Report 5b/2020

The Health Situation in Norwegian Aquaculture 2019

Gyrodactylus salaris haptor (attachment organ) magnified 2600 x. Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary

Veterinærinstituttet
Norwegian Veterinary Institute

The Health Situation in Norwegian Aquaculture 2019

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Authorship

Authors are credited for each chapter.

With the exception of chapter 8.4 'Water quality' and contributions to chapter 8.5 'Algae and fish health', written by employees of the Norwegian Institute for Water Research (NIVA), all authors are employees of the Norwegian Veterinary Institute.

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The Health Situation in Norwegian Aquaculture 2019

Contents

Can the situation be further improved by working together?

The annual 'Health Situation in Norwegian Aquaculture' report describes the health and welfare situation of all aquatic organisms farmed in Norway as well as the state of health of wild Norwegian salmonids. The report is published in both Norwegian and English languages. That the report is published by an independent public institution i.e. The Norwegian Veterinary Institute, should inspire a greater degree of confidence that the information is reported in an unbiased fashion. In other countries, it is more normal that similar information is published in a fragmentary fashion by several different actors.

Sustainability

The salmon-louse continues to represent one of the most significant challenges to sustainability. Lice treatment represents a significant economic cost as well as a significant challenge to fish health, fish welfare and the environment. The traffic light system will be an important tool for future improvement of the situation.

The traffic light system should be further developed to include measures related to reduction of prevalence of various diseases and infections that threaten the general health and behaviour of farmed salmon. During 2019, we have observed that some diseases remain a serious challenge after many years, others are under satisfactory control and new diseases continue to emerge. From a health perspective, a reduction in the cumulative disease 'load' would represent a significant contribution towards more sustainable production.

Introduction of measures promoting good health, improved data collection and collaboration relating to data analysis will represent important steps in this work.

Mortality

Total losses within the industry for 2019 were higher than normal, as approximately 8 million salmon died during the algal blooms experienced in Nordland and Troms. Disregarding these specific losses, the underlying mortality registered during the year were slightly lower than the two previous years. While these figures remain high, there is hope that there may be a positive underlying trend. Again, there appear to be large differences in mortality identified between different regions, and regions that have been previously associated with high losses showed reduced mortality in 2019. This shows that efforts to reduce mortality can be rewarded.

It is positive that cleaner-fish health and welfare have attracted increased attention during 2019 and that both the public authorities and industry are working towards improvement of the situation.

In 2018/2019, the Norwegian Veterinary Institute performed a pilot project that focussed on mortality during juvenile salmon production. Mortality during this period in the salmon's life cycle has been previously under-reported and has not been included in mortality statistics. It is intended that these statistics shall be made publically available.

Focus on biosecurity

With the exception of Pancreas Disease, the remaining infectious agents are endemic within the farmed population as a whole.

There has been increased interest in gill-associated diseases in 2019. A number of infectious agents can together with environmental factors, contribute to serious gill damage. Effective treatments are challenging or unavailable. Prevention, based on an understanding of the underlying causes, can reduce the risk of fatal consequences.

As production systems develop and change, we observe that bacterial infections may become more challenging. During 2019, the Norwegian Veterinary Institute has observed the increasing occurrence of infection in salmon caused by *Pasteurella* sp. It is extremely important to continually monitor bacterial diseases and prevent increasing use of antibiotics. The extremely low antibiotic consumption within the Norwegian aquaculture industry, maintained over the last thirty years, represents a success story for which the industry can be rightly proud. A good understanding of preventative measures and rapid availability of effective vaccines, are and will be, central factors in maintenance of this situation.

Many health problems, both infectious and non-infectious, are production related. It is commonly too late to intervene following clinical manifestation of the condition. We must become better at identification of disease prior to clinical manifestation. Good preparedness and effective biosecurity provide the possibility for early intervention before the situation becomes become irreversible.

Infections caused by more than one infectious agent i.e. mixed or multiple infections are not reported in disease statistics. This is particularly interesting in the case of notifiable diseases. ISA which has a 'sneaking' course of infection may be overlooked (and under-reported) if e.g. CMS-pathology and PMCV-titre dominate in diagnostic materials. This represents a diagnostic challenge, which must be taken seriously.

Disease in wild salmon returning to the river Enningdalselva identified during the summer of 2019 shows the need for coordinated knowledge development related to disease in wild fish, both within wild fish populations and between wild and farmed fish.

The river Rauma was declared *Gyrodactylus salaris*-free in 2019. Since introduction of this parasite to Norway, surveillance and eradication in the various rivers and watersheds has cost between three and four billion kroner. This is a significant investment, and highlights the need for maintained vigilance against new introductions.

Digitalisation

Digitalisation provides a great opportunity for sharing and thereby increasing the value of data held by individuals or organisations. That the data is comparable is a pre-condition for maximum utilisation of the potential of digital tools. Several initiatives instigated by the industry and the public authorities lead the way in this respect and the Norwegian Veterinary Institute is participating actively towards standardisation of, and data movement, both internally and externally.

Changes in this year's report

This report is dependent on good data. As national reference laboratory (NRL), the Norwegian Veterinary Institute invites the industry to an even better collaboration such that the information presented is based upon the best possible data foundation. Digitalisation opens for sharing of data based upon a structured and trustful cooperation with clearly defined roles. We expect that the increased potential in active private-public cooperation will be visible in next year's report.

This year's report as in previous years has been made possible in part due to contributions from private laboratories and via a survey of Fish Health services and inspectors within the Norwegian Food Safety Authority. Compilation of the health situation in Norwegian farmed and wild salmon in a single report provides a good basis for working towards a sustainable development of the total health situation.

The editorial committee would like to express its thanks to all who have contributed with text, data, photographs or other form of support. We are also grateful for constructive or critical comments that will lead to its continual improvement and thus provide a steadily better contribution to development of an important industry, and not least focus on the health of both wild and domestic fish.

Edgar Brun,
Responsible Editor and Scientific Director, Fish Health and Fish Welfare

Summary

By Ingunn Sommerset

59.3 million Norwegian farmed salmon were lost from production between sea-transfer and harvest (ongrowers), of which 52.8 million were categorised as mortality-related. This high number can be partly explained by losses associated with algal blooms in Nordland and Troms, which alone killed approximately 8 million fish. If excluded from the total picture, total mortality (approximately 45 million) was at a similar level as 2016 and represents a slight reduction from 2018.

For the notifiable diseases infectious salmon anaemia (ISA) and pancreas disease (PD), no significant change in the disease situation from 2018 was observed. Of the infectious diseases, cardiomyopathy syndrome (CMS) topped the list, both in terms of number of cases diagnosed and as a dedicated cause of mortality. Mechanical injury associated with delousing is reported to be the most significant cause of reduced welfare and after CMS, the most significant cause of mortality during the marine phase of salmon culture (see figure 'Top 10 problems in ongrowing salmon'). As far as welfare and mortality amongst cleaner-fish is concerned, no particular cause stands out, but several observations indicate that lumpsucker and wrasse fail to adapt to the conditions they meet within salmon cages.

Salmon lice, delousing and fish welfare

The salmon louse, an injurious ectoparasite, causes direct injury to sea-farmed salmon and is in addition a threat to outwardly migrating wild salmon smolts, seatrout and sea-run arctic char. Risk analyses performed in association with the 'Traffic light system' are not discussed in the present report, but were presented in a specific report (VI report 23-2019).

In 2019, at a national level, the sea-lice burden was higher than in 2018, during both spring and autumn, despite an increased frequency of both medicinal and mechanical delousing. The lowest lice levels were, however, recorded during the period associated with outward migration of wild salmon smolts during the spring. Nine of the 13 production zones (PO) demonstrated an increase in the average production of louse larvae, while the remaining PO's (1, 12 and 13) reported a reduction.

Anti-lice treatments in Norway in 2019 were dominated by mechanical/physical methodologies and widespread use of cleaner fish. Among the mechanical/physical treatments, thermal treatment continues to dominate despite a reduction in use of this treatment type from 2018 to 2019. The greatest increase (56% increase 2018-2019) was the number of mechanical treatments utilising either water pressure and/or brushing.

Fish Health personnel reported (via our annual survey) that particularly thermal and mechanical treatments often resulted in increased post-treatment mortality. As more than 2,000 such treatments were reported in 2019, this probably constitutes a considerable contribution to the total losses of salmon and rainbow trout in the sea phase of culture. In addition, delousing injuries are reported to be one of the most significant causes of reduced welfare in both salmon and rainbow trout. This underlines once more the direct relationship between delousing and fish welfare.

Cleaner-fish are considered a non-medicinal form of delousing and are discussed in depth in chapters 3 (Fish welfare) and 10 (The health situation in cleaner-fish). For the first time in 2019, registered mortality figures for cleaner–fish in Norwegian sea-cages were made available as part of the Norwegian Food Safety Authority 'Cleaner-fish Campaign'.

The registered median mortality for all cleaner-fish species was 42%. This is, however, almost certainly a significant underestimate, as the report also revealed that the number of cleaner-fish remaining in individual cages at the end of each production cycle are rarely counted. In the survey, 'Emaciation', 'Handling', 'non-optimal care', 'non-medicinal delousing', 'ulcers' and 'Aeromonas' (bacterial infection) were reported to be the most common causes of reduced welfare and mortality.

Viral diseases remain a problem

Three viral diseases continue to dominate new diagnoses made by the Norwegian Veterinary Institute in 2019: 152 sites with pancreas disease (PD), 82 sites with cardiomyopathy syndrome (CMS) and 79 sites with heart and skeletal muscle inflammation (HSMI). Including diagnoses made by private laboratories, the total number of diagnoses reach 237 for CMS and 197 for HSMI. The total number of PD affected sites remains the same, as this is a notifiable disease. As diagnoses made by private laboratories are reported anonymously to the Norwegian Veterinary Institute i.e. the site identity is not revealed, there is a strong possibility that overlapping diagnoses (i.e. the same site), both between private laboratories and between private laboratories and the Norwegian Veterinary Institute, occur. Lab to lab variation in diagnostic criteria may also exist.

Of the 25 diseases surveyed in the annual survey, 90% of respondents considered CMS to be the most important cause of mortality in salmon during the ongrowing phase. Due to technical error, HSMI was not included in the survey, but several respondents commented nevertheless that HSMI represents an extremely important disease. PD was considered the fifth most important disease in ongrowing salmon (by 35% of respondents). As a contributor towards reduced growth, PD came top of the list. See the figure 'Top 10 problems ongrowing salmon' below.

It is positive that the list 2 disease ISA does not appear high on the 'mortality list' in Norwegian aquaculture, and that the number of diagnoses was limited to 10 sites (+ 2 suspected cases) in 2019. The number of confirmed cases is slightly lower than in 2018. As in recent years, the cases were spread over a large geographical area. There were no other list 2 diagnoses made in farmed fish in 2019.

Koi herpes virus (list 2 disease) was identified for the first time in Norway, in a garden pond, during 2019. This is an extremely infectious virus primarily affecting carp, a species mainly found in private collections, but which may also be found as an exotic species in natural water bodies in Norway. The virus does not infect humans.

Other infectious diseases

The bacterial disease situation remains favourable in Norwegian aquaculture. Antibiotic consumption remains low and surveillance of antibiotic sensitivity amongst bacterial isolates cultured from sick fish shows an extremely low frequency of antibiotic resistance. The reduction in the number of cases of yersiniosis, caused by the bacterium *Yersinia ruckeri*, observed in 2018 continued in 2019. The industry continues to have good control over important bacterial diseases such as furunculosis and vibriosis. One change, which occurred in the period 2018/2019, is a marked increase in the number of outbreaks of disease in salmon caused by a *Pasteurella* sp. The number of cases of classical winter-ulcer, caused by the bacterium *Moritella viscosa* is difficult to estimate as the disease is not notifiable and relatively easily diagnosed at the local level. It is worth noting, however, that 'skin-ulcers' scored highly in the annual survey as a problem in sea-farmed salmon, as did *Tenacibaculum* spp. infections.

Of the parasite diseases, while the salmon louse Lepeoptherius salmonis, continues to dominate, see the section above, the sea-louse Caligus elongatus appeared to be a greater problem during 2019 than in the previous year.

Non-infectious diseases and health problems

Health problems caused by non-infectious diseases and environmental related factors are also important. Environmental influences were highlighted in the northerly regions of Nordland and Troms during blooms of the poisonous algae *Chrysochromulina leadbeaterii*, which killed approximately 8 million salmon during the early summer of 2019.

The Norwegian Veterinary Institute has observed an increasing number of cases of serious gill disease in recent years, often associated with a complex/multifactorial infection status. This increase is consistent with responses to the 2019 survey where complex gill disease was considered among the top five most important increasing health problems in ongrowing salmon.

Nephrocalcinosis (kidney stones) is a well-known phenomenon affecting farmed fish and is considered a production-related complaint. Based on the number of cases diagnosed by the Norwegian Veterinary Institute there appears to have been a reduction in the number of cases identified during 2019 (118 sites) compared to 2018 (147 sites). These statistics are almost certainly an underestimate and the actual number of sites affected is unknown. Responses to the survey indicate that nephrocalcinosis is considered as one of the most important health problems in juvenile production of salmon and is considered one of the top ten problems in ongrowing salmon.

Good water quality is decisive for good fish health. While 2018 was associated with several episodes of acute mortality related to production of hydrogen sulphide in

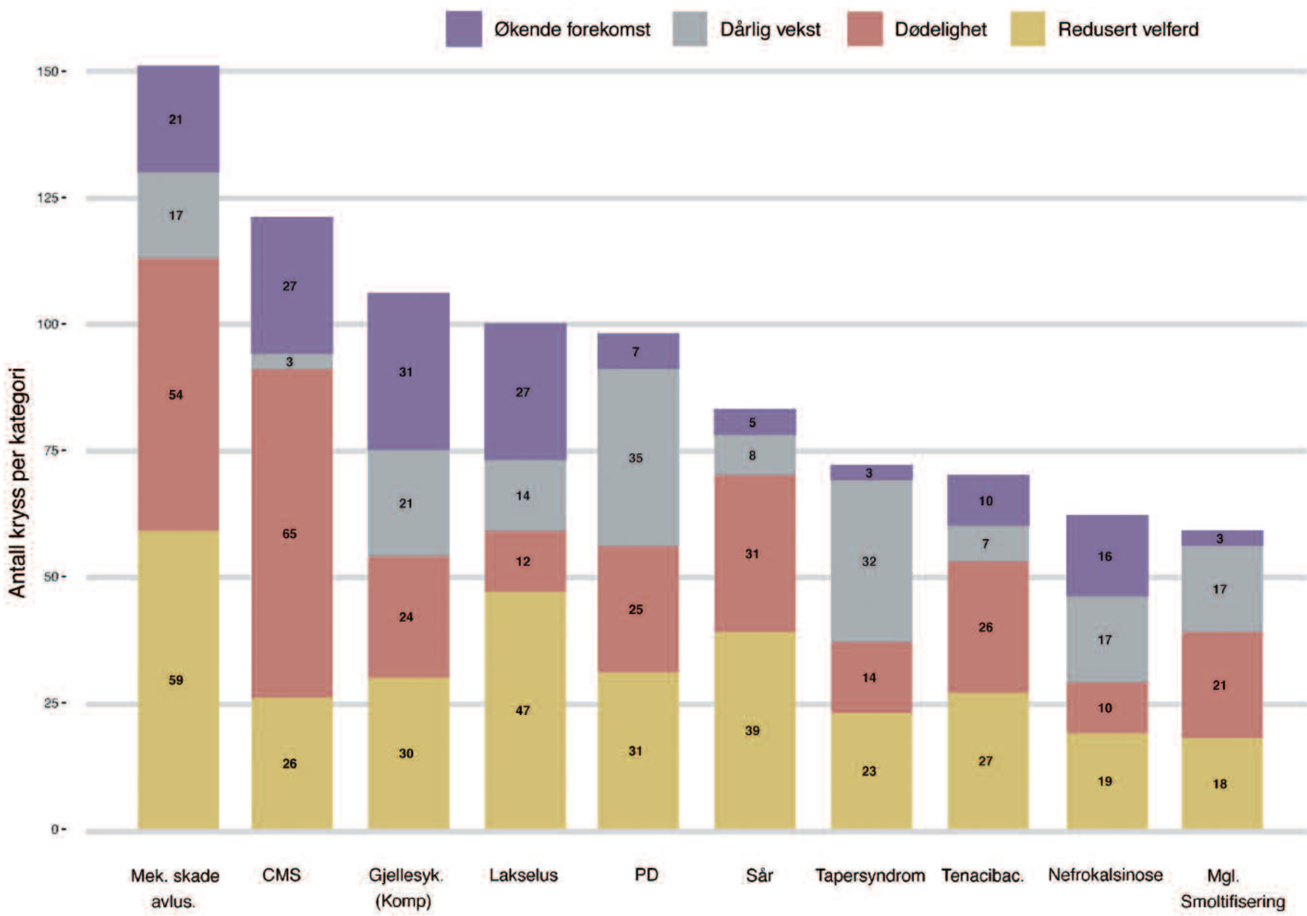


Figure 'Top 10 problems in ongrowing salmon': Respondents were asked to cross off the five main causes of mortality (N= 72 respondents), poor growth (N= 67 respondents), reduced welfare (N=72 respondents), or an increasing problem (N=65 respondents) from a list of 25 alternative diseases/conditions. Abbreviations: Mech. Injury delousing = mechanical injury following delousing; CMS = cardiomyopathy syndrome; Gill dis (comp). = Complex/multifactorial gill disease; PD= pancreas disease; Tenacibac = infection with *Tenacibaculum* spp (non-classical winter-ulcer); Poor smolt = poor smoltification. *Note: Due to a technical error, HSMI was not included in the survey.*

RAS –systems, fewer episodes of this nature were reported in 2019.

With the current intensification of production of juvenile salmon in both RAS and through-flow systems and the increase in prevalence of nephrocalcinosis in recent years, an increased focus on water quality is required. A healthy and robust juvenile fish has a better starting point for the exposed marine stage of culture, both in relation to disease resistance and the physical challenges faced.

Wild salmon

2019 was notable as the 'International year of the salmon' and that the Rauma watershed was declared free of *Gyrodactylus salaris* infection following many years of eradication work. Besides the threat posed by re-introduction of *G. salaris* from neighbouring countries, wild Atlantic salmon stocks are threatened by escaped farmed fish, salmon-lice, disease, pink salmon and climate change amongst other threats.

The number of reported escaped farmed salmon increased in 2019, which is a serious threat due to genetic pollution caused by interbreeding of farmed and wild fish. Escape of diseased fish also represents a risk of spread of infection to wild stocks. The salmon louse is a considerable threat to both farmed and wild salmon, seatrout and sea-run arctic char. The 'Traffic light system' should have been 'turned on' for the first time in the autumn of 2019. The Minister of Fisheries delayed the announcement until February 2020, and the Traffic light system' is therefore presented/discussed only briefly in chapter 9.

The Norwegian Veterinary Institute and the Norwegian Food Safety Authority share public responsibility for diagnosis of disease in wild fish. There is, however, no available 'Field apparatus' available for surveillance of disease in wild fish or sampling from wild fish. We are therefore dependent on contribution of both materials and information from members of the public, councils, environmental authorities and others.

Photo: Marin Helse AS

1 Statistical basis for the report

By Britt Bang Jensen

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 when the mortality is 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 Table 1.1.

The table presents 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 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

Table 1.1. Summary of list 2- and 3-diseases with number of diagnoses for the years 2013-2019. The statistics are based on data from the Norwegian Veterinary Institute.

Disease	List	2013	2014	2015	2016	2017	2018	2019
Farmed fish (salmonids)								
ISA	2	10	10	15	12	14	13	10
VHS	2	0	0	0	0	0	0	0
PD	3	100	142	137	138	176	163	152
Furunculosis	3	0	1	0	0	0	0	0
BKD	3	1	0	0	1	1	0	1
Farmed fish (marine species)								
Francisellosis (cod)	3	1	1	0	0	0	0	0
VNN, nodavirus	3	1	0	0	0	0	0	0
Furunculosis (Lumpsucker)	3	0	0	1	4	0	0	0
Wild salmonids (fresh water)								
Gyrodactylus salaris	3	1	1	0	0	0	0	1
Furunculosis	3	0	0	2	1	2	0	2

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 samples is stored in the institute's electronic journal system (PJS).

Data from PJS is used to generate tables, graphs, maps and text for the current report. Only results of diagnostic investigations are included. Samples submitted for research, quality assurance testing or surveillance programs are excluded. The number of individual sites affected by each disease/agent is registered. We commonly identify the same organism/disease from individual sites several times in the course of a year. For reporting purposes, each site is registered only once in any year for any particular disease/agent. In some cases, the same disease/agent may have been diagnosed in the same batch of fish in 2018, so the statistics do not necessarily describe the number of new cases in 2019. The exception is for notifiable diseases (described above).

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 as possible oversight we have asked private laboratories to contribute with data based on their own diagnostic analyses. Following this request, we have received summary data from Fish Vet Group Norway and Pharmaq Analytiq AS. This data does not include the identity of farms in which diagnoses have been made. It is therefore not possible to check whether the same farm has been diagnosed with the same disease by several different laboratories.
These statistics cannot be used to identify the total number of cases of a particular disease, but provide some indication of trends from year to year. The Norwegian Veterinary Institute and private laboratories are presently working towards a better solution for a national oversight of non-listed diseases.

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 treatments, various parameters relating to fish welfare, problems related to algae/jelly fish and problems associated with large-smolt production.

The survey was sent to 140 fish health professionals working in Fish Health Services or farming companies with in-house health personnel and a response was received from 24 individuals working for private Fish Health Services and 34 individuals working for farming companies (total response 58 individuals). The survey was also sent to 106 Norwegian Food Safety Authority inspectors and we received responses from 26 inspectors. 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.

2 Changes in risk of infection

By Atle Lillehaug, Britt Bang Jensen, Victor Oliveria, Mona Dverdal Jansen and Arve Nilsen

An important part of the annual 'Health Situation in Norwegian Aquaculture Report' is a review of the changes observed in the disease situation for important infectious diseases. Individual diseases in farmed fish and the health status for wild salmonids are discussed in specific chapters. In the present chapter devoted to risk, we will discuss production related factors within the aquaculture industry in 2019, which may have been important for fish health and transmission of infectious diseases in farmed fish in Norway, primarily salmon.

Consumption of different pharmaceutical products e.g. antibiotics and chemotherapeutants for control of salmon lice and intestinal worms, together with prescription data, provide a good basis for evaluation of the status of different types of infection.

Production statistics, fish biomass, post sea-transfer losses, number of active farming sites, together with regional production of salmon smolts also constitute important parameters upon which a picture of the risks of different types of disease may be drawn. Statistics related to production volumes of fish, number of production units, biomass, mortality and loss of fish, together with regional supply of smolts, are important factors which taken together allow evaluation of the importance of disease and the risks of transmission and spread of infection. Changes in production conditions and implementation of new technologies as well as regulative changes may all contribute to change in the risk situation.

Infection pressure and biomass

Until 2012, production of salmon in Norway had increased annually by 10-20% over several decades. In recent years, production has stabilized, but preliminary sales figures for 2019 indicate an increase in production of around 5% (table 2.1). Biomass reported in the marine phase at the end of 2019, together with preliminary figures for sea-transfer of smolts and juveniles produced, indicate a similar total production in 2020. Preliminary figures for sea-transferred smolts and juvenile fish production indicate, however, an approximate 5% reduction.

Production of rainbow trout has increased over the last two years. Production figures for arctic char and various farmed marine fish species e.g. halibut, turbot were not available at the time of publication.

There is a significant annual increase in the number of wild caught and farmed cleaner-fish stocked in Norwegian salmon farms. An increasing proportion of these fish are of farmed origin, which allows greater control of infection than is the case with wild-caught cleaner-fish. There was a rapid annual increase in the number of cleaner-fish stocked in salmon cages in the years leading up to 2017. Recent years have seen a stabilisation in the situation with around 50 million fish stocked annually. Stocking of aquaculture facilities (ongrowing and broodstock) with wild-caught cleaner-fish represents a considerable risk of introduction of infection. Use of farmed cleaner-fish therefore represents an important improvement in biosecurity.

Production and husbandry of this type of fish does however, result in new health and specific welfare challenges. Cleaner-fish are susceptible to serious bacterial infections and the majority of prescriptions for antibiotic treatment in farmed fish in Norway are prescribed for cleaner-fish. In 2018, all antibiotic prescriptions written for cleaner-fish, with one exception, were prescribed for lumpsucker.

Fish losses during the seawater phase of culture

Fish losses occurring between sea transfer and harvest must be reported to the Directorate for 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. 'Rejected' 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. Post sea transfer losses are an indicator of fish welfare and an indirect measure of fish health. Mortalities resulting from treatment procedures or other management routines represent a serious welfare problem (See chapter 3, Fish welfare).

In this chapter, we focus on mortality, but also report on losses attributed to the other loss categories. Calculation of losses include data on all sea-transferred salmon and rainbow trout, including ongrowing, broodstock, fish from research and development and teaching concessions etc. Calculated mortality for production cycles completed each year is based on reports from commercial ongrowing localities. Broodstock localities are not included (table 2.2).

In 2018, total losses of 59.3 million salmon were registered, distributed between 89.1% mortality, 6.6% reject, 4.2% 'other' and 0.2% 'escaped' salmon (Directorate of Fisheries statistics 28.01.20). One explanation for the increase from previous years was the algal bloom which killed approximately 8 million fish in Nordland and Troms during the late spring of 2019 (See chapter 8.5, Algae and fish health). If considered an exceptional event and not part of a general trend, total mortality for 2019 lies around 45 million salmon. This is a similar level to that experienced in 2016 and slightly lower than in 2018 (46.2 million).

