HSMI affected fish appear to tolerate delousing and other handling poorly, and such operations may result in considerable mortality. The HSMI situation in juvenile production facilities has been worsening in recent years, and responses to this year's survey can indicate that this negative trend continues.

Individual farms experience repeated HSMI outbreaks which may occur over many months, while some farms have few or no problems with this disease, despite the presence of PRV1 virus. This may be due to differences in virulence amongst different genetic groups of PRV1 virus. The increasing importance of HSMI in juvenile production farms may be due to persistent infections and development of 'house strains'. This may be due in part to the virus's high degree of resistance to UV-treatment.

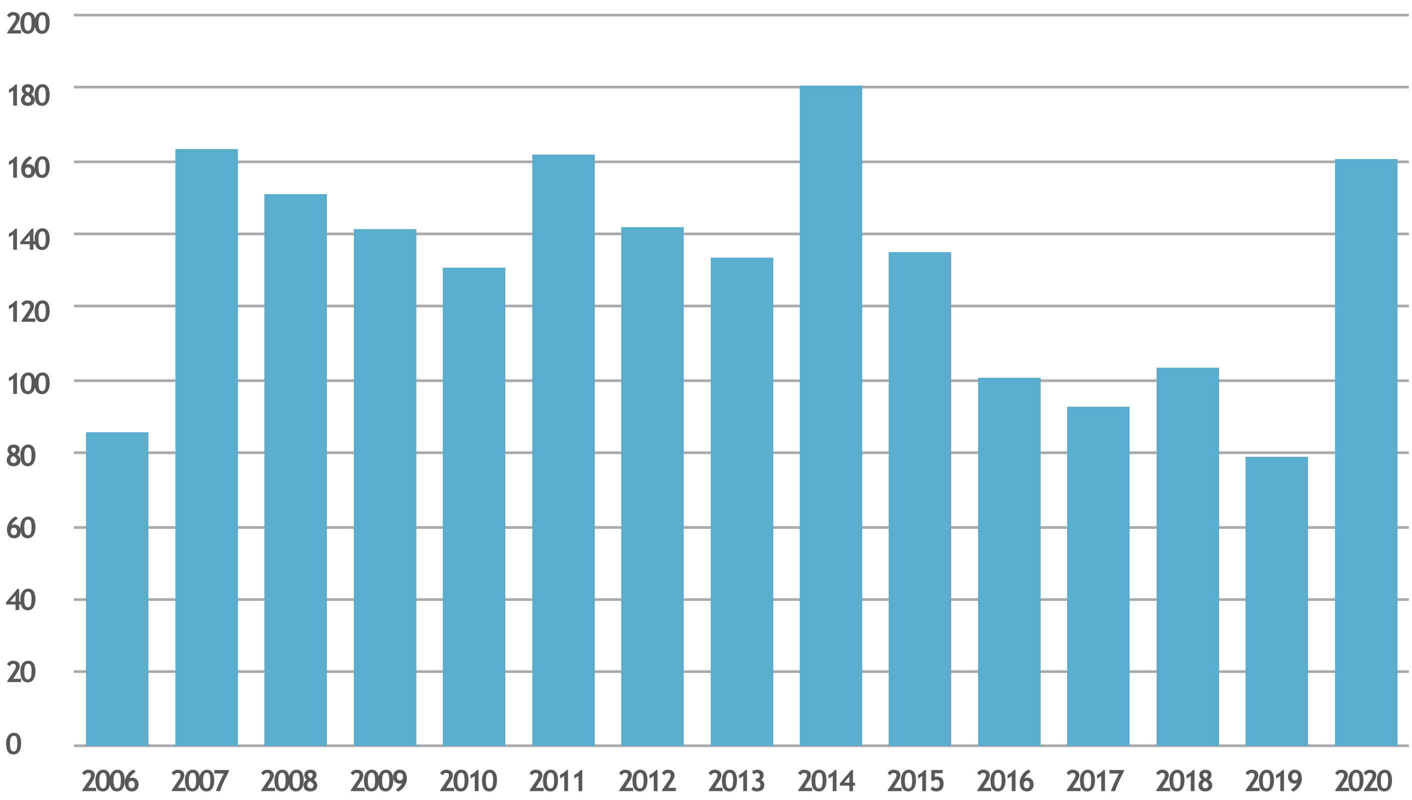


Figure 4.4.2. Number of farming sites affected by HSMI per calendar year. For the period 2006 – 2019, the statistics are based on samples submitted to the Norwegian Veterinary Institute (VI). For 2020 the statistics are consolidated diagnoses made by VI and private laboratories (see Chapter 1).

Replies to the annual survey indicate that PRV3 related outbreaks of disease have occurred in rainbow trout in 2020 and have resulted in reduced growth and poor welfare in ongrowing fish. This was also reported in 2019. It does not appear that HSMI-like disease has been a problem in juvenile rainbow trout production in 2020.

PRV-associated disease is also of international importance, and it is reported that PRV also causes diseases other than HSMI. In particular, PRV1 has been associated with liver necrosis in Chinook salmon in Canada and a third PRV variant, PRV2 has been associated with anaemia in Coho salmon in Japan. PRV3 has been associated with disease in rainbow trout in Denmark and the United Kingdom and the virus has also been identified 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.

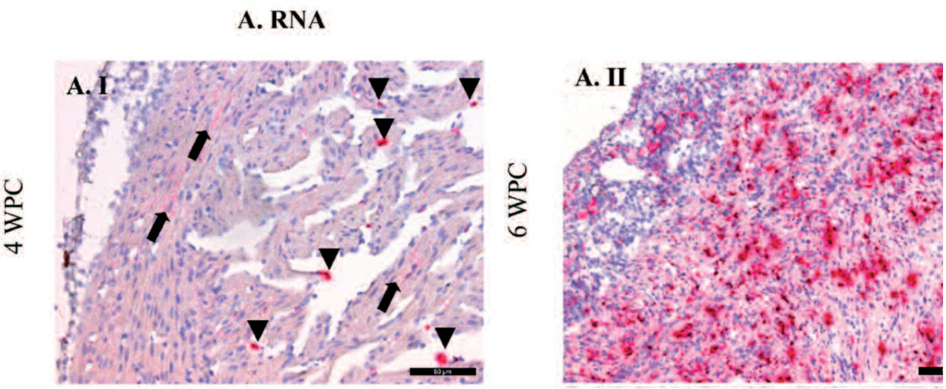


Figure 4.4.3.The heart of a salmon 4 and 6 weeks post experimental infection with PRV-1. The virus is stained red (in situ hybridisation) (Dhamotharan et al. 2020).

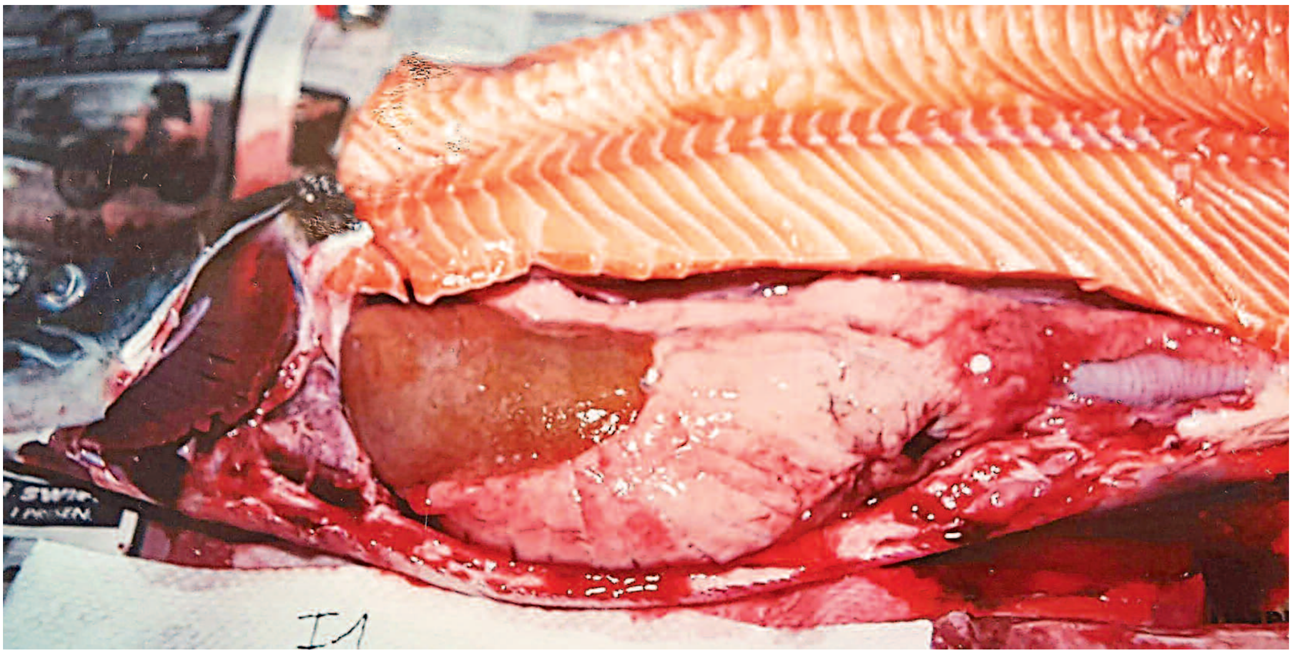


Figure 4.4.4. Samples taken from the first recognised case of HSMI in 1999. The fish has a grey/white membrane covering the heart and liver due to inflammation and circulatory failure, with bloody fluid present in the cardiac- and peritoneal- cavities. Photo: Anne Berit Olsen, Norwegian Veterinary Institute.

Heart and skeletal muscle inflammation (HSMI) is an extremely common viral disease in Norwegian farmed salmon. Losses may be reduced by avoidance of management routines that stress the fish. Photo: Rudolf Svensen

4.5 Cardiomyopathy syndrome (CMS)

By Camilla Fritsvold and Britt Bang Jensen

The disease

Cardiomyopathy syndrome (CMS) is a serious infectious cardiac disease affecting sea-farmed salmon. CMS was described for the first time in 1985 and has in recent years been identified outside Norway: Increasing numbers of outbreaks have made CMS one of the most significant economic and welfare challenges for the farming industries of Scotland, the Faroe Isles and Ireland.

CMS continues to be one of the most significant causes of loss to the Norwegian aquaculture industry. As effective countermeasures do not exist, the potential future impact is huge.

The disease normally strikes at the most economically unfavourable time i.e. close to harvest, but is becoming increasingly common during the earlier stages of the culture cycle, as early as five months post sea-transfer. Mortality due to CMS has also been reported in fish as small as 100-300g. The presence of CMS in a site throughout nearly the whole production cycle may have serious consequences in terms of production and economy.

CMS is caused by the totivirus-like Piscine myocarditis virus (PMCV), a naked double stranded RNA-virus with a relatively small genome of around 8800 base pairs. Horizontal transmission is known to occur. Samples investigated 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 farmed salmon. Some farms are affected more often than others and there may be as yet unidentified reservoirs of infection.

Clinical histopathological findings normally include inflammatory changes in the inner, spongious parts of the atrium and ventricles, while the compact muscle layers of the heart are relatively unaffected. In extreme cases the wall of the heart may effectively burst. A CMS diagnosis requires histological investigation with identification of typical, microscopic cardiac inflammation. The disease results in pathological changes similar to PD, ISA and HSMI, but moribund fish are not commonly observed. CMS does not normally result in changes in the exocrine pancreas or skeletal muscle tissues. CMS has not been identified in juvenile fish, although small amounts of PMCV have been identified in juvenile fish in freshwater.

There is a general lack of knowledge on the virus, infection pathways and development of CMS (pathogenesis). It may take 3-13 months between detection of PMCV in a population and development of CMS with subsequent mortality. Even if PMCV is detected early during the sea-phase of culture, clinical CMS does not necessarily develop in all affected populations. When and how the fish are infected, and what causes development of clinical disease in fish infected with PMCV are amongst the knowledge gaps that need to be filled.

Control

CMS is not a notifiable disease in Norway or for the World Organisation for Animal Health (OIE). There is no official control program for CMS in Norway. The virus and the disease are present along the entire Norwegian coastline.

A vaccine against CMS does not currently exist, but the work towards a vaccine continues. CMS-QTL smolts are available on the market. For more information on this, see 'The annual survey' below.

For more information on CMS, see our fact sheet: http://www.vetinst.no/sykdom-og-agens/kardiomyopatisyndrom-cms

The health situation in 2020

Data from the Norwegian Veterinary Institute and other laboratories

Over the last 3-4 years the Norwegian Veterinary Institute has alone registered around 100 cases of CMS annually. As the disease is not, and has never been notifiable, and as diagnoses have also been made by other private laboratories in the same period, it is reasonable to presume that the disease has been under-reported.

We can for the first time in 2020 present consolidated statistics based on Norwegian Veterinary Institute diagnoses and data made available from private laboratories. As described in chapter 1 this data probably represents around 70% of all active farming localities in Norway. According to these data, CMS was diagnosed in 154 individual farms in 2020 (see Figure 4.5.1). In 121 farms PMCV was identified by PCR but a CMS diagnosis was not necessarily registered. Of these 154 farms diagnosed with CMS, 72 of these cases were also confirmed PCR positive. A total of 191 individual farms were therefore either diagnosed with CMS (but not PMCV), PMCV (but no CMS diagnosis) or CMS with

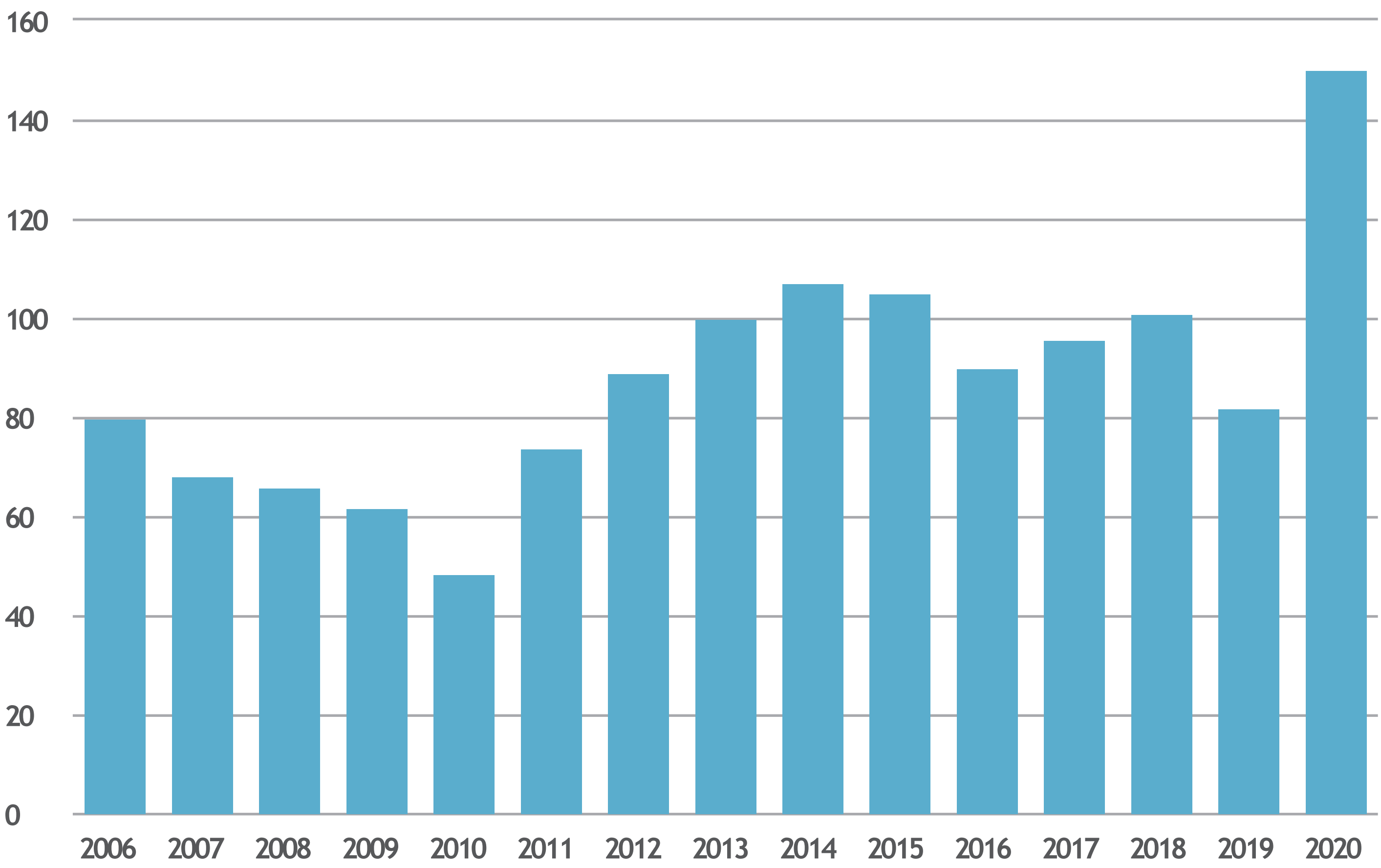


Figure 4.5.1 Number of CMS affected localities per calendar year. For 2006– 2019, the data is based on material submitted to the Norwegian Veterinary Institute, for 2020 the data is based on consolidated data from private laboratories and VI (ref. Chapter 1)

concurrent PMCV detection. That most CMS diagnoses do not have confirmed PMCV detection is due to the fact that CMS is a histopathological diagnosis with no requirement for concurrent PMCV detection.

The majority of CMS diagnoses in 2020 were made between January and July (average of 16.4 diagnoses per month), with fewer diagnoses (average of 7.8 diagnoses per month) made in the late summer, autumn and early winter (august – new year). Two months deviated from this trend with only six diagnoses made in March and May. While the highest monthly total was registered in January when 28 cases were diagnosed, the real total may be lower as reporting of some December cases may have been delayed.

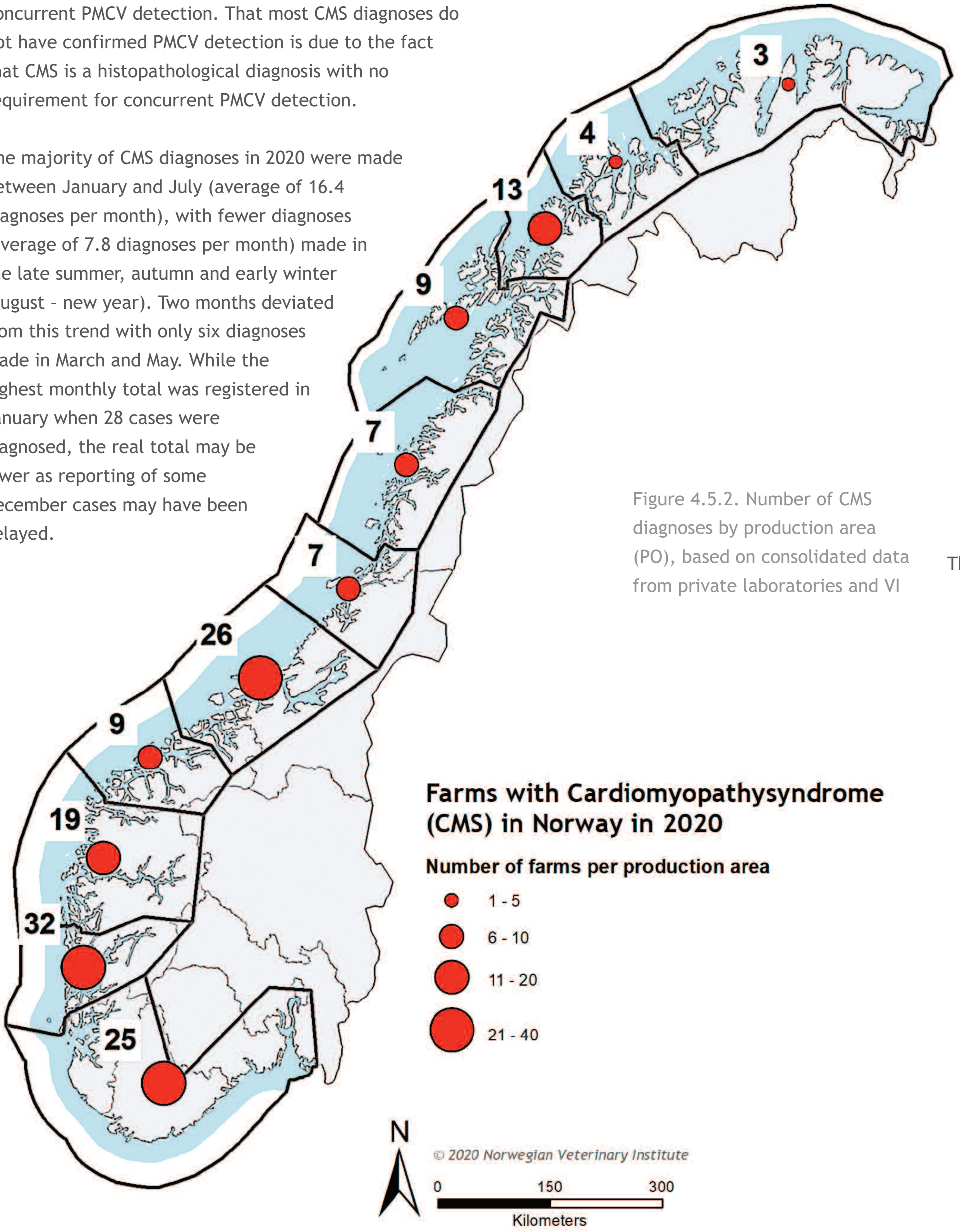


Figure 4.5.2. Number of CMS diagnoses by production area (PO), based on consolidated data from private laboratories and VI

The

three northernmost production areas (PO 11, 12 and 13) had relatively few cases of CMS with seven cases diagnosed in 2020 (see Figure 4.5.2). PO10, Andøya to Senja, had 13 cases in 2020, which is a relatively large number given that this PO is relatively small. Nordmøre and Sør-Trøndelag, PO6, historically a core area for CMS, continued to be so with 26 diagnosed farms in 2020. The Norwegian Veterinary Institute has diagnosed an increasing number of CMS cases over the last three years in the earlier Hordaland region, and while this year's statistics are based on production areas rather than regions, the trend appears to have continued: 38 CMS diagnoses were made in Rogaland, Hordaland and Sogn- og Fjordane in 2019. In 2020 a total of 71 cases were diagnosed in PO's 2, 3 and 4 (Ryfylke, Karmøy to Sotra and Nordhordland to Stadt).

There has been in increase in the number of CMS cases registered by the Norwegian Veterinary Institute over the last three years in the region previously known as Hordaland, and while statistics are now presented in terms of production area rather than region, unfortunately the same trend continues: Rogaland, Hordaland and Sogn- og Fjordane had in 2019 a total of 38 CMS cases, with 27 of these in Hordaland. In 2020 a total of 71 cases were diagnosed in PO2, PO3 and PO4 (Ryfylke, Karmøy to Sotra and Nordhordland til Stadt). Ryfylke had 20 cases in 2020 compared to 3 in the whole of Rogaland in 2019. The situation for Vestlandet is of course difficult to interpret as the 2019 statistics were based on Norwegian Veterinary Institute diagnoses alone and that many farms have used private histopathology labs in recent years. It is however concerning that the trend of increasing numbers of outbreaks continues in the PO's representing the previous region Hordaland, which until in recent years had a low incidence of CMS.

Annual survey

Based on experiences gained on farms where they have responsibility for fish health, fish health personnel and officers of the Norwegian Food Safety Authority were asked to indicate the five most important problems in relation to a) mortality, b) Reduced growth, c) Reduced welfare and d) whether the problem is on the increase.

For ongrowing salmon, 78 respondents listed CMS with at least one cross in categories a) mortality and c) reduced welfare while 71 respondents indicated the other two categories. For broodstock salmon, 16 respondents crossed off for category a), 9 in category b), 13 in category c) and 4 in category d).

As in 2018 and 2019, CMS appears to be one of the most important problems in both ongrowing and broodstock salmon farming (for more details see Appendices B1 and C1).

Mortality

CMS was considered the clear leader amongst the various causes of mortality, by 87% of respondents from ongrowing farms and 100% from broodstock farms. That broodstock farms consider CMS to be the most important cause of mortality is consistent with the appearance of CMS in large fish. That CMS is also ranged as highly as a cause of ongrowing fish mortality is serious. This illustrates that CMS is no longer just a disease of broodfish and harvest ready fish. Other important causes of mortality in ongrowing fish are mechanical injuries related to delousing in 'second place' (72% crossed off), followed by 'complex gill disease (53%), HSMI (51%) and tenacibaculosis (47%). In broodstock farms, HSMI is ranked in second spot after CMS with 56%, followed by the salmon louse (38%).

Reduced growth

AS CMS most commonly affects large fish in the sea, it is unsurprising that CMS is not considered one of the primary causes of reduced growth in ongrowing salmon (ranked 17th). PD is ranked clearly first (61%), trailed by complex/multifactorial gill disease (38%). PD is also considered one of the most important causes of reduced growth (56%) only beaten by the salmon louse (67%) while CMS lies further down the list (22%).

Reduced welfare

CMS is ranked the second most important cause of reduced welfare in broodstock salmon only beaten by the salmon louse. In ongrowing salmon, CMS scores lower than delousing injuries, the salmon lose, and various ulcer conditions.

Increasing problem

CMS is considered the fifth most increasing problem after ISA, the salmon louse, pasteurellosis and complex gill disease. For broodstock, CMS was not mentioned. As CMS is an important differential diagnosis for ISA, it is important to consider ISA on finding fish with CMS symptoms.

QTL-smolt

When questioned on use of CMS QTL-smolts in 2020, around 16% of respondents (N=44) replied that they were used extensively while 27% of respondents replied that they were used to some extent. This is a level similar to previous years, with a slight increase in 'extensive use'. Of the 19 respondents who replied that CMS QTL – smolts are in use, 7 reported outbreaks of CMS in these stocks in 2020. The survey does not reveal whether the proportion of fish developing disease or dying as a result of CMS differs from that experienced in the years before QTL-smolts were introduced.

Non-medicinal delousing and welfare

Delousing involves greater or lesser degrees of handling, grading, crowding, pumping and other stressing routines, which can result in direct physical injury and/or stress. Stress in its different forms is a recognised risk factor for development of CMS and it is reasonable to assume that delousing associated stress may cause 'latent' infections to manifest as clinical CMS. Clinical CMS results in the heart wall becoming fragile and as a result fish with CMS tolerate stress and stressing situations particularly poorly. Of 62 respondents 8% and 34% had experienced CMS outbreaks 'often' and 'rarely' after non-medicinal delousing operations respectively.

In recent years use of non-medicinal delousing technologies has increased considerably (See chapter 3.6 and chapter 7.1). Fish populations often present a complex disease picture e.g. gill disease combined with HSMI and/or CMS, and in such cases, post non-medicinal delousing mortalities may be significant. That CMS now occurs in smaller fish that will spend a considerable amount of time in the sea prior to harvest, magnifies and prolongs the problems related to frequent non-medicinal delousing. On both health and welfare grounds, delousing represents a significant challenge which must be addressed immediately: legal framework, methods, techniques and routines must all be improved. Perhaps compulsory restitution periods of different duration dependent on the health status of the fish could be part of the solution? Use of equally effective, gentler, less frequent and less stressful methods will not only increase fish welfare but also result in less disease and mortality following delousing. The situation today represents a considerable welfare problem which must be acted upon soon.

Evaluation of the CMS situation

The new cooperation regarding transfer of data related to disease diagnosis between the various laboratories offering histopathology based diagnostics allows for identification of a more precise number of farms diagnosed with CMS in 2020 than has been possible in recent years. The uncertainty around the number of 'double registrations' has been removed (See Chapter 1 ' statistical basis'). At the same time we have changed the way we report the data: From 2020 the statistics are based on registrations per production area (PO) rather than political region.

While this makes comparison of 2020 statistics with previous years difficult, it will make future reporting much improved. It is therefore challenging to evaluate the CMS situation in Norway for the last few years. Based on the number of diagnoses and their geographical distribution, we are of the opinion that the CMS situation appears to be relatively stable at a moderately high level, or possibly slightly increasing in impact.

That CMS achieves, as last year, ‘first place’ as the most important cause of mortality in salmon along the whole coast with concurrent, high mortalities and record numbers of non-medicinal delousing, underlines the seriousness of the situation.

Cardiomyopathy syndrome (CMS) is a serious infectious disease of the heart that affects farmed salmon in the sea. The disease was identified for the first time in 1985, and has since become a problem in other countries. Photo: Colourbox

4.6 Viral haemorrhagic septicaemia (VHS)

By Torfinn Moldal and Ole Bendik Dale

The disease

Viral haemorrhagic septicaemia (VHS) outbreaks are characterized by high mortality, bulging eyes, haemorrhage, anaemia and abnormal behaviour involving spiral swimming. 'Flashing' may also be observed. On post-mortem, a swollen kidney and pale liver with patchy haemorrhage can commonly be observed (Figure 4.6.1) and histological investigation normally reveals haematopoietic tissue damage. The VHS virus belongs to the genus *Novirhabdovirus* within the Family *Rhabdoviridae* and has been identified in around 80 different fish species, both farmed and wild.
Outbreaks with high mortality in farmed fish populations are primarily associated with rainbow trout.

Control

VHS is a notifiable disease (list 2 non-exotic diseases, as the disease is not exotic to the EU) which is controlled through destruction (stamping out) of all fish on an infected farm. A risk-based surveillance program is in place in Norway, based on examination of samples sent in for routine diagnostic investigation. Following diagnosis of VHS, control and observation zones are established. Vaccination is not relevant for the Norwegian situation.

See our fact sheet for more information on VHS: www.vetinst.no/sykdom-og-agens/viral-hemoragisk-septikemi-vhs

The health situation in 2020

Official data

Norway has a risk based surveillance programme that utilises samples submitted for diagnostic investigation. VHS was not identified in 2020 in Norway. The last Norwegian outbreak occurred in rainbow trout farmed in Storfjorden in 2007-2008.

Evaluation of the VHS situation

VHS was diagnosed six times in four European countries during 2020 according to the Animal Disease Notification System (ADNS). This represents a considerable reduction from the previous year. No outbreaks were identified in countries neighbouring Norway. Previous identification of VHSV in various wrasse species in Shetland in 2012 and lumpfish in Iceland in 2015 highlights the need for vigilance, as these fish species are used as cleaner-fish in Norwegian salmon farming. The Norwegian Scientific Committee for Food and Environment (VKM) recently considered the risk (probability x consequence) for transmission of disease between wild cleaner-fish and farmed fish to be high. Given the serious consequences of a VHS outbreak, surveillance for VHS is important such that 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 this country since 2009 following a successful eradication programme. Although France published plans for an eradication programme in 2017, two outbreaks were registered in that country in 2020.

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

4.7 Infectious Hematopoietic Necrosis (IHN)

By Torfinn Moldal and Ole Bendik Dale

The disease

Infectious hematopoietic necrosis (IHN) is a viral disease that primarily affects salmonid fish. IHN-virus belongs to the genus *Novirhabdovirus* in the Family *Rhabdoviridae*. Juvenile fish are most susceptible. Outbreaks occur most commonly during the spring and autumn at temperatures between 8 and 15oC. Externally, exophthalmos is common. Internally, haemorrhage in internal organs, swollen kidney and ascites may be observed (Figure 4.7.1). Histologically, disruption of hematopoietic tissues is seen and the disease is classified as a haemorrhagic septicaemia.

IHN was first isolated from Sockeye salmon (*Oncorhynchus nerka*) in a juvenile production unit in Washington State, USA during the 1950's. The virus has since been identified in a number of salmonid species including Atlantic salmon and rainbow trout. Significant mortality in large salmon in the sea is reported in British Columbia. The virus can be divided into five main types (U, M, L, J and E) based on phylogeographic differences with U, M and L representing the upper-, middle- and lower-parts of the North American 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 Europe (Finland) for the first time in six rainbow trout farms over a relatively short period of a few months. The infections were identified during a surveillance programme for IHN and VHS. The infection was spread from state-owned broodstock farms and hatcheries that had delivered fish to ongrowing farms in Bottenviken. The original 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.

Control

IHN is a notifiable disease (list 2 non-exotic diseases as the disease is not exotic to the EU), controlled by 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.

See the factsheet for more information: www.vetinst.no/sykdom-og-agens/infeksiøs-hematopoetisk-nekrose-ihn

The health situation in 2020

Official data

Norway operates a risk-based surveillance programme utilising samples submitted for diagnostic investigation. IHN has never been diagnosed 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 as mentioned above. Fourteen outbreaks of IHN were diagnosed in four European countries and registered in the EUs Animal Disease Notification System (ADNS) during 2020.This is a similar level to the previous year.

Spread of infection is generally related 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 like pink salmon to Norwegian coastal waters and rivers is a potential source of infection, despite the fact that this species is considered to have a low susceptibility to this virus. Given the serious consequences of an outbreak in Norway, constant vigilance is important such that infected fish may be rapidly destroyed. Further, all import of fish, including rainbow trout, from areas which are officially free of VHS and IHN, should be subject to a risk analysis in light of the Finnish situation. 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 disturbance, haemorrhage and ascites. Macroscopic changes in fish moribund 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, Ole Bendik Dale and Brit Tørud

The disease

Salmon pox i.e. disease due to infection with salmon pox virus has in recent years, become recognised as potentially catastrophic, with high mortality in some hatcheries (Figure 4.8.1), while in others the infection does not result in visible disease. The source of infection remains unknown, but development of a new infection tracing tool (Multi-Locus Variable number of tandem repeat Analysis, MLVA) now opens up for study of transmission of the virus in aquaculture.

Salmon pox virus isolates (SGPV) of different geographic origin in Northern Europe appear to be highly related. Isolates from the same country do appear to be more related than between countries. Although some fjord systems and hatcheries appear to have their own 'house strains' that persist over time, it is not known whether this situation is caused by repeated re-infection from the same source or whether the infection is persistent within the farm. 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.

Most outbreaks of serious salmon pox appear to be dependent on factors other than infection alone e.g. stress. This is supported by experimental work, where salmon treated with the stress hormone cortisol in combination with salmon pox virus infection have developed clinical disease.

By investigating gene expression in the gills during different stages in the infection process, we have shown that infection with salmon pox virus disturbs the protective function of the gill mucus and that recruitment of inflammatory cells is abnormal. The results strengthen the hypothesis that salmon pox virus damages the barrier function of the gills, not only physically, but also immunologically, thereby opening up for secondary pathogens. This hypothesis is consistent with experiences from the field indicating that salmon pox virus is also involved in complex and very variable gill disease at all life-stages, in both hatchery and ongrowing fish.

Gene expression studies of salmon pox reveal that the infection caused a shift to the freshwater isotype of ATPase in the gills of infected salmon. This is consistent with the high mortality observed following sea-transfer of salmon pox infected fish.

The economic losses associated with salmon pox infections vary between negligible and extremely serious. Surveillance of wild salmonids has shown that SGPV infection occurs in wild broodstock salmon.

Control

There is no public control programme for salmon pox in Norway. Fundamental knowledge relating to prevention of infection remains lacking.

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 an attempt to eradicate the virus, new cleaning and disinfection routines were introduced, including change from a neutral to an acidic disinfectant. Samples taken from juvenile fish at different stages of production did not identify SGPV until after vaccination. 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 SGPV was identified, suggesting a new introduction to the farm.

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

The health situation in 2020

Consolidated data from the Norwegian Veterinary Institute and private laboratories

There is a degree of uncertainty surrounding diagnosis of salmon pox in Norway. Routine surveillance is performed in a number of farms, but the number of cases which are investigated histologically, and thereby allowing insight into the degree of gill damage and whether the virus is responsible for the damage observed remains unknown.

Infection with SGPV often occurs together with other infectious agents in what is known as complex gill disease, and in such cases it is not possible to identify the contribution of individual agents to disease development. Histologically the pathological changes associated with salmon pox virus can also be difficult to identify. Salmon pox virus was detected in 10 juvenile production facilities for salmon, 51 ongrowing farms, 1 restocking hatchery and 1 broodstock farm. There is little information on the extent to which these infections were associated with clinical disease. Most infections appear to be associated with seawater.

The annual survey

Respondents to the survey consider salmon pox virus to represent a relatively minor threat to fish health and welfare in hatcheries, which is not on the increase. The impact in ongrowing fish is also considered minor in relation to mortality, reduced growth and reduced welfare. A few respondents consider it to be on the increase in ongrowing fish. Salmon pox is not reported as a problem in broodstock. For more details on the importance of salmon pox in different production phases see appendices A-C.

Evaluation of the salmon pox situation

Salmon pox can represent an important component of complex gill disorders during both the freshwater and seawater stages of production, and there may be a strong epidemiological association with both environments. Fish with salmon pox may have reduced defences in the gills, both physical due to weakening of the barrier represented by the gill epithelia and via weakening of the immune system itself. This will also allow establishment of other infectious organisms in the gills and we suspect secondary infections to be a problem. It is however, difficult to say whether this really is a new phenomenon or one that has been previously overlooked.

As far as we know, it appears that only Atlantic salmon become infected with salmon pox virus. The Norwegian Veterinary uses MLVA infection tracking analysis that can be used to provide an indication of the relationships between poxvirus isolates from different farms. So far, the reservoir for poxvirus has not been established. The Norwegian Veterinary Institute encourages fish health services and others who suspect salmon pox to submit suitable samples for investigation using this method. Results indicate that vertical transmission is not an important route of infection, but that the virus transmits readily horizontally.

While the gill disease situation is dominated by complex or multifactorial cases, poxvirus infections alone continue to be identified in relation to episodes of acute, very high mortality. Salmon pox has also been identified in the Faroe Isles, Scotland and Iceland.

A related poxvirus has been identified in wild Atlantic salmon on the east coast of Canada, but this virus is genetically distinct from European SGPV. This virus has not been related to clinical disease in the wild fish concerned.

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

Figure 4.8.1. Acute, large scale mortality in salmon (approx. 200g) caused by salmon pox. The red coloured abdomen is a normal finding.

5 Bacterial diseases of farmed salmonids

By Ingunn Sommerset

Overall, the situation regarding bacterial diseases of farmed salmonids is relatively favourable and stable. Consumption of antibiotics remains at an extremely modest level. Surveillance of antibiotic resistance in bacteria isolated from sick, farmed fish reveals a favourable situation with a very low frequency of resistance.

Of the notifiable infections (all list 3), classic furunculosis (caused by *Aeromonas salmonicida* subsp. *salmonicida*), was diagnosed in five ongrowing salmon farms in 2020, all situated near the mouth of the river Namsen (in PO7). In two of these farms, furunculosis was also diagnosed in lumpfish held for delousing purposes. The 2020 isolates of Aeromonas salmonicida subspecies salmonicida again displayed reduced sensitivity to quinolone antibiotics, a trait considered as a marker for the local endemic strain of the bacterium.

Systemic infection with *Flavobacterium psychrophilum* in rainbow trout was identified in two farms in the same fjord system as in earlier years (PO3), and bacterial kidney disease (BKD) was identified in one case involving large sea-farmed salmon.

Of the non-notifiable infections, classical winter-ulcer (caused by *Moritella viscosa*) and atypical winter-ulcer (caused by *Tenacibaculum* spp.) cause considerable welfare problems. These two diseases are ranked amongst the five most important causes of reduced welfare and amongst the seven most important causes of mortality in ongrowing salmon. Several respondents consider these diseases to have increased in impact from 2019. The real prevalence of these diseases is difficult to estimate as they are non-notifiable and relatively easily diagnosed in the field.

The Norwegian Veterinary Institute has registered an increasing number of outbreaks of pasteurellosis in salmon over the last three years. Information from private laboratories also shows a similar increase. In 2020, a total of 57 salmon farms were diagnosed with this disease, which is a considerable increase from 2019. The majority of outbreaks are diagnosed in Vestland (PO2-PO4). After ISA and the salmon louse respectively, pasteurellosis is ranked as the third most important increasing problem for ongrowing salmon and is considered an increasing problem in broodstock salmon.

Photo: Siri Ag, Årøya, Lyngen

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 'boils' and skin injuries with spread to inner organs resulting in high mortality. Rainbow trout (*Oncorhynchus mykiss*) are particularly susceptible to the disease. In recent years in Norway, the disease has, in addition to the economic losses associated with the outbreak, represented a serious welfare problem for larger rainbow trout farmed in brackish water. When infections occur in freshwater, mortality can be extremely high. It is not unusual to find the bacterium in skin lesions of salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in freshwater.

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. General hygienic precautions including disinfection of equipment, personnel and eggs are therefore important to prevent outbreak of disease.

Systemic infection with *Flavobacterium psychrophilum* in rainbow trout is a notifiable disease (list 3) in Norway.

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

The health situation in 2020

Official data

Systemic infection with *F. psychrophilum* was identified in 2 rainbow trout farms in one fjord system in Vestlandet. This disease has been frequently diagnosed in large rainbow trout in this area since 2008.

Data from the Norwegian Veterinary Institute

Rainbow trout

Systemic infection with *F. psychrophilum* was diagnosed in rainbow trout in one ongrowing site and in one broodstock site in the late summer of 2020, in the same fjord system in Vestlandet as previously.

Affected fish displayed typical signs including fluid filled 'boils' and skin ulcers. Genotyping identified the isolates to ST2, a variant of the bacterium internationally associated with systemic infection and high mortality in rainbow trout. As previously, these isolates displayed reduced sensitivity to quinolone antibiotics. The disease was suspected in a further two farms in the same fjord but the bacterium was not cultivated from affected fish.

Salmon

In 2020, *F. psychrophilum* was identified in association with fin erosion in one salmon hatchery. In one case involving broodstock salmon held on land, there was a suspicion of *F. psychrophilum* infection in skin ulcers, but the bacterium could not be cultured. Other flavobacteria were, however, cultured from the ulcers.

Annual survey

None of the respondents to the survey considered F. psychrophilum to represent one of the five most important problems related to mortality, reduced welfare, reduced growth or as an increasing problem in hatchery raised rainbow trout. For hatchery raised salmon, flavobacteriosis was crossed off as one of the five most important causes of mortality by 5 of 45 respondents (11%), while 6 and 8 considered the disease to be an important cause of reduced growth and reduced welfare respectively.

For ongrowing rainbow trout, 19% (3 of 16) respondents considered flavobacteriosis to be one of the five most important causes of mortality and 25 (4 of 16) considered it one of the five most important causes of reduced welfare. Flavobacteriosis scored lowly in relation to reduced growth or as an increasing problem in ongrowing rainbow trout. Flavobacteriosis is not considered important for ongrowing or broodstock salmon and only few respondents consider it a problem for broodstock rainbow trout. For details see appendices A1-C2.

Evaluation of the flavobacteriosis situation

The disease was once again in 2020 identified in large rainbow trout in the same fjord system in which *F. psychrophilum* ST2 has been previously identified.

The survey indicates that the disease is considered an important cause of reduced welfare in ongrowing rainbow trout. Replies to the survey mirror the clinical disease picture that results in systemic infection and skeletal muscle lesions in large fish.

While the material submitted from salmon is insufficient to base a situation summary, the annual survey shows that the disease can be challenging during the hatchery phase.

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

Photo: Siw Larsen, Norwegian Veterinary Institute

5.2 Furunculosis

By Duncan J. Colquhoun

The bacterium and the disease

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

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

A. salmonicida subsp. *salmonicida* causes classical furunculosis. The various other strains and subspecies continue to be generally referred to as 'atypical'.

All variants of *A. salmonicida* pathogenic for fish are non-motile short rods. *A. salmonicida* subsp. *salmonicida* produces rich quantities of water-soluble brown pigment when grown on media containing tyrosine and/or phenylalanine. Atypical variants produce variable quantities of pigment, from much to none.

The main mode of transmission is assumed to be horizontal, from fish to fish. Vertical transmission has not been demonstrated. Outbreaks of furunculosis in Norway have, in the main been associated with the marine phase of culture and in hatcheries utilising seawater.

Control

Classical furunculosis is a notifiable (list 3, National disease) in Norway

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

For more information see:
https://www.vetinst.no/sykdom-og-agens/furunkulose

The health situation in 2020

Official data

Furunculosis was identified in five ongrowing salmon farms, all in the Namsen fjord area in Mid-Norway in 2020. None of the outbreaks were considered serious and the disease was diagnosed mainly at the individual fish level. In at least two of these farms furunculosis was also diagnosed in lumpfish. *A. salmonicida* subsp. *salmonicida* was not identified in wild fish during 2020, possibly due to high water levels. Isolates cultured during 2020 displayed reduced susceptibility to the antibiotic oxolinic acid. This characteristic is considered a marker for the local endemic strain of A. salmonicida subsp. salmonicida.

The annual survey

Furunculosis in salmon usually scores very lowly in the annual survey, but in 2020, 4 and 3 of 78 respondents respectively, considered furunculosis to be one of the five most important causes of poor welfare and mortality in ongrowing salmon and 3 of 71 respondents consider furunculosis to be an increasing problem in ongrowing salmon (see appendix B1). This illustrates that there is a real concern amongst fish health personnel surrounding the outbreaks experienced in 2020.

Evaluation of the furunculosis situation

Despite the diagnoses made in the Namsen fjord area the furunculosis situation in Norwegian salmon farming must be considered extremely satisfactory due to extensive use of effective vaccines. That the disease remains identified almost annually in wild salmon illustrates that the bacterium is still present in the environment and that vaccination against furunculosis remains necessary.

Salmon with furunculosis. Photo: Geir Bornø

5.3 Bacterial kidney disease (BKD)

By Duncan J. Colquhoun

The disease

Bacterial kidney disease is a serious chronic disease of salmonid fish 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 e.g. KDM agar.

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

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

Control

BKD is a notifiable (list 3, National) disease in Norway. As no effective treatment or vaccine exists, avoidance of infection is the primary element of control of BKD. The alternative is destruction of affected stocks.

For more information see: https://www.vetinst.no/sykdom-og-agens/bakteriell-nyresjuke-bkd

The health situation in 2020

Official data

Bacterial kidney disease (BKD) is now only sporadically identified in Norway with between none and three cases occurring annually. BKD was identified at low prevalence in a population of large sea-farmed salmon, 14 months post-sea transfer, in western Norway in 2020.

Evaluation of the BKD situation

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

5.4 Winter ulcer

By Duncan J. Colquhoun and Anne Berit Olsen

The disease

Ulcer development during the sea-phase of culture is a serious fish welfare problem and results in both increased mortality and reduced quality at harvest. Ulcer development is a typical autumn and winter problem, but may occur at any time of the year.

The term 'winter-ulcer' (classical winter-ulcer) is primarily associated with infection with the bacterium *Moritella viscosa*, 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 salmonids occurs almost exclusively as surface or topical infections. Classical winter-ulcer develops in the main on the lateral surfaces of the fish, while tenacibaculosis most commonly manifests as deep lesions around the jaw, head and as tail and fin erosion. Although both types of infection occur throughout the whole sea-phase of culture, tenacibaculosis is most commonly associated with relatively newly sea-transferred fish. Tenacibaculosis is less common than winter-ulcer, but may be severe.

Outbreaks of both types of disease can often be associated with earlier handling e.g. delousing. While *M. viscosa* and/or tenacibaculum spp. may cause ulcers alone or as mixed infections, other bacteria such as *Allivibrio wodanis, Aliivibrio logei* and *Vibrio splendidus* are also commonly identified in fish displaying skin lesions.

Moritella viscosa has for many years been considered a homogenous species. Access to new molecular biological tools led, however, to identification in 2008-2010 of two genetically different populations of Norwegian *M. viscosa*. One extremely closely related group could be related to winter-ulcer in farmed Atlantic salmon, while the other, more variable group could be associated with (in the main) other fish species. The Norwegian Veterinary Institute has now developed and utilised more sensitive molecular biological tools developed for mapping the genetic variation in *M. viscosa* from 1980 until the present. We have made several significant findings (under preparation for publication):

- *M. viscosa* can now be separated into several large, closely related, sub-populations (clonal complexes), smaller clusters and singletons.
- From the 80's until ca. 2004, *M. viscosa* isolated from Norwegian salmon represented a very homogenous population, in our analyses described as clonal complex 1 (CC1)
- After 2003, we have identified two genetic shifts amongst *M. viscosa* isolated from farmed salmon, from CC1 to CC2 (2004-2011) and from CC2 to CC3 (2012 to the present). CC1 and CC2 remain present, but are no longer the dominating genotype.

Tenacibaculum spp. are naturally widespread in the marine environment, where they have an important ecological function in degradation of organic material. The Norwegian Veterinary Institute has, together with several international collaborators, previously characterised *Tenacibaculum* spp. from farmed salmon and have identified several ulcer-associated species and genetic groups. As whole genome sequencing has now become more available and steadily cheaper, we have used this technology to study the variation amongst *Tenacibaculum* isolated from fish displaying skin lesions. Recent research confirms that tenacibaculosis in newly sea-transferred smolts is associated primarily with *T. finnmarkense* and that two genomic variants of this species exist i.e. genomovar finnmarkense and genomovar ulcerans. Both types can be identified in fish with tenacibaculosis. That several different genetic variants are commonly found in most outbreaks, indicates that transmission from the

Salmon with Tenacibaculum sp and Moritella viscosa infection. Photo. Geir Bornø Norwegian Veterinary Institute.

environment is more important than fish-fish transmission.

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* infection. There are no commercial vaccines available against tenacibaculosis. Antibiotic treatments are performed on occasion, but the effect is variable.

As discussed above, research performed by the Norwegian Veterinary Institute indicates that the majority of *M. viscosa* isolated from salmon displaying winter-ulcer in recent years belong to a different genotype than that dominating previously. Whether this has any effect on vaccine protection is as yet unclear. Preventative production related measures 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 around 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 factsheets:

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

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

The Norwegian Veterinary Institute has, together with national and international collaborators characterised Tenacibaculum from farmed salmon and identified several new ulcer-associated species and genetic groups. Photo: J. A Holm Fishguard.Fishguard.

The health situation in 2020

Data from the Norwegian Veterinary Institute

Again in 2020, winter-ulcer was diagnosed in farmed salmonids along the whole coastline, with variation in severity between areas. The number of diagnoses south and north of Nordland, were perhaps a little more balanced than in previous years with ca. 55% of *M. viscosa* diagnoses and 66% of tenacibaculum cases diagnosed from Nordland and northwards.

The annual survey

Tenacibaculosis and classical winter-ulcer were considered the fifth and seventh (ulcers took sixth place) most important causes of death in ongrowing salmon and shared third place in terms of reduced welfare. They were also considered responsible for a degree of mortality in broodstock fish (for details see appendices B1 and C1). Both classical and atypical winter-ulcer are considered important in terms of reduced welfare and mortality in sea-farmed rainbow trout at a level similar to that observed in ongrowing salmon (see appendix B2).

Photo: Marin Helse AS

Mechanical injuries following delousing are considered the most important cause of reduced welfare in ongrowing salmon and rainbow trout. There can be little doubt that delousing associated injuries predispose for ulcer development. It is therefore extremely important that production factors that predispose for ulcer development are avoided as much as possible.

Evaluation of the winter-ulcer situation

Estimation of the actual prevalence of both typical and atypical winter ulcer is difficult as neither type of infection is notifiable, and both infections are relatively easy to diagnose in the field. These infections are almost certainly under reported. The winter ulcer situation in the industry as a whole is considered relatively stable, but is worth noting that both classical and atypical winter-ulcer are ranged highly by fish health personnel as important causes of reduced welfare in ingrowing salmonids in 2020.

5.5 Mycobacteriosis in salmonids

By Toni Erkinharju, Hanne Nilsen and Lisa Furnesvik

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 changed, but the proposed new names are under debate and both '*Mycobacterium*' and the proposed new genus names can be used. The new proposals include transfer of *Mycobacterium chelonae* and *Mycobacterium salmoniphilum* to the genus *Mycobacteriodes*, *M. fortuitum* to the genus *Mycolicibacterium*, while *M. maritimum* remains within the genus *Mycobacterium*. Of these, it is *Mycobacteriodes (Mycobacterium) salmoniphilum* that has been associated with fish disease in Norway.

Typically, mycobacteriosis in fish manifests as a chronic disease with varying associated mortality, emaciation and skin lesions amongst possible clinical signs of infection. On autopsy, white nodules (granuloma) in internal organs and an enlarged spleen and kidney are amongst the typical pathological changes observed. Histologically visible granuloma (inflammatory reactions) in inner organs are a typical finding in many fish species but are normally less pronounced in salmonids (Figure 5.5.1).

Transmission of infection most probably occurs via direct contact with infected fish, through feed or water. Vertical transmission has been described, but is not considered a primary route of transmission.

Pasteurisation (heat treatment) of feed reduced the occurrence of mycobacteriosis in farmed fish considerably. The disease has a long incubation time of up to several weeks and infected fish may be symptom free for several years following infection.

Mycobacteria are acid-fast and may be stained in tissue samples using e.g. Ziehl Neelsen staining, or using immunohistochemical (specific antibody) techniques.

Whether mycobacteriosis represents a primary or secondary infection in fish remains unclear, but there are many indications that mycobacteria weaken the immune defences of the affected fish and allow entry of other pathogenic organisms.

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. Destruction of affected stocks should be considered to limit spread of infection. The cost benefit of such a control strategy is probably less in low prevalence infections compared to high prevalence, high mortality episodes.

See the fact sheet for more information on mycobacteriosis:
https://www.vetinst.no/sykdom-og-agens/mykobakteriose-hos-fisk-mycobacterium-spp

The health situation in 2020

Data from the Norwegian Veterinary Institute

In 2020, mycobacterial infections were identified in five ongrowing farms, which is a slight decrease from the previous year. In some of the affected localities, increased mortality and extensive pathological changes were identified in the internal organs, particularly the kidney, of affected fish. The diagnoses was acheived on the basis of histopathological investigations combined with bacteriological and/or immunohistochemical analyses. In three cases the bacteria involved were identified as *M. salmoniphilum* by phenotypical characterisation and DNA sequencing.

The annual survey

Mycobacteriosis was ranked by fish health personnel and officers of the Norwegian Food Safety Authority amongst the least important diseases of salmon in hatcheries and ongrowing farms. Infection with mycobacterium was considered one of the five most important causes of reduced welfare in hatchery reared salmon by 1 of 51 respondents (Appendices 1A and 1B). In addition, 1 of 31 and 1 of 71 consider mycobacterium infections to be on the increase in hatcheries and ongrowing farms respectively (Appendices 1A and 1B) .

Evaluation of the mycobacteriosis situation

As mycobacteriosis in fish is non-notifiable in Norway, there are no official statistics related to the number of outbreaks of this disease in salmon. In 2006/2007 the Norwegian Veterinary Institute diagnosed mycobacteriosis on 11 sites and several outbreaks were also registered in 2008 and 2009. The disease was identified in one RAS hatchery and 2 ongrowing sites for salmon in 2018 and in seven sites in 2019. In one of the latter cases the species involved was identified as *M. salmoniphilum*. As previously mentioned mycobacteriosis was diagnosed in 5 ongrowing farms in 2020, with three cases confirmed as M. salmoniphilum.

Regarding the possibility of zoonotic infection, there are currently no indications that consumption of mycobacteria infected fish represents a significant health risk to humans, as most fish pathogenic bacteria including *M. salmoniphilum* do not grow at 37 °C. It cannot, however, be absolutely excluded that handling of non-processed fish may represent a zoonotic risk through contact infection involving a skin lesion. This is particularly relevant for persons with reduced immune defences.

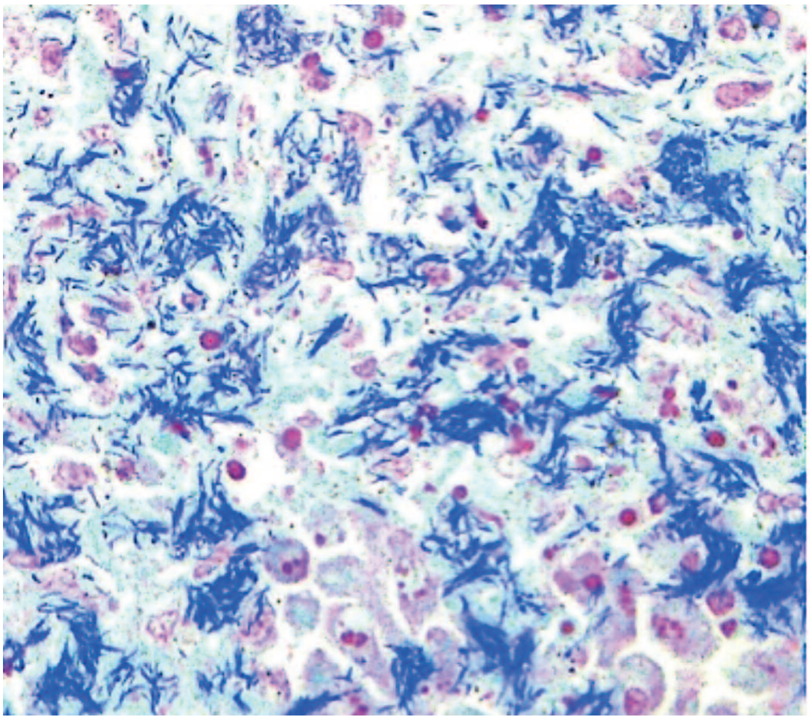


Figure 5.5.1. Gram-positive bacterial cells within a granuloma in the liver of a salmon infected with *M. salmoniphilum*. Gram Twort staining. Photo: Anne Berit Olsen, Norwegian Veterinary Institute

5.6 Pasteurellosis in salmon

By Hanne K. Nilsen, Duncan Colquhoun and Snorre Gulla

The disease

Pasteurellosis in salmon was first identified in Northern Norway as early as 1989 and has since been diagnosed occasionally in this fish species in the North and South of the country. Since 2018 a steadily increasing number of outbreaks have been diagnosed between Rogaland in the south to Møre og Romsdal in the north (PO2-5)

The disease has been also recognised in salmon farming in Scotland since the 1990's with outbreaks occurring intermittently since with a number of serious outbreaks in recent years. In 2017, severe mortalities were registered in association with this infection in a farm situated in Lewis and several outbreaks were diagnosed in 2019.
The extensive eye pathology associated with the infection gave rise to the name 'Varracalbmi' which means ' bloody eye' in the Lapp language. In later outbreaks, bloody boils in the skeletal and cardiac muscles as well as inner organs have become characteristic. Inflammation in the epicardium, peritoneal wall and pseudobranch are normal. Haemorrhage at the base of the pectoral fins is commonly reported.
Histopathological changes reflect the macroscopic picture with identification of pus and short rod-shaped bacterial cells in affected organs.

Several variants of Pasteurella are involved. The bacterium responsible for outbreaks of pasteurellosis in Scotland has been officially named as *Pasteurella skyensis* (Birkbeck et al. 2002).
P. skyensis was also cultured from diseased salmon in Norway for the first time in September 2020. The bacterium responsible for all other previous outbreaks of pasteurellosis in Norwegian salmon belongs to another, (not yet officially named) *Pasteurella* species. Pasteurellosis in lumpfish used as cleaner-fish in Norwegian salmon farming is also frequently diagnosed in Norway, and is caused by yet another apparently host-specific variant, closely related to the Norwegian salmon pathogen (See Chapter 10 The health situation in cleaner-fish). The term 'pasteurellosis' is also commonly used to describe infection with the bacterium *Photobacterium damselae* subsp. piscicida (previously *Pasteurella piscicida*) in warm water fish species e.g. sea-bass.

To elucidate the familial relationships between the diverse *Pasteurella* species/strains involved in Norwegian aquaculture, more than 80 *Pasteurella* isolates were whole-genome sequenced by the Norwegian Veterinary Institute in 2020.

The collection comprised isolates from both Norwegian and Scottish salmon and lumpfish, isolated over a number of years. The investigation revealed a group of closely related isolates (not *P. skyensis*) to be responsible for nearly all outbreaks of disease amongst Norwegian salmon, for which the Norwegian Veterinary Institute has proposed the name '*Pasteurella atlantica* genomovar *salmonicida*' as part of a preliminary working nomenclature. The investigation further showed that with two exceptions (in lumpfish held together with salmon with pasteurellosis), it is another variant of the same species (Pasteurella atlantica), that causes disease in lumpfish, independent of geographical origin. For this variant we have proposed the name '*Pasteurella atlantica* genomovar cyclopterii' as a working name.

Control

No commercial vaccines are currently available. The disease in non-notifiable. There are knowledge gaps relating to reservoir and source of infection. Outbreaks in neighbouring farms may indicate horizontal transmission. Normal biosecurity measures and hygienic routines are recommended.

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

The health situation in 2020

Data from the Norwegian Veterinary Institute and other laboratories

In 2020 the Norwegian Veterinary Institute continued to register an increasing number of diagnoses (41 in total) related to pasteurellosis in farmed Atlantic salmon. In a further two cases, typical pathological findings consistent with pasteurellosis were observed but clinical bacteriology was not performed. Two cases registered in 2020 represented the first known Norwegian cases involving *P. skyensis*. On inclusion of data from private laboratories, the disease was diagnosed in a total of 57 different farming sites from PO2 to PO5, with the majority of cases identified in PO3.

The typical clinical symptoms have, as previously stated included cardiac- and peritoneal- inflammation with deep lesions particularly near the pectoral fins, musculature and internal organs. The bacterium has also been cultured on occasion from apparently clinically healthy fish. Inflammation of the eye is observed in some individuals, but this has not been a common finding in Norwegian salmon in 2020. In fish infected with *P. skyensis,* inflammation in and around the swim-bladder has been identified.

The annual survey

At the national level, pasteurellosis in ongrowing salmon was ranked in 3rd place as an increasing problem in 2020. As a cause of mortality and reduced welfare in ongrowing salmon, 23 and 21 respondents of a total of 78, replied that they considered pasteurellosis to be one of the five most important causes, resulting in 9th and 1oth place respectively (see appendix B). If only responses from Po1-PO5 are considered, pasteurellosis was ranked in 2nd place as a cause of reduced welfare and a clear 1st place as an increasing problem (Chapter 2, Figure 3.2.1). This is consistent with the increasing number of diagnoses of disease caused by *P. atlantica* genomovar *salmonicida* registered in the various diagnostic laboratories.

In the ‘free text’ part of the survey, respondents write of significant challenges related to Pasteurella infections in salmon, which cause high mortalities, reduced welfare and poor growth.

Evaluation of the pasteurella situation

The number of farms affected by pasteurellosis in salmon increased considerably in 2020. This must be considered a ‘new’ bacterial disease that threatens fish welfare and causes loss. Management of the disease is dependent on cooperation between research institutions, the industry and public authorities.

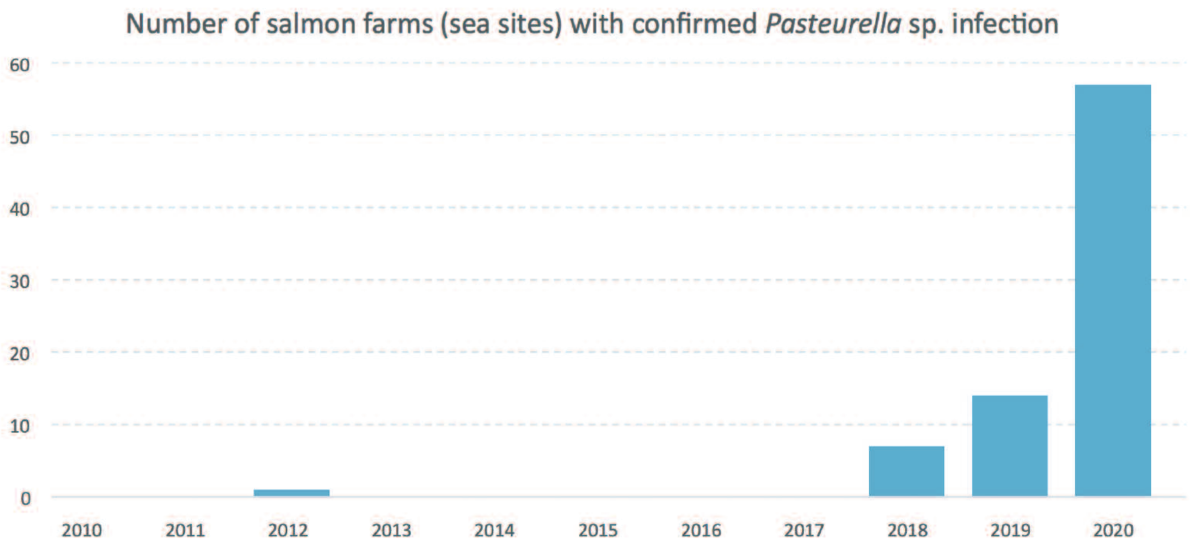


Figure 5.7.1. Number of farms diagnosed with Pasteurella infection in salmon. For the period 2010-2019 the statistics are based on diagnostic submissions to the Norwegian Veterinary Institute (VI). For 2020 the statistics are based on consolidated data from private laboratories and VI (ref. Chapter 1).

5.7 Other bacterial infections

By Duncan J. Colquhoun and Hanne Nilsen

Most bacterial infections are a result of the interplay between the bacterium, the fish and the environment. A broad spectrum of bacterial species may be isolated from sick fish, both known pathogens often associated with disease and opportunist species less frequently associated with disease. 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. Discovery of new 'emerging' pathogens is one of the main arguments for continuing use of culture based diagnostics.

The situation regarding bacterial diseases of fish in Norwegian aquaculture has been relatively stable in later years. The number of pasteurellosis outbreaks registered in 2020 (discussed in chapter 5.6) does however, give grounds for concern.

Epitheliocystis is a term used to describe bacterial gill infections, histologically visible as intracellular 'colonies' within the outer cell-layer of the gills. Several types of bacteria may cause epitheliocystis in salmonid fish e.g. *Ca. Piscichlamydia salmonis, Ca. Syngnamidia salmonis, Ca. Clavichlamydia salmonicola* and perhaps the most common, *Ca. Branchiomonas cysticola*. Mixed-infections also occur. Specific diagnoses are dependent on molecular biological investigation and identification of the aetiological agent to species level is confirmed in only very few cases.

Of 76 cases of epitheliocystis registered following histological investigation at the Norwegian Veterinary Institute in 2020, 10 were confirmed to be related to *Ca. B. cysticola* infection. Consolidated statistics from the Norwegian Veterinary Institute and participating private laboratories reveal a total of 78 confirmed *Ca. B. cysticola* infections in salmon with individual diagnoses made in rainbow trout, corkwing- and ballan-wrasse. 76 of the *Ca. B. cysticola* detections made in salmon were in fish held in seawater and 2 from freshwater.

Yersiniosis, which has been a serious problem in both freshwater and seawater farmed Norwegian salmon in recent years, now appears to be under good control, thanks to extensive vaccination. For the first time in 2021, the Norwegian Veterinary Institute has collected data related to diagnoses of *Yersinia ruckeri*/yersiniosis from several commercial diagnostic actors. For the country as a whole and for all diagnostic laboratories involved, *Yersinia ruckeri* was detected in a total of 14 salmon farms in 2020. The detections were distributed amongst 8 juvenile production facilities and 6 marine ongrowing farms spread along the coastline.

Yersiniosis was diagnosed by the Norwegian Veterinary Institute in two salmon hatcheries and three salmon ongrowing farms in 2020. None of these cases were considered serious outbreaks and several involved additional diagnoses. The Norwegian Veterinary Institute also identified in 2020 *Yersinia ruckeri* serotype O1 isolates from the egg fluid and kidney of a broodstock salmon, and from the kidney of a wild salmon (PO5), that do not belong to the pathogenic variant (clonal complex 1) usually associated with disease in Norway.

Pseudomonas anguilliseptica is a widespread pathogen of lumpfish in Norway, and a recognised pathogen of salmonid fish in the Baltic Sea. The bacterium was identified in diseased rainbow trout in Norway in 2019, but was not identified in Norwegian farmed salmonids in 2020.

Rainbow trout is a robust species in Norwegian aquaculture, and there are generally relatively few outbreaks of bacterial disease registered in this fish species annually. Vibrio *anguillarum* serotype O1 infection was diagnosed in one rainbow trout population

(~3kg) displaying classical signs of vibriosis in 2020. *Vibrio anguillarum* (non-O1/O2) was also identified in a juvenile salmon production facility at a salinity of approximately 15ppt.

Coldwater vibriosis, caused by Aliivibrio (*Vibrio) salmonicida*, was not diagnosed in salmon or other fish species in 2020.

Atypical *Aeromonas salmonicida* was identified by the Norwegian Veterinary Institute (in rich culture) from a single vaccinated farmed salmon in the autumn of 2020. This finding was not related to increased mortality on the farm. Identification of atypical *Aeromonas salmonicida* in salmon is unusual in later years as vaccination against *A. salmonicida* subsp. *salmonicida* (the cause of furunculosis) normally provides good protection against atypical variants.

Piscirickettsiosis, caused by *Piscirickettsia salmonis*, remains an extremely important pathogen of salmon in Chilean aquaculture and was identified in Norwegian salmon in one ongrowng farm in 2020.

Most bacterial infections are a result of the interplay between the bacterium, the fish and the environment.
Photo: Eivind Senneset

5.8 Antibiotic sensitivity in Norwegian aquaculture

By Duncan J. Colquhoun and Hanne Nilsen

The Norwegian Veterinary Institute monitors antibiotic sensitivity in a large number of bacterial isolates cultured from diseased fish each year. A smaller number of isolates from wild fish are also tested, primarily from wild salmonids. The results of this surveillance reveal a favourable situation in which a very low frequency of antibiotic resistance amongst fish pathogenic bacteria is identified.

Although antibiotic treatment of farmed fish in Norway is rare, it is at times necessary to control outbreaks of disease (mainly with oxolinic acid and florfenicol). It is important that use of antibiotics remains infrequent to avoid development of resistance in both environmental and fish-pathogenic bacteria.

There exist few signs of increasing resistance amongst bacteria we identify from diseased fish in Norway. As in earlier years, we have again in 2020 identified reduced sensitivity to oxolinic acid in *Flavobacterium psychrophilum* isolated from diseased rainbow trout and in *Aeromonas salmonicida* subsp. *salmonicida* isolated from both farmed salmon and farmed lumpfish in the same area of mid-Norway where this bacterial strain has been endemic in wild salmon for many years. Reduced sensitivity to oxolinic acid was also identified in *Vibrio anguillarum* (non- serotype O1/O2) isolated from large salmon smolts (200g) in 2020. The mechanism behind the reduced oxolinic acid sensitivity in Norwegian fish pathogenic bacteria has previously been related to chromosomal mutation. The risk of transmission of this type of resistance is considered low.

Reduced sensitivity to antibiotics was not identified in any cleaner-fish pathogenic bacteria in 2020.

Despite the fact that there are few grounds for concern relating to development of antibiotic resistance amongst pathogens of Norwegian farmed fish, the situation in Norwegian ornamental fish is less clear. In 2020, the Norwegian Veterinary Institute isolated atypical *Aeromonas salmonicida* from an ornamental koi carp that displayed reduced sensitivity to oxolinic acid, flumequine (both quinolones) and tetracycline. Antibiotic use in the international ornamental fish trade is less regulated than in Norwegian aquaculture, and import of such fish, bearing antibiotic resistant bacteria represents a risk for establishment of resistance genes in aquatic bacteria in Norway, including fish pathogenic bacteria.

6. Fungal diseases of salmon

By Ida Skaar

The disease

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

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. are not actually fungi, but belong to the oomycetes. Saprolegnia spp. occur in all fresh water 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 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.

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 the most cost-effective substance against *saprolegnia* and is most commonly used in treatment of outbreaks. Use of formalin in aquaculture is, however, also debated and its use is currently being considered by the EU. The use of formalin against parasites or oomycetes may thus become regulated or forbidden within the next few years. It is therefore important that focus is placed on 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 as is maintenance of good water quality to avoid build-up of spores in the farm. For eggs under incubation and during hatching, the most important measure is frequent removal of dead eggs and organic material.

See the fact sheet for more information on saprolegniosis:
https://www.vetinst.no/sykdom-og-agens/saprolegniose

The health situation in 2020

Data from the Norwegian Veterinary Institute

The disease is normally diagnosed and treated in the field without further laboratory investigation. The Norwegian Veterinary Institute therefore only registers a limited number of saprolegniosis cases each year, which does not reflect the true impact of the disease. There were in the course of 2020, additional requests for advice outside the diagnostic service in which *saprolegnia* was related to high mortality in start-feeding fry and eggs. In 2020 *saprolegnia* was identified in 14 diagnostic submissions involving salmon (11), trout (1), char (1) and cyprinid fish (1). Systemic mycosis was only identified in a single salmon in 2020.

Data from other laboratories

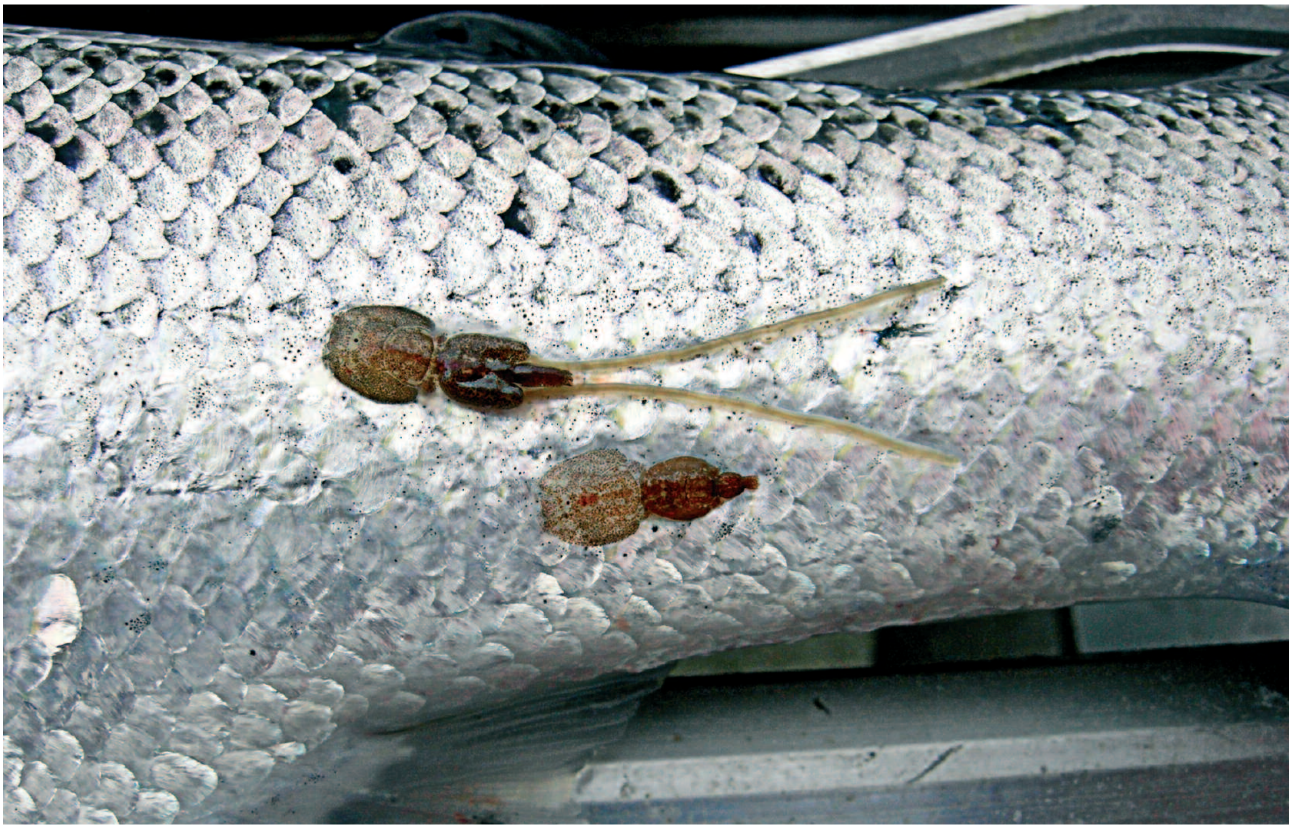
As saprolegniosis is normally diagnosed and treated without laboratory diagnosis, we have not received data from other laboratories.

The annual survey

Information from respondents to our annual survey indicate that the disease is not considered an important problem in the fish farming industry.

Evaluation of the saprolegniosis situation

The Norwegian Veterinary Institute is frequently asked to provide advice related to saprolegnia problems, but based on the number of submissions and responses to the annual survey it appears that fungus and ooomycetes are not particularly problematic at this time.



Amonst the parasitic diseases, and the parasitic diseases, and diseases in general, the salmon louse continues to represent one of the most significant challenges to farming of salmonids. Photo: Trygve Poppe

7. Parasitic diseases in 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 farming of salmonids. Despite considerable increase in use of non-medicinal delousing technologies, national louse levels in 2020 were similar to those of 2019, both during the spring and autumn. The weeks with the lowest levels of both adult female and other motile life stages were during the summer, June – July.

Salmon louse resistance to pharmaceutical treatments remains widespread along the coast, and non-medicinal treatments and other non-medicinal measures now dominate delousing strategies. A total of 2983 thermal, mechanical and freshwater based delousing operations were performed in 2020. This is a considerable increase from 2019. While thermal treatments dominated, freshwater treatments increased most, by 53% between 2019 and 2020.

In the annual survey, increased post-delousing mortality was considered an extremely important factor. Fish health services reported increased mortality following thermal and mechanical delousing in particular. Replies also demonstrate that delousing related injuries are considered an important cause of poor fish welfare.