Nine escape events were reported via 'escapee registration forms' during 2019 involving a total of 92,305

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

	2015	2016	2017	2018	2019*
Number of farms					
Salmonid. Concessions. Juvenile production	214	220	220	217	221
Salmonid. active sites. sea	990	978	986	1015	966
Marine fish. number of sites. sea	79	66	58	42	64
Biomass at end of year. tons					
Salmon	722 000	740 000	797 000	814 000	799 000
Rainbow trout	46 600	31 500	35 700	40 400	45 200
Harvested. tons					
Salmon	1 237 000	1 180 000	1 237 000	1 279 000	1 357 000
Rainbow trout	79 200	80 700	61 600	66 700	79 600
Marine species (halibut. char. cod. other)	1 713	2 473	2 683	2872	
Juvenile fish transferred to sea. millions					
Salmon	299	292	299	304	288
Rainbow trout	16.1	14.9	17.1	20.0	20.6
Cleaner-fish	26.4	37.4	54.6	48.9	49.1
Post sea-transfer mortality. millions					
Salmon	41.3	44.8	45.8	46.2	52.8**
Rainbow trout	2.6	2.4	2.4	2.8	3.1
Mortality in percent* **					
Salmon	14.2	16.2	15.5	14.7	16.2
Rainbow trout	13.4	19.2	17.5	16.6	15.9

* Preliminary estimate, Kontali analyse, February 2020

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

*** Includes approximately 8 million salmon killed by poisonous algal blooms.

fish. The Directorate of Fisheries publish annually statistics of escapes reported directly to the Directorate and during 2019, 43 such escapes were reported involving 28 9570 fish, nearly double the figure for 2018.

There is a considerable difference between the number of escaped fish reported to the Directorate of Fisheries and those reported during normal ‘loss reporting’. As most of the reported episodes involved escape of less than 100 fish, a few very large escapes are responsible for the final total figure.

Total losses of rainbow trout over the last five years have varied between 2.8 million in 2017 and 3.4 million in 2015. In 2019 total losses of 3.8 million rainbow trout, distributed amongst 82.3% mortality, 9.44% reject, 8.3% ‘other’ and 0% ‘escaped’. In table 2.1 only mortality is reported.

As in last year’s report, percentage mortality is calculated based on 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 2.1, the percent mortalities for salmon and rainbow trout for the last five years as calculated by this

Table 2.2 Median mortality (%) for completed production cycles. For calculation method see text.

	2015	2016	2017	2018	2019
Median mortality in percent for all sea-transferred salmon production cycles completed per year	12.3	15.7	15.9	15.1	13.5
1.- 3. quartile (50% of mortality % lies within this interval)	7.1 - 22.5	9.4 - 26.2	8.3 - 25.0	8.9 - 23.1	8.0 - 23.4

Table 2.3 Regional percentage post-seawater transfer losses of salmon and rainbow trout 2017-2019. Losses due to mortality are calculated as described in the text. Statistics for individual production zones and statistics for other years may be found in our interactive web-application.

	2017		2018		2019	
Region	% mortality salmon	% mortality rainbow trout	% mortality salmon	% mortality rainbow trout	% mortality salmon	% mortality rainbow trout
Finnmark	13.4	-	11.6	-	8.7	-
Troms	7.5	-	8.8	-	18.9	4.7
Nordland	9.6	6.7	12.8	9.7	18.5	8.6
Trøndelag	14.9	3.2	12.0	8.9	10.7	13.6
Møre og Romsdal	15.5	14.0	17.5	17.4	14.4	13.7
Sogn og Fjordane	16.7	17.6	19.3	18.1	20.7	16.7
Hordaland	25.4	20.1	20.2	18.5	18.7	17.8
Rogaland	18.4	-	16.9	1.0	15.8	15.4
Agder-regions	8.1	-	6.0	-	10.8	-

method are provided. These figures do not include losses due to 'reject', 'escape' or 'other'.

One may also choose to consider mortality on a 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. Using this method, mortality can be calculated from sea-transfer to harvest for all fish transferred to sea in any given year. Alternatively, total mortality of fish in farms that are completely harvested in any given year may be calculated. We have chosen to utilise the latter format as we consider that it allows us to use the newest data. For production cycles completed in 2019, the median mortality was 13.5%, while 50% of the mortality scores lay between 8.0 and 23.4 % (Table 2.2.). Thus, there is considerable variation between individual production cycles.

Regional differences in percent mortality remain extremely large (Table 2.3). This table reports only dead fish, not other reasons for loss. Special for 2019 were the extremely high losses due to algal blooms in Nordland and Troms in May/June.

Mortality in Møre og Romsdal has reduced from 17.5 to 14.4% from 2018 to 2019. The positive trend continues in Hordaland, with mortality amongst salmon falling from 25.4% in 2017 to 20.2% in 2018 and further to 18.7% in 2019, in other words by around a quarter in the space of two years.

The Norwegian Veterinary Institute has developed an interactive web page where losses and mortality in the various regions and production areas for the years 2015-2019 may be examined. This web page may be found here: http://apps.vetinst.no/Laksetap

The differences in the two mortality statistics may be due to the different regional disease/infection situations, which are discussed elsewhere in this report. There presently exist different initiatives towards improved and standardised registration of cause of death. This will be a considerable improvement in evaluation of the health- and risk situation in salmon farming.

Cleaner-fish mortality is discussed in chapter 11. The health situation for cleaner-fish.

Spread of infection via transport of live fish

Transport of live fish, both smolts and harvest ready fish, is considered to represent one of the most significant risk factors for spread of disease. Latent infections may be

Table 2.4 Regional production and sea-transferred smolts (million), with a calculated index relating production and number of smolts transferred to sea on a regional level. Figures from the Directorate for Fisheries.

Region	2015			2016			2017			2018		
	Smolt prod	Smolt s-t**	Index	Smolt prod	Smolt s-t**	Index	Smolt prod	Smolt s-t**	Index	Smolt prod	Smolt s-t**	Index
Finnmark and Troms	29.7	66.0	0.45	31.9	66.2	0.48	33.8	78.0	0.43	38.2	79.7	0.48
Nordland	83.3	57.6	1.45	83.4	66.0	1.26	92.0	64.3	1.43	96.4	69.6	1.39
Trøndelag	72.5	78.8	0.92	71.1	40.9	1.74	74.4	80.9	0.92	78.0	44.1	1.77
Møre og Romsdal	53.8	15.0	3.59	44.5	48.1	0.93	45.4	13.1	3.47	47.5	54.0	0.88
Sogn og Fjordane	15.8	24.2	0.65	15.6	25.2	0.62	17.2	25.9	0.66	15.1	22.5	0.67
Hordaland	54.9	45.9	1.20	56.3	44.9	1.25	57.0	50.0	1.14	57.5	48.5	1.19
Rogaland and Agder	15.1	19.4	0.78	13.5	20.7	0.65	14.4	19.3	0.74	14.7	20.7	0.71
Sum	325.1	307.0		316.4	312.2		334.1	331.6		347.4	341.5	

* Preliminary statistics. Directorate for Fisheries. January 2020

**s-t = sea-transferred

difficult to identify and there is always a risk that apparently healthy smolt populations may in fact be infected. Infection may be introduced to juvenile production units in several ways, including exposure to 'marine' pathogens through use of seawater.

Long distance transport is necessary when smolts are produced in one region and stocked to sea in another region, or when harvest ready fish are transported to a harvesting facility in another region.

Statistical comparison of the number of smolts produced within a region and the number of smolts transferred to sea within the same region will provide an indirect indication of the number of fish crossing regional borders (Table 2.4).

Figures for 2019 are not yet available, but for 2018, the total number of smolts transferred to sea in northern-Norway were 14.3 million greater than the number of smolts produced within the region. Since 2015, there has been a lack of 'self-sufficiency' within the region with an underproduction of 13-17 million smolts. The situation in the remainder of the country appears quite stable with the exception of Møre og Romsdal and Trøndelag, where sea-transfer of smolts appears to vary on a two-year cycle, with alternately high and low numbers transferred to sea each year. The two regions appear to operate on an opposite cycle.

Live fish are now almost exclusively transported in well-boats. It has been confirmed that well-boat activity increases the risk of spread of PD. New technologies including disinfection of influent and effluent water and logging of valve position has significantly reduced the risk of spread of infectious disease via well-boat traffic. Extensive use of closed valves during the whole or a large part of the journey also means that water is not taken in or released to the environment. New well-boats are constructed to allow efficient cleaning and disinfection of wells, pipes and pumping systems between jobs, and their transport routes are electronically logged. Together

Table 2.5 Pharmaceutical products prescribed for farmed fish (kg active substance). Figures from the Norwegian Institute for Public Health.

Antibacterial substance	2014	2015	2016	2017	2018	2019
Florfenicol	403	194	138	270	858	147
Oxolinic acid	108	82	74	346	55	66
Oxytetracycline	0	(25)	0	10	20	0
Enrofloxacin						263g**
Total antibiotics	511	276	212	626	933	213
Anti-salmon lice medication						
Azamethiphos	4630	3904	1269	204	160	154
Cypermethrin	162	85	48	8	0	0
Deltamethrin	158	115	43	14	10	10
Diflubenzuron	5016	5896	4824	1803	622	1296
Teflubenzuron	2674	2509	4209	293	144	183
Emamectin	172	259	232	128	87	114
Hydrogen peroxide (tons)*	31577	43246	26597	9277	6735	4523
Anti-tapeworm medication						
Praziquantel	625	942	518	380	171	50

*Total consumption of hydrogen peroxide, includes both treatment against salmon lice and amoebic gill disease (AGD).
**Data based on data from VetReg (Veterinary Medicines register) January 2020.

with legal constraints, these measures result in safer well-boat transport with a reduced risk of spread of infection. There appears to be increasing specialisation of individual well-boats for transport of either smolts or larger fish and towards operation within geographically restricted areas.

Harvest ready fish represent a significantly higher risk for spread of infection than smolts as they have been exposed to considerably higher infection pressures over a longer period. Transport of harvest ready fish also represents a significant risk for spread of disease along the transport route. Harvest boats designed for on-farm harvest and transport of harvested fish for further processing facilities have been introduced to a limited degree. This reduces the need for transport of live fish to harvest facilities.

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 has been low. From 1996 onwards, 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, no treatments against yersiniosis were reported, and preliminary statistics indicate that the total antibiotic consumption is once more reduced to 2015 and 2016 levels, with 223 kg reported to VetRg (Veterinary Medicines Register).

Thirteen antibiotic treatments involving sea-farmed salmon were reported in 2019, ten in marine ongrowing sites and one for experimental fish. In juvenile production, five treatments for salmon and two treatments for rainbow trout were reported (table 2.6). Two of the treatments involving sea-farmed salmon involved winter-ulcer and *Moritella viscosa* infection, one treatment of juvenile salmon related to an outbreak of classic vibriosis, while no specific bacterial agent was reported for the remaining prescriptions. Antibiotics were prescribed three times for treatment of atypical furunculosis and three times for treatment of vibriosis in halibut, while 19 prescriptions were written for ‘unspecified bacterial infections’.

Cleaner-fish were overrepresented in prescription statistics with most (79) treatments related to treatment of Lumpsucker, with a single treatment of broodstock Ballan wrasse reported. Of specific infections, vibriosis was reported on 23 occasions, *Moritella viscosa* twice and a single case of atypical furunculosis. The remaining prescriptions were written for ‘unspecified bacterial infections’.

Table 2.6 Number of prescriptions per year for antibiotic treatment for different categories of farmed fish Preliminary figures January 2019 from the Veterinary Medicines Register (VetReg).

Category farmed fish	2014	2015	2016	2017	2018	2019
Salmon, ongrowing and brood stock	11	8	11	6	13	13
Salmon, juvenile fish	39	24	21	28	9	5
Rainbow trout and trout	5	0	1	1	3	2
Marine fish (cod, halibut etc.)	18	29	30	28	18	28
Cleaner-fish	59	108	126	115	91	79*
Sum	132	169	189	178	134	127

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

The health situation associated with new production technologies

In Norway, salmonids have traditionally been farmed using through-flow technology in freshwater and in open cages at sea. Introduction of new technologies such as land-based recirculation based systems (RAS) and enclosed or semi-enclosed systems in the sea, has led to new health challenges for the fish farmed in these systems.

Land-based recirculation systems

Land-based aquaculture has traditionally been based on through-flow systems. Finite supplies of high quality fresh water has been a limiting factor for expansion of land-based farming. In traditional cage-farms there has also been increasing focus on environmental problems including salmon lice, transmission of disease, escapes, nutrient rich effluent and chemicals used for delousing. This shapes the background for the rapid recent expansion of recirculation-based (RAS) facilities that has occurred in America and Europe, including Norway.

There are an increasing number of RAS farms in Norway, based on varying degrees of water recirculation. The majority of new juvenile production facilities are based on this technology.

Recent production data from RAS based juvenile salmon farms indicates good survival and growth after sea transfer. Surveillance and documentation of various water parameters including temperature, water flow, specific water use (l/kg/min), total gas pressures, oxygen, pH, carbon dioxide (CO_2), H_2S, ammonia (NH_3), nitrite (NO_2), total suspended solids (TTS), turbidity (NTU) and heavy metals (e.g. copper) is, however, paramount. H_2S has been found to be a particularly problem in seawater RAS systems. Over the last few years there have been a series of acute mortality events, primarily during large-smolt production, in which short periods of elevated H_2S have been suspected as the causative factor (see chapter 8.4 Water quality).

On design of a RAS facility, it is extremely important to avoid areas of low water flow where organic material/sediment may be deposited.

Good biosecurity is paramount for successful RAS operation. Infections may be introduced via biological material (roe and fish) or via the water source. Pathogens, once introduced, will recirculate within the system. Eradication of infectious agents within a RAS system can be difficult as pathogens may become established within biofilms or within organic material in areas that are difficult to clean and disinfect. Examples of diseases that may be particularly challenging in RAS farms include the bacterial diseases furunculosis (reported from Denmark) and yersiniosis. Yersiniosis (*Yersinia ruckeri*) has been a serious problem in RAS farms in Northern and Mid-Norway, with repeated outbreaks and high mortality. The number of yersiniosis outbreaks registered by the Norwegian Veterinary Institute has, however, reduced significantly in the period 2018 – 2019 (see chapter 5.5).

RAS based juvenile production systems have been an option since the early days of salmon farming. RAS-based systems capable of producing harvest ready sized salmon have also been designed and built in recent years. This production form has become more popular partly due to introduction of the traffic light system, restricted allocation of new marine farming concessions and the high prices achieved when increased production quotas are sold at auction.

In addition to the H_2S problem, seawater RAS systems are also more prone to high levels of carbon dioxide than freshwater RAS farms. Seawater use also increases the risk of infection by bacteria that can cause skin injury and ulcers, a problem reported by many fish health services 2017 - 2019. Knowledge relating to the aetiology of such infections and their management is currently lacking.

Production of larger fish leads to handling related welfare challenges during transport and sea transfer. Using RAS, it is now possible, by light and temperature manipulation, to transfer smolts or large smolts to sea throughout the whole year. Sea transfer to cold seawater may lead to stress, ulcer development and mortality in the period following sea-transfer.

Non-virulent ISA-virus (HPR0) is widespread. To address the lack of knowledge of the prevalence of ISAV HPR0 in Norwegian juvenile production sites, a surveillance program was established in 2019. Details of this program are provided in the ISA chapter (chapter 4.2). A case of non-virulent ISA-virus mutation to virulent ISA-virus with consequent spread from a RAS-hatchery was reported in the 2015 'Health situation for Norwegian farmed fish report'. An additional case, in which spread of virulent ISAV from a RAS hatchery was suspected, was reported in 2016. There were also indications of transmission of virulent ISAV from juvenile production units in 2017 and 2018, but a definite link could not be established. It will be important to study whether RAS environments contribute to change in virulence status of potential pathogenic organisms entering and maintenance of their presence within the system.

New production technologies for sea farming

Production forms for salmon in the sea are also under rapid development, and a series of concepts are under planning or testing. Some were developed as a result of the 'green concession scheme' of 2013, while others were established as a result of the 'developmental concessions' released in 2015.

Two main strategies are under testing; open cages situated in the open sea (so-called offshore farms) or various forms of enclosed or partly enclosed cages situated in more sheltered locations. The initial aim of these technologies is to avoid salmon-louse settlement on the farmed fish. Completely enclosed systems have been found effective at prevention of louse settlement, while other systems involving screening and/or submersible cages have provided various degrees of protection. The effect of offshore farming on louse settlement has not yet been documented, but it is expected that such farms will experience less serious lice problems due to the low numbers of lice larvae in the open sea.

Semi-enclosed farms are expected to reduce the risk of escapes and increase the opportunities for removal of waste products, which are a resource that may be utilised in other ways. In such farms, the water quality and the aquatic environment will be significantly influenced by water volume, current speed, temperature, biomass and feeding. Most published work relating to the effect of enclosed farming technologies on health and welfare is based on small-scale trials or pilot trials in larger farms. The Norwegian Veterinary Institute published a larger scale study in 2019, which focussed on prevention of louse infestation, mortality, growth and water quality. It was shown that fully enclosed farms can provide complete protection against salmon lice, good growth and low mortality during production of post-smolts (up to 1kg). High water currents were considered one of the primary causes of increased growth rates in enclosed facilities while rapid exchange of high quality seawater ensured good health and welfare.

There remains, however, a significant requirement for more knowledge of the relationships between production intensity, environment and fish welfare before such systems may be reliably operated in a secure way.

Open offshore farms are similar in shape and use to the open cage systems used today. Rough weather and strong winds with the possibility of wave development within the cages will be a challenge for such farms. Knowledge of the effects of these new offshore solutions on biosecurity and fish welfare remains limited. Initial production cycles have been completed, but the results relating to health, welfare and productivity have not yet been made public.
Submersible cages have been taken into use in 2019 and a number of results from studies involving permanently submersed cages in which the salmon are allowed access to air via a central 'snorkel' or via a submersed air pocket, allowing the salmon to fill their swim bladders have been assessed.

Fish welfare has not been a central criterion in awarding new ‘environmentally friendly’ concessions. It is the opinion of the Norwegian Veterinary Institute that fish health and welfare should be more clearly prioritised on future allocation of new concessions. While new technologies, on land and in the sea, may result in reduced environmental impact, there may be a requirement for increased financial investment or increased running costs. That increased costs are compensated for by increasing the overall load on production systems through either increased stocking densities, poorer water quality or lower biosecurity is unacceptable.
Reduction of the fish farming industries environmental footprint is necessary, as is improvement of the present average standard of animal welfare within the industry. Environmental and fish welfare challenges will be the most important challenges for new technologies.

What developments can we expect?

Pancreas disease is notifiable within the OIE system and is a list 3 disease (national disease) in Norway together with the salmon louse and BKD. Farmed fish represent the main reservoir of infection for PD, and pancreas disease has been allowed to become endemic along the whole west coast as far as the northern parts of Trøndelag. This infection could have been controlled and possibly eradicated following the early outbreaks. Current legislation against pancreas disease requires extensive PCR screening for PD-virus. This provides an overview of the geographical range of PD-virus within the farmed fish population and a statistical basis for use in an eventual intensive eradication/control programme.

The aim of the legislation is ‘to reduce the consequences of pancreas disease (PD) in a PD zone, to hinder establishment of PD in a surveillance zone and to limit the geographical range of the individual subtypes of salmonid alphavirus (SAV)’.

The authorities have in reality, accepted that PD will remain endemic in current PD-zones but hope to prevent its establishment within surveillance zones. The legislation states that ‘The Norwegian Food Safety Authority can, after evaluation of the situation, demand that fish in a site diagnosed with PD be harvested or destroyed’. ‘Diagnosed PD’ is defined as ‘identification of SAV by PCR or culture, in addition to clinical symptoms or pathological changes consistent with PD’.

Virus shedding begins long before development of clinical signs of disease. As clinical disease/histopathological change is a necessary component of a PD diagnosis, current legislation allows infected fish to remain in the farms, shedding virus for an extended period prior to imposition of control measures e.g. harvest or movement. The farmer may appeal against control measures, thus delaying their introduction. These procedures may therefore, result in significant ‘leakage’ of infectious virus particles over an extended period of time prior to introduction of eventual counter measures. This situation increases the risk of northerly spread of pancreas disease.

PD-legislation allows the authorities to make vaccination against PD compulsory. These powers have not so far been used, but from July 1st 2020, vaccination will become compulsory within the area between Romsdalen in the south to Sømna in Nordland region. The area within which only fish vaccinated against PD may be transferred to sea thereby encompasses the most northerly area within the PD-zone (nearly the whole SAV-2 range) as well as the southern part of the northern surveillance zone.

This strategy is designed to reduce the risk of spread and establishment of PD outside the surveillance zone. PD is a disease with significantly negative economic consequences and in several areas the industry has initiated coordinated actions aimed at limiting the losses associated with this disease. This may be the reason that very few cases were registered in Rogaland in 2019. This may also show that targeted control strategies may eradicate the disease from large geographic areas.

ISA remains, after 30 years, an important disease in Norwegian salmon farming. There is broad support in the scientific community for the hypothesis that virulent ISA-virus develops from the so-called avirulent variant HPR0 ISAV. The HPR0 variant may be found in ongrowing fish in the sea and in both broodstock and hatchery raised fish in freshwater. ISA was diagnosed over a greater geographical area in 2018 and 2019 than in previous years and the clinical picture is commonly diffuse. The generally high infection pressure and increased degree of handling of fish for various reasons (commonly with a degree of associated mortality) are sufficient grounds for maintaining an awareness of the possibility of ISA development. A diffuse clinical picture may camouflage ISA and secondary ISAV infections are possible. It is therefore important to maintain a high state of awareness for this disease. ISA may be present at a much higher prevalence than initial diagnostics may suggest and is one of few diseases that may stop export of salmon to some countries.

The international situation- threats-legislation

Most fish farming countries are threatened by importation of infected animals, animal products and by sharing of aquatic areas with neighbouring countries. Norway has fairly limited import of live animals and has a thorough, strictly policed import control. This means that the threats posed by imported animals are minor. Import of various products/ possible vectors of infection are less well controlled. It is recognised that waste products from imported seafood may pose a risk of infection should they reach freshwater or seawater. White spot disease of shrimp is one such example. Bait organisms may pose a similar risk of infection spread. Introduction of disease by this mechanism will depend on the presence of susceptible species and the ability of the infectious agent in question to survive in a new environment.

Uncontrolled movement of animals may occur via illegal import, illegal release or natural changes in an organism's geographical range. *Gyrodactylus salaris* is a parasite that can travel easily with transported fish. The Norwegian Veterinary Institute is the OIE reference laboratory for *G. salaris* and shall confirm all diagnoses of this parasite.

In 2018, the Norwegian Veterinary Institute identified *G. salaris* in the river Tuloma, which runs through Murmansk. The presence of the parasite in this river is probably due to transport of infected rainbow trout. This means the parasite is now present close to the Norwegian border and that there exists a risk for its spread (and other diseases) to nearby Norwegian rivers either by illegal movement of fish and/or due to the close proximity of the river sources in the region. *G. salaris* is widespread on the west coast of Sweden as far north as the rivers Göta and Klarälven (River Trysil in Norway).

That eradication strategies for *G. salaris* in Norway have been so extremely successful (see chapter 9.4), makes it even more important that we maintain an increased focus on spread of *G. salaris* in Russia, Sweden and Finland. There is an increasing interest in Sweden for removal of the salmon migratory barrier present in the river Klarälven in Sweden, which currently prevents migration of land-locked salmon from Lake Vänern into Norway. The Norwegian Veterinary Institute continues to work closely with Russian, Swedish and Finnish authorities, institutions and researchers in order to remain informed of developments in these countries.

The Norwegian Veterinary Institute has developed methodologies for detection of *G. salaris*, salmon and rainbow trout via water sampling, utilising so-called eDNA methodology. During 2019, the institute has performed eDNA surveys in several areas of North-western Russia.

For many years, pink salmon have been observed and caught regularly in rivers in Finnmark and Troms but now occur in many rivers further south. Pink salmon have a two-year lifecycle and homeward migrations occur during odd-numbered years along the Norwegian coast. In both 2017 and 2019, this guest has been frequently registered and 21 tons of pink salmon were caught in Norwegian rivers during 2019. Large numbers of pink salmon juveniles now present in Norwegian rivers will most probably lead to higher numbers of returning adults in future years. The pink salmon is a blacklisted species in

Norway. Increasing numbers represent a threat regarding introduction of disease as well as a threat to wild Atlantic salmon populations through e.g. increased habitat and resource competition.

Norway is particularly concerned with minimisation of the risk of spread of the viral diseases infectious hematopoietic necrosis (IHN) and viral haemorrhagic septicaemia (VHS) to both farmed and wild salmon populations. Only small numbers of pink salmon have been tested for these infections. The Norwegian Veterinary Institute recently tested 60 pink salmon for the presence of VHS, IHNV, SAV, PRV-1, ISAV and *Renibacterium salmoninarum*, infections considered highly relevant for this species of fish. The only infectious agent identified was PRV-1. The study involved a limited number of fish and identification of infections present at low prevalence within the pink salmon population may not have been identified. More extensive studies are required to identify the prevalence of various infectious agents in pink salmon.

With increasing levels of fish-farming on the Kola Peninsula there is an obvious risk that these fish may carry various infectious diseases, and that migrating pink salmon may thus increase infection pressure on both farmed and wild Norwegian Atlantic salmon. Further, the effects of climate change including increased sea temperatures and reduction in ice-coverage in northerly seas may provide better survival conditions for pink salmon. How this will affect the interaction between infectious agents and competition with wild Atlantic salmon are unknown (see chapter 9.7).

IHN was identified in rainbow trout in Finland in November 2017 and January 2018. No further diagnoses have been made. IHN may be transmitted both horizontally and vertically. The source of the Finnish outbreak is unknown.
Russian fish farms situated in the eastern Baltic Sea receive fish from a number of Russian sources of largely unknown infection status. Establishment of IHN in this area would represent an increased risk of infection for Norwegian farmed salmon. It is important that focus be maintained on good disease control measures between neighbouring countries sharing coastal zones or rivers.

The disease status within the Norwegian aquaculture industry is important for export of Norwegian farmed fish. As an example, China has identified a risk related to their indigenous salmonid population and introduced import restrictions for Norwegian farmed fish from sites under restriction due to PD or ISA. Identification of virulent ISA-virus in salmon fillets exported to China has highlighted the situation. Australia accepts Norwegian farmed fish from ISA control/surveillance areas only following repeal of the control zone. Increases in the geographical range for PD and ISA-virus will clearly make export to countries such as China and Australia more difficult.

In recent years, more than 30 million fertilised salmon eggs have been imported to Norway. This is approximately 6-7% of the total required by the industry per year and is a relatively small proportion. It does however, highlight the need for strict documentation to minimise the risk of import of egg-associated infectious disease.

International regulations aimed at reduction of the risk of spread of infectious diseases have consequences for import and export of live fish and seafood at the national level. Through its EEA membership, Norway is committed to legislative procedures that are in harmony with EU legislation including that relevant for fish-health. The EU has passed a new animal health directive, which will come into power as of 2021. Norwegian legislation is therefore currently under revision. According to new legislation, ISA will be listed on list C. This means that countries or areas within the EU may declare freedom of infection, and restrict import of fish and fish products to areas free of ISA.

The World Organisation for Animal Health (OIE) also has regulations relating to 'standards' for a number of listed diseases e.g. ISA, PD, VHS, *G. salaris* and crayfish plague, which are important for Norway. Also of importance for Norway is development of new standards relating to biosecurity in culture of aquatic organisms and documentation of free status for individual diseases.

Jan Ove Wedaa presents the new RAS facilities at ILAB. Photo: Eivind Senneset

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 Lumpsucker 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 animals biological function, with good health and normal development, 2) The animals own experience, with regard to feelings such as fear and pain, or 3) a most natural life (Figure 3.1.1). When evaluating fish welfare it is 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.

Attitudes to fish welfare will improve through conscious discussion of fish as individuals and not biomass and use of 'mortality' and 'loss' rather than 'Svinn' (Norwegian expression used to describe unclassified production losses).

Consideration of fish as individuals rather than biomass, and use of terminology such as 'mortality' and 'loss' rather than 'svinn' will lead to increased consciousness that fish are living organisms capable of experiencing good and poor welfare.

Animal welfare legislation paragraph 3 states that animals have their own individual value independent of their economic value to humans, and independent of their developmental stage. Fish Health personnel and research institutions have a particular responsibility to work towards improved fish welfare, disseminate knowledge and promote good attitudes towards fish within the industry and in public fora.

This year's welfare chapter focuses on how fish welfare may be measured.

Figure 3.1.1: Animal welfare can be defined in various ways, but relates to the quality of life experienced by the animal in question within the environment provided. Good health is a precondition for good welfare. The Norwegian Veterinary Institute utilises a holistic approach to animal welfare with focus on the dynamics between fish health, infection hygiene, biosecurity and welfare. Illustration: Kristine Gismervik. Photo: Norwegian Veterinary Institute.

Thereafter we discuss the importance of use of registered data for generation of new knowledge. In this way, risk factors and requirements for new technologies may be identified. Possibilities for improvement of current legislation and public management are discussed in a specific chapter this year. As previously, we highlight some welfare related risk factors from various production forms and new technological solutions. Juvenile salmon and cleaner fish production have received more focus. We also share experiences reported by fish health personnel along the entire coast.

3.1 Welfare indicators

There are many occasions when one may need to measure animal welfare. For fish, we use welfare indicators that indicate fish welfare status. Welfare indicators are often categorised as environmentally based (such as 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 document the absence of poor welfare we require more knowledge relating to measurement of 'thriving behaviour' and fish preferences. Identification of acceptable ethical norms relating to welfare in fish is also important.

Through the project 'Fishwell', knowledge gathered on welfare indicators for farmed salmon and how these indicators may be used, is presented in the handbook 'Welfare indicators for farmed Atlantic salmon: tools for assessing fish welfare'. This handbook is a good point of reference for further systematic development of welfare indicators and welfare protocols for different farming situations. Such further developments include amongst others the project 'laksvel' (English= SalmonWell) in which methods for welfare surveillance of salmon in Norwegian ongrowing farms are being developed and evaluated (FHF project number 901554).

Only when systematic and objective measurements are registered and analysed on a large scale can suitable reference indicators be identified. Development of good methodology and technology for monitoring fish behaviour and welfare will contribute to rapid identification of any failure and allow rapid introduction of counter measures to correct the failure.

It is important to remember that animal welfare relates to the individual animals experienced life quality. Average values for a farm or a cage/tank must be used with caution such that individual values are not camouflaged. It is important that the degree of variation within the studied group is considered and particular attention paid to registration of runts as they may have the poorest welfare.

3.2 Fish welfare, health legislation and public management

It is important that legislation and public management relevant for fish welfare and health are suited for their intended purpose and allow generation of statistics relating to the health and welfare of farmed fish. Both legislation and industry- reporting to the authorities and organisation of the public authorities have the potential for improvement.

At the present time, the Norwegian Food Safety Authority, which has responsibility for fish health and fish welfare, may become involved at too late a stage in matters concerning fish welfare. Examples include allocation of developmental concessions and expansion of the industry. The fields of fish welfare and fish health have also been treated separately in legislation , such that typical health legislation relating to diseases such as PD or salmon lice have not adequately considered animal welfare.

Much data is gathered regarding the fish, the environment and disease during both juvenile and ongrowing stages of production. There is unfortunately little systematic use of this data. Correct use of 'big-data' would allow researchers, the industry and the public authorities a much-improved view of the situation. Relationships may be revealed, and new tools for improved fish welfare may be developed. It is a prerequisite that the data is collected in a uniform, standardised manner and that different systems allow 'communication' with each other.

In 2019, the Norwegian Veterinary Institute initiated a collaboration with Standards Norway and an industry cluster to establish standard definitions and registrations with the aim of improved utilisation of registered data. The effect of legislation, rules and cooperation between the farming industry and public authorities on the welfare and health of farmed salmon has been recently investigated by the Norwegian Veterinary Institute, Institute for Marine Research, Norwegian University of Science and Technology and the University of Oslo (REGFISHWELL, NFR-267664). A systematic comparison of the public legislative framework for animal health and animal welfare of farmed salmon and poultry revealed that legislation relating to farmed salmon was more complex, had potentially conflicting aims and used generally less positive wording relating to welfare. Despite the fact that much of the legislation regulating poultry and salmon production are almost identical, differences are apparent in the fields of daily husbandry, mortality registration and harvest facility surveillance.

It was also found that while prevention of infection and preventative health measures are specified as obligatory themes to be included in welfare courses aimed at poultry producers, no such themes are obligatory for salmon producers. This is despite the fact that these themes are more challenging for salmon producers than poultry producers. Applicable regulations may be difficult to interpret and are therefore open to a wide degree of interpretation, which may lead to a disagreement between individual farmers and the public authorities. It was also shown that fish welfare was not sufficiently considered in relation to delousing and that non-specific welfare regulations are more easily disregarded than specific lice infestation limits.

The Norwegian Veterinary Institute and the Institute for Marine Research established a cooperative platform designated the 'Fish welfare forum' in 2016. In addition to dissemination of knowledge of fish welfare, the forum aims to work specifically towards an improved public

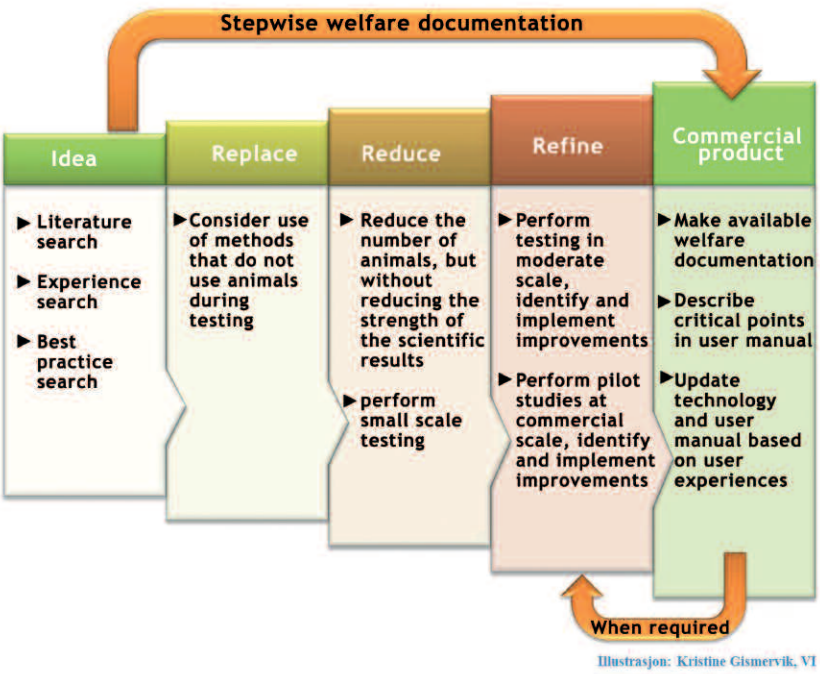


Figure 3.3.1: Stepwise welfare documentation from idea to commercial product on implementation of the «3R-s» (Replace, Reduce, Refine) during development of new technologies. Before a new technology is made commercially available, it is important that it is tested and found acceptable in terms of fish welfare. To ensure good fish welfare, relevant experiences gained in the period following introduction of the technology should be used to continually refine the method/equipment. Illustration: Kristine Gismervik.

management, legislative development and knowledge base for fish-welfare and health.

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. It is important to emphasise that the animal's owner i.e. the fish farmer and seller of the various methods/equipment have a responsibility, not least through provision of updated user manuals and updating of procedures when new information becomes available. Improvement is a continual process (see figure 3.3) and societies attitudes to what is ethically acceptable are also subject to change.

Although the general aquaculture legislation has for many years required that new technology be documented in terms of acceptable animal welfare, this requirement has only been followed up to a varying degree. Stricter requirements for documentation of welfare are also included in the application process for research concessions. The Norwegian Food Safety Authority is now revising clearer guidelines/legislation for documentation of welfare.

During development of new technologies, systems are required for evaluation of the risks of reduced welfare, such that mistakes are not repeated during implementation. Rapid collection and analysis of data can generate knowledge that may allow smarter decisions. Development of good, scientifically based welfare protocols are therefore important. It is extremely important that technologists and fish health personnel work closely together during the development and testing phases. Many recent technological developments have been aimed at either alternative delousing measures or technologies aimed at prevention of salmon louse attachment. Fish health and fish welfare in enclosed and semi-enclosed systems is an important research area (see chapter 2).

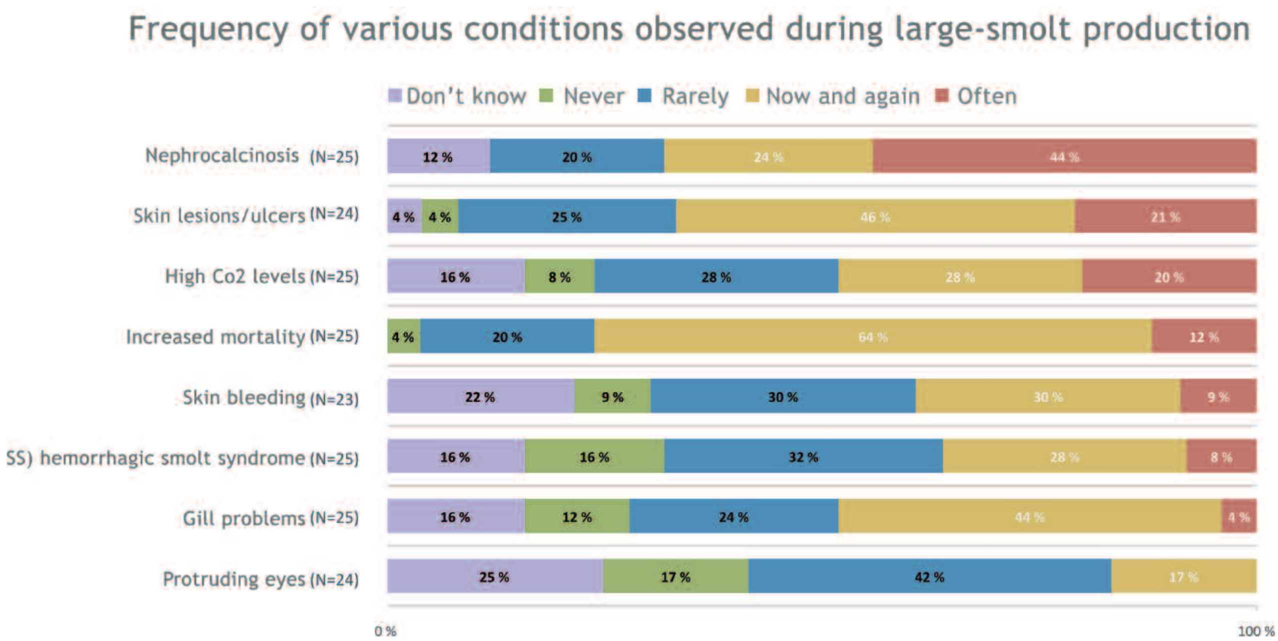


Figure 3.4.1: Frequency of various conditions observed during large-smolt (100-1000 gram) production in enclosed/semi-enclosed units in 2019. The figures are based on responses from Fish Health personnel for different production principles.

3.4 Welfare challenges related to production of large smolts

By producing a larger smolt it is possible to reduce the production period in traditional cages in the sea and thereby decrease exposure to salmon lice. Production of large smolts (100-1000g) in enclosed or semi-enclosed units is increasing. More than half of respondents (53%) working with juvenile production of salmon stated that they had experience from large-smolt production during 2019 compared to 34% in 2018. The frequencies of some clinical observations are summarised in figure 3.4.1. The summary is based upon a limited number of respondents and should be interpreted with caution. As in the previous year, nephrocalcinosis, high CO_2 levels, skin conditions, and episodes of increased mortality are most frequently observed. Ten respondents provided extensive 'free text' comments regarding large-smolt production with several mentioning water quality and/or poorly designed facilities/technical equipment for larger fish and increased biomass as factors of concern. Individual reports mentioned challenges related to smoltification and synchronisation of smoltification, while some consider infectious diseases e.g. AGD, Tenacibaculum infections, and HSMI to be important.

3.5 Welfare challenges during juvenile production

Historically, there has been less focus in the industry on reporting of mortality during juvenile production of salmon and rainbow trout compared to the ongrowing phase. In 2019, the project 'Animal welfare during juvenile fish production- Småfiskvel' was completed. This project investigated use of mortality figures reported during juvenile production as a welfare indicator. A questionnaire/survey of juvenile production facilities was also undertaken. The project found that the quality of data reported to the authorities was poor, partly due to the fact that reporting was performed on a monthly basis and at the tank level, without identification of the individual population. Whether fish destroyed or graded out should be included in these figures has not been decided. Average monthly mortality varied between 0.7 and 2.4%, and mortality levels increased between 2015 and 2018. Highest mortality was identified in the smallest weight class (<3 gram). The manner in which the data is reported does not easily allow identification of where and how the major health and welfare challenges occur during the production cycle, but the large differences in mortality identified between different forms of production show that there exists a significant potential for improvement. Although significant differences were

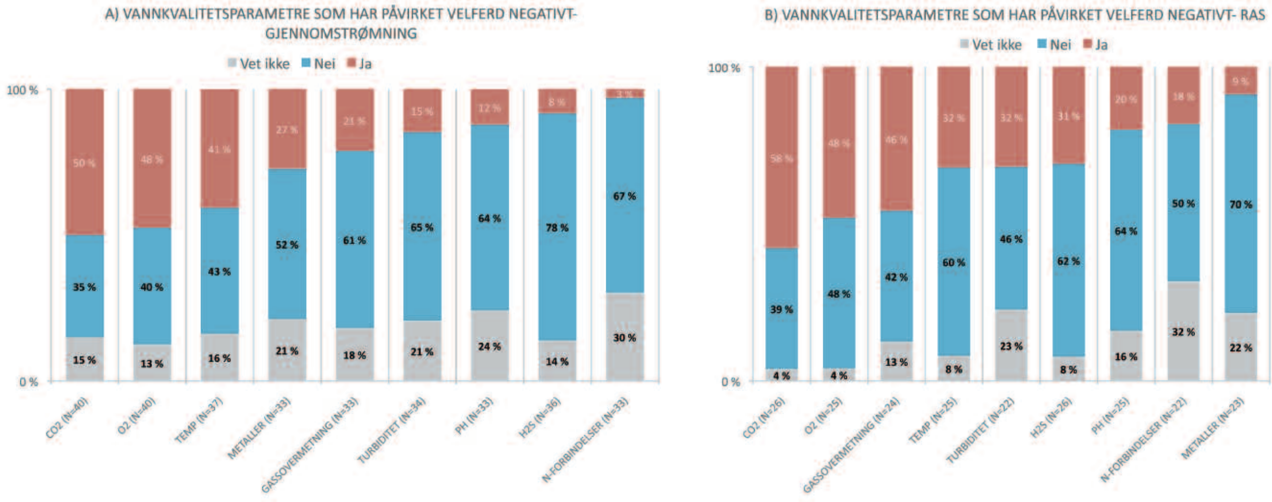


Figure 3.5.1: Fish Health personnel stated whether they had experienced water parameters negatively affecting fish welfare during 2019, and if so, how many times in A) through-flow farms and B) Recirculation farms (N-compounds = Nitrogen compounds). The number of respondents for each criteria = N. .

not identified between different production forms, it was found that there was a greater variation in mortality in RAS farms compared to through-flow and combination (both through-flow and RAS) systems. The complete report may be found here: https://www.vetinst.no/rapporter-og-publikasjoner/rapporter/2019/dyrevelferd-i-settefiskproduksjonen-smafiskvel.

Good water quality is particularly important for good fish welfare. Independent of production form, an unfavourable water status will stress the fish and affect its susceptibility to infection. Wild salmon generally live in water that is 100% saturated with oxygen, and are free to choose their position in the river based on water speed, temperature and salinity. In a farming situation, it is not possible to offer the fish the same choices and there will always be a compromise between optimal environment and economy. Under farming conditions where water exchange is limited, while the oxygen level in the water may be manipulated, concentrations of waste products like CO_2 and nitrogen compounds may increase to levels that have a negative effect on welfare.

Different types of system have different types of challenge related to water quality and RAS facilities are particularly at risk in this respect (See figure 3.5.1). 'Free text' comments to the annual survey by fish health personnel mention challenges related to excessive

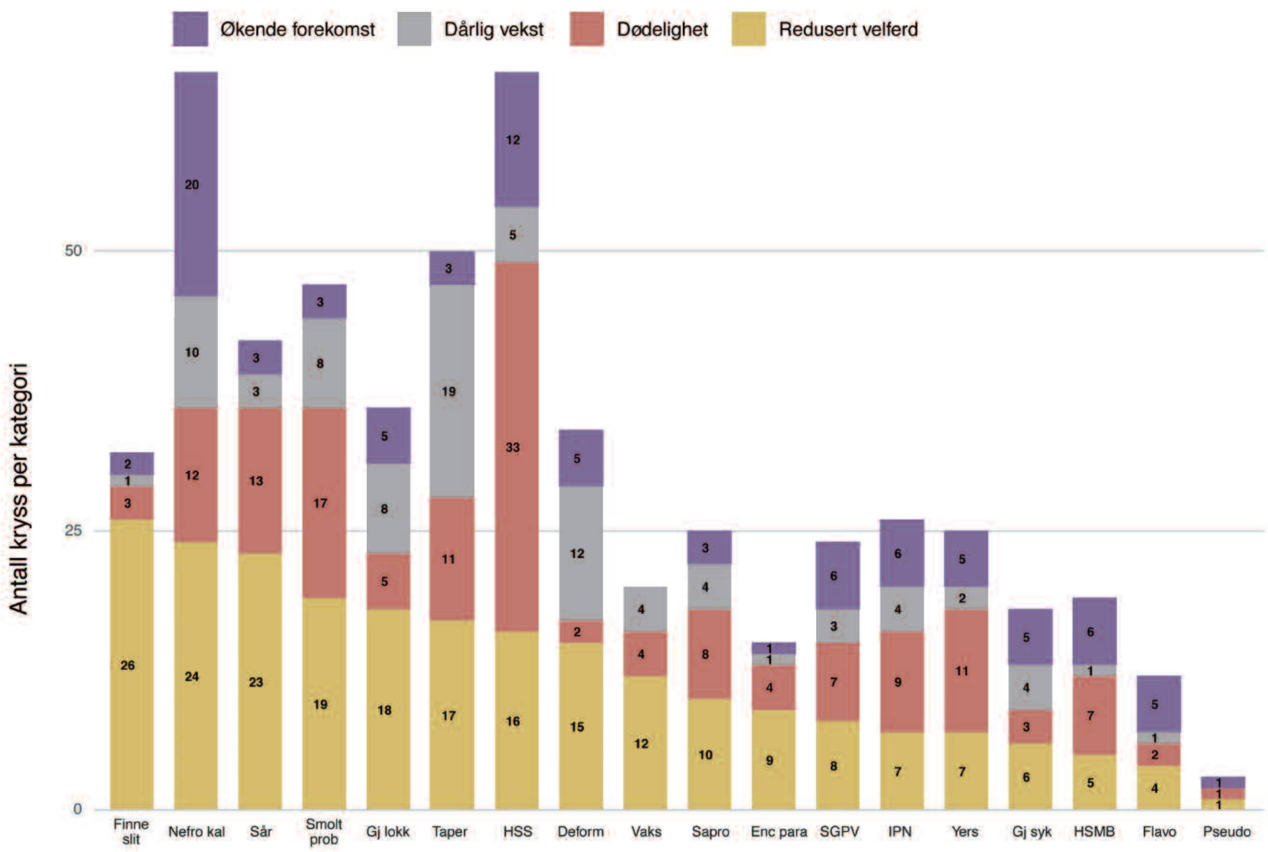


Figure 3.5.2. The five most important causes of mortality, poor growth and welfare and whether they are on the increase in juvenile salmon production (see appendix A page 149 for details and X-axis abbreviations). ISA was considered an increasing problem by two respondents (due to space limitations not included here).

biomass, gill health and opercular deformities. Further, more focus is required on quality of juvenile fish, including smoltification prior to sea-transfer at favourable sea-temperatures.

The Norwegian Food Safety Authority received 98 notifications of 'events of welfare concern' in juvenile production facilities in 2019. 47% involved cases of unexplained mortality, 47% were designated as of 'other' reason with the remaining 6% explained by vaccination, pumping or fire. As a comparison, in 2018, 58 welfare notifications were received. Whether the increase in such events reported during 2019 is due to a real increase or improved reporting procedures or both, is unclear.

In the survey, fish health personnel were asked to indicate the 5 conditions, which in their opinion, had the most negative influence on welfare, mortality and growth in 2019 and indicate whether the frequency of these conditions was increasing. The results for salmon indicate that fin-erosion, nephrocalcinosis and skin conditions were considered most important in terms of reduced welfare, while HSS and smoltification problems were most important in relation to mortality. HSS and nephrocalcinosis were considered to be increasing in frequency (see figure 3.5.2 and appendix A).

3.6 Welfare challenges related to water quality in marine facilities

Water quality in open cages utilising 'lice skirts' may be reduced during periods of high temperature and reduced water flow. Several Fish Health Personnel reported that they had, in both 2018 and 2019, experienced challenges related to low oxygen saturation when 'lice skirts' were used, particularly during the summer. Gill health is also considered critical during such episodes and appears to be negatively influenced by these treatments. Poor water quality monitoring including logging of oxygen saturation at the cage level was also mentioned. Whether water quality is an important factor in development and manifestation of disease can be difficult to identify, as water samples are often taken after and not before outbreak of disease (see chapters 8.4, Water quality and 8.5 Algae).

3.7 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

Table 3.7.1. Number of weeks with non-medicinal delousing activity reported to the Norwegian Food Safety Authority as of 07.01.20. The category 'other' relates to reports which could not be categorised based on free-text provided in the report.

Type non-medicinal delousing	2017	2018	2019
Thermal	1247	1355	1451
Mechanical	279	471	734
Freshwater	96	104	172
Other	51	72	89
Total	1673	2002	2446

during lice-treatment.

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 2019, we have seen further increases in use of such methods (Table 3.7.1). For further details, see chapter 7.1 on 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. Thermal delousing requires transfer of fish to a warm water bath. The temperature in the bath is dependent on ambient sea temperature, effect of treatment and fish welfare. In 2018, 30 seconds exposure to temperatures of between 29 and 34ºC were reported as normal. Whether there were any changes to this practice in 2019 are unclear.

Research has shown that the temperatures used in thermal delousing are painful to fish. Salmon displayed discomfort and pain reaction at temperatures over 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 par 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. During 2019, the Norwegian Food Safety Authority forbade thermal delousing at water temperatures in excess of 34ºC, as welfare testing and documentation has not been performed at such high temperatures. Further, thermal delousing using water temperatures of 28ºC and higher must be phased out within the next two years unless documentation becomes available that demonstrates that this technology can be used with acceptable levels of welfare (mattilsynet.no, updated 15.10.19).

Mechanical delousing represents various forms of physical removal of lice from the skin of the salmon. Currently there are three different methodologies in use; one based on water flushing alone, one based on a turbulent water current, and another which combines water flushing and physical brushing.

A common factor involved in all non-medicinal lice treatments is the need for crowding of the fish prior to pumping into the delousing system. Crowding is in itself

Figure 3.7.2 Distribution of welfare related incidents reported to the Norwegian Food Safety Authority in 2019, for each category. The reports (total N = 1392) relate to ongrowing fish and brood stock. Data as registered in MATS.

Number of welfare related events in ongrowing/brood stock farms	2018		2019	
Non-medicinal delousing with handling	629	(61%)	842	(60%)
Unexplained mortality	196	(19%)	240	(17%)
Other	112	(11%)	167	(12%)
Handling	40	(3.9%)	58	(4.2%)
Medicinal delousing with handling	40	(3.9%)	51	(3.7%)
Grading/pumping	7	(0.7%)	18	(1.3%)
Force of nature (2019)/ reduced resistance (2018)	1	(0.1%)	8	(0.6%)
Medicinal delousing without handling	9	(0.9%)	6	(0.4%)
Non-medicinal delousing/ preventative without handling	3	(0.3%)	2	(0.1%)

known to represent a considerable welfare risk. Thermal, mechanical and freshwater treatments involve considerable handling and a series of stressful situations resulting in direct physical injury to gills, fins, eyes, skin etc. Additional stressors include changes in water quality e.g. fall in oxygen levels or gas supersaturation.

Water temperature may also be decisive in relation to ulcer development. Underlying or active infections e.g. CMS, HSMI, AGD and generally poor gill health are reported to result in significant mortality.

Delousing systems are relatively new and under continual development. Limited documentation regarding the effect on treated fish (i.e. mortality, injury and stress) is available and that available was generally produced early in the developmental phase. The effects of frequent lice treatment on the skin, mucus layers and gills is poorly documented. In this year's survey, most respondents considered gill disease to be increasing in prevalence amongst sea-farmed salmon. Mechanical injuries occurring in association with delousing were considered the main cause of poor welfare in 2019 (see appendix B). A complete review of all welfare problems and risk factors associated with non-medicinal delousing remains lacking.