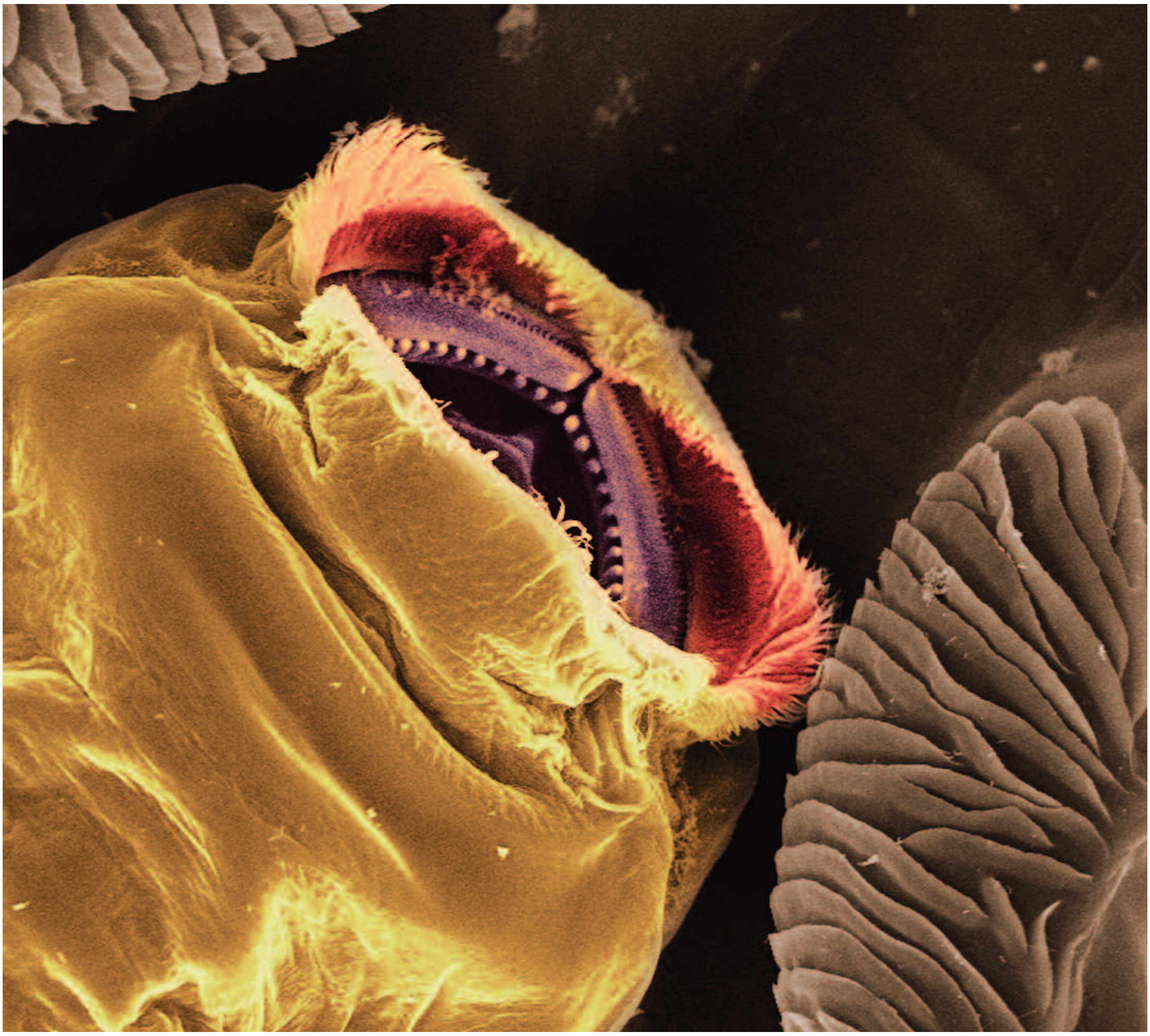
The sea louse (*Caligus elongatus*) continued to be a problem in 2020, being particularly challenging in some areas and in some cases infestations have required treatment.

The parasite *Parvicapsula pseudobranchicola* is a particularly serious problem in salmon farming in the most northerly areas of the country, with challenges related to mortality, growth and welfare particularly serious in Troms and Finnmark. The parasite was also detected in most production areas in 2020.

The amoeba, *Paramoeba perurans*, the cause of amoebic gill disease (AGD), was detected throughout the year from Vestland to Trøndelag. In cases of complex gill disease this parasite may be present in co-infections with other parasites e.g. *Desmozoon lepeophtherii*.

Other parasites are considered normal findings in farmed salmon but can be problematic on occasion. An increase in tapeworm (*Eubothrium* sp.) infection has been observed in sea-farmed salmon since 2010. This problem appears to be greatest in Vestlandet and in mid-Norway. The single-celled parasites *Ichthyobodo necator* (salmon in freshwater), *I. salmonis* (salmon in freshwater and the sea) and *Trichodina* spp. are normal findings in Norwegian fish farming. Most diagnoses of both tapeworm and single-celled parasites are made by fish health services. Responses to the annual survey indicate that such infections are considered of relatively low importance on a national scale.

The Norwegian Veterinary Institute has, since 2000, sporadically diagnosed a disease in salmon and rainbow trout that has most frequently resulted in low mortality, although individual fish have displayed extensive pathological changes. There have been between none and few cases per year and until last year there have been few cases south of Trøndelag. We have recently identified similar cases in Nordland. The majority of cases involve adult salmon or rainbow trout, but the disease may affect fish at all stages of the marine cycle. The disease is normally identified on autopsy of dead fish, or following a period of raised mortality. Most cases appear in the autumn and early winter. Visible signs of disease include pale spots or nodules in the inner organs and the skeletal musculature. Typical histopathological findings include necrosis (dead tissues) and inflammatory changes in most organs, including the pseudobranch. Characteristic parasite structures can be observed in the affected tissues and are easily seen following routine histopathological staining. The work of characterisation of these parasites is underway, such that this disease may be more easily diagnosed in the future.



Electron micrograph of a salmon louse. Photo: Jannicke Wiik-Nielsen

7.1 The salmon louse – *Lepeophtheirus salmonis*

By Kari Olli Helgesen, Lars Qviller and Leif Christian Stige

The disease

The salmon louse (*Lepeophtheirus salmonis*) is a naturally occurring crustacean parasitic for salmonid fish in marine environments in the northern hemisphere. The lifecycle comprises eight developmental stages separated by exoskeletal shifts. 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.

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 pharmaceutically based, 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 cleaner-fish) and both pharmaceutical and non-pharmaceutical methods.

The increased frequency of treatment and increased use of non-pharmaceutical control 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, see the factsheet: https://www.vetinst.no/sykdom-og-agens/lakselus

The situation in 2020

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 cyclical variation with the lowest lice counts in spring and the highest during the autumn (Figure 7.1.1). The highest numbers of adult female lice were recorded in September 2020 (week 38) and the highest numbers of other mobile stages (pre-adults and adult males) were observed in Jan/Feb (week 5).

The lowest numbers of adult female lice were recorded in June (week 23), while the lowest numbers of other mobile stages were recorded in July (week 29). Overall, louse numbers for 2020 were somewhat higher than those observed in 2019, but with slightly fewer motile lice in the latter half of 2020 compared to the latter half of 2019 and early 2020.

To analyse the louse situation at a level deeper than average numbers of lice, we have modelled 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 (PO) around the coast (See chapter 1. Statistical basis for the report). Each area is considered separately in association with the so-called traffic light system regulating further expansion of the aquaculture industry. For discussion of the traffic light system and status in 2020, see chapter 9.6 ‘The salmon louse and sustainability’.

Highest larval production occurred in production areas 2, 3, 4 and 6 (Figure 7.1.2). PO1, PO6 and PO8 all displayed an increased larval production from 2019 – 2020. In PO5 and PO7, a reduction in the number of lice larvae was observed during the same time period, while there were only slight changes in the remaining POs. On consideration of the period of outward migration (as defined by Kristoffersen et al. 2018, Epidemics 23:19-33) of wild salmon smolts alone, production during these weeks increased in POs 2 and 8. In the other POs, production during smolt migration either went down (POs 4, 5, 7 and 9) or was stable from 2019 – 2020. In other words, of the POs with highest larval production (POs 2, 3, 4 and 6), larval production increased in PO2 alone, during the smolt migration period.

On division of 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 7.1.3). The median value for average louse production per fish per week was highest in production areas 3 and 4 and decreased with increasing and decreasing latitude. This shows that the effect on numbers of lice produced by eventual expansion of the aquaculture industry will depend on where in the country the expansion occurs.

The numbers of the various anti-louse treatments in 2020

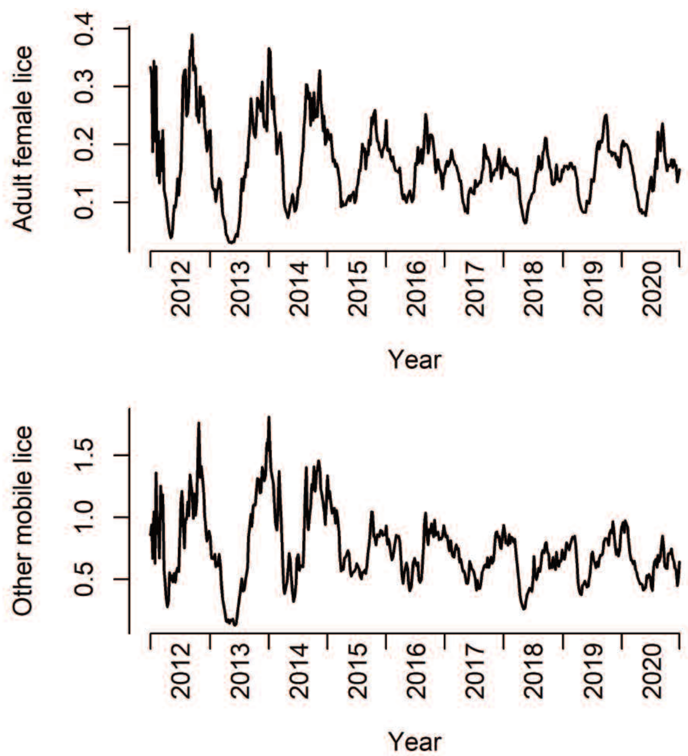


Figure 7.1.1. Average numbers of lice reported by all marine sites in Norway farming salmon or rainbow trout for the period January 2012 until December 2020 (as reported to the Norwegian Food Safety Authority 24.01.21). The upper panel describes the number of adult female lice and the lower panel other mobile stages (pre-adults and adult males)

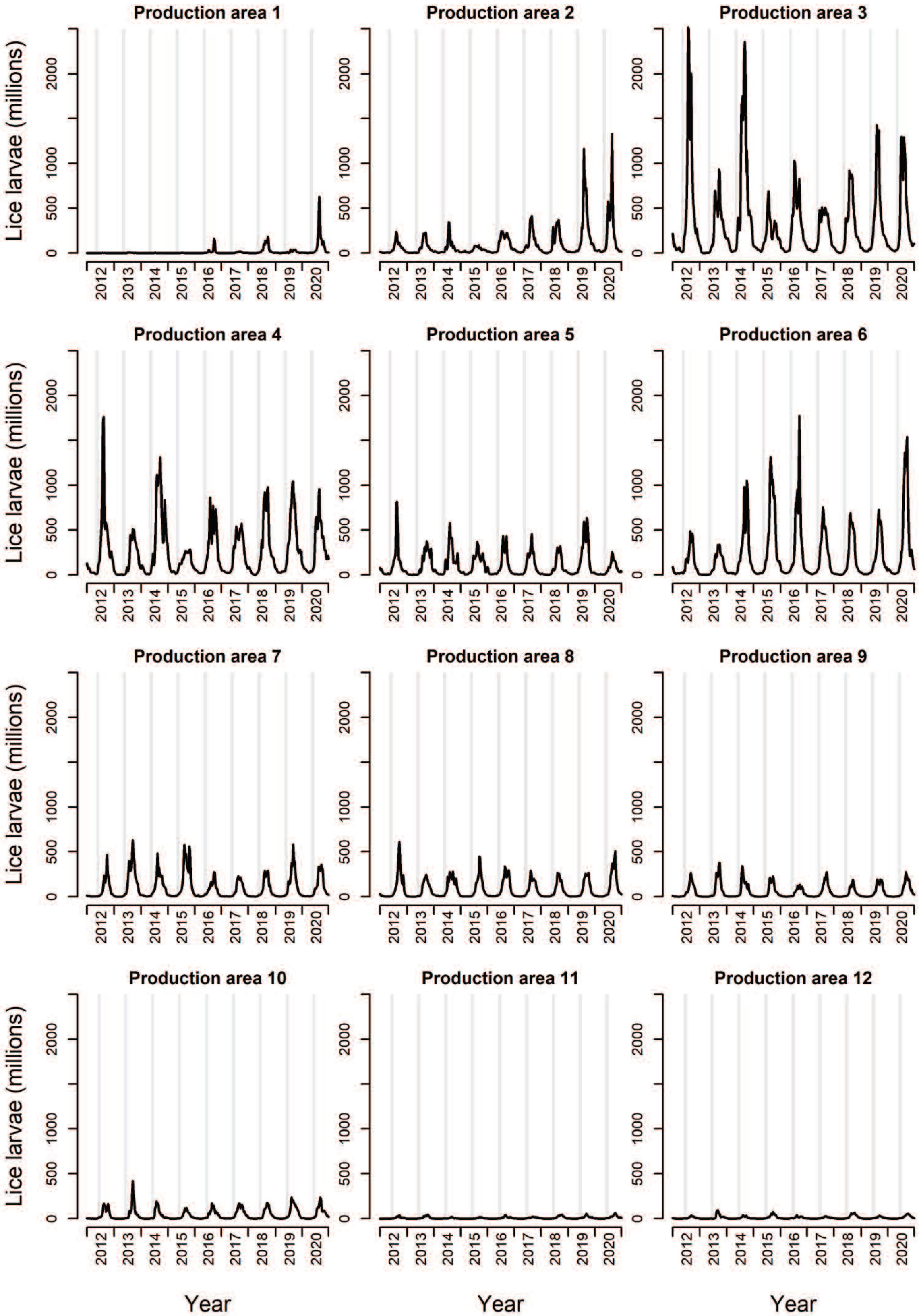


Figure 7.1.2. Calculated total production of louse larvae (in millions) per week per locality in each production area (PO) for the period 2012-2020. Production area 13 is not included. This area had insignificant larval production throughout the whole period. The grey areas show the period for typical outward migration of wild salmon smolts in each area.

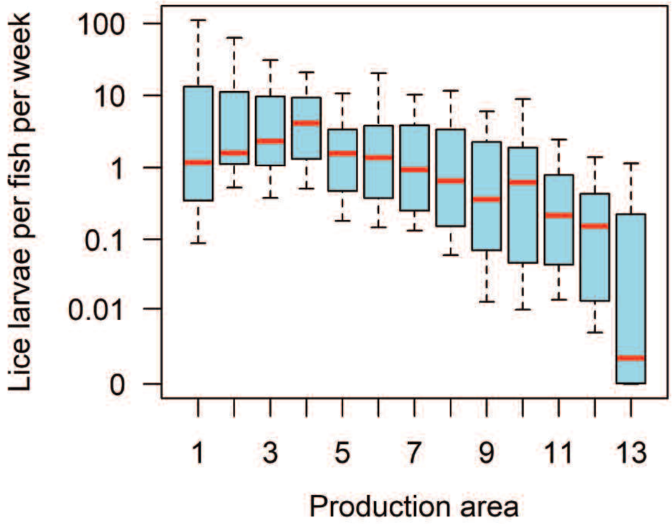


Figure 7.1.3. Calculated average louse larvae production per fish per week in each production area (PO1-PO13) in 2020. The red lines represent the median values, while 50% of the values are within the blue boxes.

Table 7.1.1. Number of prescriptions categorised by active ingredient, prescribed for treatment of salmon lice 2011-2020. Pyrethroids = deltamethrin and cypermethrin. Flubenzurones = teflubenzerone and diflubenzurone. The number of prescriptions was obtained from VetReg 13.01.21.

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

Table 7.1.2. Number of reported non-medicinal treatments[1]. Treatments relate to the number of individual weeks in which mechanical lice-treatments were reported to the Norwegian Food Safety Authority, as of 24.01.21. Treatment methods are separated into 4 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 first combination category relates to thermal and mechanical delousing reported for the same farm in the same week. The other combination category relates to use of freshwater and thermal and/or mechanical delousing.

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020
Thermal	0	0	3	36	684	1247	1355	1463	1736
Mechanical	4	2	38	34	312	236	428	673	816
Freshwater	0	1	1	28	73	75	87	150	238
Thermal and Mechanical	0	0	0	0	12	42	38	58	57
Therm./Mech. + Freshwater	0	0	0	0	23	22	25	34	43
Other	132	108	136	103	75	51	69	87	93
Sum	**136**	**111**	**178**	**201**	**1179**	**1673**	**2002**	**2465**	**2983**

[1]The difference in statistics from the Fish Health Report of 2019 is caused by use of new combination categories, updated routines used to identify treatment type based on textual descriptions in the reporting forms and late registrations.

are summarised in Tables 7.1.1. and 7.1.2. The number of medicinal treatments relate to the number of prescriptions submitted to the Veterinary Medicines Register (VetReg), while the number of non-medicinal treatments is based on the number of such treatments reported as part of the weekly 'louse 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 treatments and non-medicinal treatments may have been performed at the cage- or farm-level.

The table shows that the drastic reduction in the number of prescriptions for medicinal treatment of salmon lice between 2016 and 2018, has stabilised. Delousing prescriptions fell by 9% between 2019 and 2020. At the active substance level, the statistics show that prescription of azamethiphos increased from 2018 to 2019, and again between 2019 and 2020, while prescription of hydrogen peroxide fell in this period. Prescription of the other relevant pharmaceutical products increased between 2018 and 2019, but fell between 2019 and 2020. The table does not distinguish between hydrogen peroxide prescribed for treatment of salmon lice or AGD, or between salmon lice treatments and sea-lice (Caligus) treatments. Emamectin benzoate was the most prescribed anti-louse pharmaceutical prescribed in 2020. 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.

The number of reported non-medicinal delousing treatments has increased steadily since 2016 and continued to increase in 2020. The increase is largely related to the number of thermal-, mechanical- and freshwater- treatments. The greatest increase was in the number of freshwater treatments (53% increase from 2019 to 2020). Thermal treatments continued to be the most frequently used non-medicinal treatment in 2020 (representing 61% of all reported treatments, including weeks where several non-medicinal techniques had been used). In around 3% 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 and mechanical delousing.
In addition to non-medicinal methods, various prophylactic measures, with cleaner-fish as the dominating form, have been widely used.

Figure 7.1.4 shows the results of the surveillance programme for salmon louse resistance for 2020 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 2019, the map indicates widespread resistance to emamectin benzoate, deltamethrin and azimethiphos in salmon lice from different farming sites along the coast. For hydrogen peroxide, the map shows a degree of resistance in some areas while other areas showed satisfactory sensitivity. Resistance remains present despite the reduction in medicinal treatments. This is probably because resistance genes are now well established within the louse population of both wild and farmed salmon and because all use of medicine selects for resistance.

Survey

In our annual survey of Fish Health Services, the Norwegian 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 28 health- and welfare-problems relevant for ongrowing salmon farming, 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 2020. Of 78 respondents who replied in regard

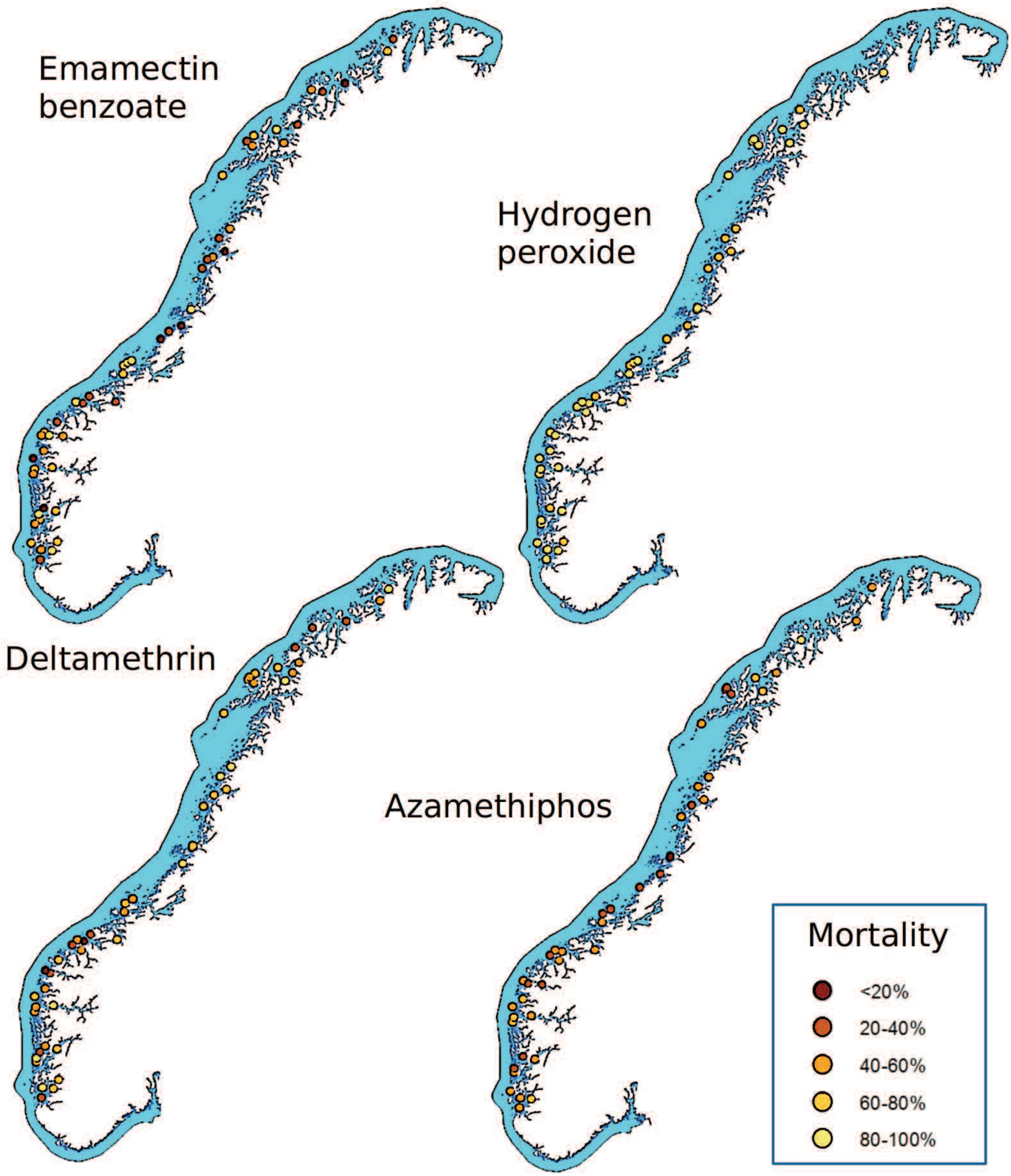


Figure 7.1.4. Louse mortality during a biossay (toxicological resistance testing of live lice) with emamectin benzoate, hydrogen peroxide, deltamethrin and azamethiphos, where the darker the colour represents lower mortality on exposure to a specific concentration of the active substance and therefore more resistant lice.

to mortality, 19 (24%) chose salmon louse as one of the most important, while 56 (72%) chose 'delousing associated injuries' resulting in 10th and 2nd place respectively in the 'mortality' list. Regarding reduced welfare in ongrowing salmon, of the 78 respondents, 46 (59%) crossed off for salmon louse as one of the most important causes and 62 (79%) crossed off delousing related injuries, resulting in 2nd and 1st place respectively of the causes of reduced welfare. Of the 71 respondents who expressed a view on the 5 most increasing problems in ongrowing salmon in 2020, 27 (38%) crossed off salmon louse, resulting in an equal first place together with ISA in this category. Delousing injuries were awarded fourth place in the same category.

For further evaluation of the salmon louse and delousing related injuries as a problem in salmon farming, see appendices B1-B2 and C1 and C2. In free text replies to the survey, it was mentioned that delousing of broodstock also caused problems in 2020, a factor not considered in the list of questions included in the survey.

For replies related to delousing mortality, score 1 = never or extremely rarely observed, to 5 = observed on nearly every delousing. N is the number of respondents who have replied to that particular question. Increased mortality (>0.2% for the first three days post-delousing), scored an average 3.7 for thermal delousing (n = 59), 3.1 for flushing and/or brushing (n= 51) and 2.8 for freshwater (n=42). The average score for increased mortality over the first three weeks post-delousing were respectively 2.3, 2.4, and 1.6 for thermal, mechanical and freshwater delousing.
Increased acute mortality was observed most often during thermal delousing, followed by mechanical and least commonly in freshwater. A similar ranking was also reported in 2017, 2018 and 2019. Increased delayed mortality was thereby observed most commonly following mechanical delousing and least frequently in freshwater delousing.

Evaluation of the salmon louse situation

The salmon louse situation in 2020 at the national level was similar to that of the previous year. Production of louse larvae was greatest in POs 2, 3, 4 and 6, both in terms of year-averages and during the wild smolt migratory period. Larval production during the outward migratory period for wild salmon was lower or equal to the previous year, with the exception of POs 2 and 8. Larval production has therefore decreased in the most important areas for wild salmon during their outward migration, but the overall annual figures are more variable.

Use of non-medicinal delousing methodologies increased in 2020 from 2019 (collective increase of 21%), and a slight reduction in use of pharmaceutical treatments (collective decrease of 9%) was recorded. Use of azamethiphos increased for the second consecutive year, while hydrogen peroxide use nearly halved. Resistance against pharmaceutical treatments remains widespread, and in consequence most farms can expect poor effect of any eventual pharmaceutical treatment.

Since 2017, the majority of anti-salmon louse treatments have been non-medicinal. In 2020, non-medicinal treatments were reportedly used more than four times as often as medicinal treatments. Fish health personnel reported, via the annual survey, that thermal and mechanical treatments in particular result in increased post-treatment mortality. As there were 2652 reported treatments using these technologies in 2020, this probably accounts for a considerable proportion of the overall mortality reported for salmon and rainbow trout farmed in the sea. In addition, post-delousing injuries were considered one of the most important causes of reduced welfare in both salmon and rainbow trout in this year's survey. This further underlines the relationship between delousing activities and fish welfare. The number of thermal and mechanical delousing treatments has increased markedly each year since 2016 in the absence of any marked reduction in number of medicinal treatments. The welfare challenges represented by this increase are discussed in Chapter 3.

7.2 *Caligus elongatus*

By Øivind Øines, Geir Bornø and Haakon Hansen

The parasite

Caligus elongatus is a parasitic crustacean in the same family (Caligidae) as the salmon louse, *Lepeophtheirus salmonis*. *C. elongatus* also lives on the skin of fish in seawater, but displays a much lower degree of host specificity than the salmon louse which is only found on salmonids.
C. elongatus has been identified in around 80 different species of fish including salmonids, Gadidae, herring, flatfish, gobies and lumpsucker. The lumpfish is a main host for this parasite and individual fish may be infested with several hundred parasites. *C. elongatus* is therefore not only a problem for salmon, but also for lumpfish used in control of salmon lice.

As the salmon louse, *C. elongatus* has a direct life cycle without intermediate hosts, comprising eight exoskeletal shifts. The developmental stages differ somewhat from those of the salmon louse. The adult lice are more mobile than the adult stages of the salmon louse and may shift host species, such that lice from lumpfish can infect salmon and vice versa under farming conditions. Cage held salmon and cleaner- fish within the same cage may become infected with *C. elongatus* from wild fish. High-density infections may therefore appear suddenly in the absence of a gradual build-up of louse numbers.

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

C. elongatus can be readily distinguished from *L. salmonis* by the presence of so-called lunules on the anterior ventral surface of the cephalothorax (head) and by their more transparent exoskeleton, are generally smaller and often more mobile than the salmon louse. Experience is required however to distinguish the two lice with certainty. Their greater mobility means that *C. elongatus* may hop off the fish prior to counting. *C. elongatus* is more sensitive to changes in salinity and readily abandon fish in low salinity water.

Control

Infestations have been reported which are so problematical that they have required treatment. Good results are reported after emamectin benzoate (Slice vet.) treatment of *C. ellongatus*.

The health situation in 2020

The annual survey

Most respondents to the survey who have experience with *C. elongatus* consider this parasite to be associated with reduced welfare in ongrowing salmon, and some consider it a contribution to mortality. Several also crossed off *C. elongatus* infection as an increasing problem in ongrowing salmon. There were few respondents with experience of *C. elongatus* infection in broodstock salmon, but the few who replied consider this to be an increasing problem that can result in reduced growth. *C. elongatus* infection was not registered as a problem in rainbow trout in either ongrowing or broodstock farms.

Evaluation of the *C. elongatus* situation

C. elongatus infections do not appear to have increased in number in 2020.

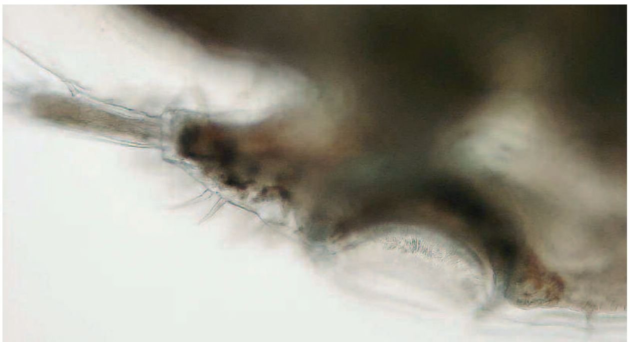


Figure 7.2.1. The lunules, small pits (~0.3mm) found in the anterior part of the head of parasites belonging to the genus *Caligus*. Their presence/absence can be used to distinguish the salmon louse (*Lepeophtheirus*) from species such as the cod-louse *Caligus curtus* and the sea-louse *Caligus elongatus*

7.3 *Parvicapsula pseudobranchicola* (parvicapsulose)

Av Haakon Hansen, Lisa Furnesvik og Geir Bornø

The disease

Parvicapsulosis, caused by Parvicapsula pseudobranchicola has been recognised as a particular problem in salmon farming in Troms and Finnmark since 2002, and may result in high mortality in ongrowing salmon.
P. pseudobranchicola is a eukaryotic parasite belonging to the Myxozoa, Class Myxosporea, myxosporideans. *P. pseudobranchicola* has a complex lifecycle with a polychaete worm as its main host and fish as the intermediate host. The parasite is a normal finding in wild salmonids (salmon, seatrout and char) along the entire Norwegian coast.

The target organ for *P. pseudobranchicola* is the pseudobranch, which supplies oxygen rich blood to the eye. The parasite spores accumulate in that organ and can cause considerable damage, which can result in complete degeneration of the pseudobranch. This results in reduced blood and oxygen supply to the eye, which may lead to reduced vision or blindness.

For more information on *P. pseudobranchicola* see the factsheet.
https://www.vetinst.no/sykdom-og-agens/parvicapsula-pseudobranchicola

The health situation in 2020

Data from the Norwegian Veterinary Institute and other laboratories

In 2020, the Norwegian veterinary Institute identified the parasite during histopathological investigation of 28 farming sites. This is around the same level as in 2019, and slightly fewer than identified in 2017 (35 farms). On consolidation of these results with those of private laboratories, a total of 37 unique farming sites were diagnosed with *Parvicapsula pseudobranchicola* in 2020. These diagnoses include both histopathological diagnoses and PCR detections. Private laboratories have identified infections in POs in which the Norwegian Veterinary Institute has not. The parasite has been detected in the following POs (the figures in parenthesis show the number of affected sites): PO2 (1), PO4 (1), PO5 (1), PO7 (4), PO8 (1), PO9 (3), PO10 (6), PO11 (8) and PO12 (12).

The annual survey

Parvicapsulosis has for many years been recognised as a recurring and significant problem in ongrowing salmon particularly in the northernmost regions. Responses to the annual survey for 2020 do not appear to contradict previous experiences (see figure 3.2.1C in Chapter 3 'Fish welfare'). This disease is reported to cause significant mortality and reduced growth. Serious outbreaks represent a serious welfare problem. Some respondents consider parvicapsulosis to be on the increase in ongrowing salmon and one respondent reported reduced growth in salmon broodstock.

Evaluation of the parvicapsulosis situation

Parvicapsulosis is an important disease in farming of ongrowing salmon. While the parasite is widely present in wild salmon along the coast, the disease is a particular problem in the northernmost regions of the country, and in Troms and Finnmark in particular. This trend appears to have continued in 2020. There are no treatments available and research on this disease is complicated due to the final host for the parasite remaining unknown. The disease causes increased mortality, reduced welfare and reduced growth. The parasite has also been identified in ongrowing fish in other regions, but clinical disease does not appear to be a problem in the south 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* (synonym *Neoparamoeba perurans*). AGD is not a notifiable disease.

Since the mid 1980's the disease has caused large losses in production of farmed salmon in Tasmania. In the mid 1990's *P. perurans* was discovered in the Atlantic Ocean and the amoeba has since been steadily identified 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.

P. perurans and AGD were first identified in Norwegian aquaculture in 2006, but were not identified in the years immediately following. The disease has however, since 2012, caused considerable losses to the industry. Genetic analyses reveal differences between the amoeba involved in the 2006 outbreaks and later outbreaks. The origins of the amoeba involved in the Norwegian outbreaks are not known. AGD occurs in fish farmed in seawater, primarily causing disease in Atlantic salmon, but has been detected from rainbow trout, turbot, lumpsucker and various wrasse species and has caused disease in some of these species.

The two most important risk factors for outbreak of AGD are considered to be high salinity and relatively high seawater temperatures. Pathological changes are limited to the gills where white mucoid patches may be macroscopically observed. Amoeba may be observed in fresh microscopy preparations of gill tissues or by PCR. Reliable diagnosis is based on histology of affected gill tissues.

Control

AGD is treated either with hydrogen peroxide (H_2O_2) or freshwater. Neither method appears to be 100% effective and treatments must commonly be repeated several times within the same production cycle. Treatment with freshwater is the milder form for salmonid fish and appears to be more effective than H_2O_2.

Treatment of AGD has best effect when performed in the early stages of disease development. This reduces the probability of treatment relapse and extends the inter-treatment period. It is therefore important to monitor the prevalence of amoeba in farmed fish in order 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 classification of the macroscopically visible changes associated with AGD. This scoring system is an important tool for Fish Health Services. Scoring of gills can be challenging following repeated treatment and may require considerable experience.

Since a number of other factors/agents may cause similar changes to the gills, it is important to confirm the diagnosis by histological investigation.

For more information on AGD see: https://www.vetinst.no/sykdom-og-agens/amobegjellesykdom

The health situation in 2020

Data from the Norwegian Veterinary Institute

Since AGD is not notifiable and diagnoses are often made locally by Fish Health Services, it is not possible to identify precisely the number of farms affected. Suspicion of AGD arises normally following visual macroscopic examination. PCR and histology are then used to confirm the suspicion.

In 2020, the Norwegian Veterinary Institute diagnosed AGD in 20 salmon and rainbow trout farms from Vestland region in the south to Trøndelag in the north. This is a reduction from 2019 (28) and 2018 (39). AGD has not yet been identified north of Nordland. There is, however, limited sampling for AGD in the north of the country.

Positive AGD diagnoses made by the Norwegian Veterinary Institute cover a smaller area of the country than previously. The disease was not diagnosed in Rogaland or Nordland. The Norwegian Veterinary Institute did not diagnose AGD in rainbow trout in 2020. This may reflect the general fall in number of diagnostic submissions made to the Norwegian Veterinary Institute.

The annual survey

Replies to the annual survey show that AGD is not considered a major problem as far as mortality in ongrowing salmon is concerned. The disease is, however, considered to be a major cause of reduced welfare and reduced growth. It is also considered by many respondents to be a problem on the increase. In ongrowing rainbow trout, AGD is considered to be a significant and increasing problem and is considered a moderate problem in relation to mortality. Reduced welfare was rated high, while reduced growth was not considered a significant problem in rainbow trout.

For salmon broodstock, AGD scored lowly in relation to mortality and as an increasing problem, but was considered to make a moderate contribution to reduced growth and a major cause of reduced welfare. For rainbow trout broodstock, AGD was considered only a minor problem in 2020, which is in contrast to 2019 when it was considered an important cause of mortality. See Appendices B1-2 and C1-2 for details of the annual survey 2020.

Use of louse-skirts is considered a risk-factor for AGD.

Evaluation of the AGD situation

AGD has become established and continues to be a serious fish disease in Norway, and the disease appears to be spreading further north each year. 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 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.

7.5 Tapeworms – *Eubothrium* sp.

By Haakon Hansen and Geir Bornø

The disease

Tapeworms (Cestoda) belong to the flatworm group (Platyhelminthes), which as adults may be found as parasites in the intestines of animals. Tapeworms have complex lifecycles involving several host species. Fish can represent both intermediate and terminal host for different species of tapeworms. Farmed salmon may be infested with *Eubothrium* sp. during the marine phase of culture. This parasite has copepods as the first intermediate host and the fish become infected upon ingestion of an infected copepod. Tapeworm become attached by the head (scolex) to the digestive caecae of the fish and adults produce large numbers of eggs which are released to the water in faeces. In untreated fish, tapeworms can reach a considerable diameter and be longer than 1 meter. Tapeworm infestations can result in increased feed consumption and reduced growth in affected fish. Tapeworms belonging to the genus *Eubothrium* can be found in wild salmon along the whole coast, but are normally not found in farmed fish north of Trøndelag.

Control

Eubothrium sp. are treated with praziquantel, but there have been reports of lack of effect and praziquantel use has fallen in recent years. Between 2010 and 2015 there was a marked increase in sales of this substance. Sales fell substantially between 2016 and 2019, when sales of 50kg were registered. In 2020, consumption once again increased, with 124 kg prescribed (see chapter 2, table 5).

The health situation in 2020

The health situation in 2020

Data from the Norwegian Veterinary Institute

The Norwegian Veterinary Institute identified tapeworm in ongrowing salmon in 19 farms compared to 10 the year before. Most of these farms lay in the south-west and middle areas of the country. These figures most probably do not reflect the true distribution of tapeworm nationally as there is no systematic registration of tapeworm diagnoses.

The annual survey

Of those respondents who consider tapeworm a problem in ongrowing salmon, mots consider it a problem in relation to reduced growth. There are also reports of reduced welfare in salmon, but tapeworm are not considered an important cause of mortality. Reduced welfare and growth are also mentioned as problematic in broodstock salmon. For rainbow trout, tapeworm were not considered a problem by any of the respondents.

Evaluation of the tapeworm situation

An increasing prevalence of tapeworm has been reported in sea-farmed Atlantic salmon since 2010 particularly in western and mid-Norway. Most diagnoses are made by fish health services. These parasites are as a rule not identified to species level, but it is assumed that most diagnoses involve the same species.

As in 2019, replies to the survey indicate that there are fewer problems related to tapeworm, but that that tapeworm represent a persistent problem. The generally low consumption of praziquantel over the last three years may be due to development of resistance to this product, but may also be related to the bureaucratic process required before this treatment may be prescribed. This is due to lack of a marketing licence for its use in fish.

The tapeworm, *Eubothrium* sp. Photo: Jannicke Wiik Nielsen, Norwegian Veterinary Institute

8.0 Miscellaneous health problems in farmed salmonids

By Geir Bornø

This chapter presents diverse non-infectious health problems in farmed fish including production related and environmentally based complaints. Here we discuss 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 side effects (chapter 8.6).

The Norwegian Veterinary Institute has in recent years observed an increase in the number of cases involving poor gill health, often involving several different agents. This observation is supported by replies to the annual survey in 2020, in which complex gill disease was ranked as one of the five most important increasing health challenge to ongrowing salmon.