The Norwegian Food Safety Authority received in 2019, 1392 reports of welfare related events in ongrowing and broodstock farms, an increase from the 1036 such events reported in 2018. Of the events reported in 2019, 842 (60.5%) were related to non-medicinal delousing and associated handling (see table 3.7.2). The degree of seriousness and extent of each event varied, and different companies may have different thresholds for reporting. In 2019, as in 2018, we consider it likely that around 1/3 of all non-medicinal delousing activities performed result in welfare related consequences serious enough to be compulsory reported to the Norwegian Food Safety Authority.

An increase in prescription of medicinal delousing products was reported in 2019 (see chapter 7.1. The salmon louse). One reason for this may be an increase in the number of treatments directed against the sea-louse Caligus elongatus in both salmon and Lumpsucker. The increase in medicinal treatment did not replace non-medicinal treatments, as the frequency of both forms of

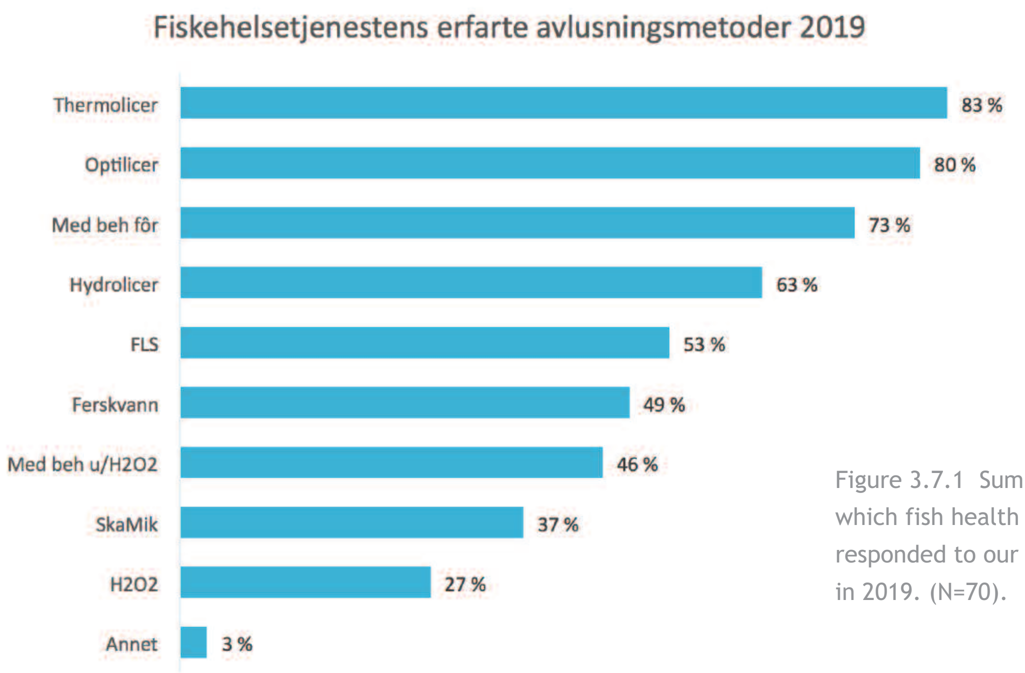
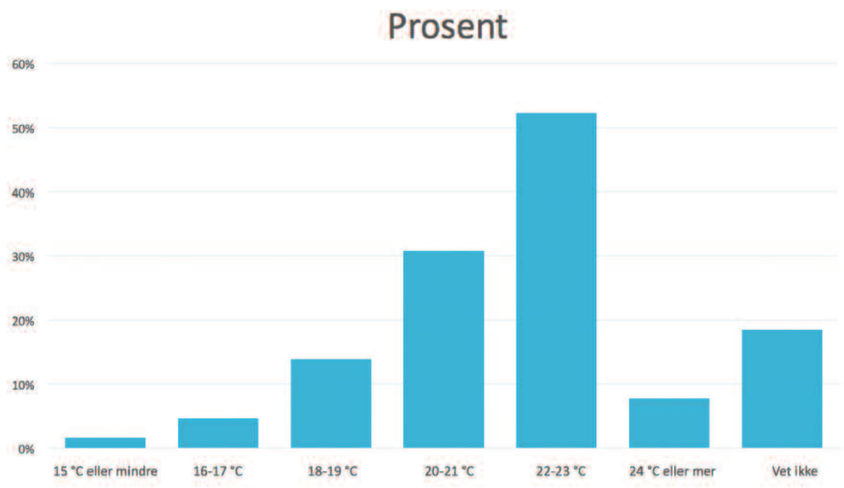


Figure 3.7.1 Summarises the methods for which fish health personnel who responded to our survey had experience in 2019. (N=70).

Figure 3.7.2. Most common temperature difference (ΔT) between sea- and thermal delousing treatment water in 2019. N=65.

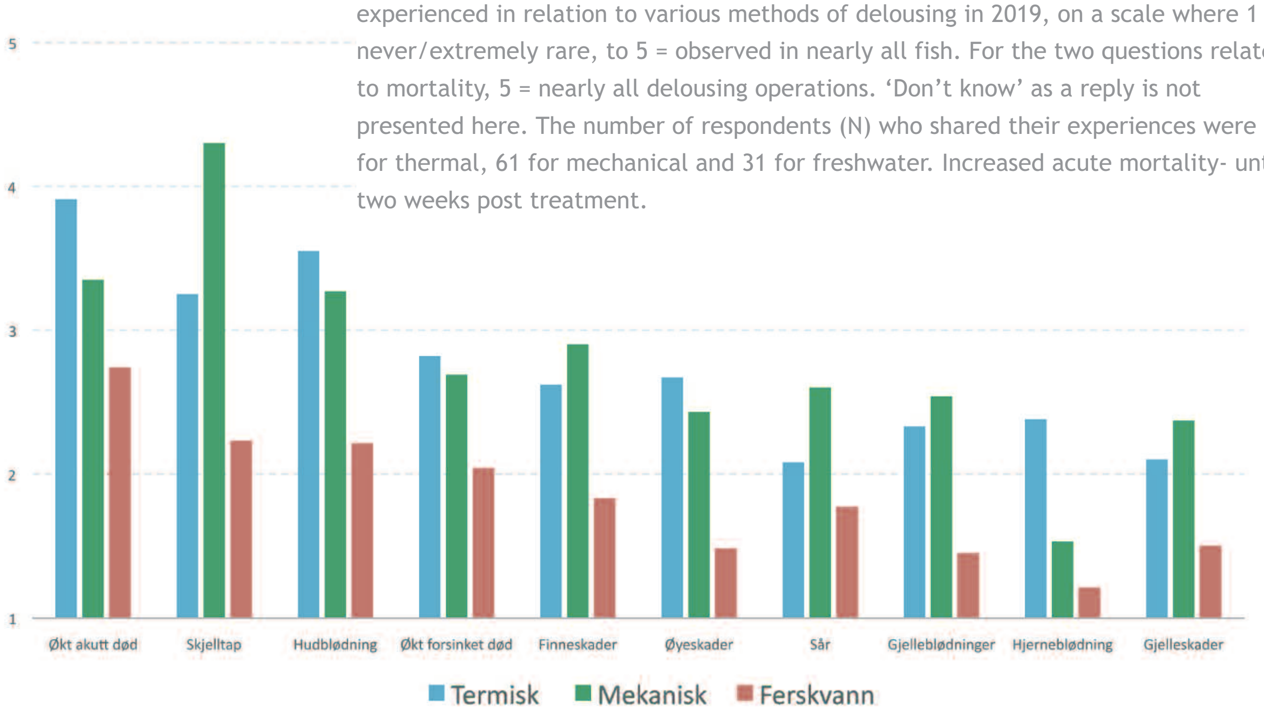


treatments has increased from 2018 to 2019.

Rapid re-infection following treatment has been reported following medicinal treatment and may lead to frequent treatment. There is a lack of documentation of how frequency of treatment relates to fish welfare. With so many treatments utilising different methods, the total effect on the fish must be considered. Other management routines such as net changing, transfer of fish between cages or localities should also be considered. There are good grounds to believe that the tolerance limits of the fish are overstepped in many farms today.

Seventy respondents (fish health personnel, farming companies, Norwegian Food Safety Authority) in total shared their experiences related to new delousing methods and welfare in the annual survey. When asked if there had been an increase in the number of delousing treatments on sites for which they had responsibility in 2019 compared to 2018, 48 percent answered that there had been an increase, 8.5% replied that there had been fewer and 30 percent replied that the numbers were similar. Fourteen replied 'don't know'. A summary of the delousing techniques for which the respondents had experience is provided in figure 3.7.1.

Figure 3.7.3. Displays the average frequency of injury or mortality each respondent experienced in relation to various methods of delousing in 2019, on a scale where 1 = never/extremely rare, to 5 = observed in nearly all fish. For the two questions related to mortality, 5 = nearly all delousing operations. 'Don't know' as a reply is not presented here. The number of respondents (N) who shared their experiences were 67 for thermal, 61 for mechanical and 31 for freshwater. Increased acute mortality- until two weeks post treatment.



The effectiveness of non-medicinal delousing may depend on many factors including the principle upon which the treatment is based, how the machinery is set up on the treatment day e.g. water pressure or temperature, model or post-production modification. Other factors include crowding and volume of fish treated per unit time.

Respondents to the survey were asked whether the effect of non-medicinal treatments had improved or reduced during 2019 in comparison with previous years. 44% responded that the effectiveness remained unchanged, 23 % that it had improved and 105 that it had worsened. 24% answered 'don't know'.

When asked about the highest temperature used during thermal treatments in 2019, one respondent stated that 36ºC had been used at a seawater temperature of 8ºC, another 35ºC at a sea temperature of 17ºC and 36 respondents stated approximately 34ºC at various sea temperatures. Over 50% of respondents stated that the usual difference between sea temperature and treatment temperature was 22-23ºC (figure 3.7.2).

When asked to comment on the frequency of injury and mortality related to the different delousing methodologies (see figure 3.7.3) a situation similar to that reported in the two previous years became apparent. Mechanical delousing is most commonly associated with scale loss and thermal treatment with acute mortality episodes. We received only half as many replies related to freshwater treatment compared to the mechanical and thermal methods, and the proportion of 'don't know' replies was also higher for this category, which means there is a degree of uncertainty around welfare aspects associated with this method. Figure 3.7.3 represents a graphical summary of replies to the survey. The statistics should be interpreted with care and only as trends. There are large differences within the categories, both between the different delousing systems and between the different platforms the systems are mounted upon. In addition, factors including the general health status of fish prior to delousing are decisive for their welfare during delousing.

Fish health personnel were asked if they had noticed (during welfare scoring) any change in the degree of external injury occurring in association with non-

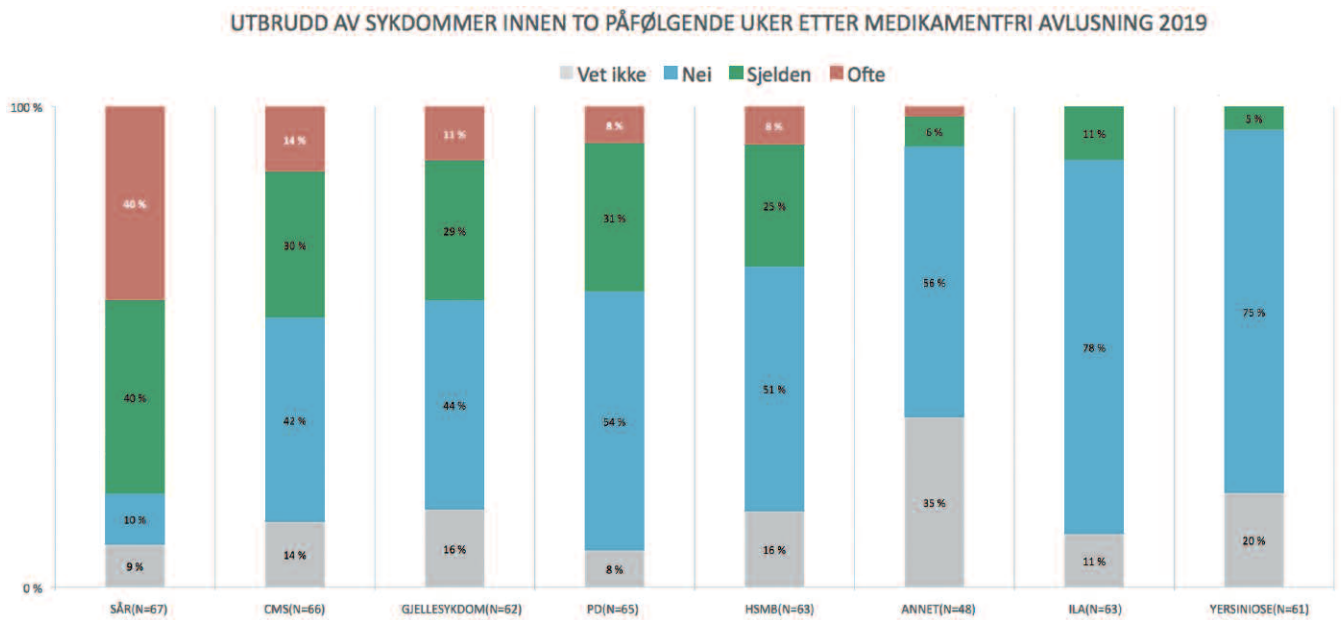


Figure 3.7.4. Fish Health personnel responding to the annual survey who reported experiencing outbreak of different diseases in the two weeks following non-medicinal delousing in 2019.

medicinal delousing in 2019 compared to 2018. 45% replied that there had been no change, 21% replied that there had been an improvement, 7% replied that the situation had worsened. 26% answered 'don't know' (N= 70).

In 2019, the Norwegian Veterinary Institute received 32 diagnostic submissions related to acute mortality in association with thermal delousing. Twenty-eight of these submissions involved salmon, two involved rainbow trout and two involved Lumpsucker. Fifty-eight such submissions were received in 2018.

3.8 Welfare challenges associated with transport

Farmed fish are transported as smolts, harvest-ready fish or as brood stock. Fish are also graded and moved during the sea-phase of culture. 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 during transport and do not transmit infection to other populations. Smolts which 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.

Well-boat transport is considered an especially significant risk for transmission of disease and significant resources are continually dedicated to reduction of these risks including legislatorial changes. From 01.01.2021 a number of new changes to legislation come into force regarding transport of fish, including treatment of transport water during sea transport.

The Norwegian Food Safety Authority received 21 reports of 'welfare concern' in association with transport of fish in 2019 compared to 5 in 2018. Of these, 8 were related to transport injuries, 2 to poor water quality and the remainder as 'other'.

Transport of cleaner-fish is particularly challenging. Wrasse are caught on a large scale by local fishermen between Østfold and Sørlandet and are transported to marine farms on the west and north coasts. The associated handling and transport can be rough and high mortalities experienced (up to 40% mortality is reported). Some wrasse species are particularly vulnerable to the poor water quality that may develop during transport.

3.9 Welfare challenges associated with harvesting

All harvesting processes involve a risk of suffering associated with crowding, pumping, chilling, time out of water and collision with harvesting furniture etc. 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.

The sedation methods permitted for salmonids are electricity or a physical blow to the head (or combination). The aim of sedation is to ensure that the fish is unconscious and remains so during bleeding and thereby unable to feel pain throughout the procedure. Twenty-eight respondents to the survey reported that they had responsibility for welfare in a total of 49 harvest facilities in 2019. Most (21) had responsibility for a single site. Electrical (out of water) and physical sedation appear to be in equally widespread use. Earlier research has shown that these methods are satisfactory in terms of fish welfare as long as the systems are used and maintained satisfactorily. For sedation methods which provide a reversible sedation e.g. electrical, it is essential that the fish are bled immediately following sedation. Cutting a single gill-arch results in a slower bleed than cutting both gill arches.

According to the annual survey, it appears that manual and automatic bleeding are in equally widespread use. Some sedation methods such as 'swim in' tanks with a following 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. In the case of exhausted fish, they may enter the machine backwards or upside down resulting in a fail placed blow to the fish. The same applies to subsequent automatic bleeding.

Harvesting of fish is now generally highly automated. Small improvements and careful surveillance of welfare is highly relevant for collective fish welfare and subsequent product quality. All automated systems require human supervision and back-up systems. The legal training requirement for personnel involved increases focus on animal welfare.

Fish stressed prior to harvest rapidly enter a more rigid post-harvest rigor mortis compared to non-stressed fish. This reduces the window for pre-rigor filleting. Final fillet pH is also higher in stressed fish, which reduces shelf life.

Measures aimed at improving fish welfare in harvesting facilities must also apply to fish that are graded out. This includes cleaner-fish and 'stowaways' such as small coalfish, but also include salmonids which are not suitable for the market. These fish have the same welfare rights, with regard to handling and destruction, as fish of economic value. Several respondents report that cleaner-fish are not processed in specially adapted destruction facilities. How welfare standards are maintained for cleaner-fish during destruction is therefore uncertain.
To reduce the negative effects on sick or stressed fish, effort should be placed on development of methodology aimed at cage-side harvesting. This is based on avoidance of the cumulative negative welfare consequences of well-boat pumping, transport, queuing at the harvest facility and pumping into the harvest facility. Development of systems designed for efficient euthanisation of fish directly from the cage in which they were farmed will provide better fish welfare. Such boats are now available

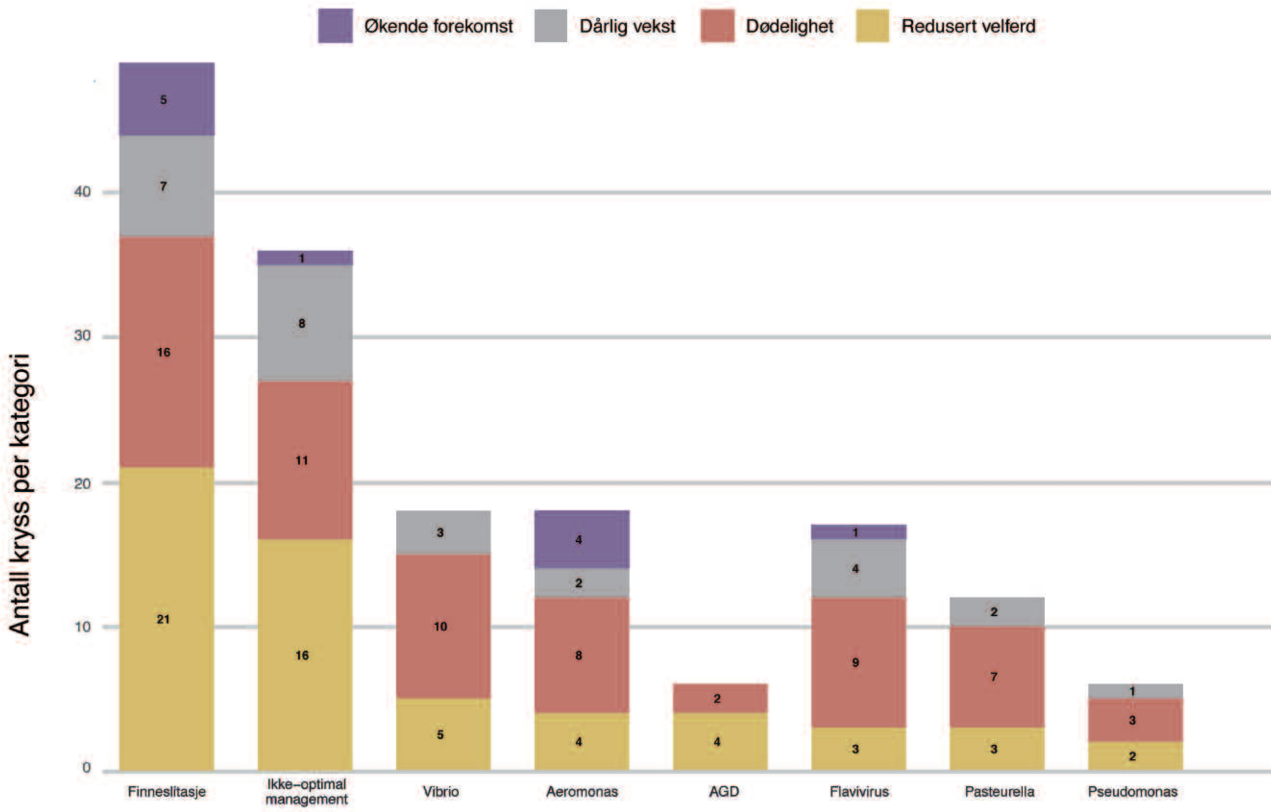


Figure 3.11.1. Respondent replies regarding the three most important problems in relation to mortality, growth, welfare and whether the frequency of these problems are on the increase in lumpsucker juvenile production.

where the whole harvest procedure is performed on board for subsequent transport to land and further processing. 'Emergency harvests' of sick fish are now also practised cage-side. It is important that the availability of such alternative harvest methodology does not lead to an increased frequency of 'risky' lice treatment and that the number of fish harvested using these technologies are registered, such that this information can be used to broaden our knowledge on their use.

3.10 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 reduce contamination of

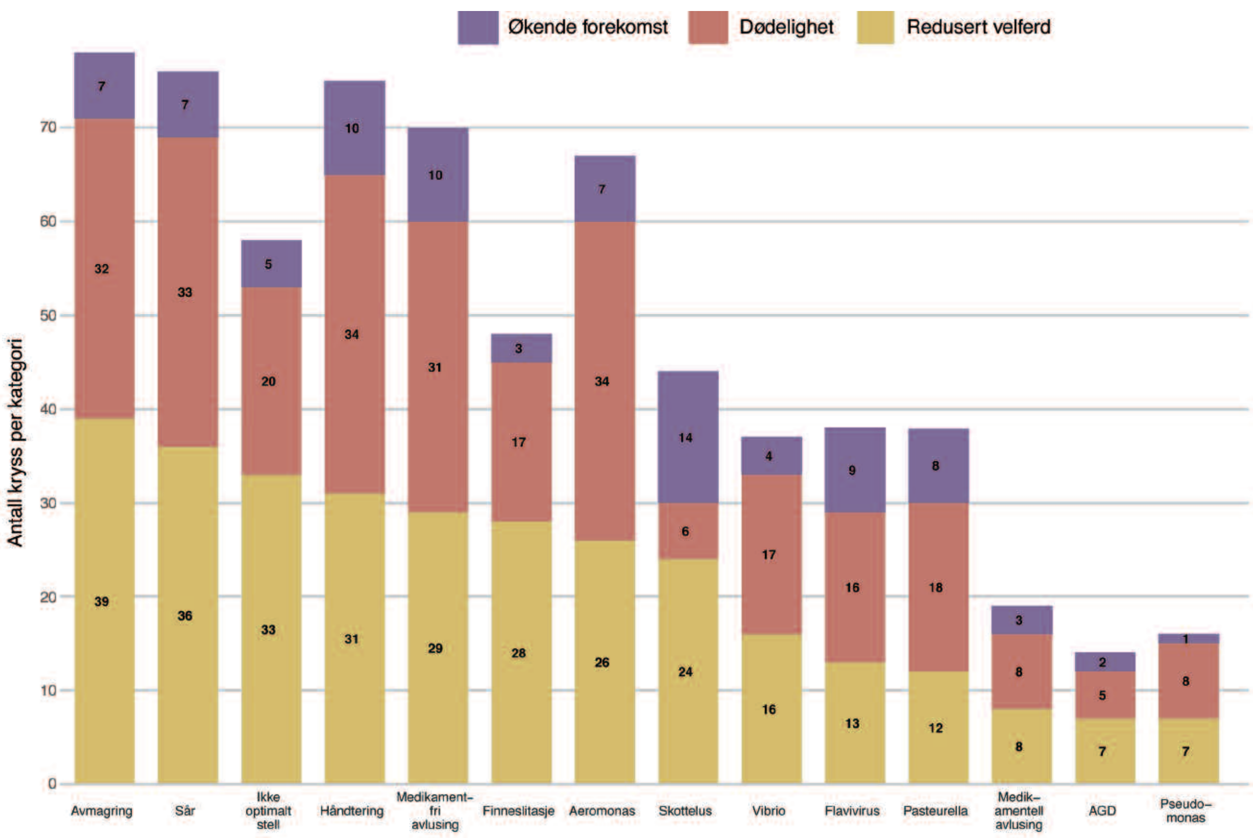


Figure 3.11.2. Respondent replies regarding the three most important problems in relation to mortality, welfare and whether the frequency of these problems are on the increase in lumpsucker stocked in salmon cages.

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.

3.11 Welfare challenges in cleaner-fish use

Wrasse and Lumpsucker have, in recent years had an important role in control of salmon lice in Norwegian farms. Despite belonging to several species, their ability to graze salmon-lice from the skin of farmed salmon has led to common use of the collective term 'cleaner-fish'.

Presently, most of the wrasse used as cleaner fish are wild-caught. 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. The most important wrasse species are goldsinny-, Ballan- and corkwing- wrasse. There are significant welfare challenges associated with capture, storage, transport and biosecurity in addition to the welfare challenges associated with confining a wild species within a farm cage.

The effect of large-scale capture on wild wrasse populations and the ecosystem from which they are removed has also been questioned. In the event of escape from the cages to which they are introduced, the effect on the local environment may also be questioned.

Lumpsucker are the dominant cleaner-fish presently farmed and have in the course of a very few years become the second most farmed fish (in terms of numbers of individuals) in Norway. According to the Directorate of Fisheries 22.6 million lumpsucker were produced in 2019. 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 large differences between the natural habitat of cleaner-fish and the farming environments to which they are exposed. Lumpsucker have naturally poor swimming capacity and stocking of farms exposed to strong currents is a challenge for these fish as are high summer temperatures.

There are significant disease related challenges for all species of cleaner-fish (see chapter 10. Cleaner-fish health). In the annual survey, fin-erosion and non-optimal husbandry during the juvenile phase of production were

Figure 3.11.3. Lumpsucker with 'crater disease'. The cause of the disease remains unknown, but bacteria belonging to the genus *Tenacibaculum* have been associated with the problem. The disease may result in high mortality and has negative welfare consequences. Photo: Mattias Bendiksen Lind, Havet..

Figure 3.12.1. The photograph shows the oesophagus and gill arches of a wild salmon found dead in a river. Note the fishing hook in the gill arch. Fish, hooked in this manner should be killed and not released. In this case the fishing line may have broken during capture. Photo: Vegard P. Sollien, Norwegian Veterinary Institute.

highlighted as particular welfare challenges (see figure 3.11.1).

Cleaner-fish welfare has attracted increasing attention in recent years. Focus on e.g. provision of satisfactory feeds and feeding strategies, the presence of cover within the cages and vaccination are all steps in the right direction of improved welfare. Despite this, it has become increasingly clear that it is extremely difficult to adapt these species to the farm environment. Replies to the annual survey indicate that emaciation and skin ulcers are among the major welfare concerns related to lumpsucker stocked in salmon cages.

Mortality in cleaner-fish in the Norwegian aquaculture industry is unacceptably high. The Norwegian Food Safety Authority carried out a surveillance campaign, completed in 2019, which for the first time, generated statistics related to mortality in cleaner-fish stocks. These statistics were based on data registered by individual farmers i.e. dead fish counted during salmonid production cycles. Only rarely were surviving fish counted at the end of a production cycle, so the real mortality rates are far from certain. It is accepted that many lumpsucker and wrasse simply 'disappear' from salmon cages either through predation by the salmon, rapid decomposition following death or that they become tangled in the net wall rather than end up in the dead fish sock. It is therefore reasonable to assume that the real mortality levels are much higher than estimated during the campaign. The registered collective median mortality from all cleaner fish species was 42%. For lumpsucker there were clear regional differences with lowest mortality registered in the north (21%) and highest in the south (57%). In mid-Norway a mortality of 48% was registered. For wild-caught wrasse, mortality varied between 37 and 44%, of which corkwing wrasse displayed the highest mortality and goldsinny the lowest. As previously mentioned these were figures registered by the farms. The real figures are probably much higher.

As part of the survey performed during the Norwegian Food Safety's recent surveillance campaign, farmers were asked to provide the most important causes of death. For lumpsucker, non-medicinal delousing technologies and disease were considered the most common causes of death. For wild-caught wrasse, non-medicinal delousing was also considered the main cause of death. Other important causes of death included disease, injuries associated with raising the dead-fish sock, incorrect water temperatures and aggression. Several farmers commented via the 'free text' option in the survey that they consider present day use of cleaner-fish as problematical. Several feel that use of cleaner-fish of all species should be forbidden, several that some species should be forbidden and several that use of wild-caught wrasse should be forbidden.

In the Norwegian Veterinary Institute's survey of fish health personnel and the Norwegian Food Safety Authority, there was a free-text question as follows 'Have you any comment on current use of cleaner-fish?' Thirty-eight replies were received and many described, directly or indirectly, significant welfare challenges for both wrasse and lumpsucker. A large proportion of fish health personnel in the industry consider the welfare situation for cleaner-fish to be extremely poor.

The health situation and lack of control of mortality results in a situation in which cleaner-fish are a treated as a consumable product. This means that there are significant welfare and ethical issues for which both the industry and the authorities must find a solution. All fish held in Norwegian fish-farms are subject to the same level of protection in animal welfare legislation. It is therefore a paradox that cleaner-fish, used to improve the welfare of farmed salmon experience extremely high levels of mortality due to 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 in the future.

3.12 Welfare challenges associated with catch and release of wild fish

There is a long international tradition of catch and release in angling. This may be due to the small size of the fish, return of a non-target species, or as a management tool to protect fish stocks. Catch and release is a relatively new phenomenon to Norway, but one that has increased dramatically over the last 10 – 15 years. This applies particularly to wild salmon angling. Compulsory catch and release has a significant financial aspect and allows riparian owners to sell many fishing licences, allows the anglers the experience and excitement they are looking for, even when the population of wild salmon is under threat. While catch and release is often compulsory in inland salmon fishing, the practice is becoming increasingly widespread in all types of angling including sea angling. Examples of this include foreign tourists who continue fishing after reaching their legal quota. Another example includes so-called 'species hunters' who fish specifically for different species of fish, including non-food species. The practice of catch and release has been debated in several fora including the Norwegian Scientific Committee for Food and the Environment. The Norwegian Food Safety Authority arranged several meetings on this theme in 2018. The Norwegian Food Safety Authority write on their homepage (updated 15.02.19) that 'Routine catch and release, where the sole aim is to experience the thrill of fishing followed by release of the fish, strides against animal welfare legislation and is forbidden in Norway'. It has, however, been decided at the political level, that limited catch and release of salmon and trout is permitted.

There is today knowledge on how catch and release may be performed in a manner that reduces the risk of death of the fish. This applies to equipment, angling practices and handling of fish. Welfare considerations go further than whether the fish survives or dies. Animal welfare relates to the stresses and fear, pain and injury the fish experiences during hooking and capture. Finally, there is the ethical aspect around whether it is acceptable to subject the fish to fear, pain and exhaustion when the only objective of the exercise is excitement and fun for the angler. Such an ethical evaluation is covered by animal welfare legislation, which states that animals must be protected against danger and unnecessary stresses and strains. A balance must be found between the gains for humans and the welfare of animals.

3.13 Overall evaluation of fish welfare in 2019

Animal welfare in juvenile production facilities has been a focus in 2019. In the project SMÅFISHVEL it was found that mortality statistics reported to the Norwegian Food Safety Authority are difficult to use as a welfare indicator due to their poor quality. This is due mainly to the fact that mortality data is reported monthly and at the tank level, without identification of individual fish populations. This makes it difficult to follow the fate of individual populations and identify risk factors. An increase in mortality amongst juvenile fish was recognised between 2015 and 2018. The highest mortality was identified in the smallest weight class (<3 gram) of fish. Again in 2019, water quality was described as a challenge by several fish health personnel in regard to fish welfare. This is exacerbated by high stocking densities and low water supply in many cases. Gill health and opercular deformities are considered important contributors. Juvenile fish quality including satisfactory smoltification in advance of sea-transfer is also a challenge.

The Norwegian Food Safety Authority received 98 reports of welfare related incidents from juvenile fish production facilities in 2019. This is a significant increase from 2018. Whether this increase was related to a real increase in welfare related incidences or whether it reflects a change in reporting practices is unknown.

As far as marine farmed fish are concerned, the increasing number of delousing procedures continue to represent a significant welfare threat for both salmonids and cleaner-fish. There is a lack of knowledge relating to use of non-medicinal delousing and fish welfare including tolerance to repeated treatment and restitution requirements. Exposure to unnaturally high temperatures (thermal delousing) can result in pain and panic in treated fish. Experience has shown that fish already stressed for some reason tolerate this type of treatment poorly. Mechanical delousing commonly leads to scale-loss. Such adverse effects on skin health and mucosal surfaces will make the fish more susceptible to winter-ulcer at low water temperatures while the effects on fish welfare may be overlooked under warmer conditions that allow the injuries to heal.

The number of welfare related incidents involving delousing, serious enough to trigger compulsory reporting to the Norwegian Food Safety Authority continues to increase. In total, the Norwegian Food Safety Authority received 1392 welfare related reports in 2019, and of those 842 (60.5%) were related to non-medicinal delousing and handling. This is an increase of over 200 from the level registered in 2018. Some of the increase may be explained by an increased willingness amongst fish farmers to report such incidences. Nevertheless, we find the trend alarming. The total number of non-medicinal delousing treatments has also increased in 2019 and around 1/3 of all delousing events lead to a welfare related report to the Norwegian Food Safety Authority. As far as other welfare related events are concerned in salmon farming in open cages, large-scale mortalities caused by algal blooms proved extremely challenging in 2019 (see chapter 8.5 Algal blooms).

The Norwegian Food Safety Authority's surveillance campaign directed at cleaner-fish was completed in 2019. This campaign provided mortality figures for the first time for cleaner fish in Norwegian cage farming. The statistics must be considered as minimum estimates as there are no available statistics covering the number of viable cleaner fish present in cages at completion of the farming cycle. Registered median mortality for all species of cleaner fish was 42%. Unacceptable levels of mortality and the poor health situation beg the question on whether these species can adapt to cage farming conditions. Responses to the Norwegian Veterinary Institute's annual survey clearly indicate that many actors consider cleaner-fish related welfare to be extremely poor. Fish Health personnel consider emaciation and skin ulcer development to be two of the major reasons for reduced welfare in cage held lumpsucker.

The aquaculture industry is in need of concrete drivers and a product development that focusses more on the welfare of the fish and less on quantity. This applies equally to cleaner-fish production and use. There are significant welfare concerns around how fish are currently farmed. The focus on welfare has, however, increased in the last year and is reflected in the fact that welfare as a theme has been discussed in several scientific meetings and conferences in 2019, and is also presented in company reports relating to sustainability. Fish Health personnel are strongly engaged in the work of improving fish health, welfare and general biosecurity. To improve the situation further, concrete measures need to be introduced in 2020 and future years.

Current legislation needs revision. There is a lack of coherence between legislation related to animal welfare and that related to the environment and expansion of the industry. Use of environmentally friendly non-medicinal delousing methodologies and cleaner-fish are conflicting in terms of current legislation. Conflicts such as these must be resolved in the near future, as dispensation from animal welfare legislation is not possible.

Photo: Rudolf Svensen.

4 Viral diseases of farmed salmonids

Viral diseases remain responsible for the largest losses related to infectious disease in Norwegian aquaculture in 2019. A short summary over the current situation is provided in the tables below. The figures stated for the notifiable diseases PD and ISA are the official statistics, for the remaining diseases the statistics relate to cases registered by the Norwegian Veterinary Institute.

In 2019, as in the previous six years, three viral diseases dominate diagnoses made by the Norwegian Veterinary Institute: Pancreas disease (PD), heart and skeletal muscle inflammation (HSMI) and cardiomyopathy syndrome (CMS) (Table 4.1). On inclusion of diagnoses made by private laboratories in 2019, CMS dominates, with 155 new localities in addition to the 82 diagnosed by the Norwegian Veterinary Institute (Figure 4.1). It should be born in mind that overlapping diagnoses and differences in diagnostic criteria probably exist. Equivalent figures for HSMI are 125 diagnoses made by private laboratories and 79 by the Norwegian Veterinary Institute. In the annual survey, when fish health personnel were asked to indicate the five most important causes of death in farmed fish among 25 alternatives. Of 72 respondents representing the whole country, 90% had CMS in their top five, while 75% had mechanical delousing and 43% had skin ulcers among their top five most important cause of mortality. Unfortunately, due to technical error, HSMI was not included in this survey, but was mentioned by several fish health personnel as an extremely important disease in the free text part of the survey. PD was also considered one of the most important causes of mortality in ongrowing salmon, and was considered the most important disease in terms of reduced growth in both ongrowing fish and brood stock.

For pancreas disease (PD), a list 3-disease for which all cases must be reported to the Norwegian Veterinary Institute, the number of infected localities in 2019 (152) was slightly lower than in 2018 (163) and 2017 (176). This reduction applies mainly to fewer cases in Rogaland, which experienced 10-26 cases per year between 2010 and 2018, but only two cases in 2019. Ninety-eight new localities were diagnosed with SAV-3 in western Norway during 2019, compared to 100 in 2018 and 54 new SAV-2 diagnoses in north-western and mid-Norway in 2019 compared to 56 cases in 2018. SAV-2 was diagnosed for the first time as far south as Rogaland. With the

Table 4.1 Prevalence of various viral diseases in farmed salmonids during the period 2009-2019. For non-notifiable diseases, the data is based solely on diagnoses made by the Norwegian Veterinary Institute.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ISA	10	7	1	2	10	10	15	12	14	13	10
PD	75	88	89	137	99	142	137	138	176	163	152
CMS	62	49	74	89	100	107	105	90	100	101	82
HSMI	139	131	162	142	134	181	135	101	93	104	79
IPN	223	198	154	119	56	48	30	27	23	19	23

exception of a slight reduction in the number of diagnoses in Rogaland and in Trøndelag, the PD situation remains largely unchanged in recent years.

Infectious salmon anaemia (ISA), which is a list 2 disease, was diagnosed in 10 farms in 2019 (and suspected on two farms). This is slightly fewer than in 2018 (13 diagnoses, four suspected farms). The positive farms are, as in previous years, widely distributed over a large geographic area rather than local epidemics.

As in previous years there were few diagnoses of infectious pancreatic necrosis (IPN) in 2019. There were, as in all recent years, no diagnoses of the list-2 diseases VHS or IHN in Norway.

The status for individual diseases, including salmon pox, and information on the causative viral agents involved, are presented in chapters 4.1-4.8

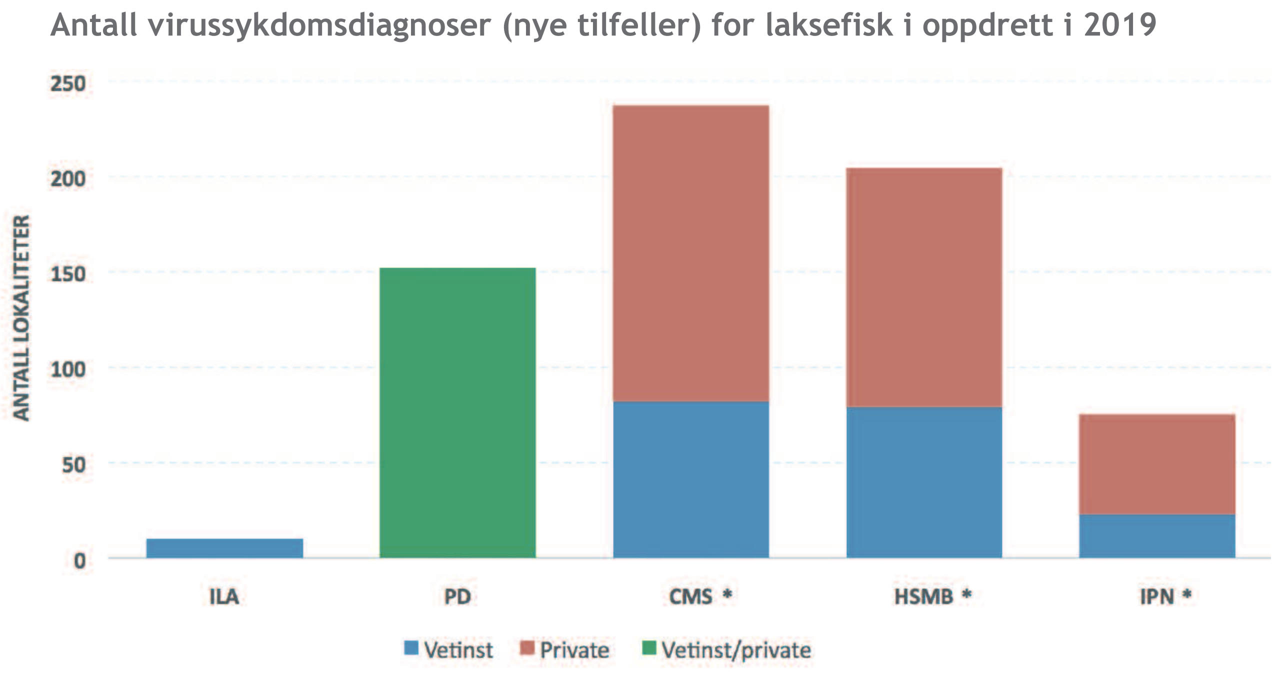


Figure 4.1 Prevalence of various viral diseases in farmed salmonids in 2019 based on data received from the Norwegian Veterinary Institute and private laboratories. The figures for PD are based on diagnoses reported to the Norwegian Food Safety Authority. Not all cases were verified by the Norwegian Veterinary Institute. * uncertain statistics due to lack of farm identification.

4.1 Pancreas Disease (PD)

By Hilde Sindre 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. Infection with SAV2 leads to low feed conversion and development of runted fish. 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 health surveillance to identify early stage disease forms the basis for prevention of spread.
Since 2017, according to law, 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. Vaccination is less widely used in Trøndelag. The effect of vaccination is debatable and protection is undoubtedly lower than for equivalent vaccines against bacterial agents such as furunculosis. 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 vaccines, based on DNA-technology, have recently been released. Field reports suggest that these vaccines may have a better effect than previously available vaccines, although this has not yet been documented. From July 2020, vaccination against PD will become compulsory for all salmon and rainbow trout in ongrowing and brood-stock

farms within production zones 6 and 7 (Taskneset to Langøya).

The Norwegian Veterinary Institute is both national and international reference laboratory for SAV. The Norwegian Veterinary Institute cooperates 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/sykdom-og-agens/pankreassykdom-pd

The PD situation in 2019

Official data

IA total of 152 new cases of PD were diagnosed in 2019, a reduction from 163 in 2018 and 176 in 2017. This reduction is largely due to the lower number of cases identified in Rogaland, which between 2010-2018 experienced 10-26 cases per year, but only 2 in 2019 (see below). The number of SAV2 cases stagnated at 100 in 2018 and 98 in 2019. The number of SAV2 cases identified in north-western (southern) Norway and in mid-Norway was 54 in 2019, around the same level as 2016-2017, with an almost equal number in Trøndelag and Møre og Romsdal. While Møre og Romsdal experienced an increase in PD incidence from 14 in 2018 to 26 in 2019, there was a reduction from 50 cases in 2018 to 27 in 2019 in Trøndelag. While no new cases of SAV3 were identified north of Hustadvika in 2019, two SAV2 cases were identified in Rogaland. In addition, mixed infections involving SAV2 and SAV3 were identified in two farms in Møre og Romsdal. SAV was not identified in the three most northerly regions in 2019.

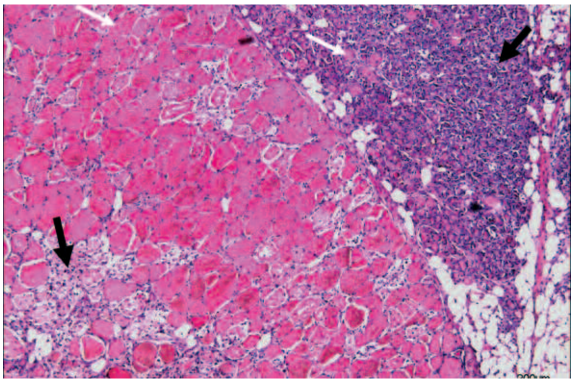
Due to an outbreak of PD within the surveillance zone north of Skjemta in Flatanger (Nord-Trøndelag), a control zone was established to prevent and control PD in the council areas of Nærøy, Vikna, Leka, Bindal, Brønnøy and Sømna in Trøndelag and Nordland. This control zone was extended in December 2017 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. A surveillance zone was also established in December 2019 covering the council areas of Tysvær, Vindafjord, Suldal, Stavanger and Hjelmeland following a SAV2 outbreak in Tysvær in Rogaland.

SAV3

SAV3 PD occurs mainly in Hordaland and Rogaland i.e. the southerly part of the PD range. PD was first diagnosed in Rogaland in 2004 and 2019 was the first year since 2004 that SAV3 PD was not identified in the region. The situation in Hordaland in 2019 was similar to the year before (61 and 64 cases respectively), while Møre og Romsdal and Sogn og Fjordane experienced an increase of 4 and 7 cases respectively compared to 2018. In two cases both SAV2 and SAV3 were identified in the same farm in 2019 in Møre og Romsdal (see figure 4.1.1).

SAV2

The number of new SAV2 diagnoses fell from 65 to 56, a level similar to that experienced in 2016-2017. While the number of cases in Møre og Romsdal increased from 14 to 26, the number of cases in Trøndelag fell from 50 to 27 in 2019. SAV2 was also diagnosed in a single farm in Sogn og Fjordane in 2019. SAV2 was diagnosed on a farm in Rogaland for the first time in 2019. Restrictions relating to movement of fish and equipment were imposed and the population was emergency harvested on the owners initiative. The diagnosis was made in an area of intensive fish-farming and during surveillance of the area SAV2 was also identified on a neighbouring farm. At the time of writing PD had not been diagnosed. As described above, a control zone was established around these sites.



PD can affect the swimming behaviour of affected fish through inflammation and degeneration of red and white muscle tissues. Black arrows indicate inflammation and white arrows indicate normal muscle cells (red musculature to the right of the photograph). Photo: Anne Berit Olsen, Norwegian Veterinary Institute.

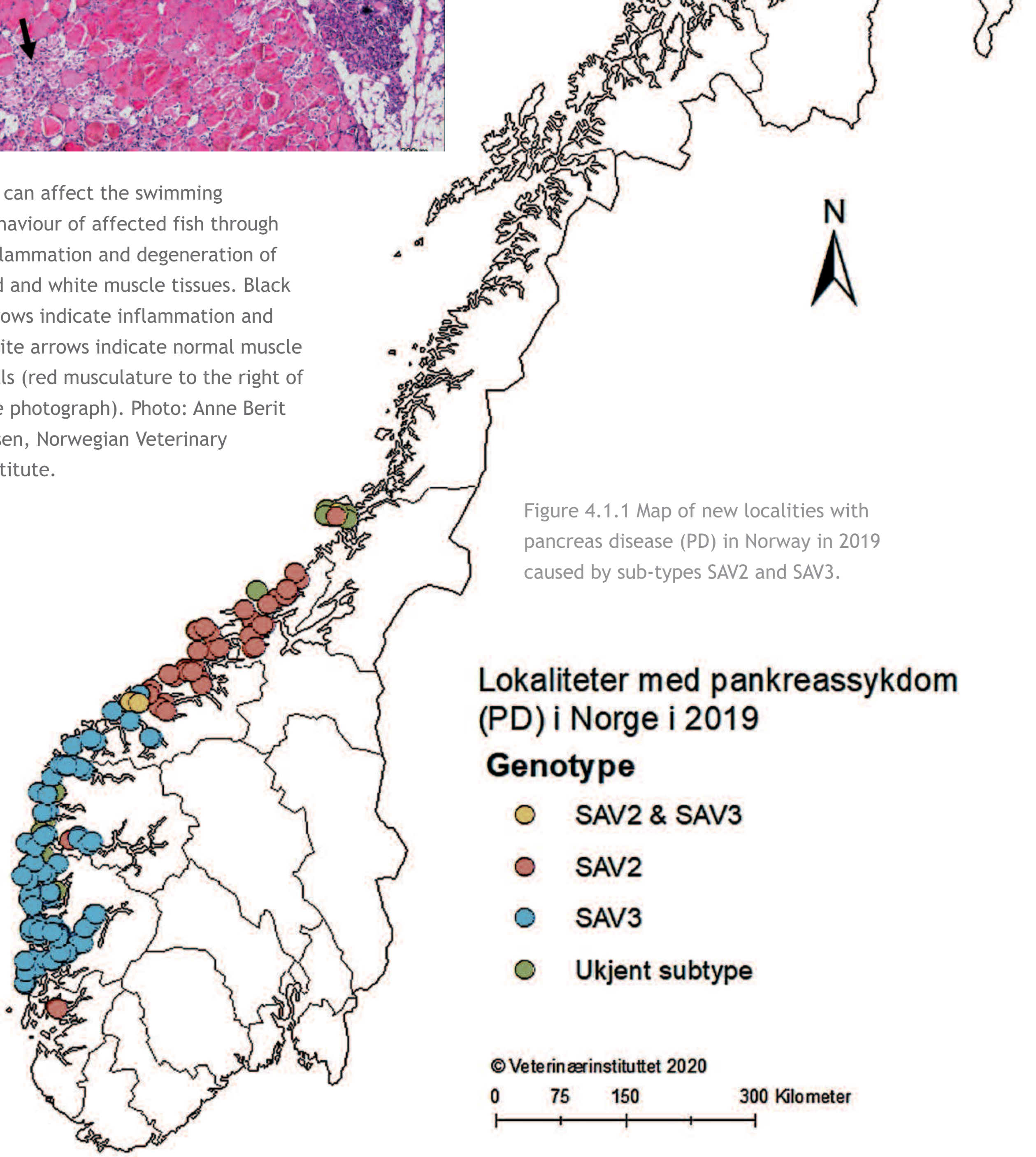


Figure 4.1.1 Map of new localities with pancreas disease (PD) in Norway in 2019 caused by sub-types SAV2 and SAV3.

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 cases.

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 consider PD to be one of the most important virus diseases affecting salmon farmed in the sea, only surpassed by CMS. PD was also considered the most important cause of reduced growth in ongrowing salmon and in both salmon and rainbow trout broodstock. The disease was also one of the most important causes of poor welfare, after mechanical injury, salmon lice and skin ulcers (see appendix B and C for details).