Smoltification problems and development of runts continues to be considered an important problem along the whole coast. This appears to be particularly challenging in relation to production of large smolts displaying variable smoltification status and consequent difficulty in identifying an optimal time for sea-transfer. Norwegian Veterinary Institute data and replies to the annual survey suggests that this was not an increasing problem in 2020.

Nephrocalcinosis is a well-known condition in farmed fish and is considered a production related disease. Just over 110 farms were diagnosed with nephrocalcinosis in 2020, which is around the same level as previous years.

The real number of cases is likely to be much higher however as the condition is commonly diagnosed without submitting samples for laboratory confirmation. In the annual survey, nephrocalcinosis was ranked as the most important of the five most important increasing health problems in juvenile production of salmon and rainbow trout and is considered one of the most increasing problems in salmon hatcheries.

Haemorrhagic smolt syndrome is also reported to be a relatively important disease resulting in mortality particularly during the freshwater phase of production, but also immediately following sea-transfer. The cause of this disease remains unknown and it is speculated that it may be related to osmoregulatory failure during smoltification. This disease is considered the most important cause of mortality during juvenile salmon production and is considered by some respondents to represent an increasing problem.

Good water quality is essential for good fish health. While there have been previous incidences of hydrogen sulphide poisoning in RAS facilities, fewer problems are now reported. There are reported water quality problems caused by high biomass densities during large smolt production.

The Norwegian Veterinary Institute occasionally registers tissue damage related to injection with oil-based vaccines. While few respondents to the annual survey consider vaccine side effects to represent a serious problem relative to other diseases/conditions, some consider vaccination to represent a welfare problem, and slightly increased mortality as a result of vaccination is reported from hatcheries.

8.1 Gill disease in farmed salmonids

By Brit Tørud, Anne Berit Olsen and Mona Gjessing

The disease

Gill anatomy and function

The gills of fish are multifunctional organs with 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. The gills have important immune defence functions. 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 lifecycle 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.

In some cases there may be a single triggering infection behind outbreaks of gill disease, but more commonly the causes are complex. This may result in difficulty in interpretation of the importance of individual agents or environmental conditions in relation to the pathological changes involved.

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 purification systems do not operate optimally, considerable differences in the amount of e.g. metals are experienced with changing season. Precipitation of iron and poisonous aluminium compounds on the gills may result in acute, high mortalities. In marine farms precipitation of aluminium compounds may occur during freshwater AGD or salmon louse treatments.

In recirculation aquaculture systems (RAS), based farms particles and metals may increase in the water and lead to gill irritation. There are also indications that pathogenic agents may accumulate in enclosed systems. For more information on water quality in land- and sea- based farms, see chapter 8.4 Water quality.

Bacterial gill disease or infection with the oomycete *Saprolegnia* spp. 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 pox virus (see Chapter 4.8 Salmon pox).

Algal and jellyfish blooms can also injure gills during the sea phase of culture in Norway, as can fouling organisms e.g. hydroids, freed from the cage sides during net cleaning. Hydroids (Figure 8.1.1 and the cover of this year's Fish Health report) are a Cnidarian, closely related to the jellyfish and can dominate the fouling organism population of a farm cage. Secondary infections with ubiquitous marine bacteria e.g. *Tenacibaculum* may often follow such events. For further details on the individual microorganisms see relevant chapters on AGD (Chapter 7.4) and SGPV (Chapter 4.8).

There are good grounds 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 degree 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 checking of gill health is therefore very important (Figure 8.1.2).

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.

In an effort to improve gill disease diagnosis, the Norwegian Veterinary Institute has developed a multiplex PCR (gill package) that detects four organisms related to gill disease in the marine phase: *Paramoeba perurans, Desmozoon lepeophtherii, Ca*. Branchiomonas cysticola and Salmon gill poxvirus. Comparison of PCR results with histopathological analysis is recommended to allow identification of the pathogens and extent of the tissue damage. Recently developed histopathological methods represent important advances in interpretation of the dynamics involved in development of gill injuries. Using special staining, immunohistological methods and molecular hybridisation (RNA-scope) the microorganisms may be visualised in affected tissues and thereby provide valuable information on the cause and effect on gill tissues (Figure 8.1.3).

Control

There are indications that smolts may already be infected with gill pathogenic microorganisms at sea-transfer. Disinfection of the biofilter should be considered in cases of recurring gill disease in freshwater. On outbreak of disease due to salmon pox, feeding should be ceased, stress avoided and adequate oxygen levels maintained.

Regular *in situ* cage net cleaning using high-pressure washers releases biofouling organisms like the hydroid *Ectopleura larynx* (Fig 8.1.1), which may cause irritation and damage to the gills of Atlantic salmon. Efforts to avoid exposure to released biofouling organsims is importance to avoid gill problems.

Treatment of *Paramoeba perurans* is discussed in Chapter 7.4 Amoebic gill disease (AGD).

The health situation in 2020

Gill complaints are non-notifiable and are not reported to the Norwegian Food Safety Authority. The prevalence of these conditions nationwide cannot therefore, be estimated with any degree of certainty.

Over 70% of submissions received by the Norwegian Veterinary Institute from hatcheries in which gill injuries are registered as the main or partial diagnosis are submitted between January and June. Several farms experience extended periods of disease, lasting several months. The dominating findings include gill irritation (most commonly increase in size and the number of epithelial cells) without any specific identifiable cause. There are reasons to believe that water quality is an important factor in such cases. Few cases involving parasites or fungus have been identified. Infection with

Figure 8.1.1. Electron-micrograph of a hydroid. Photo and colouring: Jannicke Wiik-Nielsen.

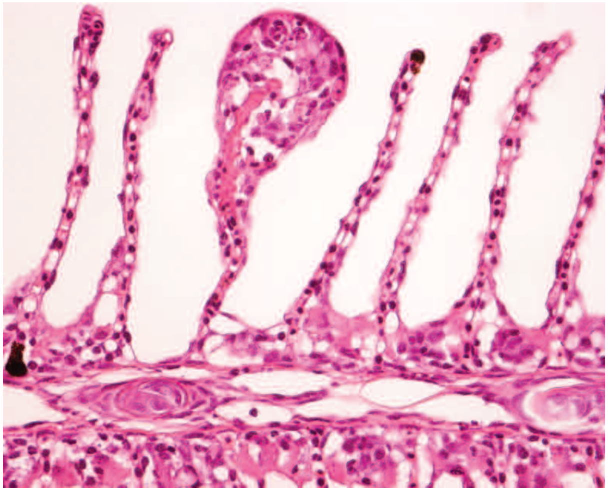


Figure 8.1.2. Respiratory unit with blood vessel damage caused by jellyfish (laboratory trial). Photo: Mona C. Gjessing.

salmon gill poxvirus (SGPV) is discussed in Chapter 4.8.

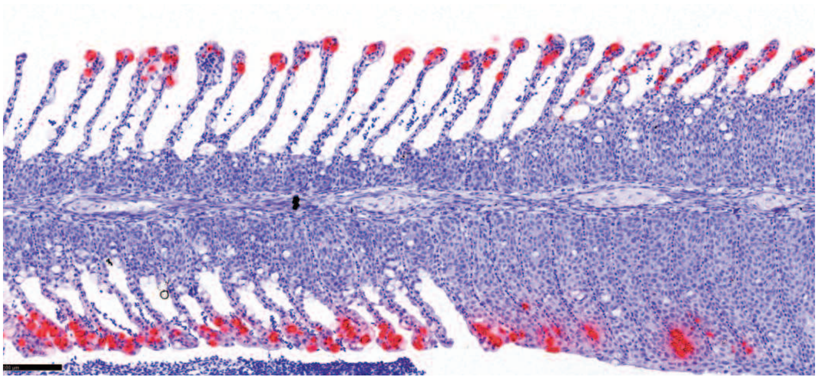
In 2020, submissions to the Norwegian Veterinary Institute involving gill disease in ongrowing fish were spread evenly throughout the year, with slightly fewer submissions received in the period June - September. In previous years, submissions peaked in the Spring/early summer and in the autumn. In some farms the conditions appeared to persist over time. Most submissions involved salmon, with only a small proportion from rainbow trout. In a number of cases a complex aetiology was suspected.

A number of statistics are available for the gill pathogen *Ca*. Branchiomonas cysticola, based on registrations made by the Norwegian Veterinary Institute and private laboratories. The bacterium was detected by PCR in a total of 78 marine salmon farms and one rainbow trout farm. The bacterium was also detected in two hatcheries. *Ca*. Branchiomonas cysticola is most commonly identified in association with epitheliocystis in the gills. There were in addition, a number of histologically diagnosed cases of epitheliocystis in the gills.

The annual survey

In the annual survey, fish health personnel and inspectors of the Norwegian Food Safety Authority were asked to indicate the 5 most important health problems of 2020 and how relevant they were for: mortality, reduced growth, reduced welfare and increasing prevalence. For salmon in the hatchery phase, gill disease was ranked as one of the most important causes of mortality and reduced growth. Opercular deformities scored highest as the most important cause of reduced welfare in salmon, while rainbow trout scored equally low for all categories.

In ongrowing salmon and rainbow trout, complex gill disease is considered one of the most important causes of increased mortality. Complex gill disease also scores relatively highly in terms of reduced growth, reduced welfare and as an increasing problem. For details regarding ranking of gill health problems see appendices A – C.



Figur 8.1.3. In situ hybridisation for detection of *Ca* B.cysticola (red colour). Photo: Mona C. Gjessing.

8.2 Poor smolt quality and runt syndrome

Av Jinni Gu og Synne Grønbech

Poor smolt quality can increase the risk of abnormal development, growth and health in sea-transferred salmonid fish. Osmoregulatory problems related to poor smoltification lead to increased stress levels with a resultant greater risk of disease development and mortality in the period following sea transfer.

Challenges related to smoltification in the hatchery include poor water quality, high biomass density, irregular light regime, early sexual maturation, development of ‘pseudo’ smolts, uneven smoltification, desmoltification etc etc. Diseases, both infectious and non-infectious will disturb the smoltification process. Haemorrhagic smolt syndrome (HSS), skin ulcers, salmon pox and nephrocalcinosis will all affect smolt quality negatively. Good control of smoltification, with sampling from fish representative of the population as a whole combined with precise evaluation of smoltification status are important for production of good quality smolts.

‘Runting syndrome’ is a term used to describe a condition in which the fish become emaciated and do not grow normally. While the term is usually used to describe fish post sea-transfer, runted fish may also be found in hatcheries. Typical histological findings include little or no fat around the internal organs (perivisceral fat) and increased melanin containing pigment in the kidney. Bacteriological and virological investigations are commonly 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 surviving 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 may also increase the probability of runt development. Optimal smoltification and transfer to sea at the correct time, good follow up during the first period in seawater and optimising of feeding strategies are important for normal development, growth and health in salmonid fish

It is considered likely that runted fish are more susceptible to parasitic infection and disease in general and thereby represent a significant risk of disease transmission.
Tapeworm infections are a normal finding in runted fish. Runted fish may also survive for extended periods and represent a welfare problem. In many cases 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 reduction of the risk of transmission.

The health situation

Data from the Norwegian Veterinary Institute

Lack of systematic registration of the prevalence of smoltification related problems, smolt quality and runted fish make compilation of reliable statistics difficult. We have however, attempted to provide an oversight of the situation based on information received by the Norwegian Veterinary Institute from Fish Health personnel.

Problems associated with runt development were investigated by the Norwegian Veterinary Institute in 14 ongrowing farms in 2020. The prevalence has fallen by almost 50% compared with 2018 and 2019. The diagnosis ‘emaciation’ was awarded in 11 ongrowing farms in 2020, which is a level similar to 2018 and 2019. As in previous years, runt development was only associated with salmon. Most affected farms are located in mid- and northern- Norway and the geographic pattern seems fairly stable.

The annual survey

In the annual survey, fish health personnel and inspectors of the Norwegian Food Safety Authority were asked to indicate the 5 most important health problems of 2020 and how relevant they were for: mortality, reduced growth, reduced welfare and increasing prevalence on ongrowing farms and hatcheries.

As far as problems with smoltification are concerned in the freshwater phase, the survey indicates that the problem is greater in salmon than in rainbow trout. Smoltification received the most crosses in relation to mortality and reduced welfare and was rated as the fourth and seventh most important cause of these parameters respectively. Only two respondents considered smoltification to be an important mortality related problem in rainbow trout.

Problems related to sea-transfer of poorly smoltified salmon are considered of minor importance by respondents to the survey. Smoltification appears to be considered a greater problem in salmon than in rainbow trout. Mortality and poor welfare in salmon seem to be particularly related to poor smolt quality.

Runt syndrome scores highly in regard to poor growth in both ongrowing salmon and rainbow trout, moderately in terms of reduced welfare and mortality in salmon, with a slightly greater impact in rainbow trout.

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

Evaluation of smolt quality and runt syndrome

The use of large smolts as part of the fight against the salmon louse and other viral and bacterial diseases continues to increase. Several RAS facilities are designed specifically for large smolt production, and some have established good routines for production of smolts up to 600g in weight. Increased biomass is challenging in terms of maintenance of good water quality and synchronisation of smoltification. Production of 'pseudosmolts' associated with continual light and seawater supplementation and desmoltification are mentioned as problematic in RAS farms. Unstable water temperature in flow-through farms is still challenging for smoltification, particularly in production of spring smolts.

In 2020, nephrocalcinosis and haemorrhagic smolt syndrome were still considered the most important challenges in salmon in the freshwater phase (see discussion in Chapters 8.2 and 8.3), and it may be presumed that HSS is a contributory factor to smoltification related mortality in the freshwater phase of culture.

Despite the fact that poor smolt quality remains closely linked to mortality, ulcer development and runt development in a number of farms/fish populations, data from the Norwegian Veterinary Institute and the annual survey indicates an improved situation compared to previous years. Health problems associated with poor smolt quality and runt development fell, thereby, out of the top ten list of problems of ongrowing salmon in 2020.

The health related challenges associated with runt development following sea-transfer remain greater in northern Norway than in the remainder of the country. Runt development in northern-Norway seems to have a clear association with Parvicapsula pseudobranchicola infection. Over the last two years 75% (2020) and 56% of populations affected by runting were also (or had been) diagnosed with Parvicapsulosis. Efforts to reduce the impact of parvicapsulosis will hopefully reduce the runt situation. Some fish health personnel report that vaccination with DNA-vaccines against PD appears to shorten the duration and lessen the effect of disease and results in fewer runted fish post-outbreak.

8.3 Nephrocalcinosis

By Anne Berit Olsen and Arve Nilsen

The disease

Nephrocalcinosis (calcium deposition in the kidney, kidney stones) is a normal finding in rainbow trout and is now also common in farmed Atlantic salmon. The disease is considered production related and is not infectious. Nephrocalcinosis related mortalities are generally low, but can be higher following sea-transfer and the condition is also associated with 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 changes in the excretory parts of the kidney, including calcium-containing deposits, are normally identified during histological investigations. The deposits cause blockage of the kidney tubules, resulting in dilation of these tubules. The cells (epithelial cells) lining the inner surfaces of these tubules are often damaged. Consequently the haemopoietic tissues surrounding the tubules will become fibrinous. In serious cases deposits may burst the tubule system and lead to inflammatory reactions and granuloma formation in surrounding tissues.

Precipitation in the kidney tubules will eventually be visible as longitudinal white stripes. The kidney may also be swollen and nodular. The changes may be extensive, such that kidney function may be severely compromised. 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 may probably result from different and possibly complex causes. The deposits can have different consistencies, which may indicate different composition or cause. They may also represent different stages of development following a common cause. Based on investigations performed it appears that the composition of the stones varies, but consist mainly of potassium phosphate, with magnesium also commonly 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.

It has also been speculated upon whether unstable water quality parameters may be a risk factor. The mechanisms are not completely understood, but it is thought that high CO_2 levels in the water may change the composition of blood plasma in the fish, resulting in metabolic challenges. While the recommended maximum concentration of CO_2 in salmon hatcheries is 15 mg/L, recent research has shown that injurious effects may occur at lower concentrations, perhaps particularly on supplementation of seawater. Several projects are currently focussing on identification of risk factors for development of kidney stones.

Nephrocalcinosis is a common finding in association with haemorrhagic smolt syndrome (HSS), see chapter 8.4. Typical HSS related findings include bleeding in the kidney tubules leading to production of bloody urine. Whether calcium precipitation is related to this bleeding is not yet known, but is under investigation.

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 at all stages of production. Mild and moderate kidney damage will most commonly heal without treatment. Extensive kidney damage does not heal and results in increased mortality.

Control

Nephrocalcinosis is mainly considered to be an environmentally dependent disease. 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 throughflow (specifically water consumption), will reduce the risk of nephrocalcinosis development. Systematic surveillance of water parameters and metabolic waste products, using equipment designed to suit the farms size and biomass production is important. Nephrocalcinosis may also be associated with nutritional imbalance. Feed composition adapted to the needs of the fish under different environmental conditions and developmental stages, may possibly contribute to prevention of this disease. There may also be grounds to reconsider seawater supplementation during smoltification and the transition to post-smolt.

The situation in 2020

There is uncertainty around the number of farms diagnosed with nephrocalcinosis in 2020, but consolidated data from the various diagnostic laboratories indicates that more than 110 farms were affected. This is clearly an underestimate and the real prevalence is unknown. The disease is non-notifiable and is commonly diagnosed locally in the field, based on typical macroscopically visible changes. Histologically diagnosed nephrocalcinosis is a normal 'additional' diagnosis during routine diagnostics or in relation to exclude notifiable diseases e.g. BKD may result in similar changes in the kidney.

The annual survey

In this year's survey, nephrocalcinosis achieved the highest collective score for hatchery based diseases in terms of mortality, reduced growth, reduced welfare and as an increasing problem, for both salmon and rainbow trout.

In ongrowing fish, nephrocalcinosis was ranked in the middle of the conditions resulting in poor growth and reduced welfare in salmon, but as an important cause of mortality in rainbow trout.

Respondents were also given the opportunity to score water quality as a parameter in relation to mortality, growth, welfare and as increasing problem in hatcheries. Water quality was ranked as the third most important parameter associated with the health of the fish, and was ranked highly in terms of fish welfare. There are grounds to believe that improvement in water quality may improve the nephrocalcinosis situation. For details, see Figure 8.5.1 in Chapter 8 'Water quality' and appendices A1-A2 and B1-B2.

Evaluation of the nephrocalcinosis situation

In the absence of official statistics of the prevalence of nephrocalcinosis it is impossible to identify the true impact of this condition in the industry. Based on the diagnostic material received and replies to the annual survey, we have reason to believe that it remains a normal diagnosis, with a high prevalence in many cases.

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

In marine sites, nephrocalcinosis is commonly diagnosed during the first three months following sea-transfer. There is a high probability that a significant proportion of these fish have been affected since the freshwater stage. Some farms have experienced high mortalities as a result of nephrocalcinosis shortly after sea transfer. The condition may be present for some months following sea-transfer, and was also identified in large fish in 2020.

Figure 8.3.1. In serious cases of nephrocalcinosis the kidney may become enlarged with white 'stripes' caused by calcium deposition in the urinary tracts. In this case the fish did not display clinical signs of disease, but the precipitations indicate abnormal physiological conditions that affect the health of the fish. Photo: Anne Berit Olsen, Norwegian Veterinary Institute.

8.4 Haemorrhagic smolt syndrome (HSS)

By Geir Bornø, Ingunn Sommerset 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 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 of high acute mortality are registered. The situation usually normalises within several weeks post sea-transfer.

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. On suspicion of HSS, samples should be taken for histological examination for HSS and for PCR detection of VHS-virus.

The health situation in 2020

Data from the Norwegian Veterinary Institute and other laboratories

Based on available consolidated statistics related to diagnosis of HSS, a total of 36 unique farms were diagnosed in 2020. Of these, 25 were hatcheries, 10 were ongrowing farms and 1 was a broodstock farm.

The annual survey

Fish health personnel and inspectors of the Norwegian Food Safety Authority, 39 of 45 respondents (87%) consider HSS to represent one of the 5 most important causes of mortality in hatchery raised salmon, and it is therefore considered the most important cause of mortality in this category of fish (Appendix A1).

As a cause of reduced welfare, 19 of 51 respondents (37%) considered that HSS is amongst the 5 most important causes of reduced welfare, while a smaller proportion (22%) consider it an important cause of reduced growth or as an increasing problem in hatchery raised salmon. HSS is considered a minor problem in hatchery raised rainbow trout. (Appendix B1).

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 both 2019 and 2020, HSS was, in the annual survey, considered the most common cause of death in hatchery raised 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) is to identify risk factors and aetiological relationships. It is perhaps surprising that HSS has had so little previous research attention.

Figure 8.4.1. Hatchery raised salmon with HSS, with visible haemorrhage in the skeletal musculature and liver. Photo: Lisa Furnesvik, Norwegian Veterinary Institute.

8.5 Water quality

By Sondre Kvalsvik Stenberg and Åse Åtland, Norwegian Institute for Water Research (NIVA) Aquaculture section

Water quality in aquaculture systems is one of the most critical parameters for ensuring high survival, good welfare and health in the farmed fish. The field of water quality is complex as many water quality parameters work together and may result in both negative and positive effects. New technologies such as RAS, increasing intensification, land-based production and large-smolt production also represent new challenges in monitoring of water quality. This is the third consecutive year in which water quality is discussed as a separate theme in this report and water quality was also included in the annual survey. Many of the water quality challenges reported for 2018 and 2019 were also relevant in 2020. Here we will focus on the trends we have observed over the last year in both land-based and sea-based farms.

Land-based farms

Negative effects of water quality on fish health and mortality were reported in both flow-through and RAS facilities in 2020. Some of these events were related to the quality (either chronic or episodic) of intake water, while others were related to water quality within the farm due to fish density, technical problems or unexpected events.

Gas supersaturation

There were several reports of acute mortality in hatcheries related to gas/nitrogen supersaturation in 2020. This is mirrored in replies to the annual survey, where 19% and 27% of respondents reported that gas supersaturation had a negative effect on the health of fish held in throughflow and RAS farms respectively in 2020. These results were also consistent with the situation reported in 2019, and underline gas supersaturation as an extremely important risk factor in hatcheries, particularly as this type of mortality commonly occurs suddenly.

Gas supersaturation can occur when water under high pressure comes into contact with air. It is important that the difference between 'dissolved' air and 'suspended' air is understood with respect to supersaturation. Dissolved air consists of individual molecules of gas distributed amongst water molecules, while suspended air is a mixture of air bubbles and water. Suspended air is visible as individual bubbles or cloudiness in the water, while dissolved air is invisible.

It is dissolved air that is measured in relation to total gas pressure (TGP). TGP is the sum of partial pressures of all the gas molecules dissolved in the water. If the sum of partial pressures is higher than the equilibrium content of dissolved gas at the surface, gas supersaturation has occurred. The equilibrium content is 100% TGP, so water at 110% saturation is 10% supersaturated. The gas content is mainly nitrogen (N_2) and oxygen (O_2). In water, the nitrogen content is normally around 64%, oxygen around 35% and other gases around 1%. With oxygen supplementation and CO_2 excretion from the fish, a 'normal' gas balance is not normally found in intensive fish farming.

Pressure, temperature and dissolved salts all influence gas supersaturation, with pressure and temperature being the most important. Simply put, there is less space for gas in warm, salty water. For each degree rise in temperature, the TGP increases by approximately 2.3%. Pressure is also important in that the fish are less susceptible to gas supersaturation at higher pressures. The effect of pressure compensation with increasing depth is approximately 10% per meter depth.

There is no clear upper limit for negative effects of gas supersaturation in Atlantic salmon. While the limits established for pacific salmon vary from region to region and country to country, available literature generally report acute mortality from 100% TGP, with increased mortality and sub-lethal injuries at lower values. It is therefore presumed that mortality in Atlantic salmon is likely to occur between 110 and 120% TGP.

ILAB and NORCE performed laboratory trials in 2018 where they exposed Atlantic salmon par to different gas concentrations (100-130 TGP). Symptoms of acute gas bubble disease (GBD) with acute mortality and morbidity were observed within a few hours. At 114.8% TGP acute mortality occurred within 24 hrs. Cage trials in rivers have also identified mortality related to gas bubble disease in Atlantic salmon exposed to 110 TGP (Stenberg et al. 2020).

In fish farming, gas supersaturation has normally been considered to represent high nitrogen partial pressures rather than TGP. The reason for this is that the fish use oxygen dissolved in the water, and oxygen has therefore been considered less dangerous than nitrogen. Nitrogen is not used by the fish, and may therefore represent an indicator that air (mostly nitrogen) under pressure has entered the system and become dissolved in the water. The problem with this is that acute mortality can also occur at low nitrogen concentrations. With nitrogen levels at 102%, which is often considered the upper limit in the literature (e.g. Lekang, 2007 and Noble et al. 2018), the TGP may be 110%, which has resulted previously in mortality (at e.g. O_2 138%, CO_2 10 mg/l and temp. 10 °C).

A study performed by Dawley and Ebel (1975) demonstrated the importance of TGP by exposing two groups of fish to identical levels of nitrogen saturation (115%), but different oxygen saturation (98.8 and 88.2%). This resulted in 50% mortality in fish exposed to the higher O_2 levels and no mortality in the fish exposed to the lowest O_2 level. The TGP values for high and low O_2 levels were 112% and 110% respectively. Nitrogen saturation is nevertheless an important parameter for surveillance, as it indicates air being drawn into the water.

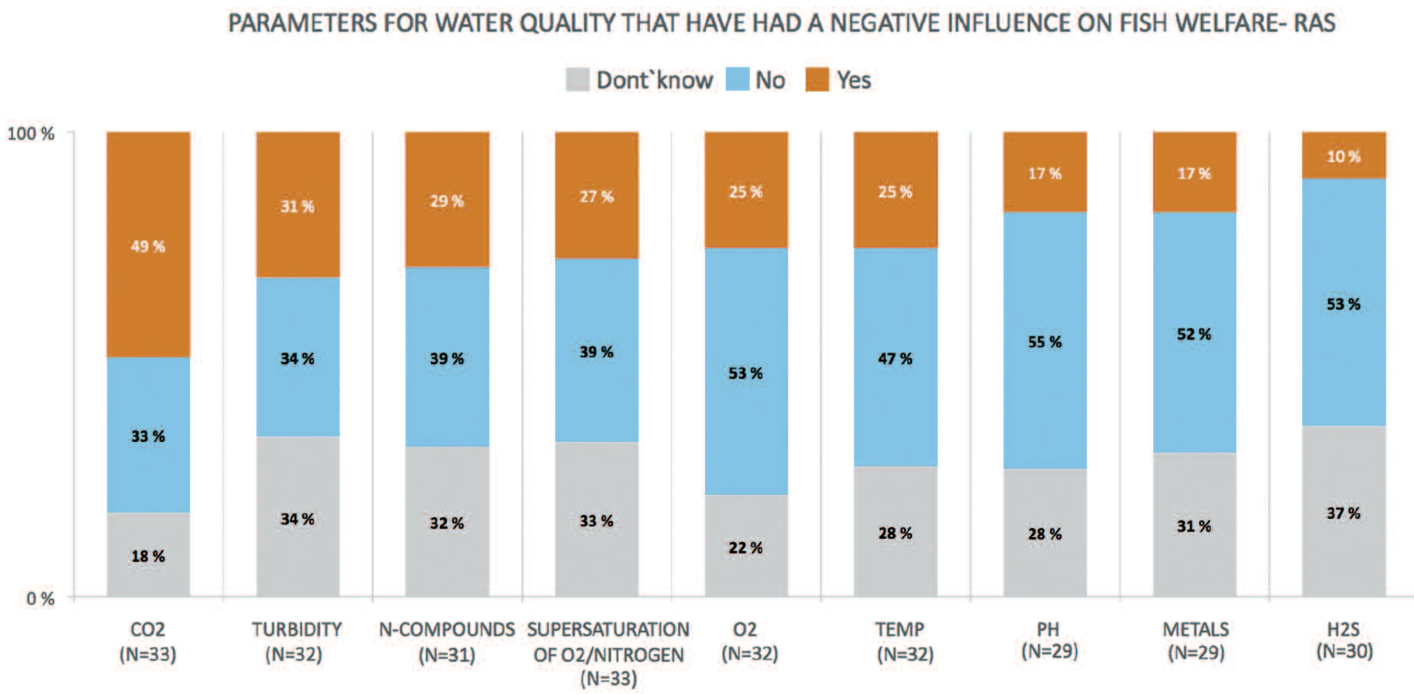


Figure 8.5.1. Proportion of respondents who stated that they had, in 2020, experienced that various water quality parameters had influenced fish welfare negatively in recirculation farms (RAS). The number of respondents are given following each water quality parameter (N). N-compounds = Nitrogen compounds.

Episodes of acute mortality related to high TGP values were registered in 2020 in throughflow farms, RAS farms, well-boats and snorkel-cages. Some of these supersaturation events were caused by intake of air under pressure, lack of equilibration with air at normal water pressure in combination with high O_2 and increased nitrogen values and rapid temperature increases in combination with pressurised air, used for 'stirring' in snorkel-cages. Another important factor in regard to supersaturation is the apparent lack of stable and robust equipment for monitoring TGP.

Hydrogen sulphide

Large scale mortality episodes in 2018 and 2019 resulted in a focus on hydrogen sulphide. Hydrogen sulphide is formed by bacterial degradation of sulphate containing organic substances. Such degradation to H_2S requires the presence of sulphate, low nitrate levels and anaerobic conditions. Seawater contains more than 1000 times more sulphate (SO_4) than freshwater and the risk of hydrogen sulphide formation is therefore greater in seawater.

We have observed fewer incidences of acute mortality

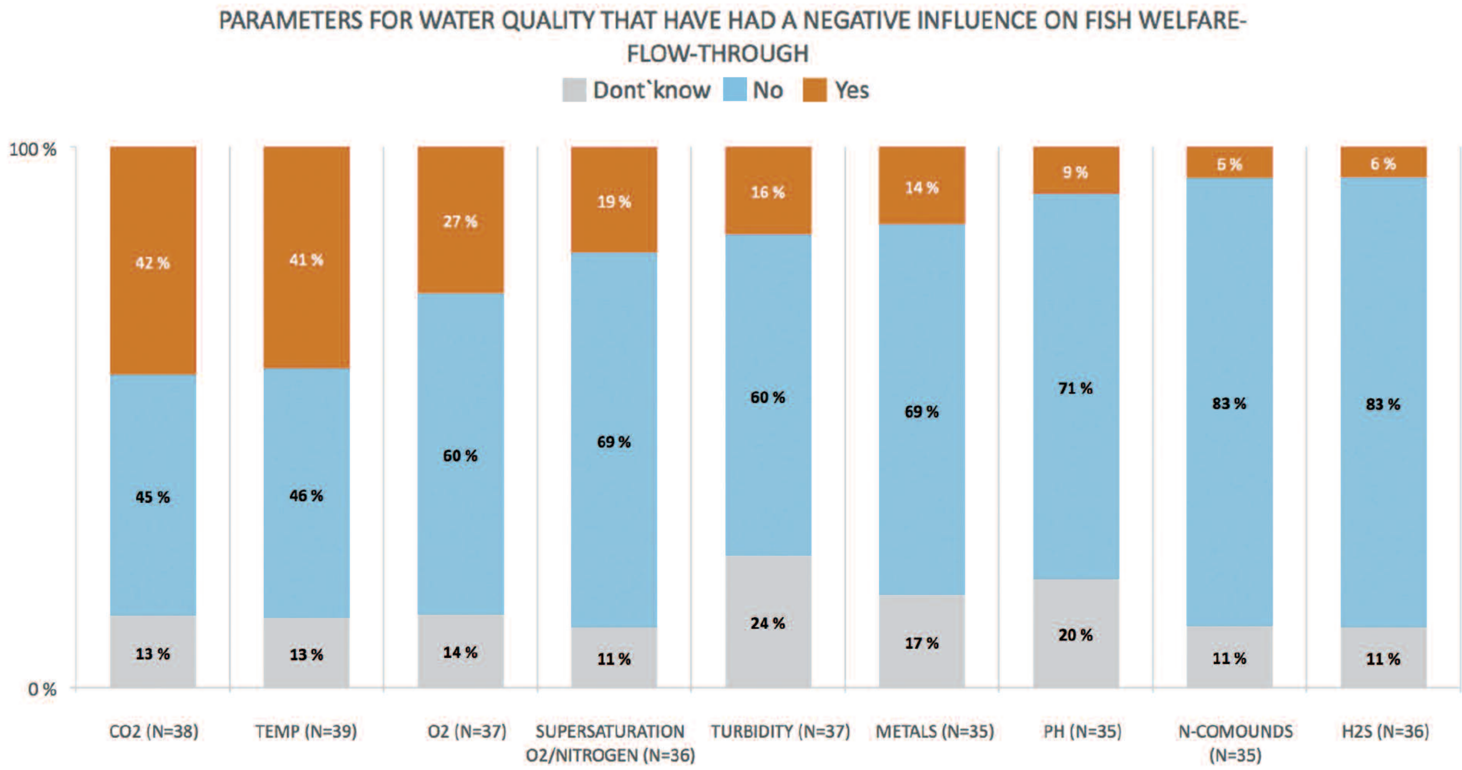


Figure 8.5.2 Proportion of respondents who stated that they had, in 2020, experienced that various water quality parameters had influenced fish welfare negatively in throughflow farms. The number of respondents are given following each water quality parameter (N). N-compounds = Nitrogen compounds.

related to H^2S poisoning in 2020 than in the previous two years. As improved analytic methods now allow identification of lower concentrations of H_2S than previously, H_2S production has been identified in more farms. Increased focus on H_2S in the industry has led to introduction of counter measures in a number of hatcheries to reduce the risk of H_2S production (feeding, sediment, cleaning, pH-regulation), and monitoring of H^2S levels, optimise throughflow and removal of water flow 'dead zones'.

The trend in fewer events was reflected in responses to the annual survey. In 2018, 57% of respondents had experienced H^2S problems in RAS farms, in 2019, 31% had experienced the same type of problem, while only 10% had experienced H^2S related problems in 2020. We hope that increasing knowledge of the problem has helped in this reduction in number of cases.

Aluminium

NIVA have received several reports of mortality and reduced appetite in fish in relation to increased concentrations of aluminium (Al) in both throughflow and RAS farms. Aluminium is a naturally occurring metal in rocks and soil and is released into freshwater bodies following acid rain and under low pH conditions. International agreements have led to a significant reduction in sulphur pollution in Norway. A number of smolt production facilities in the south of the country continue to suffer low pH and higher aluminium concentrations in the intake water than is desirable. Aluminium deposits on the fish gills, resulting in problems related to ion regulation and gas exchange. Smolts are particularly sensitive as aluminium on the gills results in reduced Na-K-ATPase activity. In throughflow farms, such events occur following heavy rainfall or snow melting, particularly after long dry periods. In RAS farms there have been several incidences of Al accumulation in the gills following increased introduction of freshwater (e.g. on suspicion of poor water quality within the farm). Several of the hatcheries experiencing aluminium related mortality in 2020 had mixed freshwater and seawater. Mixing of aluminium rich freshwater with seawater increases the risk of mobilisation of poisonous aluminium, particularly in the region 1 – 10 ppt. This is particularly relevant on use of humus rich freshwater, which may have considerable levels of metal bound to organic material/humus, which is in turn released on addition of seawater in combination with low pH.

The mechanisms behind this phenomenon were described in the Fish Health Report 2018. There are also well documented effective treatments for reduction in the toxic effect of aluminium for fish described in the Fish Health Report 2019.

Problems with other metals

NIVA has in 2020 as in 2019, observed a number of cases involving increased copper (Cu) concentrations in RAS and throughflow farms, which may be related to the freshwater source, from faeces, feed or from technical installations. Increased levels of zinc (Zn) also caused problems, particularly during well boat transport. The source of the zinc has not been identified with certainty, but leakage from zinc anodes is one of several possibilities. This should be studied more closely.

Sampling of gills for quantitative metal analysis is, together with water sampling and histological analysis, an important tool for identification of the actual cause in suspected cases of metal toxicity. When the results of these analyses are discussed by farm employees, fish health personnel, histologists and water chemists they form a good basis for knowledge generation and prevention.

Insufficient calcium levels

Extremely low calcium levels were identified in several hatcheries during 2020. RAS farms seem to be particularly susceptible to this problem and in several farms < 0.5 mg Ca/L were identified. The affected RAS farms are mainly those utilising clean freshwater buffered with either sodium hydroxide or bicarbonate. Hatcheries in Norway generally display low calcium concentrations (average = 1.9 mg/L), but on buffering with NaOH, the free calcium in the water will be used up in forming alkalinity and thus lead to a drop in calcium concentration in the water.

The lower acceptable limits for calcium concentration in the water for Atlantic salmon is not known, but it is known that calcium concentrations of > 2 – 2.5 mg Ca/L provide protection against metal related gill damage. It has been shown that fish exposed to calcium levels below the minimum threshold may display weakened ion regulation, delayed hatching and growth (this is not studied in Atlantic salmon).

Calcium helps the fish retain salt and prevents cell membrane leakage by reducing its permeability to ions. There should now therefore be focus on knowledge generation regarding the lower limits and optimal concentrations of calcium and other ions e.g. sodium for increased fish welfare.

The main causes of poor fish welfare in RAS and throughflow farms identified by the annual survey are considered to be CO_2, nitrogen compounds (ammonia and nitrite) and turbidity (Figure 8.5.1). These parameters are often directly related to the intensity of production in the affected farm. In contrast to RAS farms, temperature was also considered an important factor related to poor fish welfare in throughflow farms (Figure 8.5.2).

The responses to the annual survey are consistent with our own observations that these parameters rarely result in acute mortality, but have long term effects which weaken the fish. From the survey and conversations with farmers it is clear that there is a considerable frustration over the lack of suitable instrumentation for e.g. CO_2 measurement. Several RAS hatcheries have increased their focus on turbidity, sedimentation, bacteria, heterotroph activity and humus content, but there is little literature available on which they can base their management activities.

As various parameters associated with intensification in hatcheries are being linked to negative fish welfare in the survey, there remains a good deal of work related to farm dimensioning and water treatment, fish densities and water consumption to ensure good welfare.

Marine farms

Modulation of water quality in marine farms is often difficult with the only practical avenues being careful location and placement of the cages in relation to local currents. Replies to this year's survey were very similar to previous years.

Several respondents report increased levels of gill injury related to use of 'louse skirts'. This damage has been related to low oxygen levels and high temperature due to poor water exchange. Water temperatures were at times high during the summer of 2020, which resulted in direct mortality in a number of sea farms due to low oxygen levels. Problems with algae and jellyfish were also mentioned in the annual survey as a source of gill injury.

Similarly to 2019, mortality was reported in association with anti-fouling agent toxicity. There is a considerable need for increased knowledge and improved risk analyses prior to taking new anti-fouling substances into use. The risk of toxicity from antifouling agents used in nets increases when fish are crowded during e.g. delousing.

Summary

Many of the same water quality problems observed in earlier years in both freshwater and seawater farms, were again observed in 2020. The increased focus on H_2S in recent years seems to have paid off with fewer incidences reported.