As in 2018, just under half of respondents stated that fish in their area are, to a lesser or greater degree, vaccinated against PD. Most of these respondents are based within the PD-zone. For Troms and Finnmark, ‘don’t know’ dominated replies on vaccine status, while

SAV3-tilfeller 1997-2019

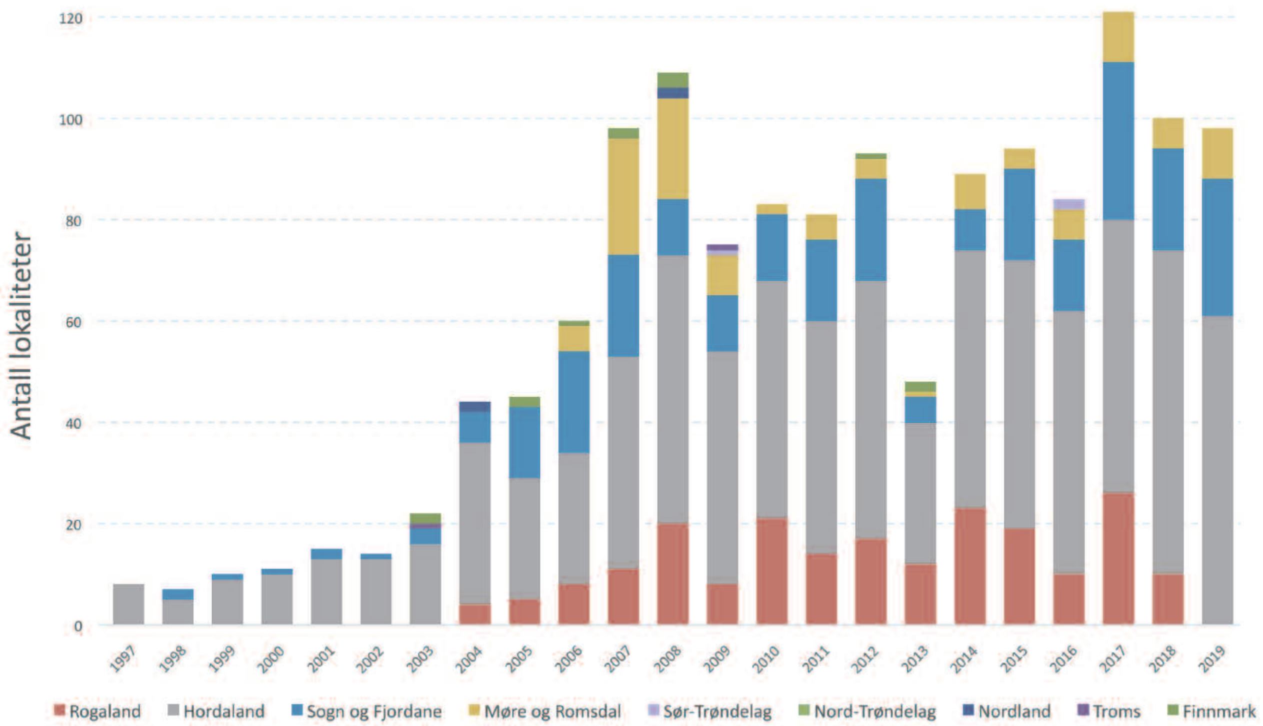


Figure 4.1.2 Regional distribution of new PD-cases per year 1997 – 2019, sub-type SAV3

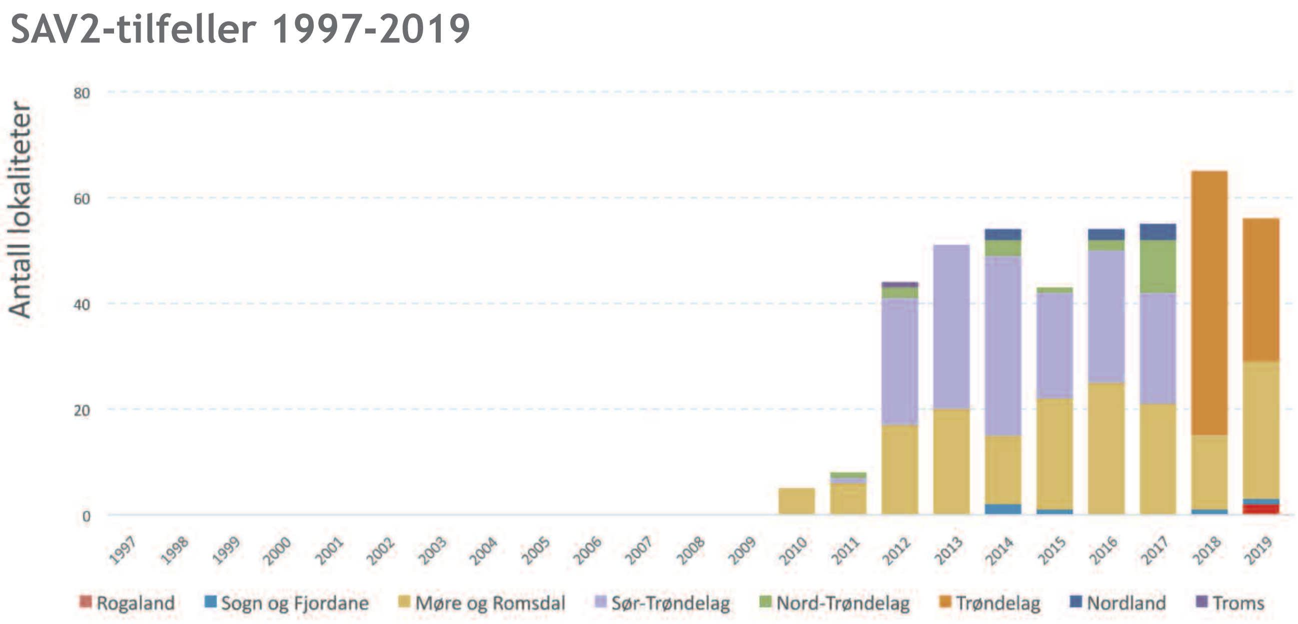


Figure 4.1.3 Regional distribution of new PD-cases per year 1997 – 2019, sub-type SAV2

in Nordland vaccination is apparently not performed.

45% (38 respondents) replied when asked whether PD QTL- strains of fish were utilised. Half of these stated that such fish were used to a degree or to a high degree in their area, mainly within the PD-zone, also in Nordland. Four respondents replied that they had experienced outbreaks of disease in PD QTL-smolts.

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).

PD is an extremely infectious chronic disease. 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. 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. It is highly likely that these infections would have developed into full-blown clinical disease at some point.

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. One of these occurred in 2019 and PD was suspected on 5 close neighbouring localities.

According to legislation introduced in 2017, it is possible for sites outside the PD-zone with positive SAV2 infections, following evaluation of the situation, to culture the fish on to harvest. This will almost certainly lead to further northerly spread of the disease. Obligatory vaccination in this area, will in contrast, reduce infection pressure and reduce the risk for further spread of infection.

SAV2 månedlig insidensrate 2010-2019

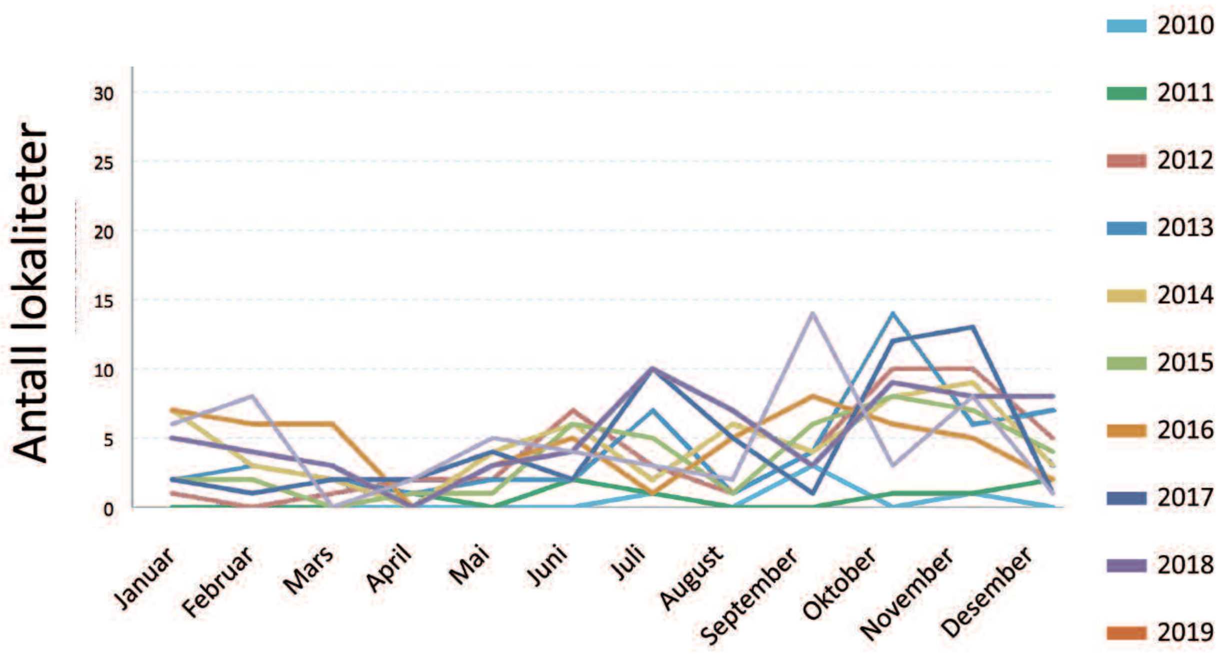


Figure 4.1.4 Monthly incidence rate of localities with PD SAV3 2010 – 2019

SAV3 månedlig insidensrate 2010-2019

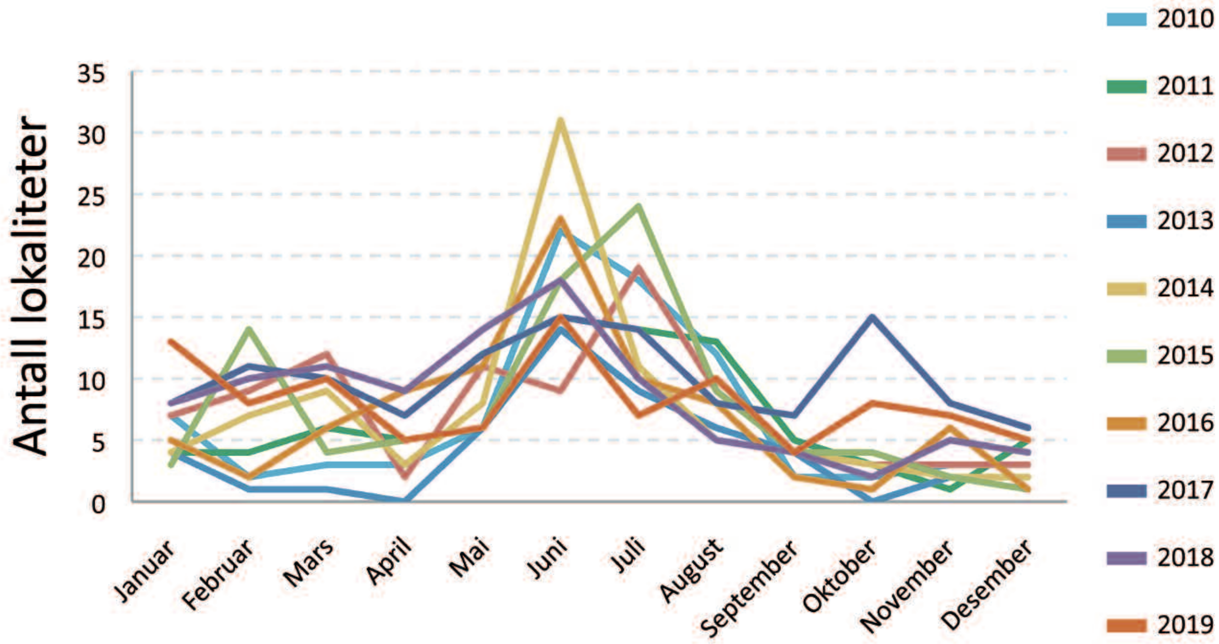


Figure 4.1.5 Monthly incidence rate of localities with PD SAV2 2010 - 2019

4.2 Infectious salmon anaemia (ISA)

By Mona Dverdal Jansen, Monika Hjortaas, Torfinn Moldal, Geir Bornø and Knut Falk

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 attacks blood vessels. On post-mortem examination, the main findings include 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.

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 and diseased. During the early stages of an outbreak, PCR testing may require analysis of many 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 separated based on 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 HPRo ISAV is now widespread in farmed salmon. 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 the transformation of HPR0 to HPR-del is an infrequent event.

Control

ISA is a notifiable disease in Norway (list 2) and in the World Organisation for Animal Health (OIE) system. 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.

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

The ISA situation in 2019

Official data

ISA was diagnosed in 10 farms in 2019, 2 in production area 2 (Rogaland), 1 in production area 3 (Hordaland), 1 in production area 5 (Møre og Romsdal), 1 in production area 7 (Trøndelag), 1 in production area 9 (Nordland), 2 in production area 10 (Troms) and 1 in production area 12 (Finnmark). ISA was suspected but not confirmed on a further two farms, in Hordaland and Trøndelag towards the end of the year. Virulent ISA-virus was also identified in material sampled from a brood-stock farm previously diagnosed with ISA in 2017-2018.

Evaluation of the ISA situation

The 10 affected sites were distributed amongst 8 different production zones, from zone 2 in the south to zone 12 in the north (Figure 4.2.1). All 10 outbreaks involved marine farmed ongrowing salmon. Since 1993, ISA has been identified in between 1 and 20 farms annually (Figure 4.2.2). In recent years, ISA has occurred both as local, geographically restricted epidemics and as

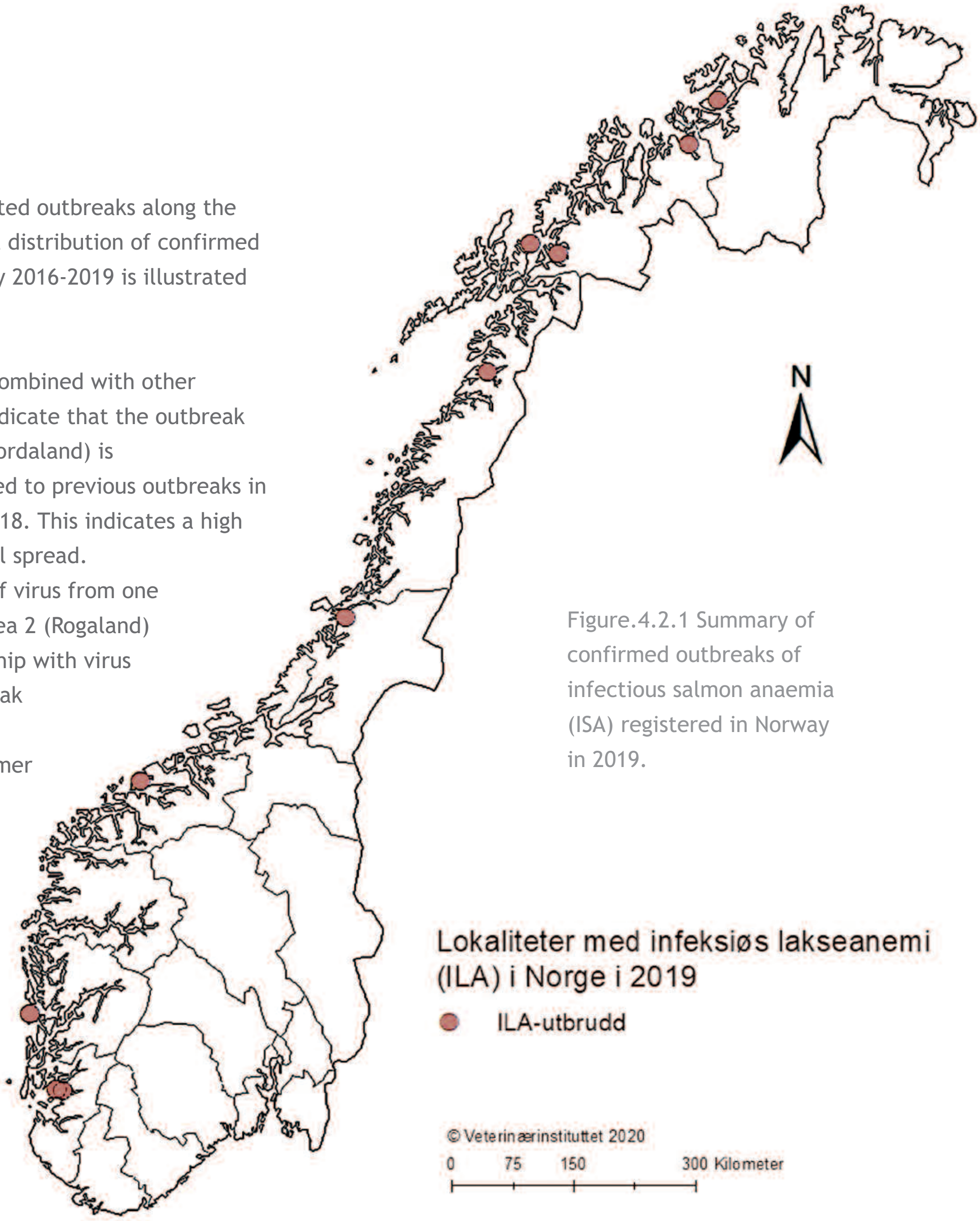


Figure.4.2.1 Summary of confirmed outbreaks of infectious salmon anaemia (ISA) registered in Norway in 2019.

widely distributed isolated outbreaks along the coast. The geographical distribution of confirmed ISA-outbreaks in Norway 2016-2019 is illustrated in in Figure 4.2.3.

Phylogenetic analyses combined with other epidemiological data indicate that the outbreak in production area 3 (Hordaland) is epidemiologically related to previous outbreaks in neighbouring sites in 2018. This indicates a high probability of horizontal spread. Phylogenetic analyses of virus from one outbreak production area 2 (Rogaland) reveal a close relationship with virus isolated from an outbreak in production area 3 (Hordaland) in the summer of 2018. The likelihood of horizontal transmission in this case cannot be estimated in this case. The remaining 2019 isolates cannot be directly related to previous known outbreaks.

As part of the Norwegian Veterinary Institute's responsibilities as an international and national reference laboratory for ISA, 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 were tested for ISAV-HPR0 (single sampling). Five of 74 tested sites tested positive for ISAV HPR0. 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 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 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 31 sea-farms in 2019. ISA was not diagnosed on any of these farms in 2019. Final statistics and an evaluation of the situation will be published as part of the surveillance program for ISAV HPRdel report.

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.

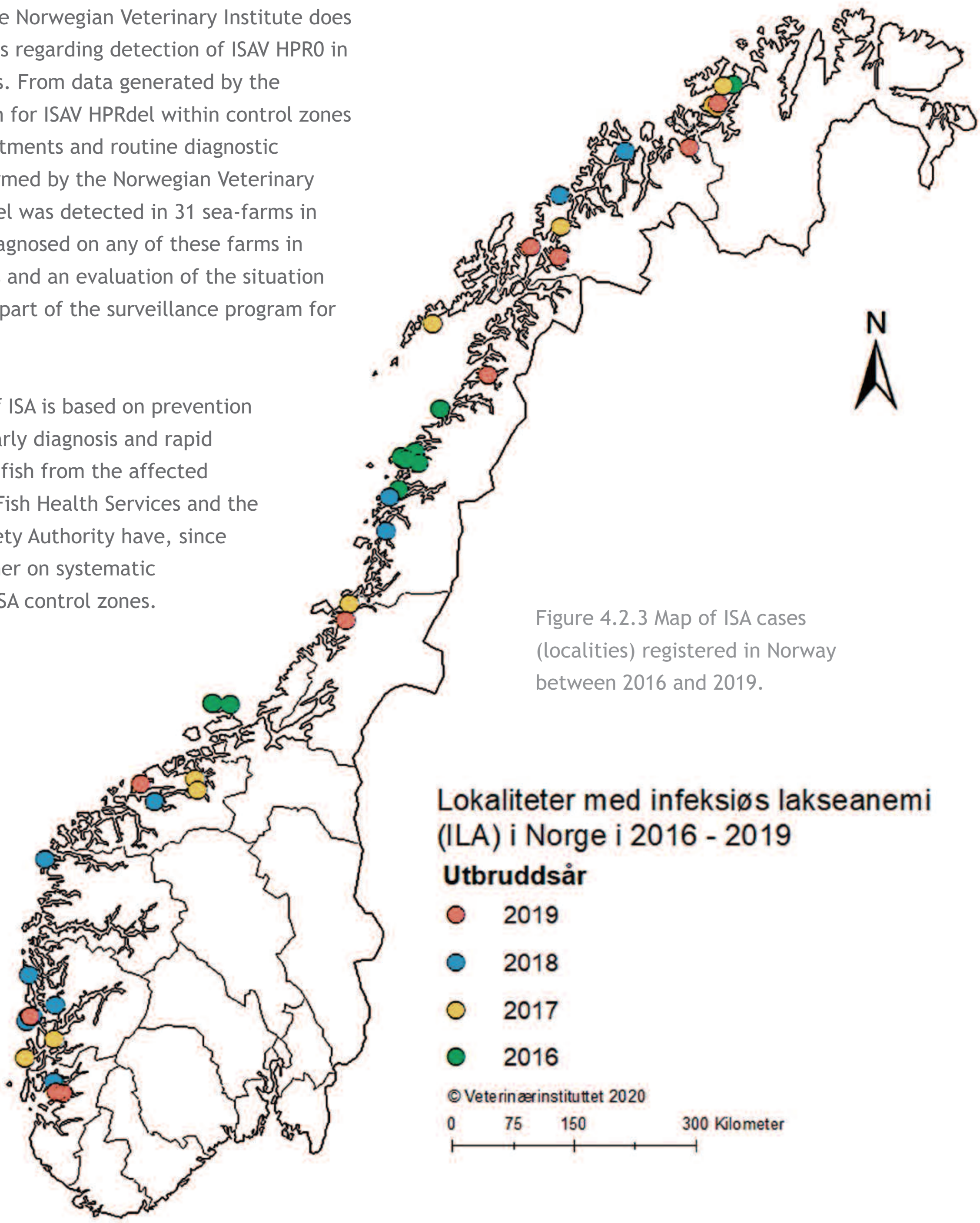


Figure 4.2.3 Map of ISA cases (localities) registered in Norway between 2016 and 2019.

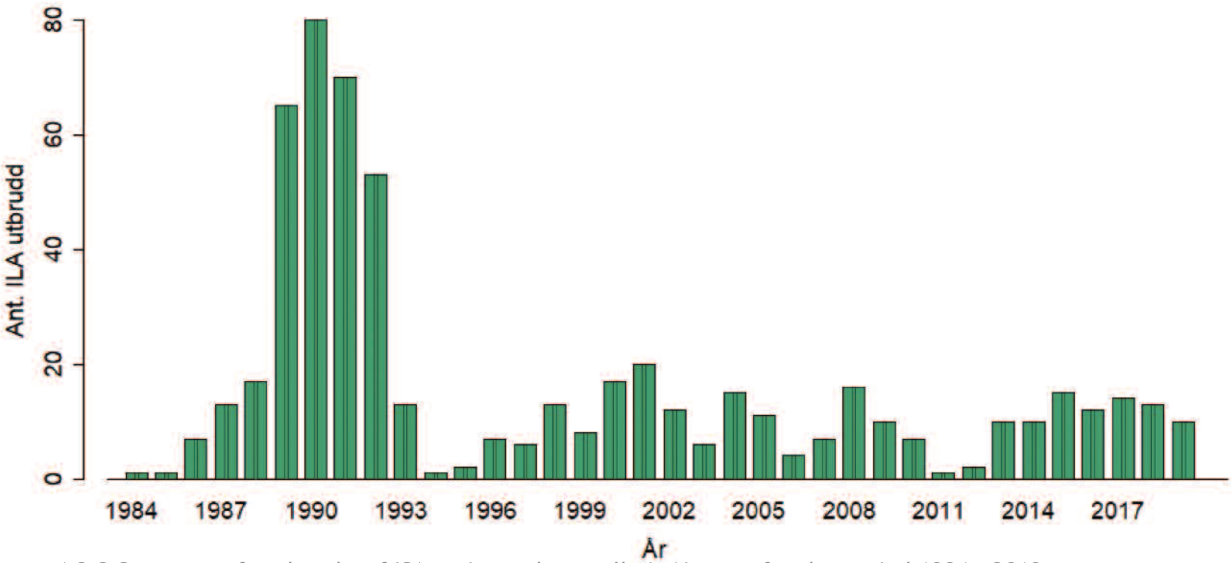


Figure 4.2.2 Summary of outbreaks of ISA registered annually in Norway for the period 1984 - 2019

Surveillance includes monthly inspection 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 4.2.4 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.

Figure 4.2.5. Skin haemorrhages are common in fish with ISA. Such changes may also be observed with other serious infections which cause circulatory disturbance e.g. IHN. Labora AS.

4.3 Infectious pancreatic necrosis (IPN)

By Torfinn Moldal 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 for resistance to IPN makes selective breeding of (QTL) salmon and rainbow trout with a high degree of IPN resistance possible. 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

Situation in 2019

Data from the Norwegian Veterinary Institute

In 2019, IPN or IPN-virus was identified in 23 farming localities, of which 21 held Atlantic salmon; 9 juvenile production units and 12 marine ongrowing sites. IPN was also diagnosed in two juvenile rainbow trout production facilities. As in 2018, IPN or IPN virus was not diagnosed in ongrowing rainbow trout. The total number of outbreaks represents a slight increase from 2018 when IPN or IPNV was diagnosed in 19 farms. Sixteen of the

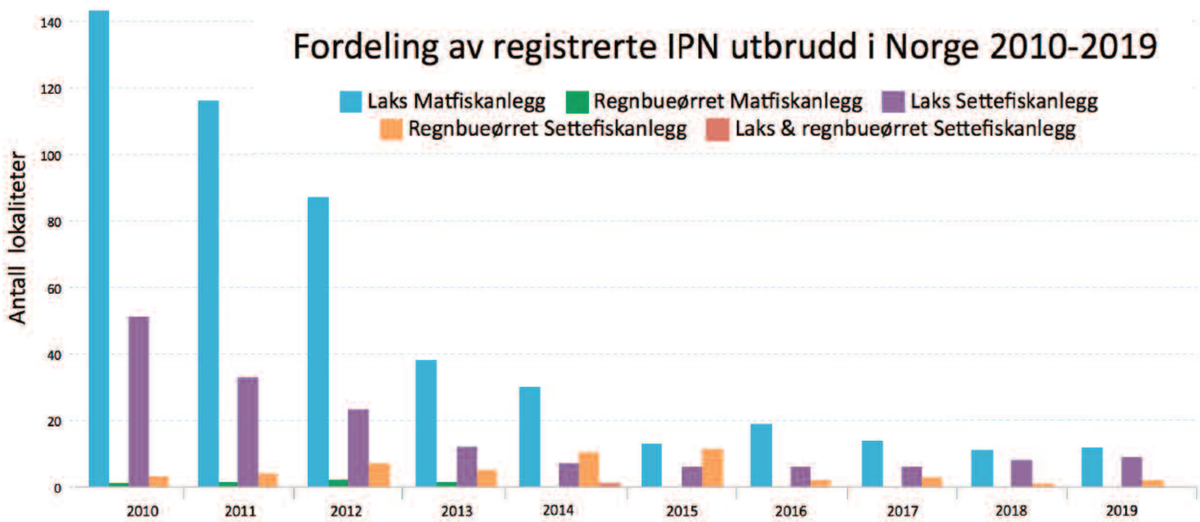


Figure 4.3.1: Number of registered IPN-outbreaks 2010-2019

farms in which either IPN-virus or IPN was identified were situated in the three most northerly regions.

Survey

Respondents to our survey generally considered IPN to be relatively unimportant. QTL-roe is much utilised, both salmon and rainbow trout and nearly all fish are vaccinated against IPN. Several outbreaks amongst IPN QTL fish have been reported.

Evaluation of the IPN situation
IPN or IPN- virus were diagnosed in a total of 45 salmon farms and 7 rainbow trout farms by private laboratories. As IPN is non-notifiable and customer confidentiality around diagnoses made by and between private laboratories makes identification of all affected farms impossible, there is likely to be overlap in cases identified by private laboratories and the Norwegian Veterinary Institute. That outbreaks are now being identified in IPN QTL fish is somewhat disturbing. It is, however, good news that the total number of outbreaks remains relatively small.

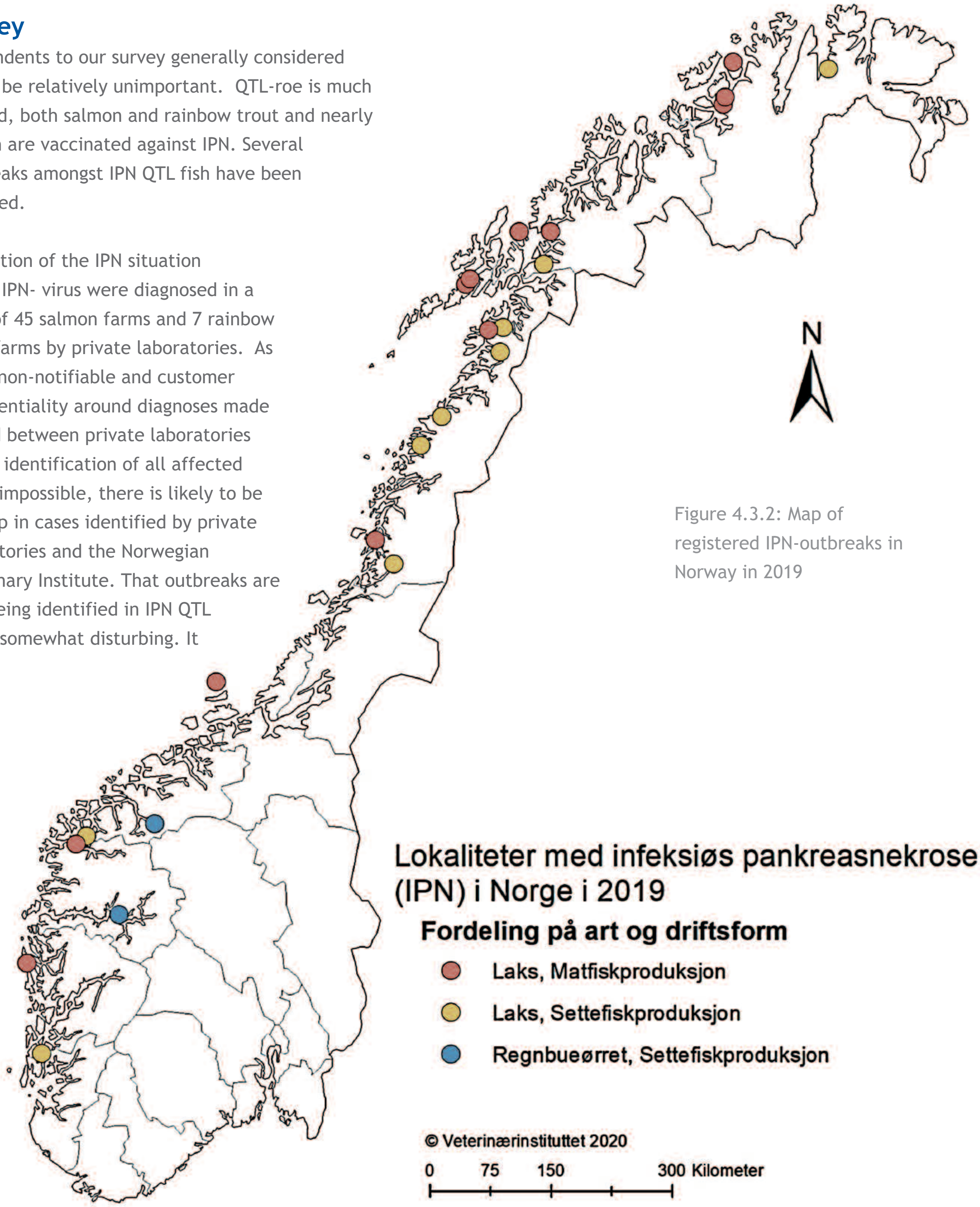


Figure 4.3.2: Map of registered IPN-outbreaks in Norway in 2019

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 freshwater. 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 is also a relatively common finding.

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 disturbances.

An HSMI-like disease was identified in Norwegian rainbow trout in 2013. Outbreaks of HSMI-like disease in rainbow trout are 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 PRV*Om*). 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 PRV-3 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 PRV-1 strains have been identified and it has been speculated that some strains may be more pathogenic than others. The condition and susceptibility of the infected fish will also contribute to the outcome of infection. HSMI has not been identified in infected Norwegian wild salmon. PRV3 is less widespread in Norwegian rainbow trout aquaculture, 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 long after disappearance of clinical disease and commonly until harvest.

In contrast, rainbow trout appear to rid themselves of PRV-3 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, but two vaccine studies published in 2018 identified moderate levels of protection against HSMI. 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. Experiments performed in 2017 have shown that salmon with HSMI are sensitive to stress in combination with reduced levels of oxygen saturation in the water. 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.

Intake of untreated seawater to freshwater facilities represents a risk of infection. 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 RAS facilities.

There are indications that many farms suffer repeated outbreaks, which may indicate persistent infection. 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, but little is known of effective ways to be rid of PRV.

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

The situation in 2019

Data from the Norwegian Veterinary Institute

In 2019, HSMI was diagnosed by the Norwegian Veterinary Institute in 79 salmon farms, 75 ongrowing sites, 1 broodstock farm and 3 hatcheries. As HSMI is a non-notifiable disease these statistics represent a small part of the overall picture. Diagnoses made by the Norwegian Veterinary Institute were chiefly located in the three most northerly regions, probably due to the domination of private laboratories in diagnostic work further south. HSMI-like disease was not diagnosed in rainbow trout during 2019, but remains a problem according to the annual survey.

Data from other laboratories

HSMI was diagnosed by private laboratories in 125 farms during 2019. Whether these cases are in addition to those identified by the Norwegian Veterinary Institute or are wholly or partly overlapping is unknown. There may also be overlap between cases identified by different private laboratories. PRV was detected in approximately 100 salmon farms and five rainbow trout farms that were not awarded an HSMI diagnosis.

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 there were relatively few respondents who replied that HSMI was an important cause of mortality, reduced growth or welfare. HSMI was nevertheless categorised in third place as an ‘increasing problem’. A number of farms report introduction of salmon less susceptible (QTL) to HSMI, but that the effective is not clear. A few farms report outbreaks of HSMI amongst QTL salmon.

Figure 4.4.1 Salmon with HSMI. Fish with HSMI may have a pale heart, a fibrinous pseudo-membrane over the liver and clear or bloody fluid in the body cavity.
Photo: A. Lyngøy

In 2019, the HSMI situation in ongrowing salmon farms was unfortunately not investigated in the annual survey due to a technical error. There are nevertheless reasons to believe that HSMI is just as significant a problem as previously as it has been considered amongst the three most important diseases for several years. Several respondents included free text comments indicating that HSMI was one of the dominating problems in their farms.

For broodstock farms, HSMI was considered the second most important cause of mortality (10 of 22 respondents crossed off HSMI) and was amongst the top 5 causes of poor welfare. HSMI was not considered an increasing problem or important in regard to reduced growth.

HSMI-like disease was not considered a problem in rainbow trout juvenile production sites or broodstock farms in 2019. AS far as ongrowing rainbow trout are concerned, a few respondents considered PRV-3 infection an important cause of mortality and one considered the disease to be on the increase.

For further details on the considered importance of various health problems in the survey for salmon and rainbow trout, see appendices 1-3.

Evaluation of the HSMI situation

HSMI is reported to be a problem in both juvenile production and ongrowing countrywide. The Norwegian Veterinary Institute receives diagnostic submissions mainly from northern Norway where HSMI dominates the virus disease situation along with CMS. That the Norwegian Veterinary Institute now diagnoses fewer cases in the southern parts of the country does not mean that HSMI is less of a problem in these areas than previously. The main reason behind the reduction in registered cases is that the disease was removed from the national list of notifiable diseases in 2014, and that private laboratories have taken over a large proportion of diagnostic investigations in the south of the country. HSMI diagnoses made by private laboratories are not reported to the Norwegian Veterinary Institute at the locality level and it is therefore impossible to identify overlap.

The annual survey indicates that the HSMI situation in ongrowing farms is at a similar level as the year before but may be increasing in juvenile production farms. The significance of HSMI in juvenile farms has been on the increase for several years, thus the indications for a negative trend continue. HSMI affected fish have a low tolerance to treatment and handling, and high levels of mortality may result following such procedures.

There are considerable indications of varying impact of HSMI with some farms experiencing significant problems while most others experience few or no problems. The increasing importance of HSMI in juvenile production is a result of failure to eradicate the virus and establishment of 'house strains' which result in recurring outbreaks of disease.

The Norwegian Veterinary Institute survey indicates that there were outbreaks of PRV-3 associated disease in sea-farmed rainbow trout in 2019 and that the problem is on the increase. The Norwegian Veterinary Institute has not, however, diagnosed such cases and such disease was not reported by private laboratories. HSMI-like disease was not reported as a problem in juvenile production of rainbow trout in 2019. Previous surveys focussed on PRV-3 in juvenile production and it was reported of low to moderate importance in 2018. It is possible this experienced importance was due to a general focus on the virus at that time. On consideration of the available evidence, it may seem that problems with HSMI-like disease have now moved from juvenile production to ongrowing production.

PRV-associated disease is also of international importance and it is reported that diseases other than HSMI may also

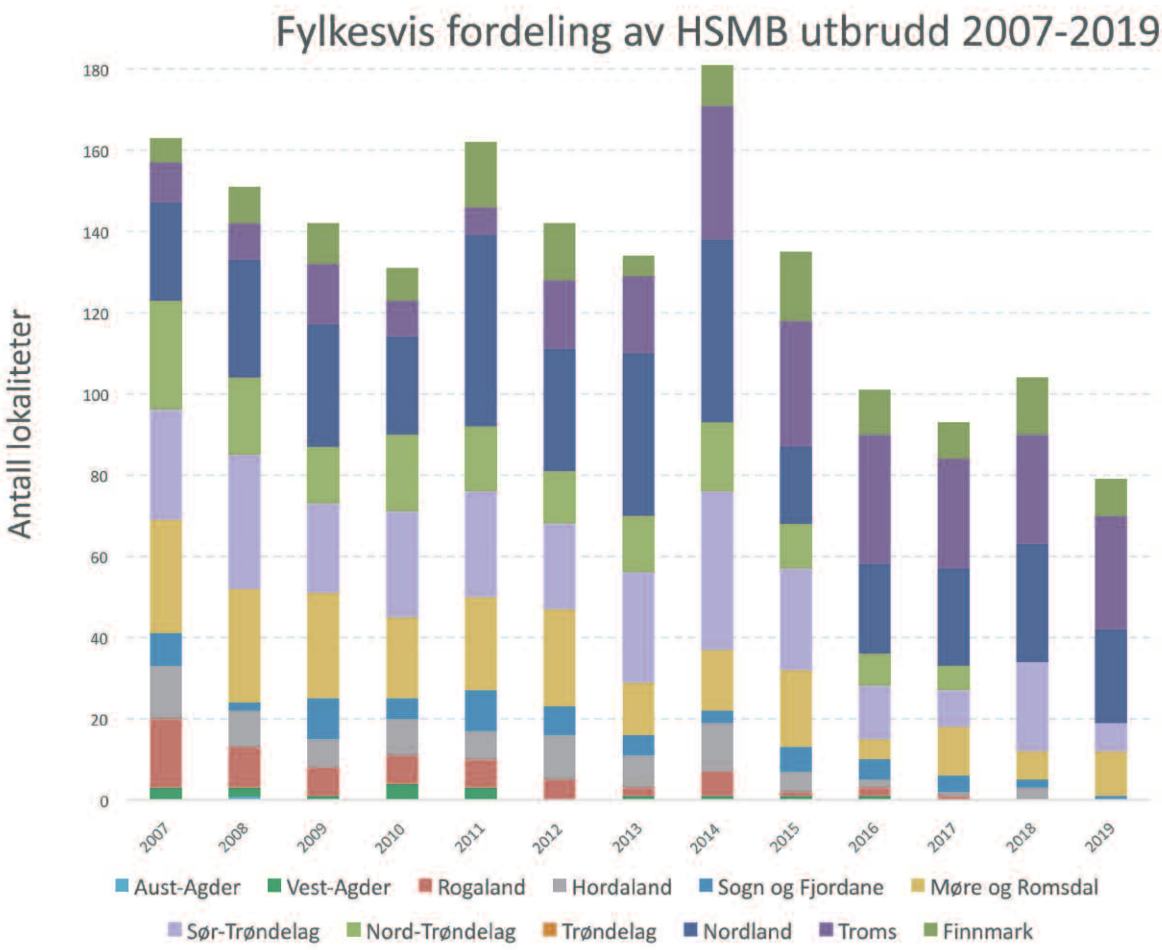


Figure 4.4.2 Norwegian Veterinary Institute HSMI diagnoses in farmed salmon in 2019. Diagnoses are largely limited to the three most northerly regions and only partly illustrate the current situation.

be caused by PRV. PRV-1 has in particular been associated with liver necrosis in Chinook salmon in Canada and a third PRV variant, PRV-2, with anaemia in Coho salmon in Japan. PRV-3 has been associated with disease in rainbow trout in Denmark and Britain and the virus has been identified in brown trout in several European countries. There is a research focus on how variations in the genome of PRV-1 and PRV-3 cause variations in virulence. This may result in development of diagnostic tests capable of differentiation between highly virulent and less virulent strains.

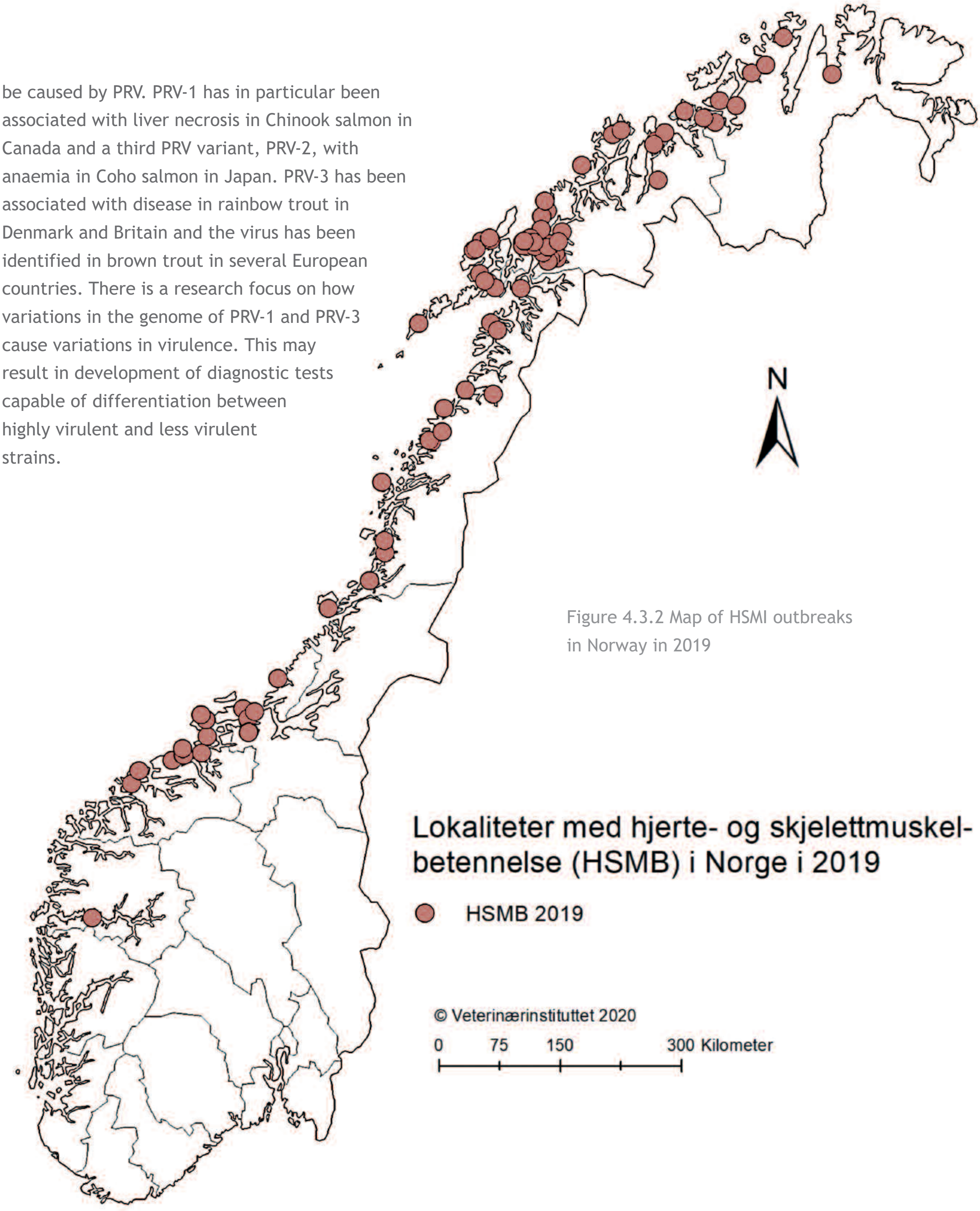


Figure 4.3.2 Map of HSMI outbreaks in Norway in 2019

Cassettes holding formalin fixed salmon tissues. Photo: Eivind Senneset

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. Scotland, the Faroe Isles and Ireland have significant and increasing problems with CMS.

CMS is currently one of the major causes of loss to Norwegian aquaculture and has the potential to become an even greater problem given the lack of available prophylactic or remedial measures.

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 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. 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). When is the fish infectious, and what causes development of clinical disease in fish infected with PMCV? 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.

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. Over the last three years, the Norwegian Veterinary Institute has registered over 100 cases of CMS annually. As the disease is non-notifiable it is reasonable to assume that the Norwegian Veterinary Institute statistics represent a minimum number of farms affected by CMS.

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

The situation in 2019

Data from the Norwegian Veterinary Institute

Diagnosis of CMS requires histopathological investigation. The Norwegian Veterinary Institute diagnosed CMS in 82 localities during 2019. All were ongrowing sites or broodstock farms. As during 2012-2018 between 89-107 cases were registered annually, this represents a slight reduction in prevalence compared to previous years (Fig. 4.5.1 and 4.5.2)

Data from other laboratories

Two private laboratories registered CMS in a total of 155 different farms in 2019. This is a significant increase from 2018 when 125 such diagnoses were made. A degree of overlap in cases identified between private laboratories and between private laboratories and the Norwegian Veterinary Institute is likely.

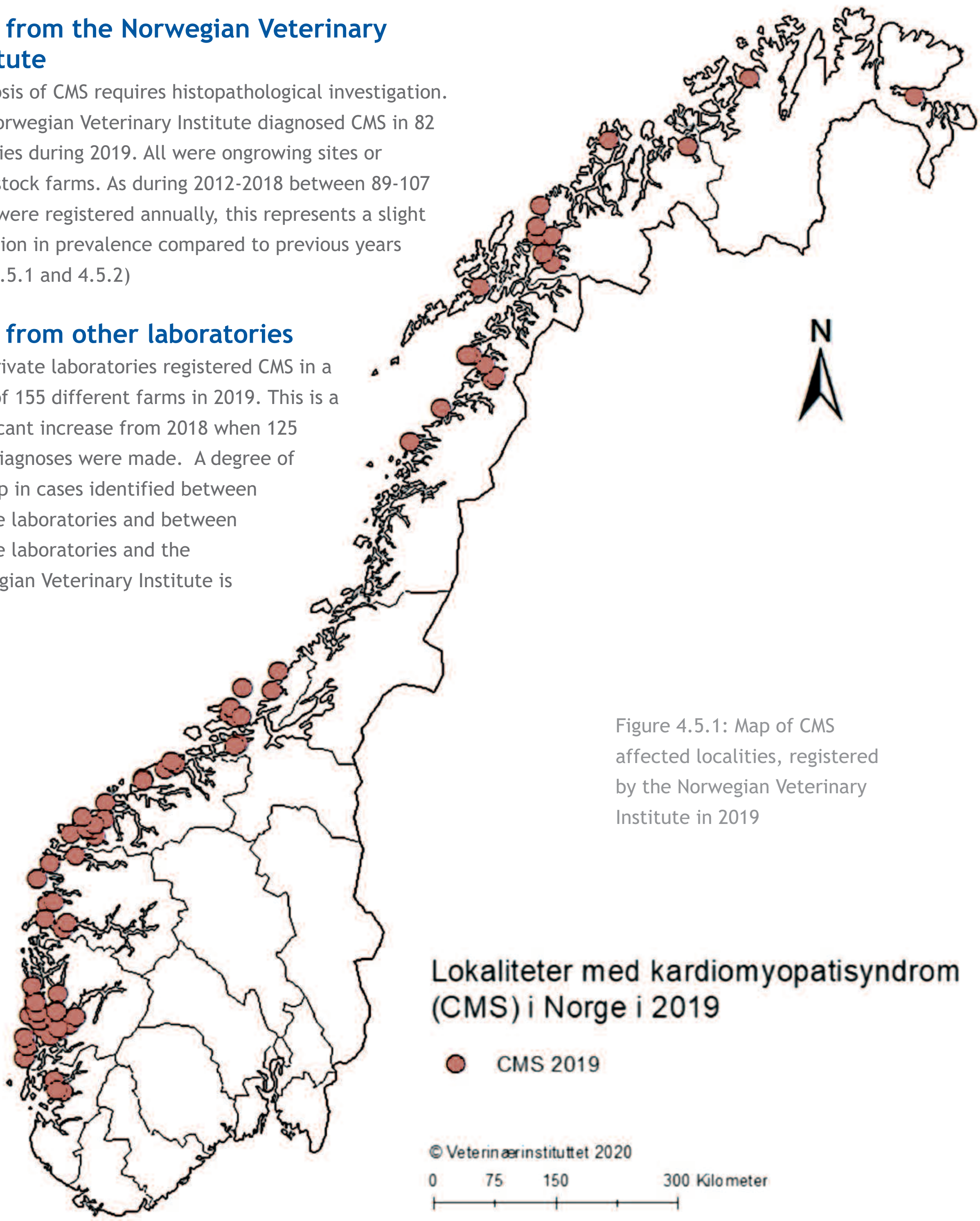


Figure 4.5.1: Map of CMS affected localities, registered by the Norwegian Veterinary Institute in 2019

This makes evaluation of the Norwegian situation as a whole in recent years difficult, but it would appear that the situation appears to be stable or deteriorating slightly in recent years.

Regional distribution

The largest regional changes in the number of CMS diagnoses made by the Norwegian Veterinary Institute between 2017 and 2019 relate to a reduction in Nordland, Troms and Finnmark, from 33 and 44 in 2017 and 2018 respectively to 20 in 2019. In contrast, an increased number of cases was identified in Hordaland. Prior to 2016, between 1 and 10 cases were registered in this area. In 2018, 19 cases were registered and in 2019 the number rose further to 27 (see Fig. 4.5.2).

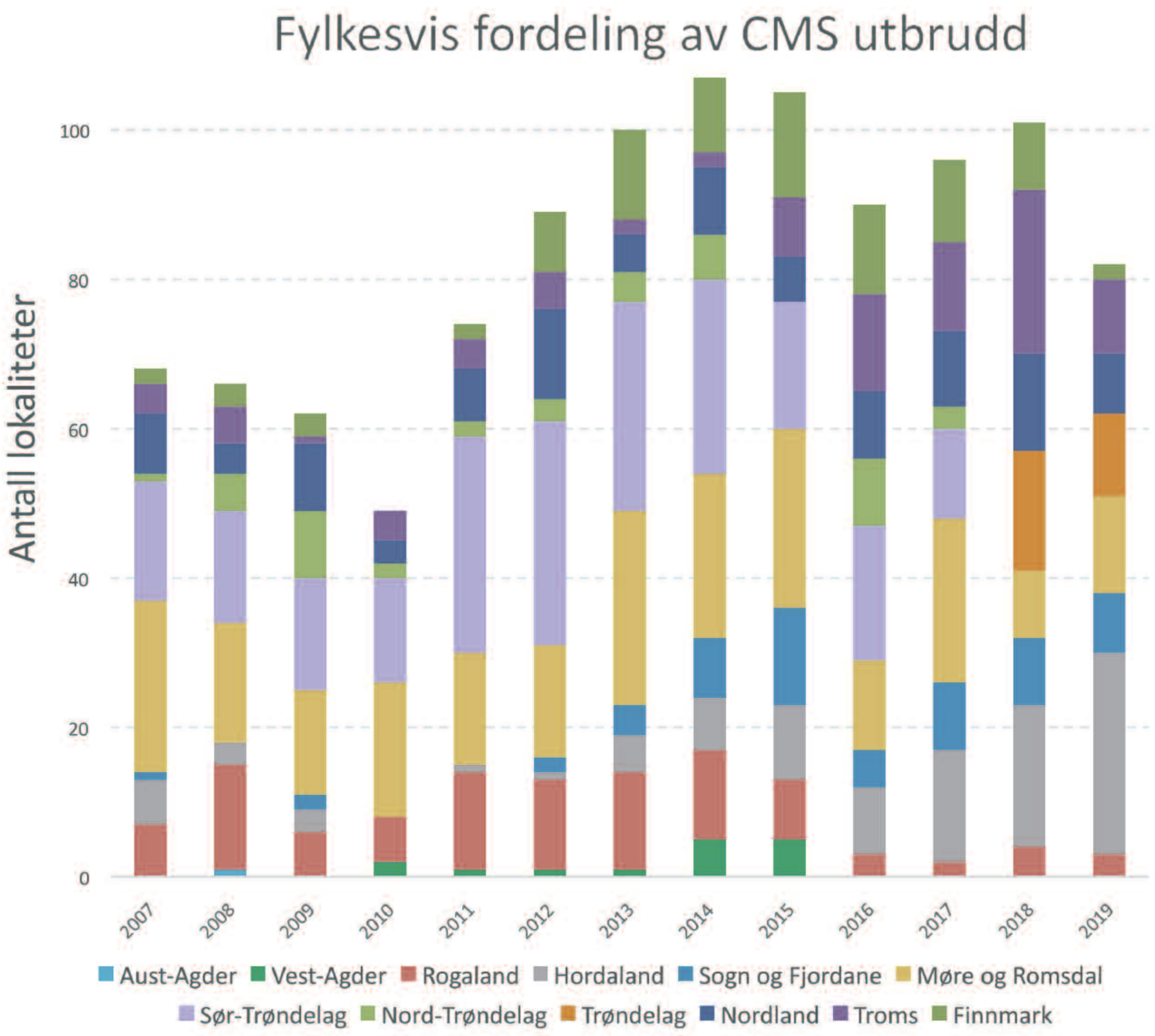


Figure 4.5.2: Summary of CMS affected localities 2007– 2019, distributed by year and region. The data is based on material submitted to the Norwegian Veterinary Institute (illustration Britt Bang Jensen, Norwegian Veterinary Institute)

Some of the reduction in Norwegian Veterinary Institute registered cases in the three most northerly regions may be due to increased use of private laboratories for disease diagnostic work. It is therefore difficult to say whether there has been a real fall in the number of CMS cases in these areas. In Hordaland, an opposite trend is observed: The increase in number of diagnoses made in this area may indicate an increasing problem in this area as it is only in recent years that private laboratories have included CMS diagnostics in their portfolio.