Many hatcheries appear to have a greater focus on water quality as a result of intensification of production and use of RAS. In addition many hatcheries appear to have initiated routine sampling and storage of water samples allowing retrospective investigation of subsequent acute events.

Water quality in aquaculture systems is one of the most critical parameters for ensuring good survival, welfare and health. Photo: Colourbox

8.6 Vaccine side effects

By Kristoffer Vale Nielsen, Siri Kristine Gåsnes and Ingunn Sommerset

Fish may be vaccinated by dip, bath, via feed and by injection. In Norway, intraperitoneal injection of multivalent oil-based vaccines is the most common form of vaccination in salmonid fish, but the method also generates the most significant side-effects. Additional vaccination, with single component vaccines is common, utilising oil-adjuvanted intraperitoneal (e.g. inactivated PD or Yersinia vaccines) or non-adjuvanted intramuscular DNA vaccines (e.g. PD).

Vaccination of fish is regulated according to aquaculture legislation (Akvakulturdriftsforskriften, §§ 11 and 28) and chapter 13 of 'Trade and disease in aquatic animals' legislation. The legislation describes in general terms the requirement to perform relevant infection prevention measures including vaccination. From 1 July *2020 §7 of the PD-legislation came into force 'Salmon and rainbow trout transferred to sea in the area between Taksneset (Fræna) in the south to Langøya by Kvaløya (Sømna) in the north, shall be vaccinated against PD'.*

Farmed salmon in Norway are normally vaccinated against furunculosis, vibriosis, coldwater vibriosis, winter-ulcer (M. viscosa) and IPN. Vaccination against PD has been normal in Vestlandet (endemic area for SAV3), but less so in Trøndelag (endemic area for SAV2). In Trøndelag and parts of Vestlandet it is usual to vaccinate

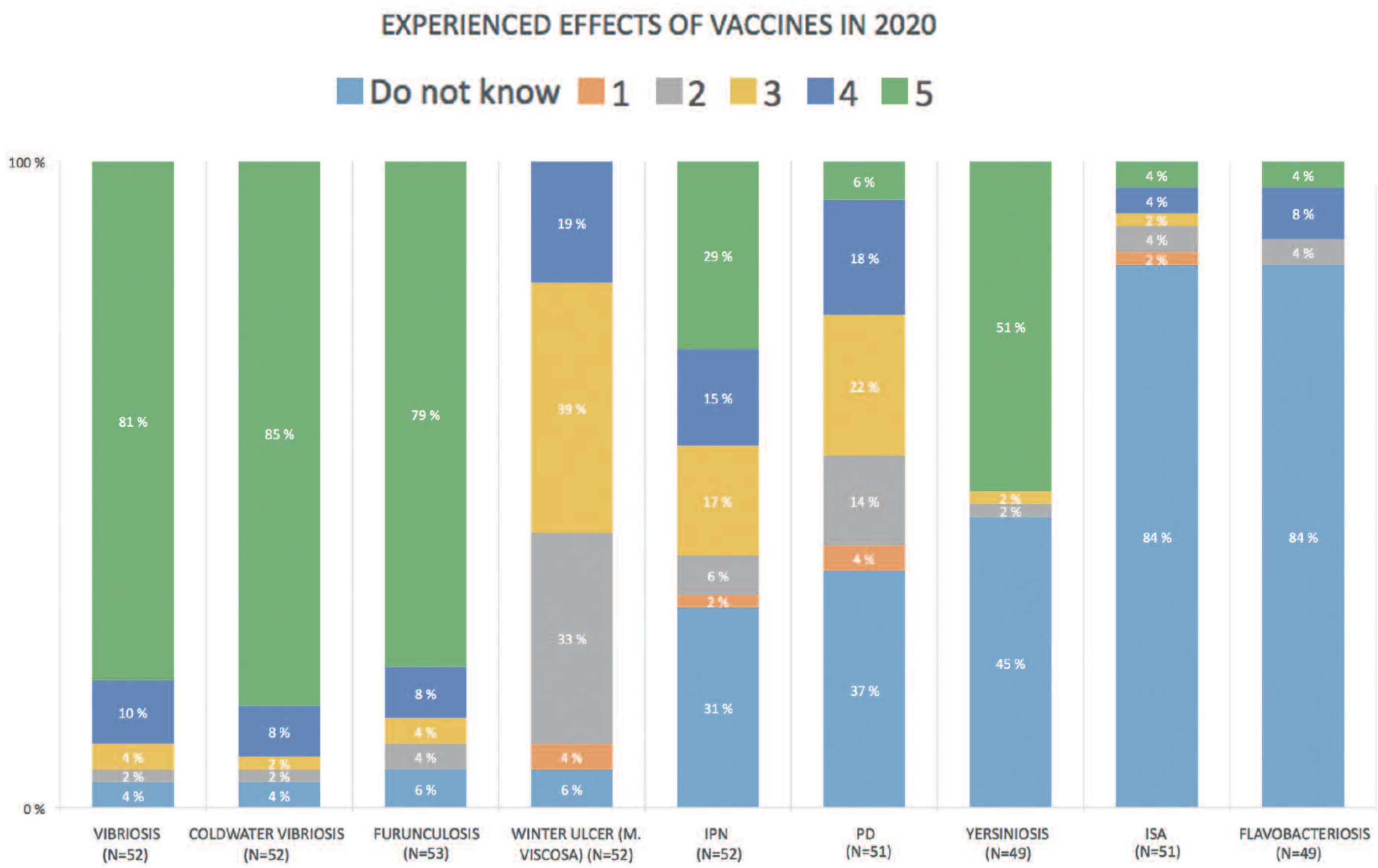


Figure 8.6.1. Considered effect of intraperitoneal vaccination against various infectious diseases, from 1 = no protection to 5 = good protection as well as 'don't know'. The columns for each disease indicate the percentage awarding the various reply categories and N represents the number of respondents.

against yersiniosis. In one fjord in Vestland region vaccination of rainbow trout against flavobacteriosis (autogen vaccine) is normal. Vaccination against ISA in Norway has until now been limited, but there is reportedly increasing interest for this in 2020. Only a limited number of vaccines are available for marine fish species.

Recognised vaccine side-effects following injection vaccination utilising oil adjuvants in salmonid fish normally consist of growth of connective tissues between the inner organs and between the inner organs and the peritoneal walls, melanin deposition, reduced appetite and reduced growth. Spinal deformities are registered, with a particular 'cross-stitch vertebrae' deformity associated with oil-adjuvanted PD-vaccination. This type of vaccine side-effect, which manifests after the fish has reached 2.5 – 3 kg, was characterised in a newly completed FHF research project (901430). Calculation of the prevalence of this type of side-effect has proven difficult as identification is dependent on X-ray investigation of individual fish. In the vaccine documentation for one of the relevant PD vaccines the following is stated: 'Spinal deformities of the 'cross-stitch' variety are usual following vaccination, primarily in fish transferred to sea in the autumn (S0 generation). The term 'usual side-effect' is used when the side-effect occurs in more than 1 but less than 10 fish per hundred individuals.

The various vaccine side-effects are presumably painful for the fish and the degree of side-effect will vary with vaccine type and various parameters such as fish size, degree of misplaced vaccination, injection pressure, water temperature, hygiene etc.

Vaccination of salmonid fish has reduced the number of outbreaks of historically important bacterial diseases to a minimum. Vaccination has therefore contributed to lower losses, dramatically reduced antibiotic use and improved fish welfare.

While vaccines and vaccine administration undoubtedly lead to a degree of negative side effects, the consensus

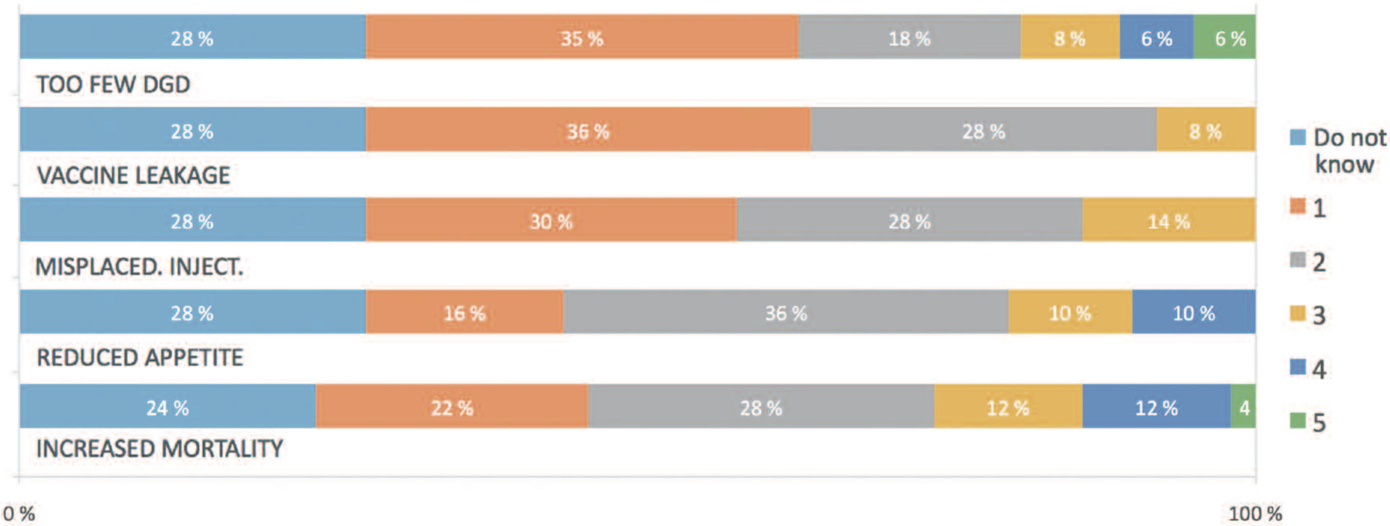


Figure 8.6.2. Experiences regarding acute side-effects or problems following intraperitoneal vaccination. Replies were ranked on a scale of 1 – 5, where 1 = 'very rare/never', 5 = 'very common' and 'don't know'. The columns for each acute side-effect indicate the percentage awarding the various reply categories and N represents the number of respondents. Legend: 'too few dgd' = transferred to sea before reaching recommended post-vaccination period (N=51). 'Vaccine leakage' = visible oil droplets (adjuvant) in the tank following recovery from sedation (N=50), 'Misplaced inject.' = misplaced injection or deposition in more than 5% of the vaccinated fish, 'Reduced appetite' = Reduced appetite exceeding 7 days (N=50). 'Increased mortality' = increased mortality after vaccination (N=51).

is that on balance, fish vaccines are positive for both the health and welfare of farmed fish. However, as vaccination is widespread and does undoubtedly have a direct negative effect on fish welfare, it remains very important that focus continues to reduce further the side-effects of oil-based vaccines. The vaccination process itself should be performed under optimal conditions on healthy fish under continual monitoring.

The annual survey

Fish health personnel and the Norwegian Food Safety Authority were asked on the effect and side-effects of current vaccines used in salmonid fish. Fifty three of 92 respondents (58%) replied that they had experience with vaccination of salmonid fish, side-effects or degree of protection following vaccination. The form of the survey necessitates an oversimplification of the real vaccination situation as e.g. the different types of vaccines are not discussed. There is a widespread consensus that available vaccines vary in effectiveness and side-effects. The responses to the survey reflect therefore general impressions of the situation and the results must be interpreted with caution.

Respondents were first asked on the degree of protection awarded by the various vaccines they used against outbreak of disease. The replies, summarised in figure 8.6.1, were ranked on a scale of 1- 5, where 1 is equivalent to ‘no protection’ and 5 equals ‘good protection’. Protection appears to be generally considered good against the diseases vibriosis and furunculosis, while opinions are mixed regarding winter-ulcer (*M. viscosa*), for which no-one seems to think that these vaccines give good protection (score 5). Opinions

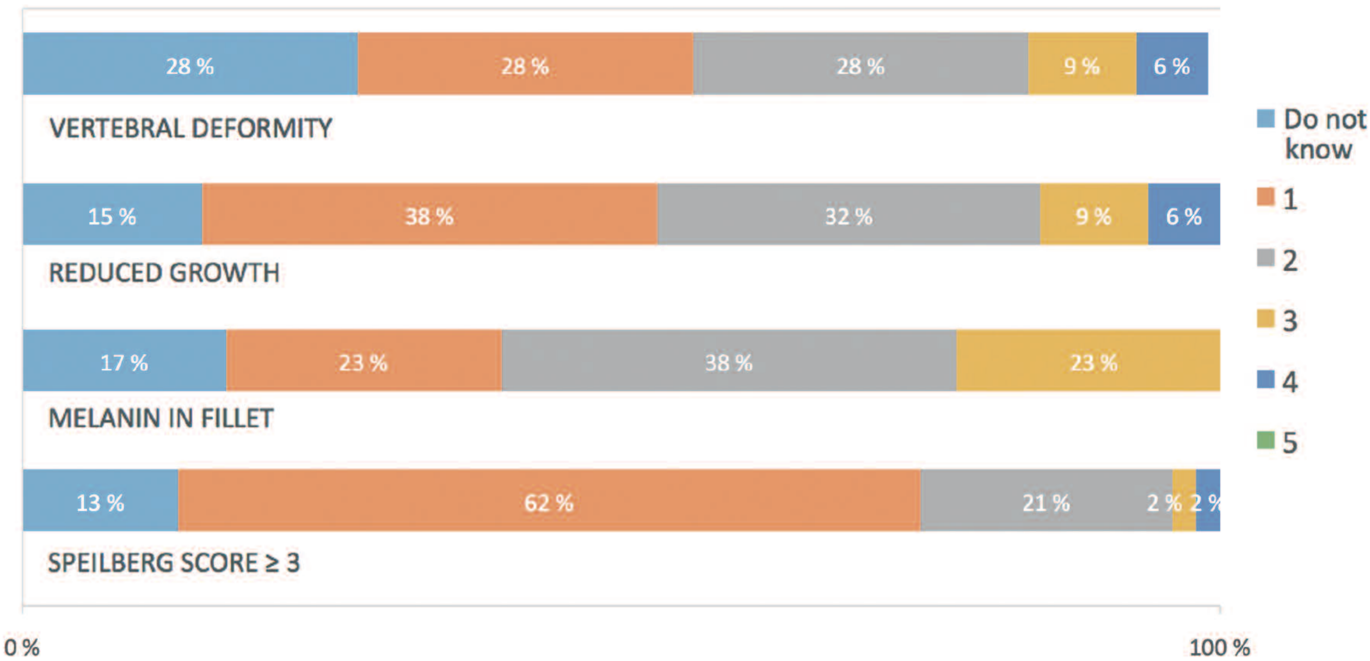


Figure 8.6.3. Experiences regarding chronic side-effects or problems following intraperitoneal vaccination. Replies were ranked on a scale of 1 – 5, where 1 = ‘very rare/never’, 5 = ‘very common’ and ‘don’t know’. The columns for each chronic side-effect represent the percentage of respondents providing each reply alternative and N is the number of respondent replies received. Legend: ‘Vertebral deformity’ = suspicion of vaccine-induced vertebral deformity in more than 5% of the fish (N=53), ‘Reduced growth’ = suspicion of reduced growth caused by vaccination (N=53), ‘Melanin in fillet’ = Melanin deposition expected to result in downgrading at harvest (N=53), ‘Spielberg score ≥3’ = Spielberg score grade 3 or above in more than 10% of investigated fish (N=53).

are also mixed in regard to vaccines against IPN and PD, with some respondents stating 'don't know'. Relatively few respondents had experience with vaccination against ISA and flavobacteriosis with many replying 'don't know'. Yersinia vaccines are considered protective by most, but again many replied 'don't know'.

Acute side-effects are often associated with intraperitoneal vaccination in the hatchery phase. These events are perhaps more related to the process 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 injection or deposition may result in increased side-effects or reduced vaccine effect. Transfer to sea before the recommended number of degree days may result in exposure to the pathogen before the fish are fully protected. Respondents were asked 'how often do you experience acute side-effects related to the vaccine and vaccination process in hatcheries?' Replies were ranked on a scale of 1 – 5, where 1 = 'extremely rarely/never' and 5 = 'extremely commonly'. The results (Figure 8.6.2) show that most respondents consider acute side-effects and undesirable events to occur relatively rarely. The variable responses do indicate, however, that there is room for improvement in a number of farms.

We asked 'How often do you experience the following long-term vaccine side-effects in ongrowing farms/during post-harvest processing', in regard to skeletal deformities, reduced growth, melanin deposition in the fillet and degree of adhesions (Spielberg score). Replies were ranked on a scale of 1 – 5, where 1 = 'extremely rarely/never' and 5 = 'extremely commonly'. The results (Figure 8.6.3) show that most respondents consider that chronic side-effects occur relatively rarely. The variable responses do indicate, however, that there is room for improvement in a number of farms.

With regard to fish welfare, vaccine related injuries are not ranked particularly highly when compared to other serious problems in salmon and rainbow trout farming. Some respondents do, however, consider vaccine related consequences among their 'top five' problems during certain phases of production (see Table 8.6.1). In the hatchery phase, vaccination is considered important in terms of increased mortality, poor growth and reduced welfare, while in the ongrowing phase for salmon, certain respondents consider vaccination to cause poor growth and poor welfare. Extremely few consider vaccine side-effects to be a significant problem in farming of rainbow trout. There are also extremely few that consider vaccine side-effects to be an increasing problem in farming of salmon or rainbow trout.

Table 8.6.1. Number of persons (number or replies). Number of respondents considering vaccine side-effects to be one of the five most important causes in relation to mortality, growth, welfare or as an increasing problem.

	Mortality	Poor growth	Reduced welfare	Increasing problem
Juvenile salmon	5 of 54	5 of 54	7 of 54	1 of 54
Juvenile rainbow trout	0 of 17	0 of 17	1 of 17	0 of 17
Ongrowing salmon	0 of 78	3 of 78	3 of 78	1 of 78
Onggrowing rainbow trout	0 of 19	0 of 19	0 of 19	0 of 19

8.7 Algae and fish health

By Trine Dale (NIVA) and Geir Bornø

The health situation in 2020

There exist several thousand species of marine phytoplankton. Of these, around 300 are known to cause 'blooms', around 80 species are known to produce potent toxins, and a few are known to be injurious to fish. While those capable of causing injury to fish are few, they are distributed between several taxonomic groups, have different growth requirements and bloom dynamics and affect fish in different ways. The degree of toxicity may vary within the same species depending on environmental conditions. This represents a challenge in terms of early warning, surveillance and mitigation.

Some algae are toxic only when present in high concentrations, while others may be toxic even at low concentrations. Typical clinical signs of algal toxicity in fish include abnormal swimming behaviour, morbidity, gasping at the surface, increased respiration rate, poor appetite and mortality. Several physiological mechanisms may be involved alone or in combination and may lead to mortality, gill injury or reduced appetite and growth. Simply put, the effects either represent poisoning, mechanical injury and/or suffocation.

There remain many unanswered questions related to algal toxins and their effect on fish. Of the causative organisms, it is representatives of the *Chrysochromulina* (see under), *Prymnesium*, *Verrucophora* and *Karenia* families in particular, that have caused problems in Norway. Some species have sharp protrusions that can cause physical injury and may result in over production of mucus in the gills and suffocation in the worst cases. Such gill damage may also make the fish susceptible to secondary infection. Very high concentrations of algae belonging to the family *Chaetoceros* have been associated with gill injury. On occasion, the concentration of algae can be so high that the oxygen level of the water is affected. This often happens near the end of the bloom when the algal mass is decomposing or at night when respiration is high. The latter effect can also be seen on occasion as a drop in oxygen concentration in the cage late at night or early in the morning.

In May and June 2019, the regions of Northern Nordland and Southern Troms were severely affected by toxic algae. The algae *Chrysochromulina leadbeaterii* was related to the mortality. The family *Chrysochromulina* belongs to the Haptophyta and several species may produce toxins under certain environmental conditions.

The first cases were registered in Ofotfjorden in Northern Nordland in mid-May 2019. The same problem was later registered in Southern Troms, Vesterålen and in parts of Lofoten. Some sporadic cases also occurred further north in Troms.

Affected farms experienced a situation during which following a short period of abnormal behaviour acute high mortality occurred. A 'rain' of dead fish was described. The number of fish dying varied from farm to farm, but most of the earliest affected farms lost the majority of their fish, including both harvest-ready fish and newly sea-transferred fish. As soon as algal blooms were identified as the cause of the mortality, fish populations were moved as quickly as possible in what was an efficient cooperation between the farmers, service boat industry, Norwegian Food Safety Authority and the Directorate of Fisheries. A continual algae surveillance program was established in some areas to monitor the presence and spread of algae to allow introduction of preventative measures.

Total losses were estimated at 8 million fish with a biomass of 13,500 tons and a value of 2.1 billion kroner. Disposal of the dead fish also posed a serious logistical challenge.

The last time a similar algal problem was recorded was in the early nineties. It is also thought likely that this episode was caused by *C. leadbeaterii*. Experiences recorded then were very useful in predicting spread of the recent blooms. Weather data was also central in predicting patterns of spread.

Algal problems affect individual farms from time to time with varying consequences. The 2019 situation was unusually severe, but such events do happen, both in Norway and abroad.

Significant problems related to algal blooms were not experienced in 2020, but individual farms continue to suffer algae related mortality. Some fish health personnel consider algae to represent a welfare challenge which also causes reduced growth. Algae were ranked in the lower third of 28 different health and welfare problems affecting ongrowing salmon at sea (appendices B1 and B2). It is nevertheless worth noticing that 8 of 78 respondents crossed off for algae as one of the top 5 most important causes of mortality in 2020, which indicates that this is a serious problem in affected farms.

From the Northern Lights farm in Asta fjord in Troms, one of the farms hardest hit by algae in 2019. Photo: Asle Haukaas.

9 The health situation in wild fish

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

9.1 Introduction

In 2020, the Norwegian Veterinary Institute and the Norwegian Food Safety Authority launched a national reporting system for registration of sick and dying wild fish. The reporting system is an integral part of the health surveillance of wild salmonids and its main aim is early detection of serious events related to fish health in Norway. The system also provides insight into the health of wild fish generally. The reporting system is applicable to wild fish in the sea and in freshwater. Section 9.2 provides more detail on reported cases and experiences so far.

Mortality and disease was again registered in wild salmon in the river Enningdalselva (county Viken) during the summer of 2020. The condition, which has been given the name 'red skin disease' manifests as rash-like bleedings and changes in the skin soon after entry to the river. Similar observations have been made in several countries in Northern Europe, but a clear causal relationship has not been identified. None of the known serious infectious disease agents have been detected and there are few signs indicating an infectious disease. Section 9.3. describes the work done at the Norwegian Veterinary Institute in an effort to identify the cause/s.

Escaped farmed fish, salmon lice, infections, climate change and *Gyrodactylus salaris* are amongst the factors threatening the health of wild salmon. According to the Directorate for Fisheries, there were 42 reported farmed fish escapes in 2020 involving a total of 31 559 fish. Escape of farmed salmon is primarily a concern in relation to interbreeding with wild salmon and the subsequent negative effects on the gene pool of the wild fish. Escapees also represent a threat of transmission of disease to wild fish.

The salmon louse is a significant threat to wild salmon, seatrout and sea-run arctic char. The red traffic light was turned on for the first time in 2020, and in November 2020 an expert group delivered a new evaluation of the probability of salmon louse induced mortality in wild salmon smolts (read more in section 9.6).

Norway has declared the intention to eradicate the parasite G. salaris from all affected rivers. Following declaration of freedom of infection in the river Rana in the autumn of 2020, the parasite represents a steadily decreasing threat to Norwegian wild salmon. There remain infected rivers to treat however, and the parasite is present near the border in our neighbouring country (Section 9.5).

Knowledge of the prevalence and importance of infectious diseases in wild populations is limited. Little research is carried out in this field and the little that is done is directed at wild anadromous salmonid fish and infections relevant for the aquaculture industry. Interest for classic 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 inland fish is therefore, increasing in pace with this interest. Movement of fish from anadromous farming to inland farming involves the risk of introduction of new infectious agents to these ecosystems.

As part of health surveillance of wild salmonids, brown trout from lakes Femund, Selbusjøen and Snåsavannet were investigated in 2020 for infectious agents associated with gill inflammation in farmed salmonids. A simple presentation of the results are provided in section 9.4. A full report will be published later this year.

Salmon louse. Photo: Trygve Poppe.

9.2 The reporting system for diseased wild fish

According to legislation on food production and food safety, anyone who suspects the presence of infectious animal disease that may have serious consequences for society is obliged by law to report it to the Norwegian Food Safety Authority. This is also applicable to wild fish. The purpose of early notification is to aid diagnosis and limit spread of disease.

The Norwegian Veterinary Institute is responsible for diagnosis of infectious diseases in wild fish while the Norwegian Food Safety Authority is responsible for introduction of counter measures.

Together, these two institutions have established a system that enables the notification process and eases reporting of disease and mortality in wild fish by members of the public.

While the system is based on the reporting system developed by The Swedish National Veterinary Institute (SVA), in the Norwegian system each reported case is evaluated by a pathologist and everyone submitting a report receives a reply from the Norwegian Veterinary Institute. 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 and we 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.

For the period 2. June until December 31.st, 65 cases were registered in the system. For some cases e.g. red skin disease in the river Enningdalselva (Halden council area in Østfold region), several reports were received. The number of individual reports received is therefore 44. The reports were distributed throughout the country, with the majority being received from areas close to the coast (Figure 9.2.1). The reports involved parasites, bacteria, fungal- and viral-diseases, tumours, mechanical injuries and predator injuries. We present here a summary of reported cases of concern for the health of wild fish in 2020, and some additional cases identified by other means.

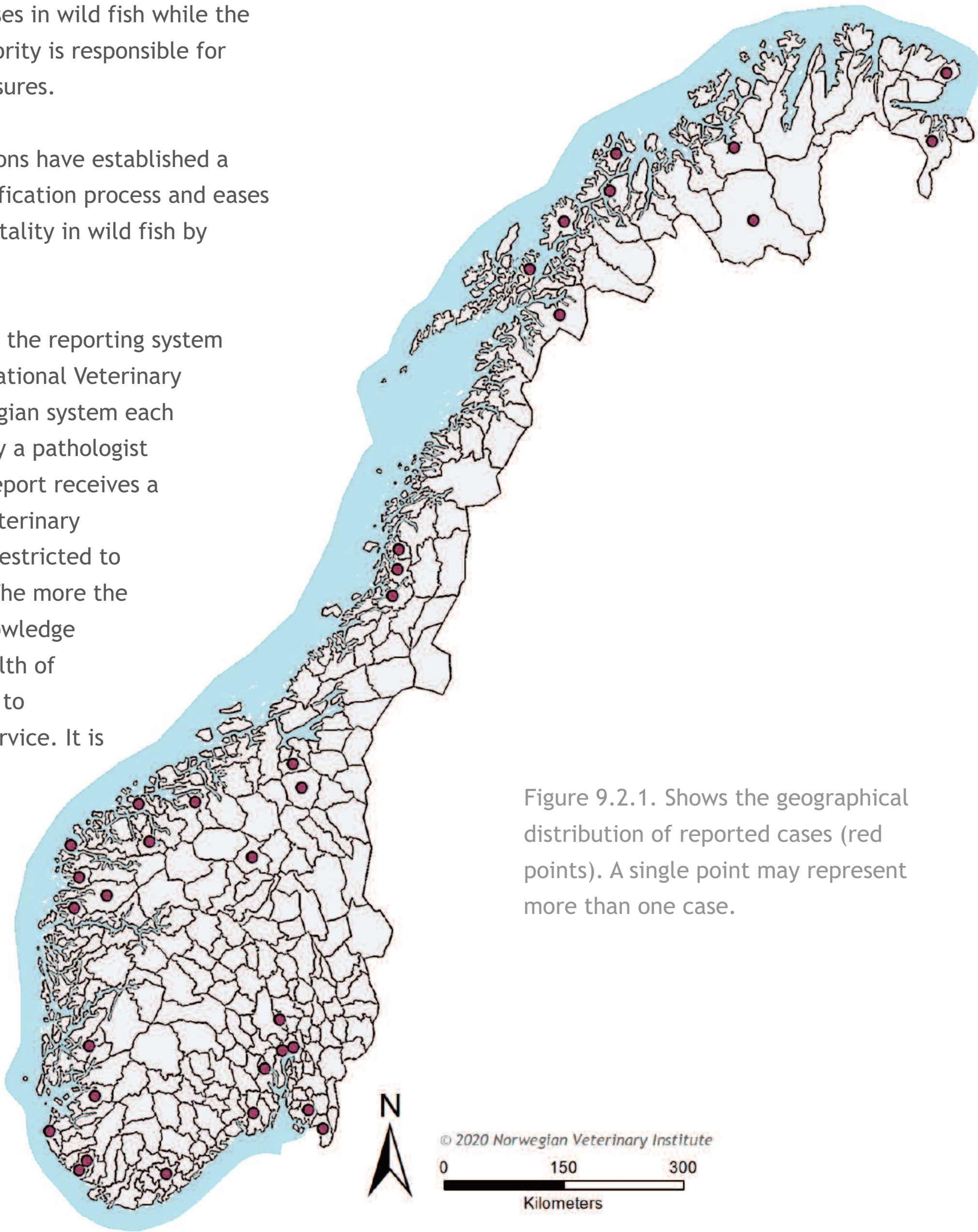


Figure 9.2.1. Shows the geographical distribution of reported cases (red points). A single point may represent more than one case.

Bacterial diseases

Vibriosis in coalfish near Molde

In September a report was received of diseased coalfish caught from a quayside in Molde council area in Møre og Romsdal. Samples of the fish were not submitted, but photographs taken and other available information resulted in a strong suspicion that the coalfish were suffering from vibriosis (Figure 9.2.2). Vibriosis in coalfish is caused by the bacterium *Vibrio anguillarum* and the disease is diagnosed by culture of the bacterium. Vibriosis is not uncommon in coalfish in the late summer and autumn.

Figure 9.2.2. Coalfish with skin lesions and bleeding are normally suffering from vibriosis. Photo: Ole-Håkon Heier.

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 of salmonid fish'). 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 disease is easily diagnosed as it results in a white, cotton-wool like layer spread across the surface of the fish. 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. In 2020 several reports of saprolegniosis in salmonid fish were received. From the river Akerselva in Oslo, several reports were received of fungus-affected fish in November and December. In the river Sandvikselva in Akershus region, there was a mortality event in which the dead fish were covered in fungus. Pathogenic agents other than *Saprolegnia parasitica* were identified in submitted samples. Saprolegniosis affected fish were also identified in the river Enningdalselva in Østfold (Figure 9.2.3).

Figure 9.2.3. A seatrout with saprolegniosis from the river Enningdalselva, autumn 2020. Photo: Anonymous. Submitted to the Norwegian Veterinary Institute.

Parasites

Isopod parasites in cod near Ringvassøy

Three large ectoparasites (Figure 9.2.4) were reported from a cod (70cm and 3kg) caught in Dåfjord on Ringvassøy in Karlsøy council area in Troms og Finnmark region. These parasites are crustaceans of the genus Aega, group Isopoda. They spend part of their lives on the sea bottom, but also live as parasites of various fish species, where they attach using hooks on their legs, suck blood and damage the skin. Such parasites are not uncommon on cod, but prefer weak fish. There are several species within the genus Aega and some are widespread in the northern Atlantic Ocean.

Figure 9.2.4.Aega sp. (Crustacea, Isopoder Isopoda) found in a cod in Dåfjord, Karlsøy council area. Photo: Kevin Kristiansen.

The gill-louse, Salmincola

A parasitic crustacean known as the gill-louse (*Salmincola salmoneus*) is commonly found in the gills of broodstock salmon. There are several species of gill-louse and they may be found in a number of freshwater fish species around the world. Five species have been identified in Norwegian salmonids; *S. salmoneus* in salmon and trout, *S. extumescens* in whitefish, *S. edwardsii* in arctic char, *S. thymalli* in grayling and another species in vendace.

These parasites attach to the gills using two ‘arms’ and their bodies can be described as gold/yellow and ‘sausage-shaped’. Mature females have two egg-sacs attached to their abdomen, in a manner similar to the salmon louse. The species vary in size, but the most usual species in salmon, *S. salmoneus* is approximately 7-8 mm without egg strings. Although *S. salmoneus* is considered a parasite of freshwater, it can survive on the fish when it migrates into seawater. Gill-lice eat the gill filaments and cause open lesions which may then become infected with fungus or bacteria. In 2020, gill-lice were reported in arctic char caught in Kautokeino council area in Troms og Finnmark. Figure 9.2.5 show gill-lice on char, salmon and grayling.

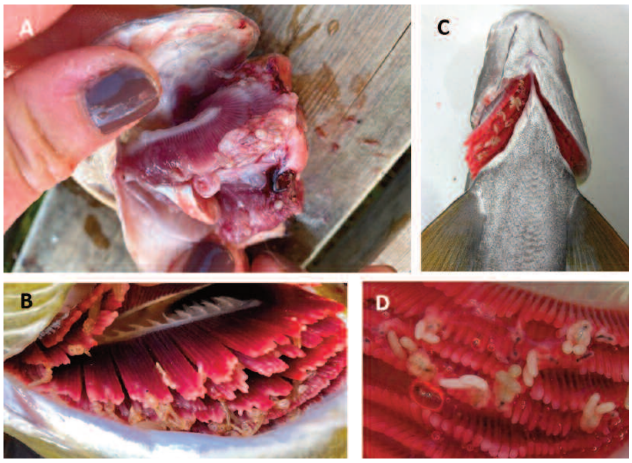


Figure 9.2.5 Gill-lice. A) Gill-lice om arctic char, *Salvelinus alpinus*, in Kautokeino Photo: anonymous, sent to the Norwegian Veterinary Institute, B) Gill-lice on salmon, *Salmo salar* Photo: Jan Arne Holm, C and D) gill-lice on grayling, *Thymallus thymallus*, Photo: Trygve Poppe

Myxozoa

A salmon with red skin disease from Enningdalselva was also diagnosed with liver damage caused by a parasite belonging to the myxozoa (Myxosporea), most probably belonging to the *Myxydioum* group (Figure 9.2.6). Myxozoa are a class of parasites in the same group as the cnidarians, a large group of organisms containing many species. Myxozoa infect fish in fresh and saltwater. They have a complex lifecycle and most have fish as an intermediate host and an annelid worm as the final host. The final hosts of freshwater species are oligochaete worms while the final host of saltwater species are polychaete worms.

In Norway we are very familiar with the species *Parvicapsula pseudobranchicola* which causes parvicapsulosis in salmon in saltwater (See chapter 7.3) and *Tetracapsuloides bryosalmonae*, which causes proliferative kidney disease, PKD in salmonids in freshwater, but many other species are also found. *Tetracapsuloides bryosalmonae* is unlike other myxozoa in that it has bryozoans as a final host.

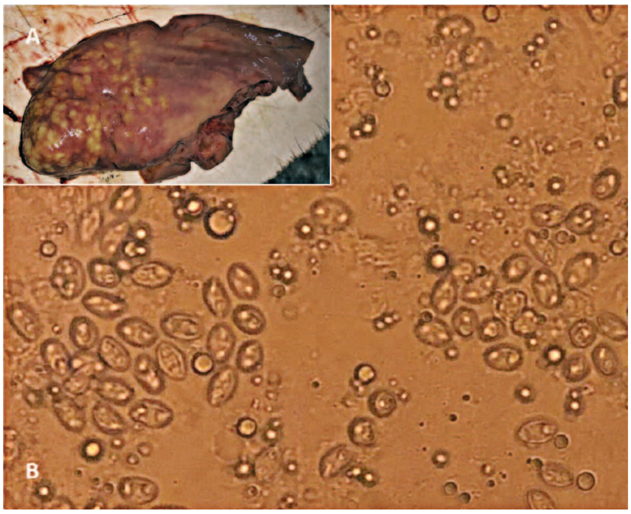


Figure 9.2.6. A) Liver of a salmon with pathological changes caused by a parasite belonging to the myxozoa. Photo: Tagnar Itland, AJFF Halden. B) Direct scrape from the liver under microscopic examination. The photograph shows several oval parasites. Photo Karoline Sveinsson. Norwegian Veterinary Institute.

Tapeworms

Salmonids in freshwater are commonly infected by different types of tapeworm, found both as encapsulated intermediate stage larvae in internal organs or as adult tapeworms in the intestine.

The photograph shows the inner organs of a trout caught in Sunnfjord council area in Vestland region (Figure 9.2.7). This trout is infected with 2 or 3 species of tapeworm; *Dibothriocephalus dendriticus*, *Dibotriocephalus ditremus* and/or *Eubothrium* sp. Both of the first mentioned species have birds as their final host i.e. they become sexually mature in the intestine of the bird and fish are the intermediate host. Fish become infected by eating small planktonic crustaceans which are the first intermediate host in this complicated life cycle. In the photograph we can see larvae encapsulated in nodules and bladders on the external surfaces of the organs (blue arrow). These tapeworms are found over the whole country. If the parasite is not firmly attached to the meat, the fish may be eaten after cooking. Eubothrium sp. has fish as the final host i.e. the adult worm lives in the intestine of the fish and attaches to the digestive caecae (green arrow). The photograph shows the white tapeworm sticking out of the fish intestine (yellow arrow).

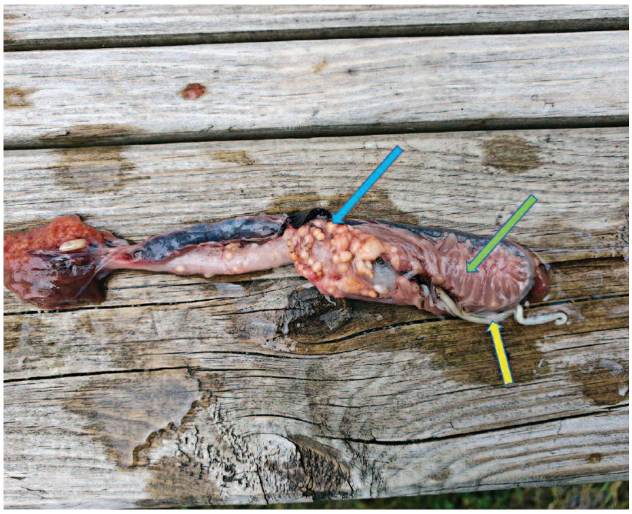


Figure 9.2.7 The photograph shows the internal organs of a trout caught in Sunnfjord council area. Blue arrows indicate encapsulated Dibothriocephalus dendriticus or Dibotriocephalus ditremus, the yellow arrow indicates Eubothrium sp. sticking out of the trout's intestine and green arrow shows pyloric caeca of the intestinal system.Photo: anonymous, submitted to the Norwegian Veterinary Institute.

Leeches (Hirudinea)

One case involving leech infestation of trout was reported from Dovre council area in 2020 (Figure 9.2.8). The leeches involved are presumed to be *Piscicola geometra*, a species which is relatively common in Norway. Leeches suck blood and in large numbers may weaken affected fish. The red colour of some of the leeches in the photograph is a result of blood feeding. It is not known if the fish was weakened prior to infestation, but the trout in the photograph is clearly emaciated with abnormally prominent eyes. As well as being parasitic, leeches may also act as intermediate hosts for blood parasites which may be transmitted during blood feeding.

9.2.8. Trout from Dovre with leeches. Photo: sent to the Norwegian Veterinary Institute.

Tumours

Tumours in cod from Ofotfjorden

A growth at the base of a fin in a wild cod was reported from Ofotfjorden in Narvik council area in Nordland region. This may be a tumour. A diagnosis could not be reached as the cod was not available for investigation by the Norwegian Veterinary Institute.

Figure 9.2.9. Blood-filled tumour at the base of a fin in wild cod. Photo: Anders Millerjord.

Mechanical injuries and predation

Different types of injury represented a significant proportion of cases reported. The injuries were of diverse cause e.g. mechanical injury caused by fishing gear and wind turbines, injury caused by predatory birds or animals e.g. seals, otters and cormorants. From Breivika in Troms and Finnmark a report was received involving several salmon displaying lesions possibly related to mechanical injury or predation.

Figure 9.2.10. Salmon from Enningdalselva, probably injured by a predator (seal, bird). This salmon was also suffering from red skin disease (read more chapter 9.3) and was infected with liver myxozoa (chapter 9.2.6) Photo Ragnar Itland, AJFF Halden.

9.3 Red skin disease in Enningdalselva

Background

Enningdalselva, also called Berbyelva, is the southernmost national salmon river. The river enters the sea in Iddefjorden in the Halden council area, but has its source in Sweden and is managed in cooperation with Sweden. In the summer of 2019, sick and dying freshly sea-run salmon (5-15kg) were found. The fish were typically in good condition, but with a characteristic red rash on the ventral surface (belly), appeared morbid and were easily caught. Over the summer salmon from several rivers were examined, and similar reports were received from other north-European countries. To enable international communication the term 'red skin disease' was coined to describe the clinical picture. In 2019 a limited number of salmon were investigated, but no cause of disease could be arrived at. The clinical picture looks dramatic, but diagnostic investigation resulted in only vague findings.

The situation was followed closely in 2020 to see if the same disease occurred again. At the end of April, the local fishing association cleared the river banks to improve observation of the river. Even then, large salmon were observed occupying unusual positions in the river, but none were captured. The first salmon displaying clinical signs was captured on the first day of the salmon fishing season (23_{rd} May). The Norwegian Veterinary Institute was again contacted to investigate the disease. As in 2019, the salmon were in good condition, but displayed bleeding in the ventral skin surfaces and fins (Figure 9.3.1).

Registration and sampling

All fish captured in Enningdalselva are registered in a local database. The following data was recorded: Species, length, weight, water height, water temperature and whether the fish was healthy or showed signs of disease. In the course of the season, 42 healthy fish and 33 diseased (or dead) fish were captured or recovered. Four seatrout were caught, with none showing signs of disease. Figure 9.3.2 shows how the prevalence of sick or dying salmon changed over the season. According to the fishermen, many of the sick and dying fish were suffering from fungal infection. There is a netting station for salmon in the inner Iddefjorden fiord where 38 salmon were captured in 2020. Further out in the fiord two net-fishermen caught a total of 10 salmon, 5 of which had been nearly eaten up by seals. The netting season was curtailed by the number of seals and level of fouling on the nets. Skin disease was not observed in fish captured in seawater.

All salmon caught in Enningdalselva and investigated by the Norwegian Veterinary Institute in 2019 were confirmed to be of wild origin. This was confirmed by scale analysis by the Norwegian Veterinary Institute and genetic testing performed by the Norwegian Institute for Nature Research (NINA). The sampled fish included both first time- and returning- spawners. In 2020 the local fishing association submitted scales for analysis to NINA. NINA then estimate the fish age at smoltification, period spent at sea, whether the salmon is of wild origin, escaped farmed fish or escaped/released as a smolt.

The Norwegian Veterinary Institute performed its own sampling in Enningdalselva, but to ensure further submissions of samples from affected fish, local anglers were taught how to take samples. With the help of local anglers, samples from 20 salmon were collected throughout the season.

Figure 9.3.1. Salmon from Enningdalselva with skin lesions 23.05.2020. Photo: Bjarne Granli, AJFF Halden.

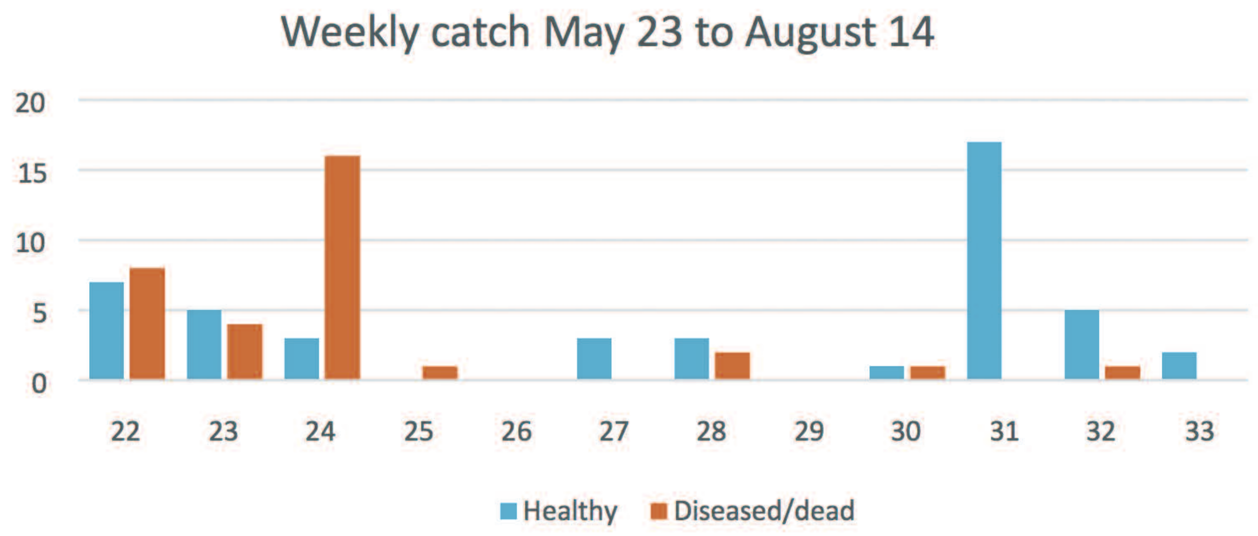


Figure 9.3.2. The diagram shows the number of healthy and diseased/dead fish caught or removed from the river per week during the fishing season 2020.

Diagnostics

Diagnostic criteria are a series of pathological changes and analysis results that define a particular disease. Such criteria are not yet established for red skin disease. The diagnosis is currently based on findings including red ring-shaped changes of the skin on the ventral surface of recently returned salmon.

Norwegian Veterinary Institute investigations of diseased fish start with an autopsy of whole fish (Figure 9.3.3). In cases of red skin disease, the skin of the fish, including underlying tissues, is especially closely studied for pathological changes. The inner organs are also examined to establish whether any observed changes can be linked to the skin changes. During the autopsy, tissue samples are taken to establish whether infectious agents are present (by culture or PCR) and for microscopic examination (histopathology). Autopsy of fish during 2020 resulted in similar findings to those identified in 2019. Skin bleeding was observed, but no pathological changes were observed deeper in the fish.

Histopathology

During microscope based examination of tissue sections, special staining and immunohistochemical methods were used. The skin injuries were characterised by scale loss and loss of the outer skin layer (epidermis) in the middle of the lesion, but in the border of the lesion the epidermis was intact, but undermined by shallow bleeding (Figure 9.3.4). In more advanced cases, the lesions were infected with fungal hyphae with visible inflammatory reaction, most probably due to the injured skin barrier.

Figure 9.3.3. Autopsy of salmon from Enningdalselva. Photo: Mari Press, Norwegian Veterinary Institute.

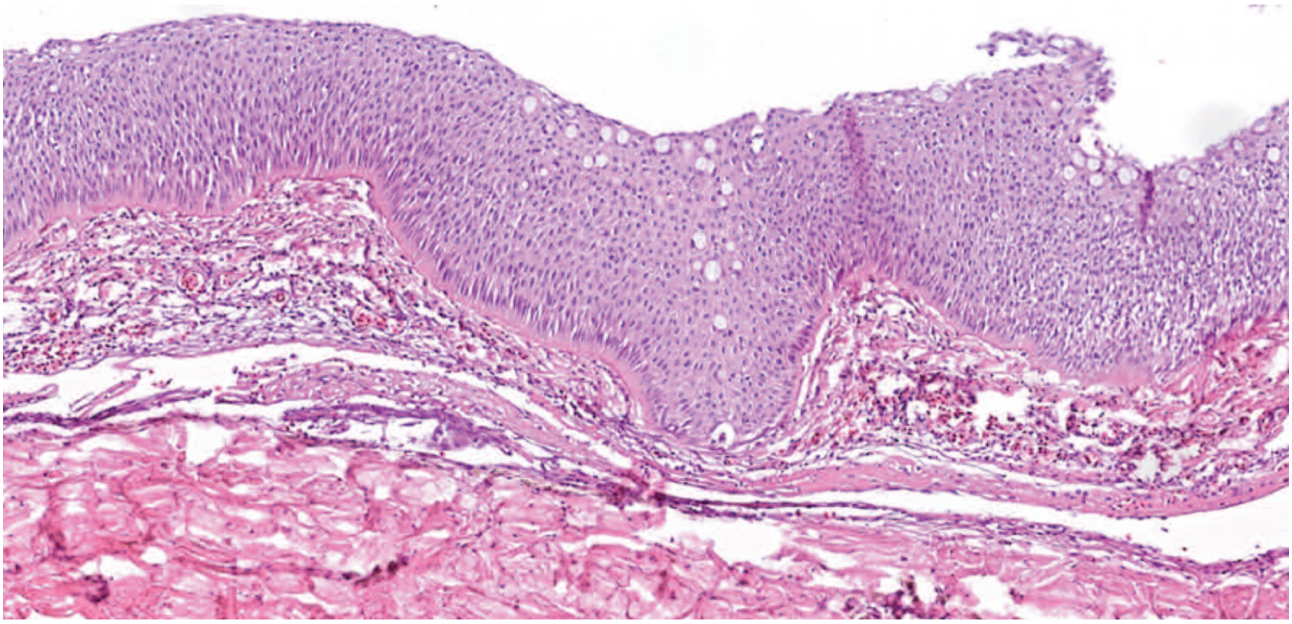


Figure 9.3.4. The photograph shows the border of a skin lesion with characteristic changes. Bleeding between the epidermis and the dermis can be seen. Photo: Ole B. Dale, Norwegian Veterinary Institute.

Investigations for infectious agents (bacteria, virus, fungus)

Different types of bacteria have different growth requirements. Utilisation of a number of different agar types allows culture of a broad range of bacteria including those with specific nutritional requirements. Samples from the Enningdalselva salmon were taken from the skin and kidney and plated on blood agar, blood agar with 2% NaCl, Ordal agar, CHAB and KDM-2 agar. While a few different types of bacteria were identified in very low quantities, the results did not indicate bacteria as the cause of the disease. Samples were also taken for 16S rRNA analysis, which is capable of identifying any bacteria (also non-culturable), but bacteria were not identified.

Samples were also taken for virus culture from kidney and skin and these were used to inoculate the following cell-lines: EPC, BF-2, CHSE-214, CHH-1, ASKII, ASG10 and Skin br 1). The virological investigations were terminated 02.12.20 without identification of virus.

The histological findings did not provide grounds for further investigation using PCR analyses for detection of specific infectious agents. PCR for *Aphanomyces invadans*, the causative agent of epizootic ulcerative syndrome (EUS) and salmon gill pox virus, were however, performed. Both analyses gave negative results. Samples preserved in RNAlater have been stored for eventual future analysis for other agents.

Electron-microscope investigations of skin did not shed light on the condition. The samples were not of optimal quality, so it is difficult to conclude with certainty on these results. There are no indications that these wild salmon are suffering any disease known from salmon farming.

Thiamine levels

In Sweden, thiamine deficiency has been identified in salmon from some rivers that run into the Baltic Sea. Thiamine deficiency has been one of the hypotheses under investigation in relation to development of RSD in Sweden. Thiamine levels were therefore analysed in samples from two individual fish from Enningdalselva by the Institute for Marine Research. Thiamine-HCL value was identified as 1.3mg/kg i.e. well above the level necessary for 100% juvenile survival (Reference value 0.34 mg/kg thiamine-HCL).

Investigation of juvenile fish and juvenile counting in Enningdalselva

At no time during 2019 or 2020 were diseased or dying juvenile salmon, trout or other fish species identified in Enningdalselva. The Natural History Museum (University of Oslo) performed a juvenile count in the autumn of 2020 and concluded that the disease had not affected recruitment. The Norwegian Veterinary Institute performed a sampling of 30 juvenile salmon and 9 juvenile brown trout. The aims of the investigation were identification of signs of disease or reduced health in the

Figure 9.3.4. Salmon and trout juveniles. Photo: Brit Tørud, Norwegian Veterinary Institute.

Figure 9.3.5. The large larvae in the stomach of this trout indicates a good appetite. Photo: Brit Tørud, Norwegian Veterinary Institute.

juvenile fish and obtaining sample material for subsequent analysis for an eventual specific agent identified in association with development of RSD. The juveniles were in good condition and displayed no visible signs of disease (Figure 9.3.4). Their appetite also appeared to be good (Figure 9.3.5).

Other investigations and hypotheses

Salmon migrating up the rivers Tista and Enningdalselva have the same genetic background. Sick or dying fish have not been observed in the Tista, so the problem is most probably not genetic. Toxicological analyses have not been performed, but samples of muscle and liver have been frozen should this type of investigation become relevant. In some Swedish rivers, abnormal thyroid function has been identified. This has not been investigated in the Enningdalselva case.

The Norwegian Institute for Water Research (NIVA) sampled water at different depths without finding any factor that could indicate why salmon migrating up Enningdalselva should become sick.

Conclusions

Is red skin disease caused by local conditions in Enningdalselva and Iddefjorden fiord, or by one or more ecological factors related to salmon development in freshwater or seawater? Neither possibility should yet be discounted.

When investigating a new disease of unknown aetiology, it is important to use as wide a spectrum of methods as possible to enable identification of both known and unknown causes. For wild fish, the local environment must be closely studied and for the salmon the ocean must also be considered. Much is unknown of oceanic conditions, and there is a need for cooperation between different scientific disciplines and institutions if the causes of the disease are to be identified.

The work of the Norwegian Veterinary Institute has largely focussed on general pathological investigations and specific analyses for specific agents, as this type of investigation lies at the heart of the institute's societal role. Concurrently, much information has been gathered related to a series of other factors including genetics, chemical pollution, exotic agents in ballast water, predator injuries etc. Such investigations are demanding in terms of resources and progress is dependent on cross-disciplinary cooperation.

Results generated by the Norwegian Veterinary Institute do not indicate an infectious aetiology for red skin disease. No infectious agent known from farmed salmon has been identified. The results do not support the hypothesis that thiamine deficiency is a cause of RSD.

9.4 Health surveillance in wild salmonids

The Norwegian Food Safety Authority's health surveillance programme for wild anadromous salmonids has identification of the source and prevalence of disease agents in wild anadramous salmonids (salmon, seatrout and arctic char) as its main goal.

The Norwegian Veterinary Institute has focussed on agents related to gill health in its health surveillance during 2016, 2018 and 2020. In 2020, the Norwegian Veterinary Institute has mapped the prevalence and distribution of Atlantic salmon paramyxovirus (ASPV), salmon gill poxvirus (SGPV), *Ca*. Branchiomonas cysticola, *Ca*. Piscichlamydia salmonis, *Desmozoon lepeophtherii* (syn. *Desmozoon lepeophtherii*) and *Paramoeba perurans*. The PCR analyses were performed by Patogen AS and Pharmaq Analytiq. A simple summary of the results is provided here and a more detailed summary will be published in a report later this year.

The material investigated in 2020 comprised wild salmon and trout from the sea and freshwater. A net-caught escapee rainbow trout from PO 4 was also included. Brown trout from lakes Selbusjøen, Snåsavatnet and Femund were also included in this year's survey. The material from Femund and Snåsavatnet was collected by the Norwegian Institute for Nature Research (NINA) as part of their biological survey. The material is a contribution towards a greater understanding of the health of inland salmonids and provides a basis for comparison of the prevalence of gill pathogenic agents in the sea and freshwater with and without the presence of anadromous fish.

Atlantic salmon paramyxovirus (ASPV) was identified in a single fish, a trout from Snåsavatnet. A moderate amount of virus was detected in the sample (Ct 27.9). In 2018, ASPV was identified in 5 seatrout in Nordland.

Salmon gill poxvirus was included in the survey in 2016, 2018 and 2020. In 2016 we found the virus in wild-caught seatrout held together with infected salmon, but subsequently found the virus only in salmon, despite the large number of char, seatrout and brown trout analysed. The prevalence of pox virus in salmon varies considerably with place of capture. Pox virus has been detected in 3.2% of all wild salmon analysed from netting stations in the sea (2018 and 2020 data). The prevalence amongst adult salmon in rivers varies but is higher than that observed in the sea. In 2018, 90% of broodstock salmon held together in tanks prior to stripping (for restocking purposes) were carriers of pox virus. This situation is probably due to fish to fish transmission between fish held in the same tank, but also shows that broodstock based surveys are not suitable for the study of the real situation in wild fish. There are also grounds for concern related to release of these infected wild fish following stripping.

The bacterium Ca. *Branchiomonas cysticola* is widely prevalent in the sea and freshwater in both trout and salmon, in both young and old fish. Adult fish in the sea and rivers display a particularly high prevalence (77.9% and 77.6%). In seatrout netted in the sea the prevalence varied with year, with a higher prevalence in 2019 than in 2020.

Piscichlamydia salmonis is also found in both sea and freshwater, in trout and salmon and in both young and adult fish. In our material the prevalence was lower in the sea than in freshwater.

Paramoeba perurans was not identified in any of the 154 salmon or 27 seatrout caught in the sea, but was identified in the single escapee rainbow trout included in the study caught in PO4.

The microsporidian *Desmozoon lepeophtherii* (*Syn.Paranucleospora theridion*) was surveyed in salmon and trout with contact to the marine environment. We found this parasite particularly in net-caught salmon in southern Norway (PO1)

Table 9.4.1. The table summarises results for PCR screening for Atlantic salmon paramyxovirus (ASPV), Salmon gill poxvirus (SGPV), Ca. Branchiomonas cysticola, Ca. Piscichlamydia salmonis, Desmozoon lepeophtherii (*Desmozoon lepeophtherii*) and *Paramoeba perurans*.

		Positive						
		Number analysed	Atlantic salmon paramyxovirus	Salmon gill poxvirus	*Ca.* Branchiomonas cysticola	*Ca.* Piscichlamydia salmonis	*Paranucleospora theridion*	*Paramoeba perurans*
Salmon	juvenile/river	54	0	0	3	22	0	0
	Adult/river	58	0	9	45	4	12	0
	Adult/sea	154	0	6	120	7	21	0
Trout	juvenile/river	9	0	0	1	5	-	-
	Large lake	91	1	0	25	44	-	-
	Sea (seatrout)	27	0	0	12	7	0	0
Rainbow trout	Sea (escapee)	1	0	0	1	0	1	1

9.5 *Gyrodactylus salaris*

Gyrodactylus salaris was introduced to Norway in the 1970's and the parasite has since been found in 51 Norwegian rivers. The parasite has caused catastrophic decline in the salmon populations in infected rivers and the authorities have strived to eradicate G. salaris from all rivers in which it has become established. The Norwegian Veterinary Institute is the national centre of expertise in regard to eradication of *G. salaris* and as such is responsible for all eradication work in Norwegian rivers. All eradication programs are commissioned by the Norwegian Environment Agency.

Surveillance for G. salaris in Norway in 2020

The Norwegian Veterinary Institute coordinates three surveillance programmes for *G. salaris* under contract from the Norwegian Food Safety Authority. The surveillance programme for *G. salaris* in restocking hatcheries and rivers (OK-programme) and the Freedom of infection programme for *Gyrodactylus salaris* (FM-programme), and a surveillance programme utilising a combination of eDNA and electrofishing is used to survey the salmon and G. salaris populations in the river Drammenselva above Hellefossen following closure of the salmon ladder. See https://www.vetinst.no/overvaking for more detailed information (In Norwegian).

During the surveillance programme for hatcheries and rivers, 2901 salmon and rainbow trout from 87 farms were studied along with 2375 salmon from 71 rivers. *G. salaris* was not detected in any of the examined fish in 2020. In the freedom of infection programme a total of 775 salmon juveniles from five watersheds were examined. The following 'infected regions' were included: Vefsna (1 river), Skibotn (3 rivers) and Rana (one river). *G. salaris* was not detected. On the basis of results from the FM-programme the Norwegian Food Safety Authority has now declared the Rana watershed including the river Tverråga in Nordland, free of this parasite (see more under eradication measures).

Infection status and changes in threat level
Of the originally 51 infected rivers, 8 remain infected at the start of 2021 (figure 9.5.2). These are the Drammenselva and Lierelva in Viken region, Sandeelva (Vesleelva) and Selvikvassdraget in Vestfold and Telemark regions, and Driva, Usma, Litledalselva and Batnfjordselva in Møre og Romsdal. Four rivers are under surveillance related to declaration of freedom of infection: the rivers Fustavassdraget in Nordland, and Skibotnelva, Signaldalselva and Kitdalselva in Troms og Finnmark region.

Eradication measures and method development 2020

No eradication measures against *G. salaris* were performed in 2020. The work of preservation of genetic materials, planning and surveying continued in the Driva and Drammen regions.

Method development

Chemical treatment of *G. salaris* in Norway has been based on use of rotenone, with the exception of the Lærdalselva where alumimium sulphate was used in the main river in combination with rotenone in adjoining tributaries, drains and ponds. The fundamental difference between these two treatments is that while rotenone eradicates the parasite through eradication of the host fish (the salmon), the aluminium method only eliminates the parasite.

Development of eradication methodology is considered important in the fight against *G. salaris*. In this regard the Environment Agency has financed a three-year project in which the Norwegian Veterinary Institute, NINA and NIVA are working together to investigate the effect of chlorine based compounds in treatment of *G. salaris* infections in large water bodies. Chlorine has, in extremely low concentrations, been identified as toxic to *G. salaris* and may remove the parasite from the salmon without killing the fish. Trials in the Driva were extended in 2020 to study the effect of chlorine treatment at concentrations and exposure times equivalent to that required for *G. salaris* treatment on juvenile trout. New dosage equipment for chlorine treatment was also tested on a large scale. The results indicate that the dosing equipment worked well and that the trial could be considered successful.

Infected region Rana

Based on surveillance performed by the Norwegian Veterinary Institute as part of the FM-programme for *G. salaris*, the Norwegian Food Safety authority has now declared the river Rana (Rana watershed) free of *G. salaris* infection. The county governor was presented with the documentation on the 10. December as a final proof that the Rana and the Tverråga are once again free of infection. The Rana is the regions second largest river (130km) and is an important river for salmon and trout. The 'infected Rana region' comprised the rivers Ranelva, Røssåga, Bjerka, Bardalselva, Sannaelva and Slettenelva/Busteråga. *G. salaris* was dirst identified in the Ranaelva in 1975. The infection spread further to the rivers Slettenelva/Busteråga (1993).

The parasite was identified in the Røssåga in 1980 and spread further to the Bjerka (1980), Bardalselva (1989) and Sannaelva (1989). The region was treated with rotenone in 2003 and 2004 and was subsequently declared free of infection in 2009. The parasite was again identified in the Ranaelva in the autumn of 2014 and the river was treated within one month of this detection. This was possible thanks to good documentation of previous treatments and good preparatory planning. In this way the parasite was prevented from once again spreading through the whole region.

Infected region Skibotn

In this region in Troms and Finnmark, the work of re-establishment of salmon,

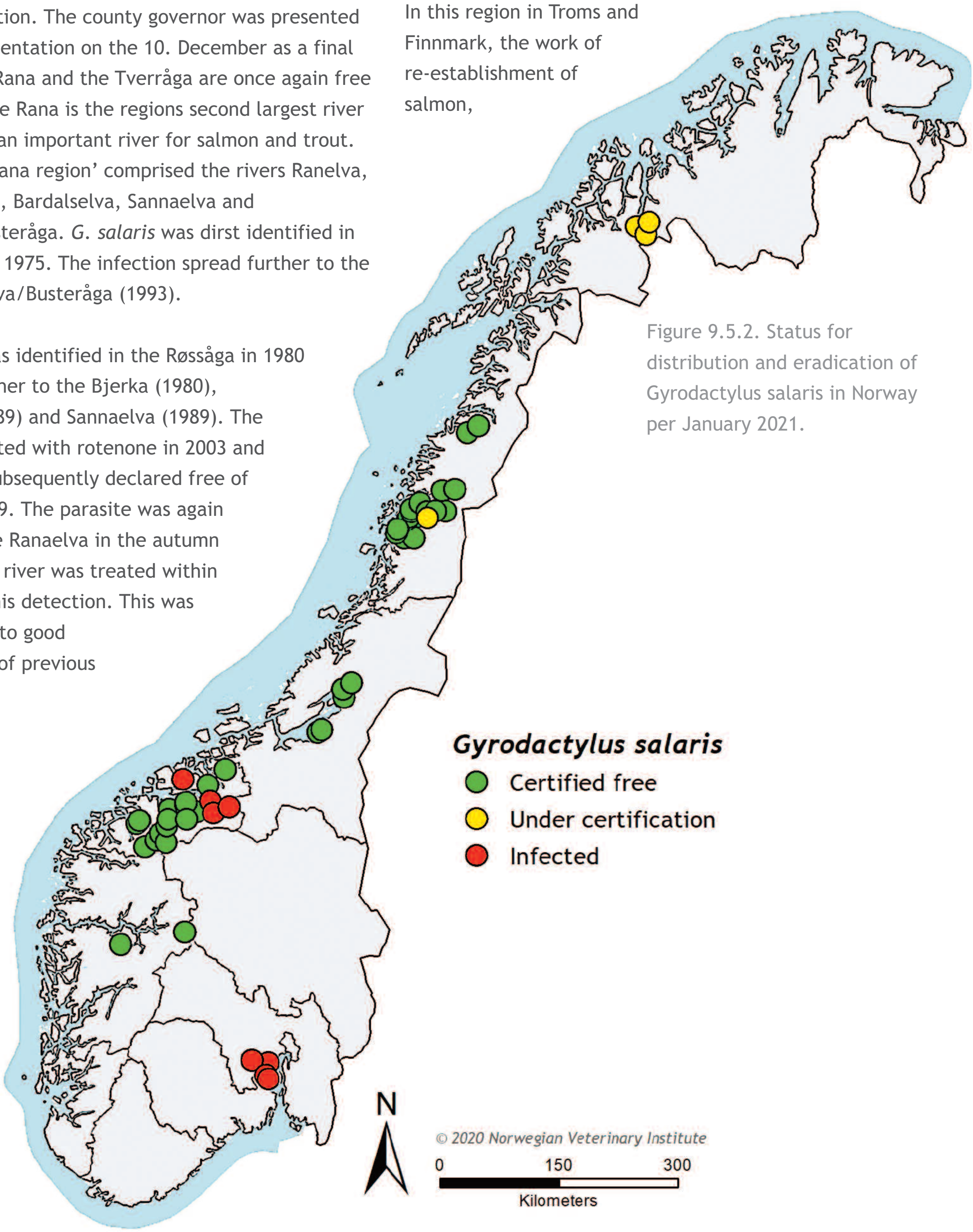


Figure 9.5.2. Status for distribution and eradication of Gyrodactylus salaris in Norway per January 2021.

seatrout and arctic char continues after treatments performed in 2015 and 2016.

Infected region Driva

G. salaris was identified in the Driva for the first time in 1980. The infected Driva region includes the rivers Driva, Litledalselva, Usma and Batnfjordelva. The Driva has a long and in places inaccessible salmon-migratory stretch. To limit the extent of 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 with chlorine is planned for the Driva in 2021. The final decision on which treatment form will be used in the various affected rivers in the region has not yet been made. Hydrological surveys started in 2019 as part of the pre-treatment planning were nearly completed in 2020.

To conserve the seatrout population in the river Driva, all seatrout stopped by the fish barrier are transported over the barrier following genetic testing and saltwater treatment. From 2020, fish have also been caught downstream of the barrier and moved upstream. The salmon population is conserved through collection for the gene bank. While the material presently held in the gene bank has aged over the years, new families were added in 2018 and 2020. The conservation work related to the salmon population of the river Batnsfjordelva has followed a similar plan to that of the Driva. In 2020, collection of material for the gene bank from the Driva region was extended to include seatrout from the Batnfjordselva and Litledalselva rivers, and salmon and seatrout from the river Usma.

The eradication and preservation project coordination group is led by the Regional Governor in Møre og Romsdal and includes representatives from the Norwegian Food Safety Authority, the Environmental Agency and the Norwegian Veterinary Institute as well as a local coordinator employed by Sunndal council.

Infected Drammen region

This region comprises the four rivers, Drammenselva, Lierelva, Sandeelva and Selviksvassdraget, all of which are infected with *G. salaris*. The parasite was first identified in the Selviksvassdraget as late as the autumn of 2019. An expert group established by the Environment Agency concluded in 2018 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. This method has the most extreme negative effects on the fish populations in any treated water body. There does not as yet exist enough experimental or practical experience with the chlorine method. It is therefore important that this method is studied more closely before the final decision regarding the treatment method used in the Drammen region is finally decided upon. This work is now underway in the Driva region. In preparation for future treatment, a hydrological survey of the river Sandeelva in Vestfold was performed in 2020.

Since 2016, the Norwegian Veterinary Institute has collected salmon for the gene bank for wild salmon in a bid to preserve the Drammen watershed strain/s of salmon. In 2020 collection was extended to include salmon and seatrout from the river Sandeelva and Selvikvassdraget in Vestfold. To preserve the seatrout population of the river Drammen, all seatrout reaching the fish barrier at Hellefossen are transported upstream following genetic testing and disinfection. This is done to prevent transport of hybrids and to remove any parasites. The fish ladder at Hellefossen has been closed for upward migration of salmon since 2018. The salmon and *G. salaris* populations above Hellefossen are monitored in a specific surveillance project. Coordination of this eradication and preservation work in the region is led by the county governor in Oslo and Viken and representatives from the Norwegian Food Safety Authority, the Environmental Agency and the Norwegian Veterinary Institute.

9.6 The salmon louse and sustainability

Expansion of the aquaculture industry shall be sustainable and be regulated by the so-called ‘traffic light system’ in which salmon louse infestations represent a sustainability indicator. In this regard an expert group has been established to perform an annual evaluation of the risk of mortality in wild salmon resulting from salmon lice originating in farmed salmon. Figure 9.6.1 summarises the expert group’s conclusions for the 13 production areas (PO) for the period 2016-2020.

In the latest evaluation, published in December 2020, PO’s 2 and 3, from Ryfylke to Sotra, were categorised as having the greatest louse-associated wild salmon mortality. PO4 and PO7 are categorised as responsible for moderate mortality while the remaining nine areas are characterised as causing low mortality. 2020 represents a so-called ‘intermediate’ year and forms the first part of the scientific basis for sustainability ‘grading’ in 2021/2022.

Based on the expert groups evaluation in 2018 and 2019, the steering group comprising representatives from NINA, Institute for Marine Research and the Norwegian Veterinary Institute, provided scientific advice to the Ministry of Trade and Industry (NFD).

Before publishing their decision on ‘sustainability grading’ in February 2020, the NFD had considered the scientific advice from the steering group, short-term developments in lice number and a social-economic study of the consequences.

Amongst other outcomes, PO3, which the steering group had estimated to demonstrate a probability of salmon-louse induced mortality in wild salmon of more than 30% (red), was awarded an amber traffic light by NFD. In addition, two areas in which the steering group had estimated the probability of salmon-louse induced mortality to be between 10 and 30 % (amber), were awarded a green traffic light by NFD. Areas awarded ‘green’ status were allowed to increase production capacity by 6% (approximately 33 000 tons), while areas awarded ‘red’ status were ordered to reduce production capacity by 6% (around 9000 tons). Production limits in ‘amber’ areas remained unchanged.

Table 9.6.1 The expert group’s evaluation for the period 2016-2020. 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
1. Swedish border - Jæren	Low	Low	Low	Low	Low
2. Ryfylke	Moderate	Low	Moderate	Low	High
3. Karmøy to Sotra	High	High	High	Moderate	High
4. Nord- Hordaland to Stadt	Moderate	High	Moderate	High	Moderate
5. Stadt to Hustadvika	Moderate	Moderate	Moderate	High	Low
6 Nordmøre - Sør-Trøndelag	Moderate	Low	Low	Low	Low
7 Nord-Trøndelag including Bindal	Moderate	Low	Moderate	Low	Moderate
8 Helgeland - Bodø	Low	Low	Low	Low	Low
9 Vestfjorden og Vesterålen	Low	Low	Low	Low	Low
10 Andøya - Senja	Low	Low	Low	Moderate	Low
11 Kvaløya - Loppa	Low	Low	Low	Low	Low
12 West-Finnmark	Low	Low	Low	Low	Low
13 East-Finnmark	Low	Low	Low	Low	Low

9.7 The health situation in the Gene bank for wild salmon

The gene bank for wild 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 a living gene bank, i.e. farms stocked with the offspring of wild broodstock. The Norwegian Veterinary Institute is the national centre of expertise for the countries gene bank and coordinates activities under contract from the Norwegian Environment Agency.

The aim of the gene banks biosecurity strategy is prevention of amplification and spread of infectious disease during reestablishment and restocking projects. The biosecurity programme shall also secure good fish health within the gene bank itself and thereby avoid loss of important genetic stocks through production of specific pathogen free stocks.

Health control of wild-caught broodstock for the gene bank for wild salmon

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 Norwegian Veterinary Institute and genetically characterised by NINA. The health control is based on post-mortem and testing for relevant infectious agents by 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 2020, all fish collected for the gene bank were tested for infectious pancreatic necrosis virus (IPNV) and *Renibacterium salmoninarum* (BKD). In addition, salmon were tested for *Piscine myocarditis* virus (PMCV) and *Piscine orthoreovirus* (PRV1). Seatrout were tested for *Piscine orthoreovirus*-3 (PRV3). The three latter analyses were conducted to identify possible sources of vertical transmission i.e. transmission of infection from parent to offspring via the eggs and milt.

In 2020, 453 salmon and 275 seatrout were tested. One seatrout tested positive for IPNV by PCR. *R. salmoninarum* was not detected, while PRV1 was found in several salmon and PRV-3 was found in several seatrout (see table 9.7.1)

Table 9.7.1. Results from PCR-analysis for *Renibacterium salmoninarum* (BKD), infectious pancreatic necrosis virus (IPNV), piscine myocarditis virus (PMCV) and Piscine orthoreovirus 1 (PRV1, salmon) and 3 (sea-trout, PRV3) performed on wild-caught broodstock destined for the gene bank for wild salmon and seatrout. For the Trøndelag region, two restocking hatcheries are included, with 76 salmon tested only for IPNV and BKD.

Production area	Salmon	Seatrout	Comment
Helgeland region (PO8)	3		
Trøndelag region (PO6)	76		1 of 37 salmon positive for PRV1
Driva- and Sunnmøre region (PO5 og 6)	180	115	78 salmon positive for PRV1, 17 seatrout positive for PRV3
Hardanger region (PO3)	115	129	2 salmon positive for PRV1, 14 seatrout positive for PRV3. 1 seatrout positive for IPNV.
Drammen region (PO1)	79	31	9 salmon positive for PRV1, 1 salmon positive for PMCV, 5 seatrout positive for PRV3
Total	453	275	

9.8 Topical

Furunculosis in wild and farmed fish in the Namdal area

Aeromonas salmonicida ssp. *salmonicida* (Ass) causes the disease furunculosis in salmonids. The bacterium was introduced to Norway with rainbow trout from Denmark (1964) and with salmon smolts from Scotland (1985). The infection spread within the fish farming industry and to wild salmonids in several areas along the coast. As effective vaccines were introduced the disease receded in both farmed and wild fish.

In the Namdal region of Trøndelag, an endemic infection became established that has resulted in almost annual outbreaks of infection in wild salmon and seatrout in some rivers in the region. High summer water temperatures and low water levels increase the likelihood of outbreaks. Since 2015 the infection has also been identified in lumpfish transferred to salmon ongrowing farms in the area as cleaner-fish. In 2020, ASS infections and to a certain degree, clinical disease, were diagnosed in 6 salmon ongrowing farms in the area, where infection in both salmon and lumpfish were diagnosed in two. One diagnosis involved only lumpfish.

The year 2020 was a relatively cold with a lot of snow melt and outbreaks of furunculosis were not identified win wild salmon. The few dead individuals observed were not submitted to the Norwegian Veterinary Institute for diagnosis. Low numbers of wild juvenile salmon have, however, been observed in the river Ferga in Namdalen, an area known for regular outbreaks in adult wild salmon. In 2019 furunculosis associated mortalities were observed in juvenile salmon in this area (See the Fish Health Report for 2019). There is a considerable need for more knowledge on how this infection is maintained in the area and the effects it has on the local wild salmonid populations.

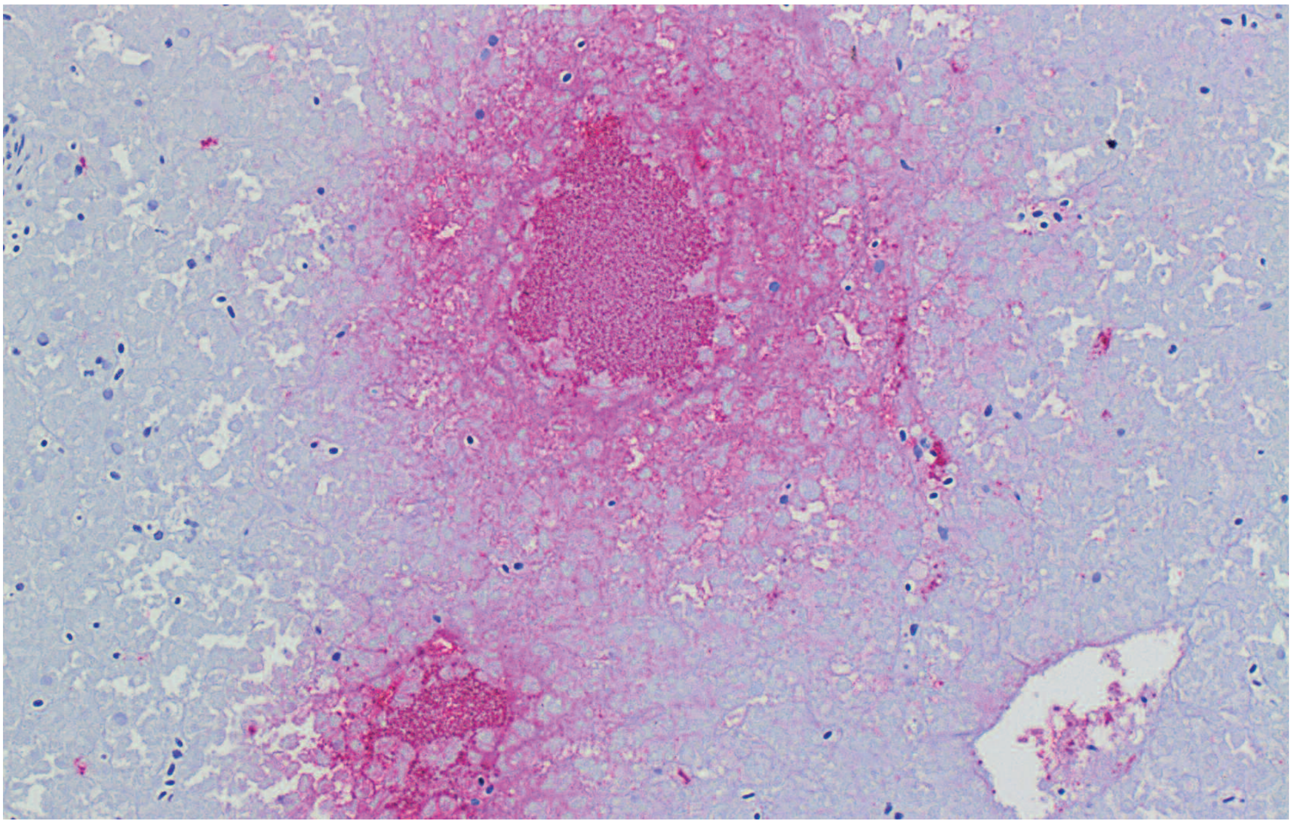


Figure 9.8.1. Immunohistochemistry section, where the red colour indicates positive marking of *Aeromonas salmonicida* in the liver cells of wild salmon. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

10 Health situation in cleaner-fish

By Toni Erkinharju, Synne Grønbech, Geir Bornø, Snorre Gulla and Haakon Hansen

Use of cleaner-fish in aquaculture

In recent years large numbers of wild-caught and farmed cleaner-fish have been used in the fight against the salmon louse. 'Cleaner-fish' is a collective term used for lumpfish and the various wrasse species used for this purpose. The most commonly used wrasse species are goldsinny, corkwing, ballan and to a lesser degree rockcook.

According to the Directorate for Fisheries (data per 21.01.2021) a total of 42.2 million cleaner-fish were transferred to sea in Norway in 2020. This statistic is based on biomass and is probably an underestimate. Alternative information from EWA consulting suggests that the total number of cleaner fish utilised in 2020 was around 59.6 million, which represents a reduction of approximately 10% from the previous year.

Lumpfish used as cleaner-fish in salmon cages are of farmed origin (38.9 million in 2020), while most wrasse are wild-caught (18.2 million in 2020) with only a minority of ballan wrasse being farmed (2.5 million in 2020). The statistics for each species made available by EWA consulting.

Lumpfish are considered easier to farm and have a much faster developmental cycle than the wrasse species. Wrasse are also less active and thereby eat fewer lice at lower water temperatures. Lumpfish are therefore more commonly used in the north of the country. High water temperatures have been found to be negative for the health of lumpfish and information from producers indicate that use of lumpfish is declining, particularly in southern Norway, probably as a measure to reduce mortality levels in this species.

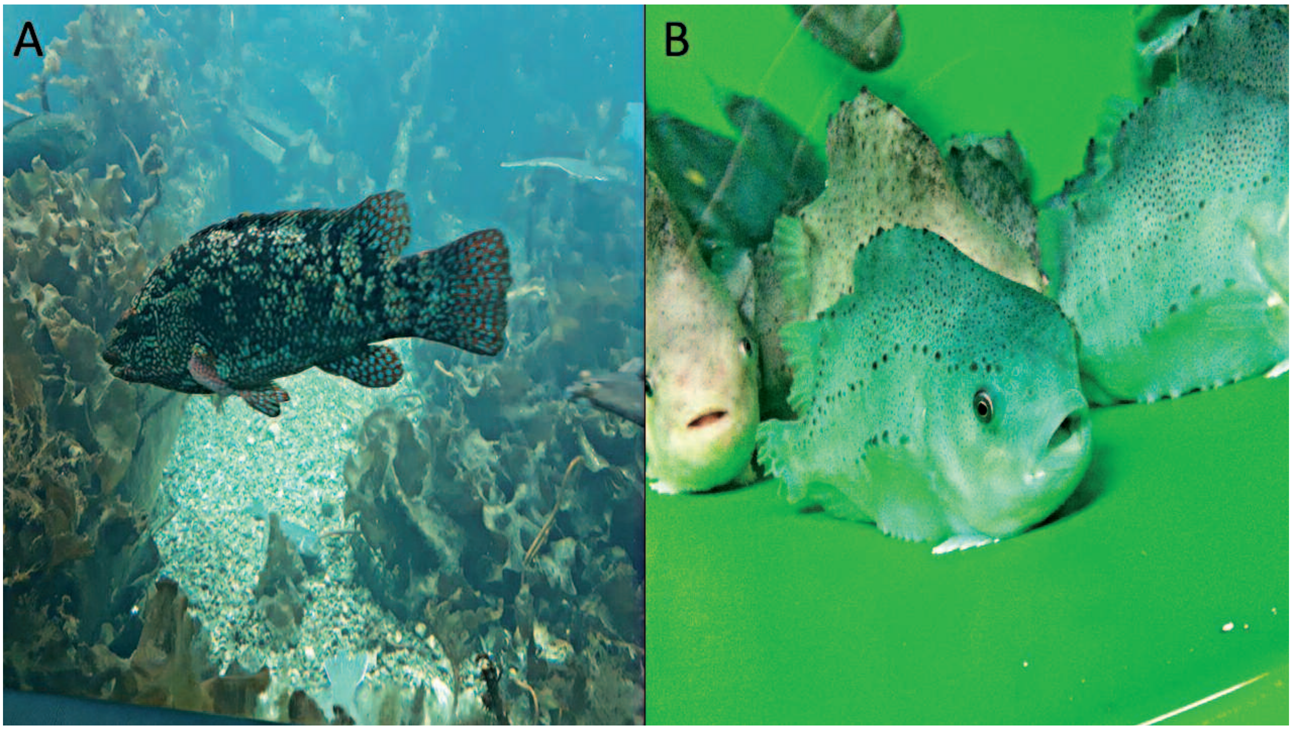


Figure 10.1. Cleaner-fish species. A: Ballan wrasse (Labrus bergylta). B: Lumpfish (Cyclopterus lumpus). Photos: Toni Erkinharju, Norwegian Veterinary Institute.

Wrasse fisheries are regulated and based on fyke netting or fish trapping in the summer. The captured fish are then transported to salmon farms in smaller boats, well-boats or overland in tank lorries. In addition to Norwegian captured fish, wild-caught wrasse are also imported from Sweden. The longest transports may therefore involve transport of fish from the Swedish west coast as far as Nordland region. From a biosecurity perspective such transport must be considered risky and involves a considerable risk of transport of infectious agents.

The most important health and welfare based challenges in Norwegian cleaner fish use include direct mortality and problems resulting directly or indirectly as a result of handling, skin lesion development and several bacterial diseases. Lumpfish in particular appear susceptible to a number of pathogenic agents often present in mixed infections, which may make identification of the primary cause difficult.

Common diseases/agents in cleaner-fish

Bacteria

The most commonly identified bacteria associated with disease in wrasse and/or lumpsucker are atypical *Aeromonas salmonicida, Vibrio anguillarum, Pasteurella* sp. and *Pseudomonas anguilliseptica*. Several other types of bacteria are regularly isolated from sick and dying fish, but knowledge of their pathogenic significance is limited.

Atypical furunculosis (caused by atypical *Aeromonas salmonicida*) is one of the most important bacterial diseases of cleaner-fish and two genetic variants of the bacterium dominate amongst Norwegian cleaner fish (A-

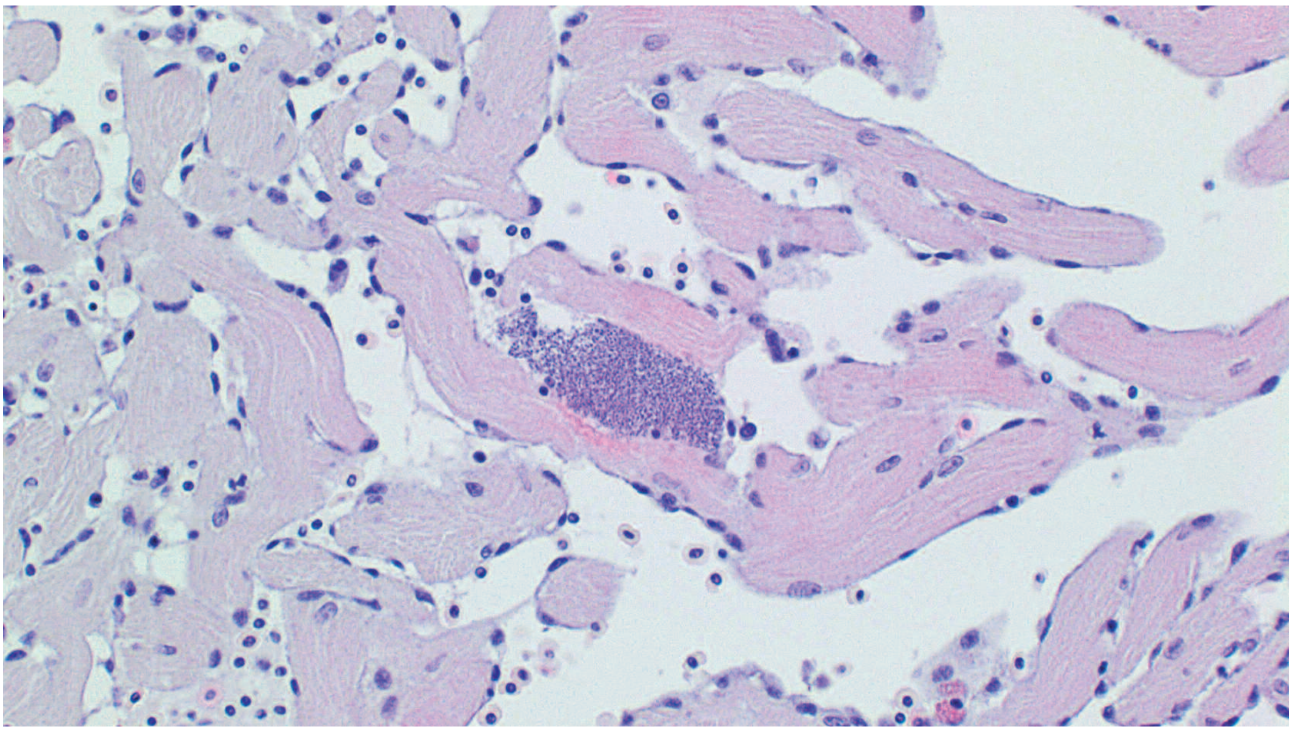


Figure 10.2. Micro-colonies of rod-shaped bacteria in Ballan wrasse with atypical furunculosis. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

layer types V and VI). A. salmonicida infection commonly manifests as a chronic disease with multi-organ granuloma and ulcer development. The notifiable infection caused by *A. salmonicida* subsp. *salmonicida* was diagnosed in lumpfish used as cleaner-fish in Trøndelag in 2015 and 2016 and in 2020.

Classical vibriosis caused by *Vibrio anguillarum* is an important disease in marine fish and occurs sporadically in cleaner fish. Clinical signs include skin lesions, fin-rot, skin haemorrhage, and haemorrhage of the internal organs. Vibriosis is associated most commonly with high water temperatures, but outbreaks have been described at temperatures as low as 6oC in lumpfish. More than 20 serotypes have been described but serotypes O1 and O2 (including sub-types of O2) are most common in Norway. *V. anguillarum* (primarily serotype O2, but also serotype O2a) was diagnosed in three lumpfish localities in 2020, but not in wrasse.

Vibrio ordalii also causes vibriosis and has been identified sporadically in lumpsucker in Norway. It manifests as a haemorrhagic septicaemia and may result in significant mortality and recurring outbreaks. There have been relatively few localities affected in recent years.

Other Vibrio species e.g. *V. splendidus, V. logei Vibrio wodanis* and *V. tapetis* are commonly isolated from cleaner fish. They are common environmental bacteria and their significance as pathogenic agents is uncertain. It may be speculated that external factors such as transport and stresses involved in being held in a salmon cage contribute to susceptibility to bacteria that normally do not result in disease.

Fin-rot is a recurring problem in ballan wrasse production. *Tenacibaculum* spp. and *V. splendidus* are commonly cultured from such outbreaks, both in pure culture and in mixed cultures. *Tenacibaculum* may also be isolated from other wrasse species and lumpfish. *Tenacibaculum* sp. has been isolated from several cases of ‘Crater disease’ in lumpfish but it has not been confirmed as the aetiological agent.

Pasteurella sp. causes pasteurellosis in farmed lumpfish in Norway and Scotland. A closely related bacterium also causes pasteurellosis in salmon in Norway (see chapter 5.6 *Pasteurella* infection in salmon). The Norwegian Veterinary Institute has recently proposed the ‘working name’ of *Pasteurella atlantica* genomovar *cyclopteri* for the variant causing disease in lumpfish. The disease manifests as a bacterial sepsis with white skin lesions, tailfin rot, ascites and haemorrhage in the gills and at the base of fins among the external signs. Outbreaks of pasteurellosis may occur in hatcheries and in sea cages. Mortality can be extremely high, at times up to 100%.

Pseudomonas anguilliseptica is an opportunistic fish pathogen and was identified for the first time in Norway in lumpsucker in 2011. The infection manifests normally as a haemorrhagic septicaemia.

Moritella viscosa is isolated regularly from cleaner-fish, often in association with skin lesions and most commonly at low water temperatures.

Piscirickettsia salmonis was identified in lumpsucker in Ireland in 2017, but has never been identified in Norwegian cleaner-fish.

Systemic infection with *Photobacterium damselae* subsp. *damselae* was recently diagnosed in wild-caught ballan wrasse on the south coast of England. This bacterium has not been reported from cleaner-fish in Norway.

Fungal infections

Fungal disease occurs sporadically in cleaner fish and can potentially lead to health problems in affected fish. Increased mortality has been reported in lumpfish with yeast (*Exophiala*) infections and three species have been identified i.e. *E. angulospora, E. psychrophila* and *E. salmonis*. Infection with *E. psychrophila* has been reported in lumpfish in Norway.

Parasites

A broad spectrum of parasites has been identified in both farmed and wild cleaner-fish. *Paramoeba perurans, Nucleospora cyclopteri, Trichodina* sp., *Ichtyobodo* sp., *Kudoa islandica, Gyrodactylus* sp., *Caligus elongatus, Eimeria* sp. and *Ichthyophonus* sp. are considered as potential serious pathogens of farmed cleaner-fish in Norwegian aquaculture. Potential cross-species transmission from cleaner fish to salmon is also a possibility for *P. perurans, C. elongatus, Anisakis simplex* and *Ichthyophonus* sp. *A. simplex* is a zoonotic agent which could potentially be spread from infected cleaner fish to salmon to humans. *A. simplex* has not, however, been identified in farmed salmon destined for consumption.

The amoeba *P. 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, this parasite causes pathological changes (tissue proliferation and adhesions) in the gills of affected cleaner fish. It has been diagnosed in cleaner fish stocked with salmon and in lumpfish farmed on land in tanks.

Microsporidea are single-celled parasites. The microsporidean *Nucleospora cyclopteri* is known to infect the nucleus of white blood cells of infected lumpfish. Infected fish often develop a pale and enlarged kidney, with or without the presence of white nodules. By infecting the nucleus of white blood cells, it is expected

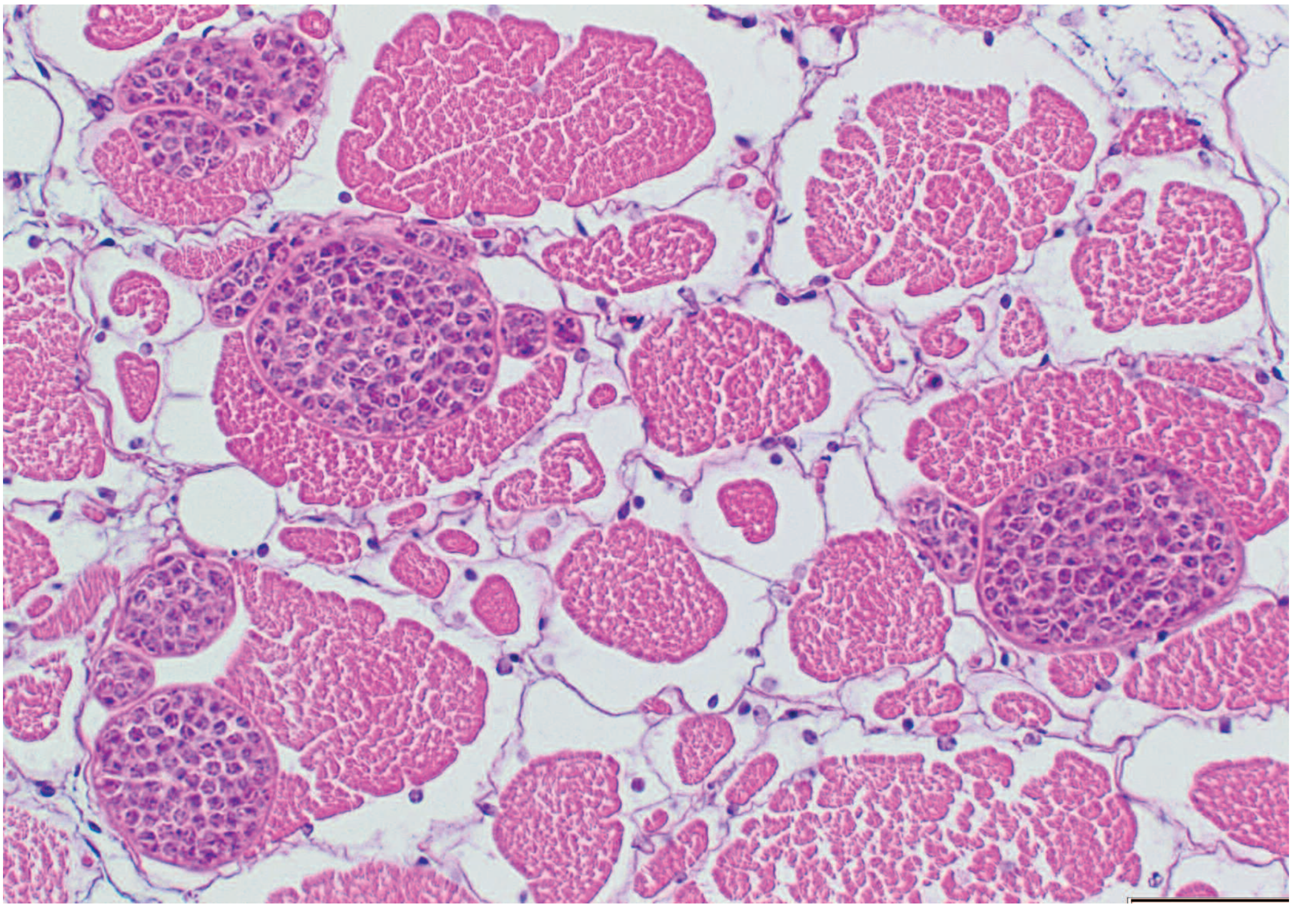


Figure 10.3. Skeletal musculature of lumpfish infected with several myxozoa (*Kudoa sp.*) plasmodia. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

that the infection compromises the immune response of the fish. The parasite is difficult to identify histopathologically and is therefore most probably under diagnosed. Newly developed in situ hybridisation techniques were found capable of visualising the parasite in tissue sections which were difficult to detect by histology alone. *N. cyclopteri* infection was not diagnosed in lumpfish by the Norwegian Veterinary Institute in 2020.

The myxosporidian *Kudoa* sp. probably *K. islandica*, is occasionally identified in the skeletal musculature of lumpfish. This species was described in 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. This parasite can lead to histolysis of the fillet, which can be problematical when the fish is intended for human consumption.

Infestation with the ectoparasite *Caligus elongatus* is considered a problem in lumpfish farmed in some regions of Finnmark and Troms. In some cases, several hundred lice have been observed on individual fish. Caligus causes skin injuries which may allow entry of secondary infections. Lumpfish have been identified as main hosts for one type 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 over the last two years. On a national level, the virus has posed one of the most significant health threats to farmed lumpfish, particularly during the hatchery stage. High associated mortalities have been reported. The liver appears to particularly affected with massive necrosis of hepatocytes and large numbers of virus particles present. In chronically infected fish, the liver appears more cirrhosis-like and the degree of reduced liver function this causes is speculated upon. The virus is thought to be present along the whole Norwegian coastline, but the Norwegian Veterinary Institute does not currently have 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 hematopoietic necrosis virus (EHNV) which is a notifiable disease. Preliminary data suggests that the virus is not a primary pathogen of lumpfish. The virus has not been identified 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 significance of these infections for lumpfish farming is unknown.

At the close of 2020 a new virus was identified in association with high level mortalities 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 diagnosed 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 a sea-cage 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 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

Cataract (degradation of the proteins in the lens of the eye) has been a frequent finding in lumpfish held in hatcheries and broodstock farms. Calcification of the kidney (nephrocalcinosis) is sporadically identified in cleaner-fish, but the clinical significance of this condition is not known.

The health situation in 2020

Data from the Norwegian Veterinary Institute and other laboratories

Bacteria

Problems with atypical furunculosis continued in 2020 (51 and 29 farms respectively) in lumpfish and wrasse. This is an increase from 2019 when 27 and 15 farms were diagnosed respectively in these species. The statistics are, however, not directly comparable as the 2020 statistics include diagnoses made by both the Norwegian Veterinary Institute and other laboratories.

'Typical' *A. salmonicida* (subsp. *salmonicida*) was identified in lumpfish in three localities in 2020 in the Namsen fjord area in mid-Norway. The pathological changes in individual fish were extensive. The bacterium was also identified in ongrowing salmon in the same area (see chapter 5.2. Furunculosis).

Infections caused by *Pasteurella* sp. have caused problems in recent years in lumpfish held in salmon ongrowing farms, and the disease was identified in 36 farms in 2020. This is higher than reported in previous years with 10 farms positive in 2019. The statistics are again, not directly comparable as the 2020 data includes diagnoses made by both the Norwegian Veterinary Institute and other laboratories. One of the private laboratories also reported detection of *Pasteurella* sp. in ballan wrasse, which is as far as we are aware, the first detection of *Pasteurella* in wrasse. Infection with Pasteurella sp. was also identified in several salmon populations (see chapter 5.6 *Pasteurella*-infection in salmon).

The number of lumpfish localities affected by *Pseudomonas anguilliseptica* has increased steadily in recent years, with the exception of 2019 when it was identified in 7 farms. In 2020 *Pseudomonas anguilliseptica* infection was identified in lumpfish in 18 farms. *P. anguilliseptica* was not diagnosed in wrasse in 2020.

Vibrio anguillarum was identified from ballan wrasse in four farms and in two lumpfish populations in 2020. Most of these outbreaks occurred in Vestland region. Of the isolates that could be classified by serotyping, serotype O1 was identified in one ballan wrasse population, serotype O2 from one population of lumpfish and a serotype O2b from a ballan wrasse population. The *Vibrio ordalii*-like bacterium (previously presented as *V. ordalii* in earlier reports) was not identified from cleaner-fish in 2020.

A broad array of Vibrio species (*V. splendidus, V. logei, V. tapetis, V. wodanis, Vibrio* sp.), *Moritella viscosa* and Tenacibaculum spp. were also isolated from cleaner-fish in 2019, often in mixed culture and the role of individual isolates in each situation is not easily identified.

Fungal agents

Specific fungal diseases were not diagnosed by the Norwegian Veterinary Institute in cleaner-fish in 2020.

Virus

Viruses were not identified in the diagnostic material submitted from cleaner-fish to the Norwegian Veterinary Institute in 2020. Statistics from the private laboratories reveal a total of 30 farms positive for cyclopterus lumpus virus (CLuV) or lumpfish flavivirus (LFV) in lumpsucker in 2020.

Parasites

AGD was identified in one population of ballan wrasse in 2020 (southern Norway). The number of AGD diagnoses made in cleaner-fish has been generally low in recent years.

Nucleospora cyclopteri was not identified by the Norwegian Veterinary Institute in lumpfish in 2020. As described previously it is probable that *N. cyclopteri* is underdiagnosed as it is difficult to detect in routine histopathological investigations.

The myxozoan *Kudoa* sp. were identified in the skeletal musculature of lumpfish from one farm in 2020. In this case relatively few spores were identified and only minor pathological change was observed. An unspeciated myxozoan parasite was identified in the kidney (excretionary part) of lumpfish.

Flagellates (probably *Cryptobia* sp.) and fungus-like parasites (probably *Cyclopptericola* sp.) were identified in the stomach of lumpfish in a few sites. These probably reflect harmless infections. Sporadic identification of ectoparasites including *Trichodina* sp. and other gill-related ciliates could not be related to significant health problems. Trematodes were identified in samples (gills, liver and intestine) from lumpfish in a very few farms. Nematodes were identified in lumpfish from two farms and goldsinny wrasse from one farm.

Other diseases

Calcification in the kidney (nephrocalcinosis) is diagnosed sporadically and was identified by the Norwegian veterinary Institute and other laboratories in lumpfish from eight farms and ballan wrasse from two farms. Cataract was also diagnosed in one case involving lumpfish in 2020.

The annual survey

In 2020, as in 2019, significant levels of mortality continue to be reported in cleaner-fish. As in 2019, the most challenging problems seem to be experienced following sea-transfer. The challenges appear to be more serious for lumpfish than wrasse.

There is considerable uncertainty as to whether there has been any change in mortality levels in cleaner-fish transferred to sea in 2020. Most respondents report either a similar situation to that experienced in 2019 or that they 'do not know' whether there has been a change. Very few report lower mortality, only 5.3% and 1.5% responded 'yes, generally lower mortality" for lumpfish and wrasse sp. held in ongrowing salmon farms, respectively for 2020.

Following sea-transfer, the disease problems are related to infectious disease, handling and non-medicinal delousing, skin disease and emaciation (Appendices D2 and E2). Of the infectious diseases, atypical furunculosis appears to be the most significant problem for both lumpfish and wrasse. Atypical furunculosis appears to have particularly increased amongst wrasse last year. For lumpfish, 'crater disease' and pasteurellosis are amongst the most important infectious diseases. There appear to be fewer problems during the hatchery phase, but fin erosion and suboptimal husbandry are mentioned (Appendices D1 and E1). As for cleaner–fish in ongrowing farms, atypical furunculosis is considered a major problem in hatcheries, in addition to vibriosis and 'crater disease'.

Replies to the annual survey give a general impression that fish health personnel saw no clear improvement in the health and welfare of cleaner fish in 2020. The majority of free text comments related to the health and welfare of cleaner fish were of a negative character, and several respondents consider cleaner-fish use difficult to justify. The challenges associated with (or lack of) removal of cleaner fish from cages during delousing, or re-stocking of cages already holding diseased cleaner fish (or fish of uncertain disease status), unsuitable sea-transfer times/unsuitable localities, are amongst the problems listed. Ineffective vaccines and difficulties related to control of disease following sea-transfer are problematic.

There is still a great need for increased knowledge regarding optimising the farming environment to suit the needs of the fish. Some consider the use of cleaner-fish in their farms acceptable as long as fish are properly looked after and their welfare is in focus and that conditions in the hatchery supplying the fish are good. Others state that the welfare and health of cleaner-fish is under-prioritised at the management level and that systematic improvements are not made or difficult to introduce. Some respondents state that some farmers have stopped using cleaner-fish due to the welfare related issues, while others state that cleaner-fish use is crucial in the fight against the salmon louse. Clear and defined legislation is required.

It is worth mentioning that replies to the survey are nor differentiated geographically, and therefore represent views for the country as a whole. There will undoubtedly be geographical differences in opinions regarding cleaner-fish use and cleaner-fish health. The smaller number of respondents replying on wrasse health and welfare compared to the number commenting on lumpfish use should also be considered.

Evaluation of the cleaner fish situation

The health and welfare of cleaner-fish has been in focus in 2020 partly because of the Norwegian Food Safety Authority campaign of 2018/2019 (final report delivered early 2020). The final report concludes that many farmers consider that cage-held cleaner-fish have a good welfare standard and that considerable efforts are made to maintain this situation. Nevertheless, many cleaner-fish die in salmon ongrowing farms. While exact figures are not available, previous reports indicated mortality levels approaching 100% in the course of a production cycle.

From the point of view of many fish health personnel, the situation is quite negative according to replies to this year’s survey with challenges associated with handling and removal prior to delousing particularly important. Many farmers are undoubtedly working to improve the situation, but the knowledge and technology necessary to make cleaner-fish use sustainable with acceptable welfare, remains lacking.

Bacterial agents remain the most important type of infectious disease and there is therefore a requirement for new and/or improved vaccines and vaccine regimes. Many of the infectious diseases experienced today would undoubtedly be less serious if the host fish were in better physiological condition. Some consider the health situation to be improving in hatcheries, but significant problems remain post-sea transfer. There is a significant requirement for improvement in knowledge of the biological and nutritional requirements of cleaner fish and the physical features of the farming environment in which they are held. There is undoubtedly much room for improvement of the health and welfare of cleaner-fish.

The welfare of cleaner-fish is discussed further in chapter 3- Fish welfare.

11 The health situation in farmed marine fish

By Hanne Nilsen, Toni Erkinharju, Lisa Furnesvik and Geir Bornø

Marine species in aquaculture

Farming of marine fish species is performed in both land-based farms and in sea-cages.

Halibut have a relatively long production period. Specially adapted land-based farms have been constructed for this species. Challenges during the juvenile phase of production include abnormal eye migration.

Turbot thrive best in warm water and imported juveniles are produced in land-based farms. The limited availability of juvenile fish has been a limiting factor for this industry.

Commercial wolffish farming has several biological challenges relating to breeding, egg survival and feed development. This species has high survival rates between fry stage and harvest. Producers aim to produce harvest ready fish within a three year year period. Wolffish are bottom dwellers and require sufficient tank floor area to thrive.

Only a few cod producers are currently active but the number of farms is once again increasing. Cod farming met significant challenges related to juvenile production and early maturation. Some wild-caught cod are fattened in cages prior to sale.

Diseases of farmed marine fish species

In Norway, nodavirus infections have caused losses in marine fish farming since the middle of the 1990's. This disease was first registered in Norway in 2006, and has only been sporadically diagnosed subsequently in recent years.

Francisellosis was first diagnosed in adult cod in Rogaland/Hordaland in 2004/2005. In the following years the disease was diagnosed in cod of all age groups as far north as Nordland. Challenges related to francisellosis led to decreasing profitability in cod farming in the affected regions.

Infection with 'atypical' *Aeromonas salmonicida* is a normal finding in marine fish species and is often associated with high mortality. Vibrio species including *Vibrio (Allivibrio) logei*, *Vibrio splendidus* and *Vibrio tapetis* are also diagnosed regularly from weakened fish, often as mixed infections with atypical *A. salmonicida*. Rich cultures of *Vibrio (Aliivibrio) logei* have been associated with high mortalities amongst juvenile fish in the absence of other findings. Species within the genus *Tenacibaculum* are also commonly identified from marine fish species and are mainly associated with external lesions of the skin and/or eyes.

«*Costia*», *Ichtyobodo* sp. are a not unusual findingo n the skin and gills of halibut and cod. Changes similar to those caused by *Kudo* asp. Have been identified in wolfish. The parsite is considered an unusual finding.

Control

Viral Nervous Necrosis (VNN)/Viral Encephalo-Retinopathy (VER) Nodavirus infection is a notifiable, list 3 viral disease in Norway. Francisellosis (*Francisella* sp.) is a notifiable, list 3 bacterial disease in Norway.

No commercially available vaccine are available against these diseases.

The Norwegian Veterinary Institute factsheets 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 2020

Official data

No suspicion or confirmed diagnosis of Nodavirus infection was made in marine fish species in 2020. Francisellosis caused by *Francisella noatunensis* subsp. *noatunensis* was not diagnosed in cod in 2020.

Data from the Norwegian Veterinary Institute

Halibut and turbot

In 2020, 31 submissions involving halibut (23) and turbot (8) were received, which is an increase from the previous year. Atypical *Aeromonas salmonicida* and *Vibrio* spp. are amongst the most common bacteria diagnosed during the early life stages of halibut. *Carnobacterium maltoaromaticum* was identified in association with inflammation of the peritoneum, pericardial membrane and gonads of broodstock halibut. *Moritella viscosa* was also identified in broodstock halibut disolaying signs of sepsis. Ocular injuries, exophthalmia and damaged cornea were identified in halibut form a sea-farm.

In turbot, atypical *A. salmonicida* has been identified in association with variable levels of mortality. Post-handling gill- and fungal- disease has resulted in high mortality.

Cod

Four submissions were received involving commercially farmed cod in 2020, which the same level as in 2019. Gill inflammation and metal precipitation in the gills was observed in early life stage cod. In a single submission from broodstock, gill inflammation associated with *Trichodina* sp., *Gyrodactylus* sp. and possibly the microsporidian *Loma morhua* as well as cysts of unknown aetiology. *Cryptocotyle lingua* (black spot) was also identified in the same fish.

Spotted wolffish

Seven submissions involving spotted wolffish were submitted in 2020, which is a slight increase from 2019. High mortalities have been experienced during the early larval phase with skin lesions and gill pathologies associated with Trichodina infection. Inflammation in the cardiac musculature and gill inflammation have been frequent findings. *Tenacibaculum* spp. were identified using immunohistochemistry in a single case.

Data from other laboratories

Atypical *Aeromonas salmonicida* was identified in four marine fish farms (consolidated data from the Norwegian Veterinary Institute and other laboratories)

The annual survey

Skin parasites have been problematic in some halibut farms, but good biosecurity works well. In cod, cases of volvulus (twisted intestines), egg-bound broodstock and deformities have been documented.

Live storage of wild-caught cod is challenging in terms of fish welfare, including capture related injuries, poor husbandry, emaciation, sun-burn and pumping injuries. In wolfish, larval mortality and gill inflammation has been associated with start feeding.

Evaluation of the health situation in farmed marine species

Mortality during the early life stages is a challenge for all marine fish species. Live storage of wild-caught cod results in significant welfare consequences.

12 The health situation in cyprinid fish

By Torfinn Moldal

Cyprinids in Norway

Farming of various species of cyprinids for food production is an extremely important industry internationally. Worldwide production of cyprinids exceeds by far the total production of salmonids. Cyprinids are also cultured for food in Europe, but in Norway are solely held as ornamental fish in private ponds and aquaria. There are also populations of 'feral' cyprinids in various water bodies around Oslo and Bergen. While some of these feral populations may have spread from private collections, there is a suspicion that anglers may have illegally stocked some waters with cyprinid fish.

The health situation in 2020

Koi herpes virus (KHV) and carp edema virus (CEV), which is a pox virus, was detected for the first time in Norway in 2019 in two different private ponds in Vestlandet. In the course of 2020 the Norwegian Veterinary Institute has autopsied four cyprinids from three different collections in southern Norway. One of these investigations involved one of the same ponds in which the infection was diagnosed in 2019. In addition, formalin fixed tissues, virus transport medium and RNAlater fixed tissues were submitted from two cyprinid fish and swabs for bacterial culture from two cyprinid fish.

In one of the autopsied fish, dermatitis, ascites and peritonitis was identified and following microbiological investigation, atypical *Aeromonas salmonicida* and *Saprolegnia ferax* were identified. Another cyprinid autopsied displayed a lesion with a channel connecting to the cardiac chamber. A granulomatous pericarditis with fibrous connective tissues between the internal organs and the peritoneal wall were identified. Bacteria were not detected either by culture or histological examination. In the two fish from the same owner, myocarditis was identified in one individual and gill inflammation in the other. KHV and CEV were not detected in any of the fish investigated during 2020.

The Norwegian Veterinary Institute has only limited knowledge of the geographical range or number of cyprinid populations in Norway and therefore little knowledge of the health status of these fish. Identification of KHV in 2019 does however mean that we should be aware of this threat. KHV is a notifiable disease (list 2, non-exotic disease as the disease is found elsewhere in the EU) and will be stamped out following eventual diagnosis. During 2020, 79 KHV outbreaks were reported from seven European countries to the EUs Animal Disease Notification System (ADNS). This is a slight reduction from previous years.

For more information on koi herpes virus see the Norwegian Veterinary Institute factsheet:

https://www.vetinst.no/sykdom-og-agens/koi-herpesvirus-sykdom-khv

The clinical signs associated with Koi herpes virus disease are often diffuse, but typically include white spots on the gills, sunken eyes and spots on the skin. Photo: Norwegian Veterinary Institute.

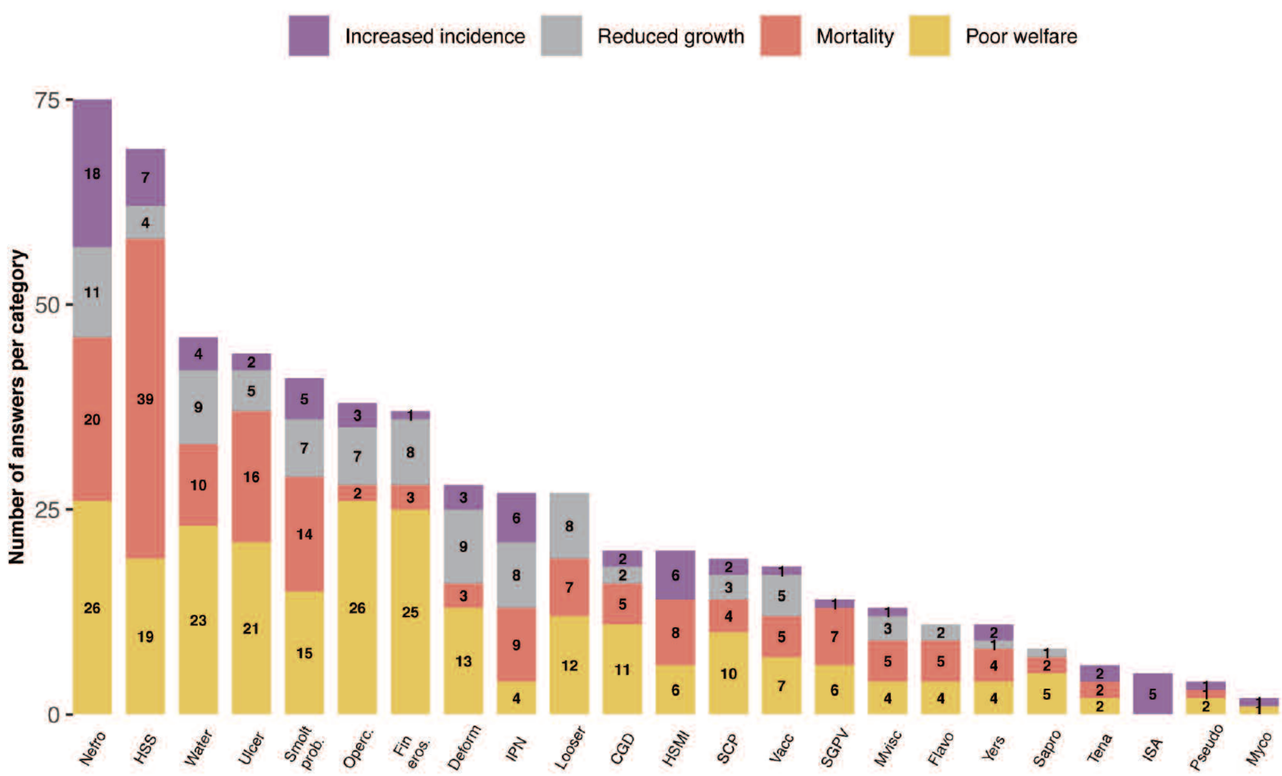
Appendix A1:

Health problems in juvenile production of salmon

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in salmon hatcheries were asked to cross off the five most important of 23 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=45 respondents who responded on mortality, N=51 on reduced welfare, N=32 on reduced growth and N=31 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were:

Abbreviations:

Deform	=	deformities
SCP	=	single celled parasites on skin and gills
Fin eros.	=	fin erosion
Flavo	=	infection with *Flavobacterium psychrophilum*
Operc.	=	opercular shortening
CGD	=	complex gill disease
HSMI	=	heart and skeletal muscle inflammation
HSS	=	hemorrhagic smolt syndrome
ISA	=	infectious salmon anaemia
IPN	=	infectious pancreas necrosis
Mvisc	=	infection with *Moritella viscosa* (typical winter ulcers)
Myco	=	infection with Mycobacteria
Nefro	=	nephrocalcinosis
Pseudo	=	infection with *Pseudomonas* spp.
Sapro	=	infection with *Saprolegnia* spp.
SGPV	=	salmon gill pox virus (gill disease)
Smolt probl.	=	smoltification problems
Ulcer	=	ulcers in the skin and underlying tissue
Looser	=	looser fish, emaciation
Tena	=	infection with *Tenacibaculum* spp (atypical winter ulcers)
Vacc	=	vaccine damage
Water	=	poor water quality
Yers	=	infection with *Yersinia ruckeri* (yersiniosis)



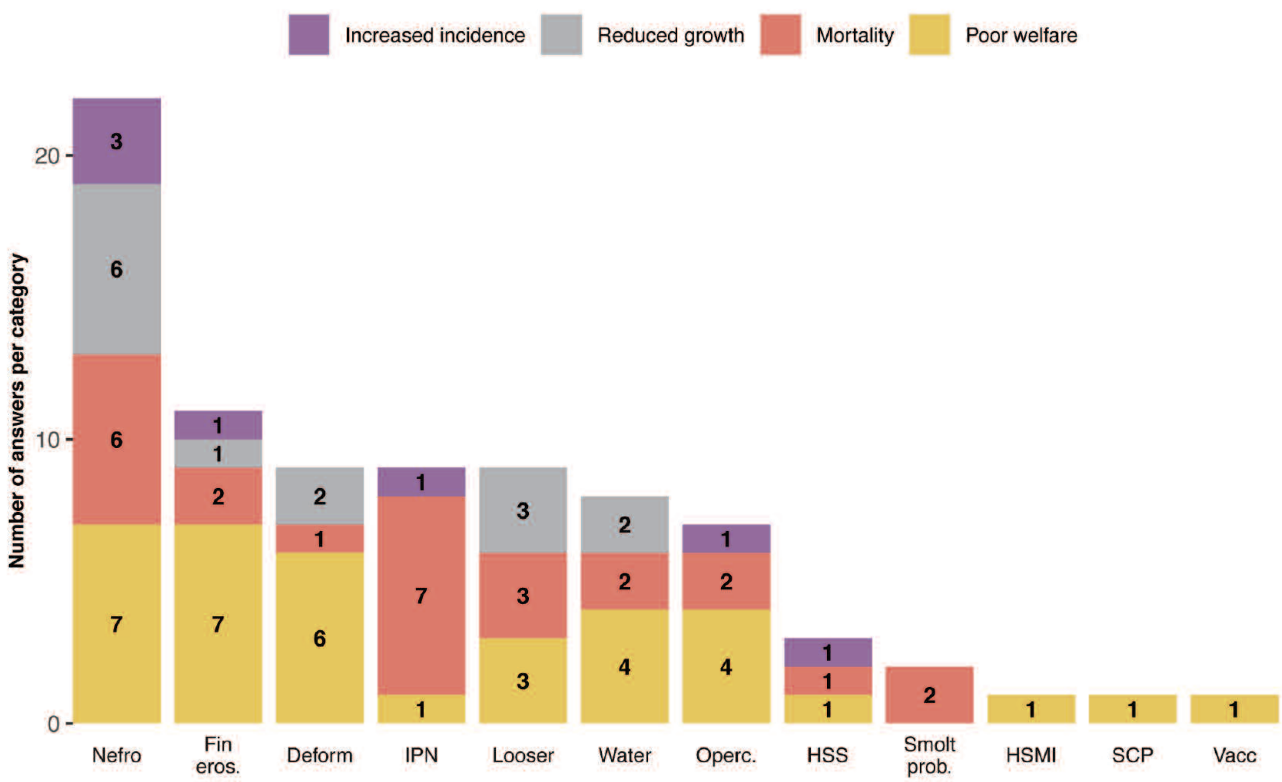
Appendix A2:

Health problems in juvenile rainbow trout production

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in rainbow trout hatcheries were asked to cross off the five most important of 22 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=11 respondents who responded on mortality, N=12 on reduced welfare, N=7 on reduced growth and N=4 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

Deform	=	deformities
SCP	=	single celled parasites on skin and gills
Fin eros.	=	fin erosion
Operc.	=	opercular shortening
HSMI like	=	PRV3/HSMI like disease
HSS	=	hemorrhagic smolt syndrome
IPN	=	infecsious pancreas necrosis
Nefro	=	nephrocalcinosis
Smolt probl.	=	smoltification problems
Looser	=	looser fish, emaciation
Water	=	poor water quality
Vacc	=	vaccine damage



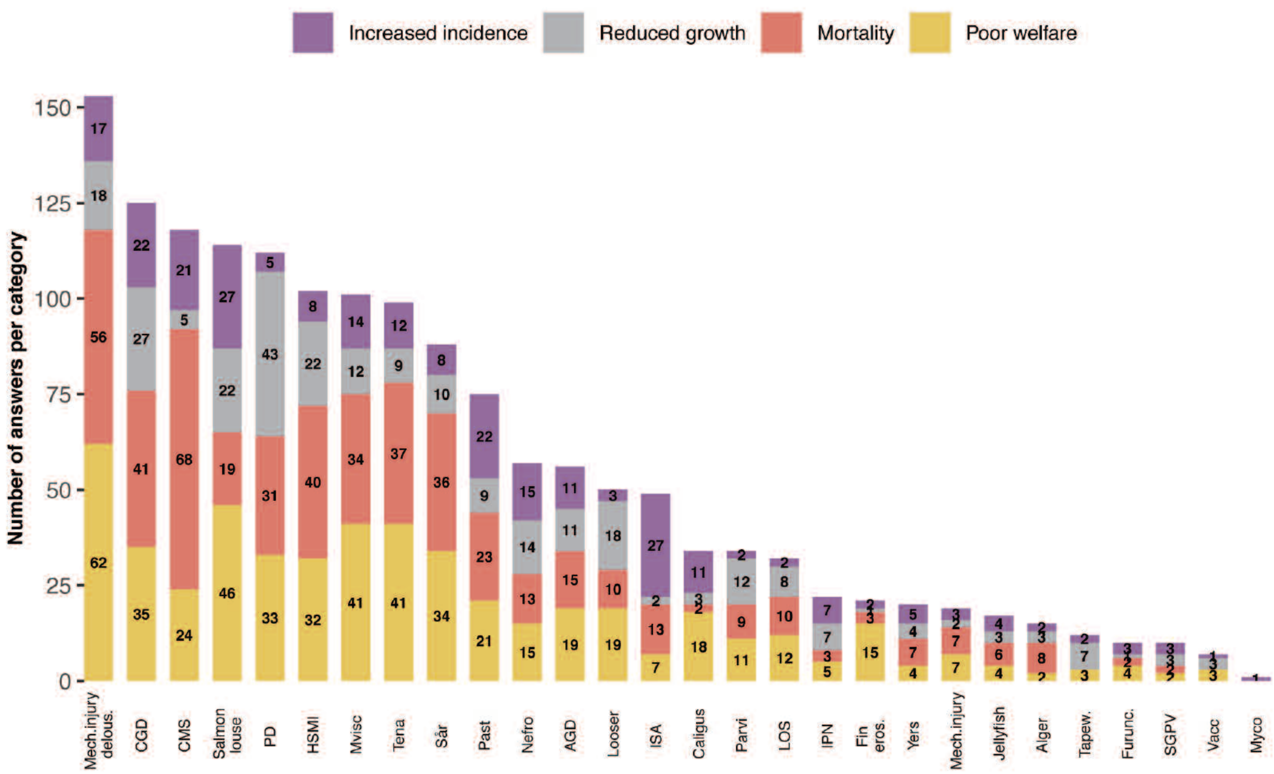
Appendix B1:

Health problems in ongrowing salmon

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in ongrowing salmon were asked to cross off the five most important of 22 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=78 respondents who responded on mortality, N=78 on reduced welfare, N=71 on reduced growth and N=71 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were:

Abbreviations:

AGD = amoebic gill disease
Algae = algae
Tapew. = tapeworm
CMS = cardiomyopathy syndrome
SCP = single celled parasites on skin and gills (*Ichthyobodo* spp., *Trichodina* spp. etc.)
Fin eros. = fin erosion
CGD = complex gill disease
HSMI = heart and skeletal muscle inflammation
ISA = infectious salmon anaemia
IPN = infectious pancreas necrosis
Salmon louse = infestation with *Lepeophtheirus salmonis*
Jellyfish = jellyfish
LOS = lack of smoltification
Mech. injury = mechanical injuries not related to lice e.g. transport injuries
Mech. Injury delous = mechanical injury related to delousing
Mvisc = infection with *Moritella viscosa* (typical winter ulcers)
Myco = infection with Mycobacteria
Nefro = nephrocalcinosis
Parvi = infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Past = infection with *Pasteurella* sp. (pasteurellosis)
PD = pancreas disease
SGPV = salmon gill pox virus (gill disease)
Caligus = infestation with Caligus elongatus
Ulcer = ulcers in the skin and underlying tissue
Looser = looser fish, emaciation
Tena = infection with *Tenacibaculum* spp (atypical winter ulcers)
Vacc = v accine damage
Yers = infection with *Yersinia ruckeri* (yersiniosis)



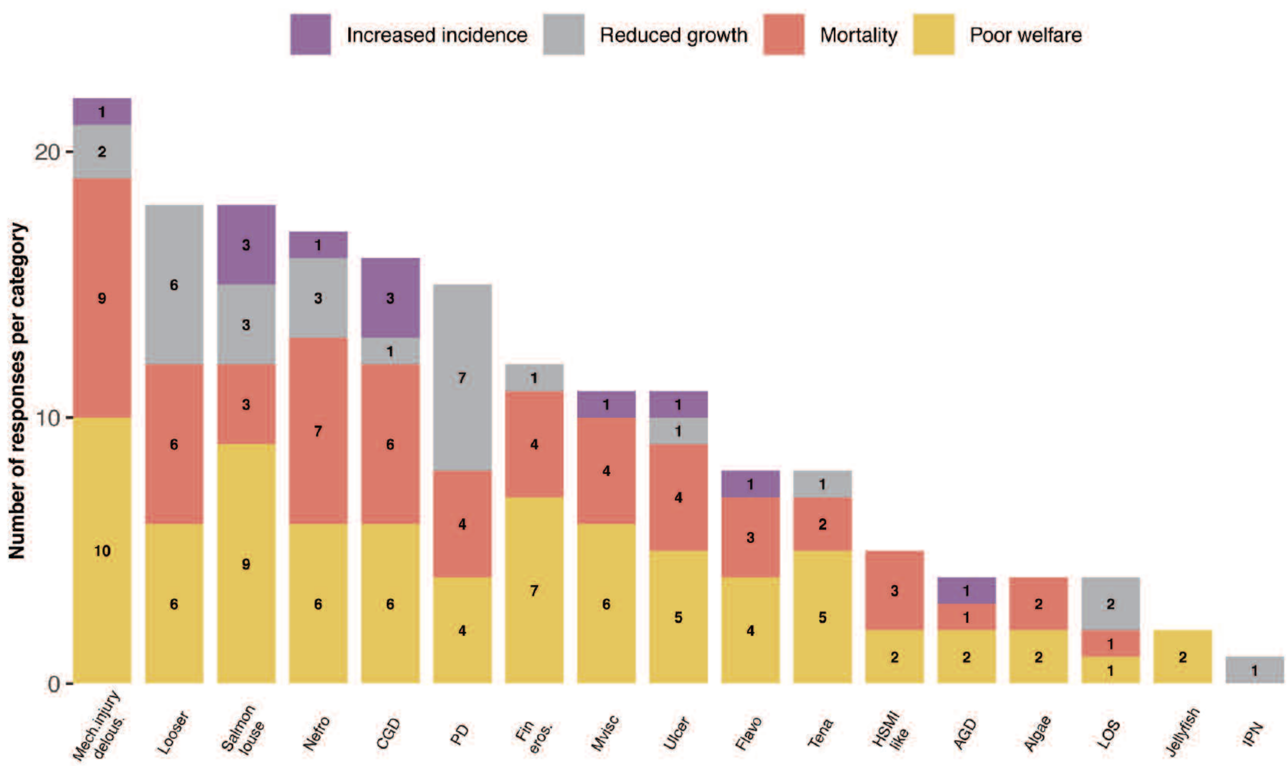
Appendix B2:

Health problems in ongrowing rainbow trout

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in ongrowing rainbow trout were asked to cross off the five most important of 24 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=16 respondents who responded on mortality, N=16 on reduced welfare, N=12 on reduced growth and N=8 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

AGD	=	amoebic gill disease
Algae	=	algae
Fin eros.	=	fin erosion
Flavo	=	infection with *Flavobacterium psychrophilum*
CGD	=	complex gill disease
HSMI like	=	PRV3/HSMI like disease
IPN	=	infectious pancreas necrosis
Salmon louse	=	infestation with Lepeophtheirus salmonis
Jellyfish	=	jellyfish
LOS	=	lack of smoltification
Mech. Injury delous	=	mechanical injury related to delousing
Mvisc	=	infection with *Moritella viscosa* (typical winter ulcers)
Nefro	=	nephrocalcinosis
PD	=	pancreas disease
Ulcer	=	ulcers in the skin and underlying tissue
Looser	=	looser fish, emaciation
Tena	=	infection with *Tenacibaculum* spp (atypical winter ulcers)



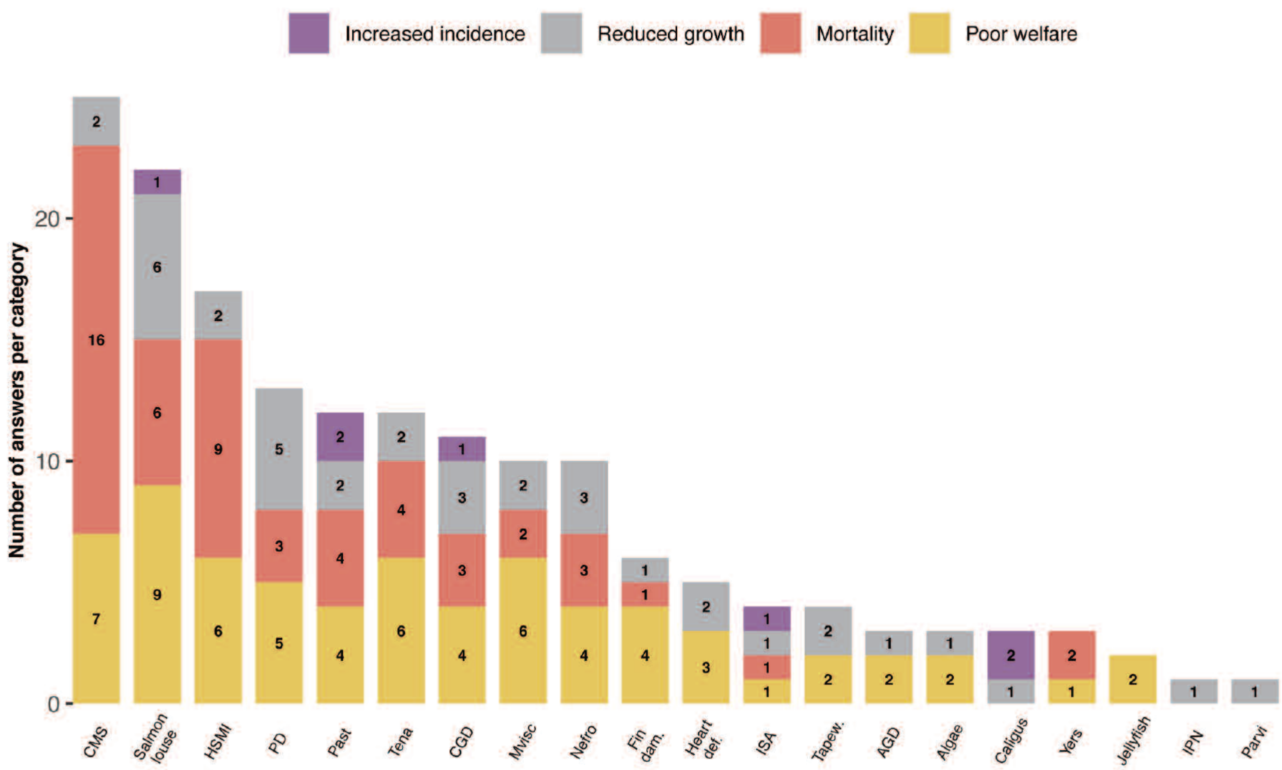
Appendix C1:

Health problems in broodstock salmon

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in broodstock salmon were asked to cross off the five most important of 21 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=16 respondents who responded on mortality, N=13 on reduced welfare, N=9 on reduced growth and N=4 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

AGD	=	amoebic gill disease
Algae	=	algae
Tapew.	=	tapeworm
CMS	=	cardiomyopathy syndrome
Fin dam.	=	fin damage
CGD	=	complex gill disease
Heart def.	=	heart deformities
HSMI	=	heart and skeleton muscle inflammation
ISA	=	infectious salmon anaemia
IPN	=	infectious pancreas necrosis
Salmon louse	=	infestation with Lepeopthteirus salmonis
Jellyfish	=	jellyfish
Mvisc	=	infection with *Moritella viscosa* (classical winter ulcers)
Nefro	=	nephrocalcinosis
Parvi	=	infection with *Parvicapsula pseudobranchicola* (parvicapsulosis)
Past	=	infection with Pasteurella sp. (pasteurellosis)
PD	=	pancreas disease
Caligus	=	infestation with Caligus elongatus
Tena	=	infection with *Tenacibaculum* spp (atypical winter ulcers)
Yers (yersiniosis)	=	infection with *Yersinia ruckeri*



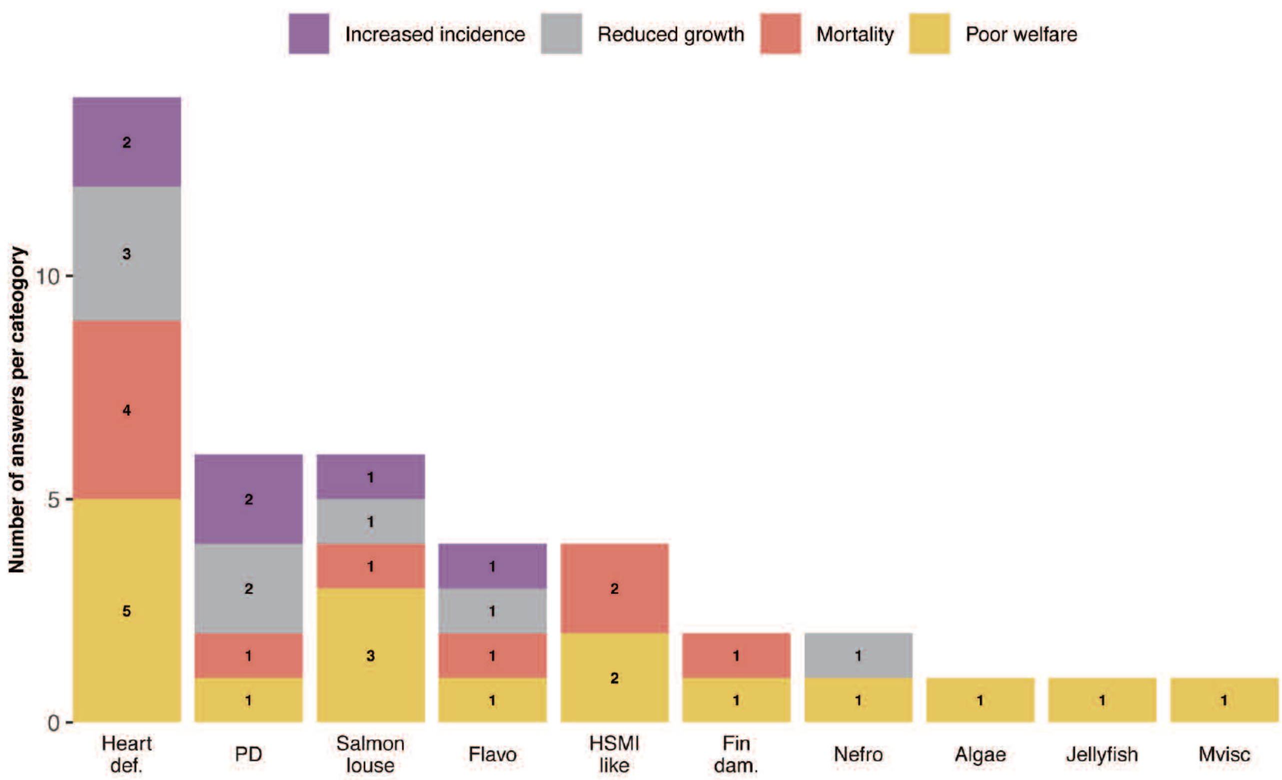
Appendix C2:

Health problems in broodstock rainbow trout

Health problems in broodstock rainbow trout Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in broodstock rainbow trout were asked to cross off the five most important of 19 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=5 respondents who responded on mortality, N=6 on reduced welfare, N=5 on reduced growth and N=3 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

Algae	=	algae
Fin dam.	=	fin damage
Flavo	=	infection with *Flavobacterium psychrophilum*
Heart deform	=	heart deformities
HSMI like	=	PRV3/HSMI like disease
ISA	=	infectious salmon anaemia
Salmon louse	=	infestation with *Lepeophtheirus salmonis*
Jellyfish	=	jellyfish
Mvisc	=	infection with *Moritella viscosa* (typical winter ulcers)



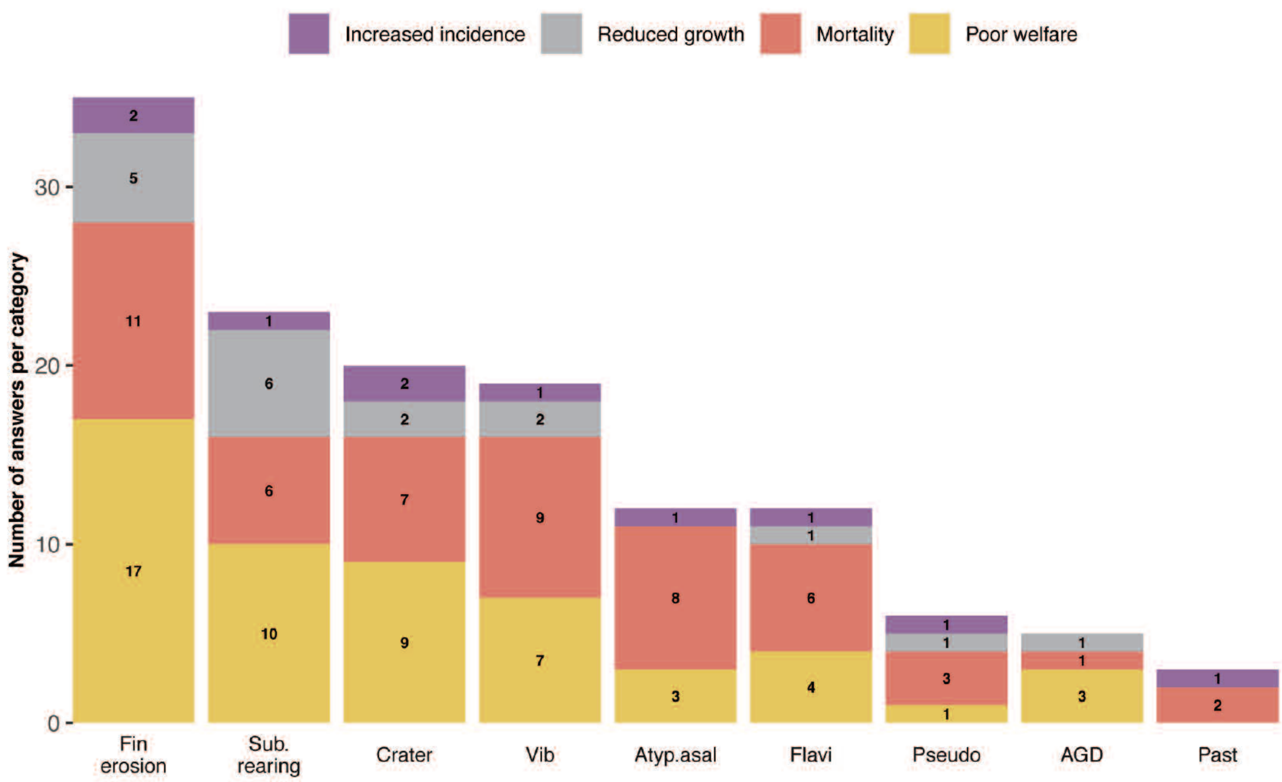
Appendix D1:

Health problems in lumpfish hatcheries

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in lumpfish hatcheries were asked to cross off the five most important of 11 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=19 respondents who responded on mortality, N=21 on reduced welfare, N=10 on reduced growth and N=6 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

AGD	=	amoebic gill disease
Atyp.asal	=	Atypical furunculosis (Infection with atypical *Aeromonas salmonicida*)
Fin eros.	=	fin erosion/rot
Flavi	=	lumpfish flavivirus
Crater	=	crater disease
Past	=	infection with *Pasteurella* sp.
Pseudo	=	infection with *Pseudomonas anguilliseptica*
Sub. rearing	=	sub optimal rearing
Vib	=	vibriosis (Infection with *Vibrio* spp.)



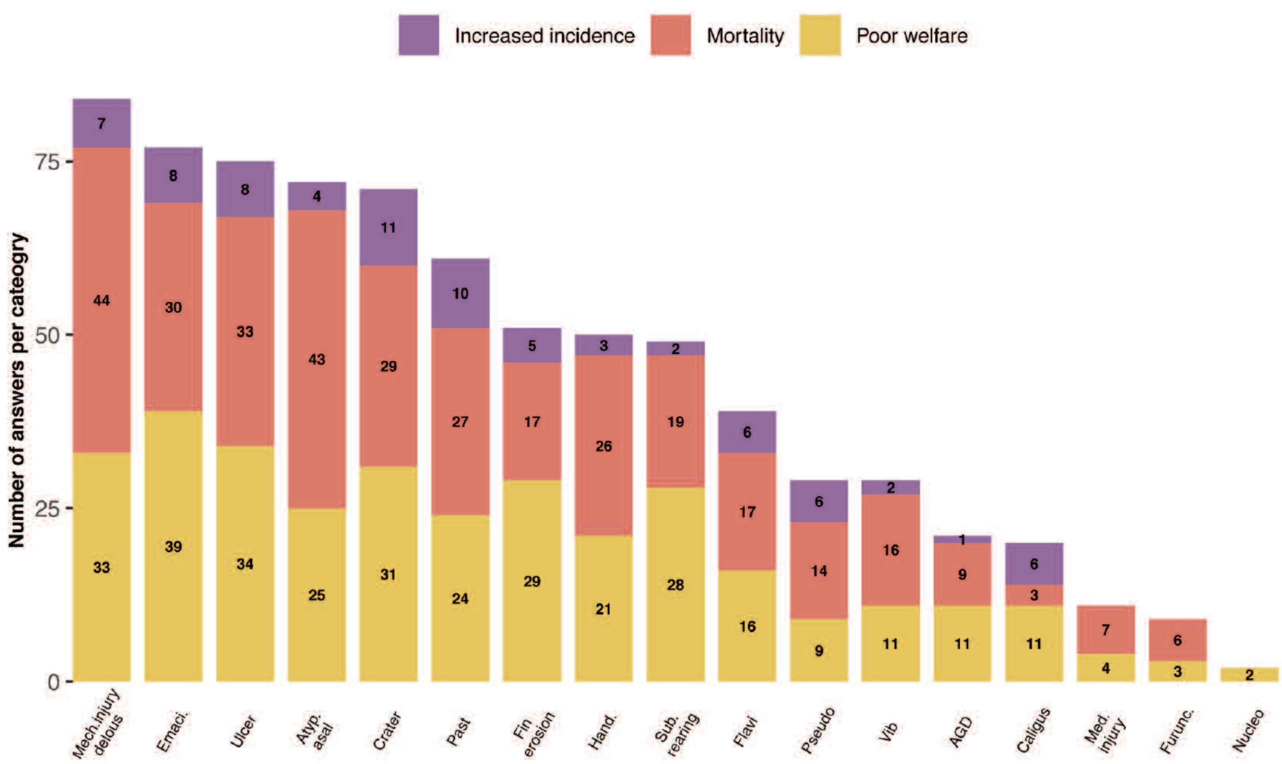
Appendix D2:

Health problems in lumpfish held in salmon ongrowing farms

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in lumpfish held in salmon ongrowing farms were asked to cross off the five most important of 18 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=68 respondents who responded on mortality, N=21 on reduced welfare, and N=64 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure): Helseproblemer hos rognkjeks i matfiskanlegg med laks

Abbreviations:

AGD	=	amoebic gill disease
Atyp.asal	=	Atypical furunculosis (Infection with atypical *Aeromonas salmonicida*)
Emaci.	=	emaciation
Fin eros.	=	fin erosion/rot
Flavi	=	lumpfish flavivirus
Furunc.	=	furunculosis (Infection with *Aeromonas salmonicida* subsp salmonicida)
Hand.	=	mortality due to handling
Crater	=	crater disease
Mech. injury delous	=	mortality related to non-medical delousing
Med. injury	=	mortality related to medical delousing
Nucleo	=	infection with *Nucleospora cyclopteri*
Past	=	infection with *Pasteurella* sp. (pasteurellosis)
Pseudo	=	infection with *Pseudomonas anguilliseptica*
Caligus	=	infestation with Caligus elongatus
Sub. rearing	=	sub optimal rearing
Ulcer	=	ulcers in the skin and underlying tissue
Vib	=	vibriosis (Infection with *Vibrio* spp.)



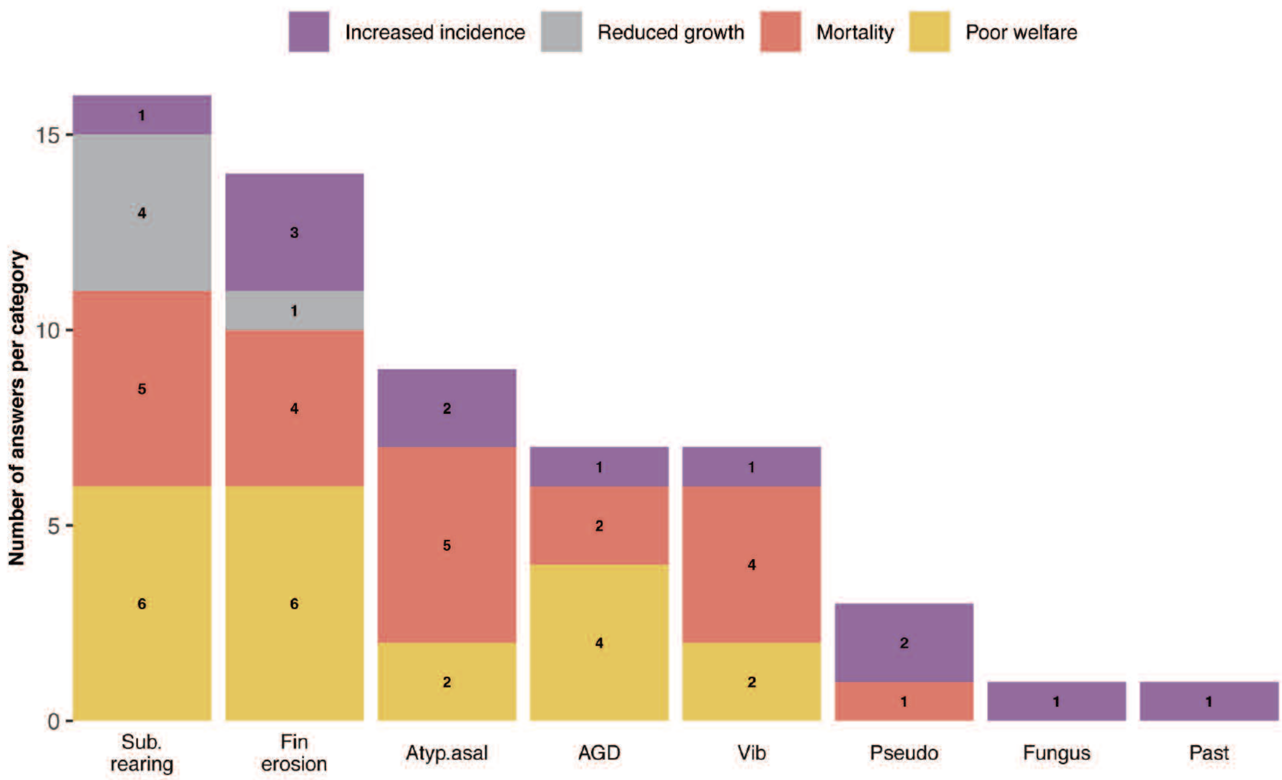
Appendix E1:

Health problems in wrasse hatcheries

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in wrasse hatcheries were asked to cross off the five most important of 8 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=10 respondents who responded on mortality, N=9 on reduced welfare, N=5 on reduced growth and N=5 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

AGD	=	amoebic gill disease
Atyp.asal	=	Atypical furunculosis (Infection with atypical *Aeromonas salmonicida*)
Fin eros.	=	fin erosion/rot
Past	=	infection with *Pasteurella* sp.
Pseudo	=	infection with *Pseudomonas anguillisептica*
Fugus	=	fungal infection
Sub. rearing	=	sub optimal rearing
Vib	=	vibriosis (Infection with *Vibrio* spp.)



Appendix E2:

Health problems in wrasse held in ongrowing salmon farms

Results from the 2020 survey of fish health personnel and inspectors of the Norwegian Food Safety Authority. Respondents with experience in wrasse held in ongrowing salmon farms were asked to cross off the five most important of 14 possible problems, based on whether they contributed to mortality, poor growth, reduced welfare or were considered to be an increasing problem (increasing prevalence). For each problem category there were N=44 respondents who responded on mortality, N=39 on reduced welfare and N=7 on increasing prevalence. The abbreviations for the various problems respondents were asked to express an opinion on were (only problems crossed off are shown in the figure):

Abbreviations:

AGD	=	amoebic gill disease
Atyp.asal	=	Atypical furunculosis (Infection with atypical *Aeromonas salmonicida*)
Emaci.	=	emaciation
Fin eros.	=	fin erosion/rot
Hand.	=	mortality due to handling
Mech. injury	=	mortality related to non-medical delousing
Med. injury	=	mortality related to medical delousing
Past	=	infection with *Pasteurella* sp. (pasteurellosis)
Pseudo	=	infection with *Pseudomonas anguilliseptica*
Caligus	=	infestation with *Caligus elongatus*
Sub. rearing	=	sub optimal rearing
Ulcer	=	ulcers in the skin and underlying tissue
Vib	=	vibriosis (Infection with *Vibrio* spp.)

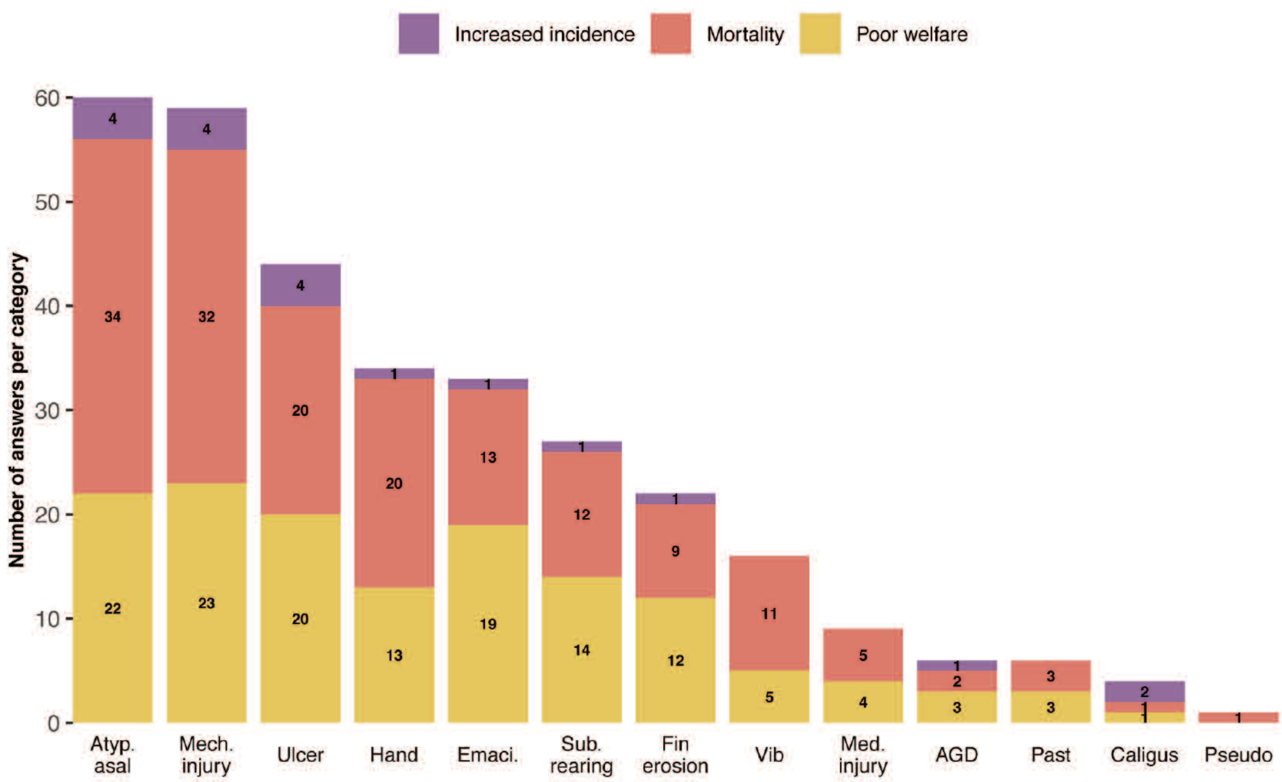


Photo: Colourbox.

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