Evaluation of the CMS situation in 2019

Uncertainty around the degree of overlap of cases registered by the Norwegian Veterinary Institute and private laboratories makes evaluation of the current CMS situation in Norway challenging. It is concerning that so many cases are registered in Hordaland, which until recently had a very low incidence of CMS.

CMS was again considered one of the most important disease problems in both ongrowing and broodstock fish in the annual fish-health survey (For an evaluation of the health problems related to CMS during different salmon production phases, see appendices A-C).

Of the 42 respondents who commented use of CMS-QTL-fish, 14.3% stated that this type of fish was utilised to a significant degree and 31% that they were utilised to 'some degree' on farms for which they had responsibility. Compared to the previous year there was a slight reduction in the proportion of 'significant degree' and a slightly larger proportion of 'some degree' replies. Seven of the 19 respondents who had experience with QTL-smolts experienced CMS in these fish populations in 2019. The survey does not reveal whether the proportion of fish that became sick or died due to CMS was different from previous outbreaks on the same farm prior to introduction of QTL-smolts.

CMS makes the fish heart fragile and affected fish do not tolerate stress well, particularly following handling. The frequency of non-medicinal delousing treatments has increased dramatically in recent years (see chapter 3 and chapter 7.1), which leads to repeated stressful and physical handling of the fish. In combination with other health challenges such as gill disease, the presence of CMS within a population may be a contributory factor to significant post-treatment mortality. That CMS may now be identified in smaller fish, many months prior to harvest, amplifies and increases the problems related to delousing. This is a significant fish welfare issue, which should motivate for an increased focus on CMS research.

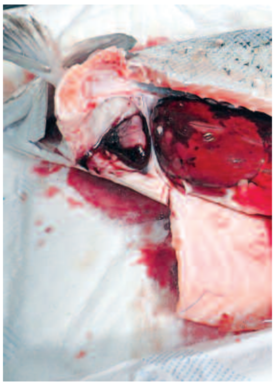


Figure 4.5.3 CMS-affected salmon dying due to cardiac tamponade i.e. ruptured atrium with coagulated blood in the cardiac chamber. Photo: Mattias Bendiksen Lind, Havet AS.

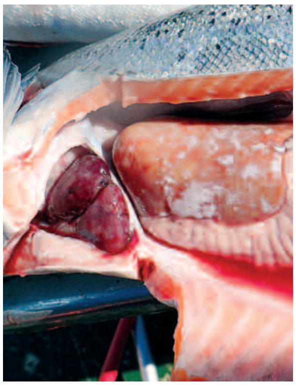


Figure 4.5.4 Post-mortem findings in salmon with chronic CMS: The atrium is enlarged and severely distended due to weakening of the atrium wall and an inability to withstand the pressure generated by the heart pumping. Chronic circulatory failure leads to a white fibrinous deposition on the liver and peritoneal ascites. Photo: Mattias Bendiksen Lind, Havet AS.

4.6 Viral haemorrhagic septicaemia (VHS)

By Torfinn Moldal

The disease

Outbreaks of viral haemorrhagic septicaemia (VHS) are characterized by high mortalities, 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 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) 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 situation in 2019

Official data

VHS was not identified in 2019 in Norway. The last Norwegian outbreak occurred in rainbow trout farmed in Storfjorden in 2007-2008.

Evaluation of the VHS situation

VHS was diagnosed in several European countries during 2019, but no outbreaks were identified in countries neighbouring Norway. Previous identification of VHSV in various wrasse species in Shetland in 2012 and lumpsucker 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. France published plans for an eradication programme in 2017. This work is supported by the EU.

4.7 Infectious Hematopoietic Necrosis (IHN)

By Torfinn Moldal

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 15°C. Externally, exophthalmos is common. Internally, haemorrhage in internal organs, swollen kidney and ascites may be observed. 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. 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).

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.

A risk-based surveillance program is in place in Norway, based on examination of samples submitted for routine diagnostic investigation. 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 situation in 2019

Official data

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. IHN was diagnosed in several countries in Europe during 2019.

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.

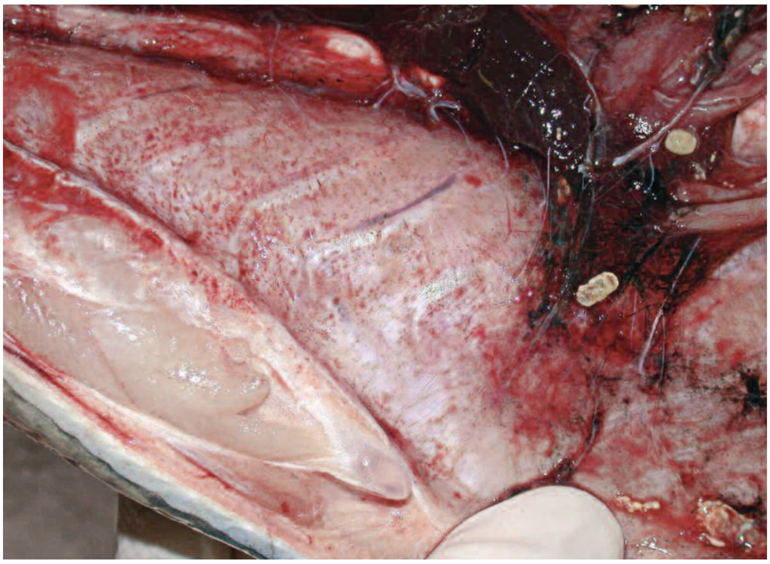


Figure 4.7.2 cutaneous haemorrhage can also be observed in fish with IHN Photo: Kyle Garver, Pacific Biological Station, BC, Canada.

Archive of paraffin embedded tissues for histological analysis. Photo: Eivind Senneset

4.8 Salmon pox

By Ole Bendik Dale, Brit Tørud and Mona Gjessing

The disease

Salmon pox, caused by the Salmon Gill Pox Virus (SGPV), is primarily a gill disease and was first identified in 1995. The virus is 'the oldest known relative' of the feared human pathogen, the smallpox virus. The disease was originally identified in juvenile fish displaying high-level, per-acute mortality. Histopathological investigation of non-complicated salmon-pox in the absence of other pathogenic agents reveals characteristic pathological changes.

SGPV was whole genome sequenced in 2015. New diagnostic techniques have revealed that infection with SGPV may result in classical salmon pox in juveniles but may also become a component of complex and varied gill disease at any stage of salmon production. The financial losses vary from almost negligible to extremely significant. Surveillance of wild salmonids has revealed that the virus is highly prevalent in wild broodstock, where it can be directly associated with gill lesions.

Control

There is no public control programme for salmon pox in Norway. Fundamental knowledge relating to prevention of infection remains lacking. We have followed a farm challenged by salmon pox. Comparison of virus isolates over time indicate the presence of a house strain. To remove or reduce infection pressure, new sanitary measures were introduced. Poxvirus is generally more sensitive to acidic disinfectants than basic disinfectants, so an acidic solution was chosen. Poxvirus has not been identified in samples taken subsequently from fish of different ages, prior to vaccination.

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. A study of gene expression during a salmon pox outbreak identified a shift to the freshwater isotype of ATPase. This is consistent with the finding that sea-transfer is extremely risky during certain phases of the infection and should be avoided. Infection trials have shown that stress is an important trigger for activation of disease.

See the factsheet for more information on salmon pox:
https://www.vetinst.no/sykdom-og-agens/laksepox

Histology laboratory, Norwegian Veterinary Institute Bergen. Photo: Eivind Senneset

Situation in 2019

Data from the Norwegian Veterinary Institute

Salmon pox virus was identified in the gills of salmon in seven juvenile production facilities during 2019. Two farms from Møre og Romsdal, one from Troms and four in Nordland. In four of the affected farms typical clinical signs allowed a salmon pox diagnosis to me made. In two cases, no clinical signs were observed. Salmon pox virus was identified alongside Branchiomonas cysticola in one case using the Norwegian Veterinary Institute's new multiplex PCR method, but in this case only PCR samples were submitted. One case involved a PCR detection in wild salmon.

Annual survey

Juvenile production facilities consider pox virus related mortality to be of moderate to high importance. It would appear that salmon pox is considered to be increasing in importance during the freshwater stage of culture. In ongrowing sites at sea, it would appear that salmon pox has little effect in terms of mortality, poor growth or reduced welfare. Few sea farms consider the problem to be increasing. Salmon pox is not reported as a problem in broodstock farms. For further details on the importance of salmon pox during 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 between 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 Institute has developed and established an 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, but the new method has proven useful for tracking infections. The Norwegian Veterinary Institute therefore encourages fish health services and others who suspect salmon pox to submit suitable samples for investigation using this method. Results of infectious challenge trials 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.
PCR investigation of other fish species has only resulted in sparse findings.

5 Bacterial diseases of farmed salmonids

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. The positive trend regarding *yersiniosis* continued with a further reduction in the number of cases in 2019 and there remains good control over the important diseases furunculosis and vibriosis. One notable change in the situation regards pasteurellosis, with a significant increase in the number of outbreaks related to infection with an as yet un-named *Pasteurella* sp. (zero cases 2013-2017, seven in 2018 and 14 in 2019).

Unless otherwise described, evaluation of the overall situation and chapters representing specific infections is based on diagnostic materials submitted to the Norwegian Veterinary Institute.

Of the notifiable infections, systemic infection with *Flavobacterium psychrophilum* in rainbow trout (list 3) was identified in four farms in Hordaland in 2019 (one additional case was suspected), a similar situation to 2018. Furunculosis, caused by *Aeromonas salmonicida* subsp. *salmonicida*, was not diagnosed in farmed fish in 2019, but was diagnosed in dead wild salmon in two rivers in Trøndelag. These rivers have experienced regular outbreaks of classical furunculosis over many years. Outbreaks are normally associated with low water levels and high water temperatures. Bacterial kidney disease (BKD), a list 3 disease was identified in a single sea-farmed rainbow trout population in the west of the country in 2019.

The annual number of outbreaks of classical 'winter ulcer' caused by *Moritella viscosa* are difficult to estimate as the disease is not notifiable and is relatively easy to diagnose locally. It is however worthy of note that skin-ulcers in sea-farmed salmonids scored high in the annual survey. *Yersinia ruckeri* was identified in 12 farms in 2019, which represents a considerable reduction from 2018 (21 farms). The reduction in number of yersiniosis cases appears to be due to good vaccine protection and good vaccine coverage.

The Norwegian Veterinary Institute registered an increase in the number of disease outbreaks related to an as yet unnamed *Pasteurella* sp. in salmon sea-farmed in Norway in 2019. The disease was identified in 14 sites in the west of the country where a number of sites affected lay in close proximity of each other. Outbreaks occurred in large salmon over a very short time period. There is a danger that this disease may become established and it has the potential to cause large economic losses and reduced welfare. In 2019, mycobacteria were associated with granulomatous inflammation in the inner organs of salmon in seven localities, which is an increase from the previous year (3 farms).

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. The disease causes ‘boils’ and skin injuries with spread to inner organs and results 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.

Flavobacterium psychrophilum transmits horizontally from fish to fish. It is also thought to transmit vertically from broodstock to eggs. Basic hygiene such as disinfection of equipment, personnel and eggs is important for prevention of outbreaks. So-called autogen vaccines are available. Systemic infection with *F. psychrophilum* in rainbow trout is a notifiable disease in Norway (List 3).

See the fact sheet for more information on flavobacteriosis:
https://www.vetinst.no/sykdom-og-agens/flavobacterium-psycrophilum

The situation in 2019

Official data

Rainbow trout

Systemic infection with *F. psychrophilum* was identified in 4 rainbow trout farms between June and September in the same fjord system as in previous years in western Norway. Affected fish weighed between 3-4.5kg and displayed typical signs including fluid filled ‘boils’, skin ulcers and scale loss. 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. Another outbreak was suspected in the same fjord early in the autumn but the bacterium was not cultivated from affected fish.

Salmon

Long, slender, rod-shaped bacteria which react with polyclonal antiserum raised against *F. psychrophilum* are commonly identified on examination of formalin-fixed tissue samples from salmon farmed in freshwater and displaying ulcers.

In 2019, suspicion of such an infection was raised in relation to an outbreak of eye inflammation in juvenile salmon.

In two outbreaks involving bacterial gill infection and associated high mortality in start feeding larvae infection with *Flavobacterium columnare* was suspected (Figure 5.1.1). Sample material suitable for culture was not received and the suspicion was not confirmed. F. columnare infections are not common in Norway

The annual survey

As far as juvenile salmon are concerned, 2 of 45 (4%) respondents considered *F. psychrophilum* infection to represent one of the five most important diseases in relation to mortality. Five of 32 (15%) considered the disease to be increasing in importance. Less than 10% considered the disease to represent a cause of poor welfare and growth.

For rainbow trout, 2 of 11 respondents (18%) considered the disease to represent one of the five most important causes of mortality during juvenile production. In ongrowing rainbow trout, 11 (9%) considered the infection a serious cause of mortality and reduced welfare and 6 (16%) considered it an increasing problem. For broodstock rainbow trout, one of four respondents considered the disease as one of the five most important causes of mortality and one of three considered it an important cause of reduced welfare. For more information regarding ranking of importance of health problems in farmed salmonids see appendices A-C.

As far as autogen vaccine use against *F. psychrophilum* is concerned, 6 of 74 respondents stated that few farms vaccinate while 3 state that all farms vaccinate. The remainder replied that they do not vaccinate against *F. psychrophilum* or don't know.

Evaluation of the flavobacteriosis situation

The disease was once again identified in the fjord system in which *F. psychrophilum* ST2 has been previously identified. For salmon, the impact of flavobacteriosis is less certain.

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.

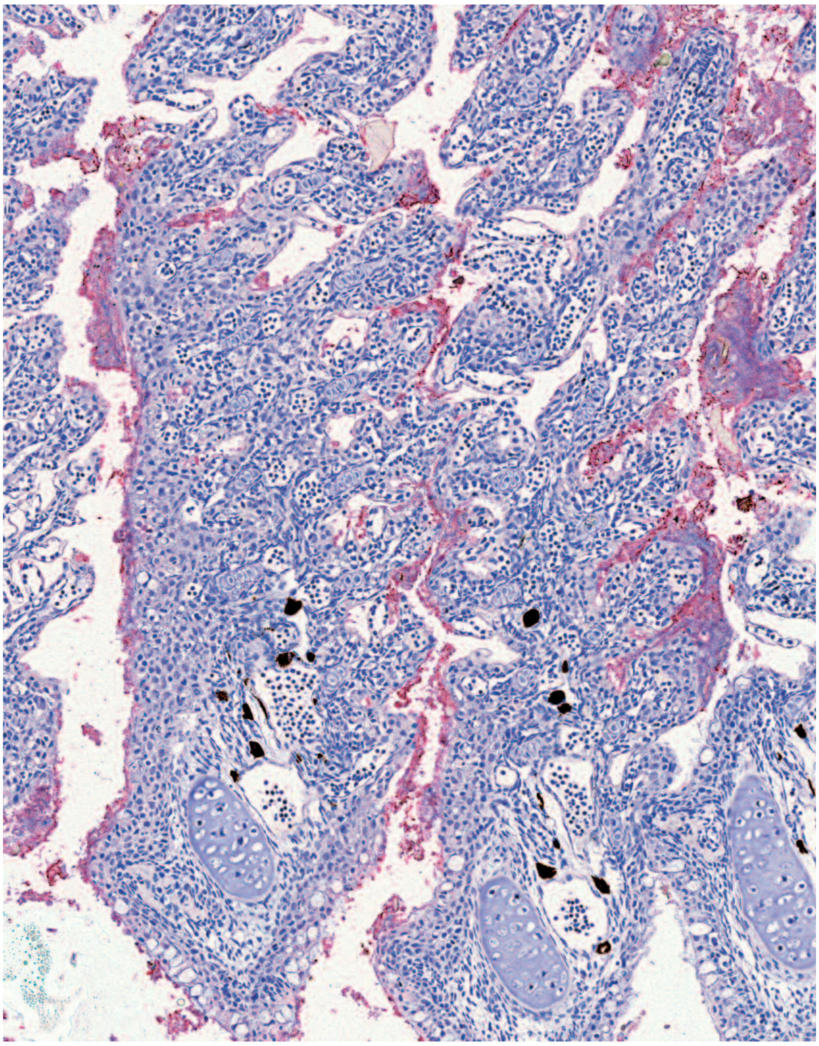


Figure 5.1.1. Juvenile salmon with gill infection in which bacterial cells were stained (red) by an antiserum raised against *Flavobacterium columnare* (immunohistochemistry). Photo: Ole Bendik Dale, Norwegian Veterinary Institute.

Agar plate used for bacterial culture. The Norwegian Veterinary Institute laboratory at Marineholmen in Bergen.
Photo: Eivind Senneset

5.2 Furunculosis

By Duncan J. Colquhoun

The bacterium and the disease

Classical furunculosis (infection caused by *Aeromonas salmonicida* subsp. *salmonicida*) is a notifiable disease (list 3 national disease) in Norway. Classical furunculosis is an infectious disease which can result in high mortality in salmonid fish both in freshwater and in seawater. In recent years, cage-held lumpsucker have 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.

Despite identification of many equally different types of *A. salmonicida*, the various strains and subspecies continue to be generally referred to as either 'typical/classical' (subsp. salmonicida), or 'atypical' (all remaining types).

All variants of *A. salmonicida* 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. Outbreaks of furunculosis in Norway have, in the main been associated with the marine phase of culture and in hatcheries utilising seawater.

Control

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 situation in 2019

Official data

Furunculosis was not identified in farmed salmon or lumpsucker in 2019, but *A. salmonicida* subsp. *salmonicida* was again isolated from dead wild salmon found in the rivers Ferja and Sandøla in Nord-Trøndelag. Both isolates displayed reduced susceptibility to the antibiotic oxolinic acid. This characteristic is considered a marker for the local endemic strain of *A. salmonicida* subsp. *salmonicida*.

Evaluation of the furunculosis situation

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 and in recent years in farmed lumpsucker, illustrates that the bacterium is still present in the environment and that vaccination against furunculosis remains necessary.

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*. BKD is a notifiable disease (list 3, national disease) and only affects salmonid fish.

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.

The bacterium can transmit vertically from parent to offspring. BKD was first identified in Norway in 1980 in juvenile fish produced from wild broodstock. BKD outbreaks are most frequently identified in western Norway where several rivers are most probably endemically infected.

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

As BKD is a notifiable disease and counter measures may have significant economic consequences, the diagnosis must be verified. This is done by relating pathological changes consistent with BKD to detection of the bacterium by at least two biologically independent laboratory analyses. 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 situation in 2019

Official data

Bacterial kidney disease (BKD) is now only sporadically identified in Norway with between none and three cases occurring annually. No cases were identified in 2018.

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.

Ulcer 'syndromes' associated with salmonid farming in cold seawater (mainly salmon but also rainbow trout) can be separated into two main types.

Most common is 'typical' winter-ulcer, which is primarily associated with *Moritella viscosa* infection. The bacteriological picture may be complex and while experimental *M. viscosa* infection results in ulcer development consistent with the disease, other bacteria including *Tenacibaculum* spp. and *Aliivibrio (Vibrio) wodanis* are also commonly found during diagnostic investigations. The skin lesions associated with this type of disease are found primarily on the flanks of affected fish and at all stages of the seawater phase of culture.

Several genotypes of *M. viscosa* have been described, which can be roughly separated into phenotypically 'typical' or 'atypical' groups.

'Atypical' winter-ulcer or 'tenacibaculosis' is less common but can be very severe. The condition is commonly associated with high mortality and is characterised by deep lesions of the jaw (mouth rot) and head, tail and fins.

While all sizes of salmon may be involved, it is most commonly newly sea-transferred smolts that are affected. Outbreaks in larger fish are often associated with recent events involving handling, including salmon lice treatment. Such cases are associated in the main with infections involving diverse strains of *Tenacibaculum* spp. which may be identified in pure culture.

Moritella infections are commonly systemic i.e. all internal organs are infected. *Tenacibaculum* are almost exclusively found in and around the lesion. Both types of bacteria may affect the eye.

Control

Winter-ulcer is non-notifiable, is relatively easily diagnosed in the field and as such is almost certainly under-reported. No official statistics relating to the prevalence of such infections are maintained. Nearly all Norwegian farmed salmon are vaccinated against *M. viscosa* infection. Antibiotic treatments are performed on occasion, but the effect is variable. Recent (as yet unpublished) results of a study performed by the Norwegian Veterinary Institute indicate 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. There are no commercial vaccines available against tenacibaculosis in salmon and antibiotic treatment is largely ineffective. Removal of fish displaying visible wounds should be considered.

The situation in 2019

Official data

Information from Fish Health Services and Norwegian Veterinary Institute regional laboratories indicates that ulcers were prevalent in Norwegian farmed fish along the whole coast during 2019. The prevalence varies from area to area, but most identifications of both *Moritella viscosa* and *Tenacibaculum* spp. related to ulcer development in salmon were made in northern Norway. More than 80% of all cases in which *Tenacibaculum* spp. and *M. viscosa* were registered were situated in Nordland or further north.

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. Information received from the field indicates that winter ulcer is often associated with delousing and other management routines requiring handling or stress.

The annual survey reveals that skin lesions, atypical winter-ulcer and post delousing mechanical injuries are considered as almost the most important of the diseases and conditions impacting mortality in ongrowing salmon and rainbow trout. Skin lesions also seriously impact fish welfare. It is therefore extremely important that management routines that may predispose development of skin lesions be avoided.

Figure 5.4.1: Viscous *Moritella viscosa* colonies.
Photo: Duncan J. Colquhoun, Norwegian Veterinary Institute.

Figure 5.4.2: Sea-farmed salmon with mouth-rot, typically associated with *Tenacibaculum* infection.
Photo: Anne Tjessem, Grieg Seafood.

5.5 Yersiniosis

By Snorre Gulla and Anne Berit Olsen

The disease

Yersiniosis, caused by the bacterium Y*ersinia ruckeri*, has been identified in several types of fish, but is most common in salmonids. In Norway, the disease, also known as enteric redmouth disease, is almost exclusively associated with farmed Atlantic salmon, manifesting with classical signs of systemic bacterial disease (Figure 5.5.1).
The disease may occur before and after sea-transfer, but infection is presumed to occur primarily during the freshwater phase. While historically the disease in seawater has been associated with newly sea-transferred smolts, it is now more common in large seawater farmed fish. It has been speculated that these outbreaks may be related to the handling and stress of delousing.

Research published by the Norwegian Veterinary Institute revealed that all clinical outbreaks in Norwegian salmon investigated over the last 20 years or so have been caused by a single genetic complex (clone) of Yersinia ruckeri serotype O1. Other clonal complexes of serotype O1 dominate in other countries. A number of different clones of serotype O1, O2 and O5 are also found in Norway in e.g. clinically healthy fish and yersiniosis-free hatcheries, and these cannot be related to serious outbreaks of disease.

Control

Several commercial actors consider vaccination necessary to maintain production in certain juvenile production units. No commercial oil-based vaccines are currently licensed for use in Norway, but intraperitoneal vaccination with water-based vaccines is increasingly used. Several hatcheries have apparently succeeded in eradication of virulent *Y. ruckeri* serotype O1. Antibiotic treatments have been used to a degree in recent years for treatment of yersiniosis. Such treatments can lead to development of resistance, a phenomenon identified in Norwegian *Y. ruckeri* in recent years.

See the fact sheet for more information on yersiniosis.
https://www.vetinst.no/sykdom-og-agens/yersinia-ruckeri-yersiniose

The situation in 2019

Official data

The diagnostic service of the Norwegian Veterinary Institute diagnosed 18 cases involving 12 salmon farms (6 freshwater hatcheries, 5 marine ongrowing sites and one broodstock farm). This represents a considerable reduction in number of cases from 2018 (31 cases/21 sites Figure 5.5.2). *Yersinia ruckeri* serotype O1 was cultured or identified using immunohistochemistry in all but two farms in which serotype O2 was identified.

The reduction in number of cases in 2018 and 2019 is related mainly to fewer cases in large sea-farmed fish in mid-Norway, which is most probably in turn related to the increasing number of fish vaccinated in this area (discussed later). In 2019, the Norwegian Veterinary Institute diagnosed only four cases of yersiniosis in large sea-farmed salmon and in two of these cases the clinical picture was complicated by the presence of other diseases (e.g. CMS and PD). On one of the latter localities (from which *Y. ruckeri* was cultured) the fish were

Figure 5.5.1: Yersiniosis in large sea-farmed salmon (left) and freshwater farmed juvenile salmon (right). Photo: Øystein Markussen, Marin Helse AS and Jannicke Wiik-Nielsen, Norwegian Veterinary Institute.

reportedly vaccinated against *Y. ruckeri*. The farms affected during 2019 appear to be fairly evenly spread across the country. (Figure 5.5.3).

Data from other laboratories

Four cases of yersiniosis were reported by private laboratories in 2019 (all from the one laboratory). There are grounds to believe that this represents an underreporting of the actual number of cases not diagnosed by the Norwegian Veterinary Institute in 2019.

Evaluation of the situation

It would appear that the extensive problems experienced in recent years in sea-farmed salmon in mid-Norway have reduced considerably and that this situation has been arrived at following extensive vaccination. It would

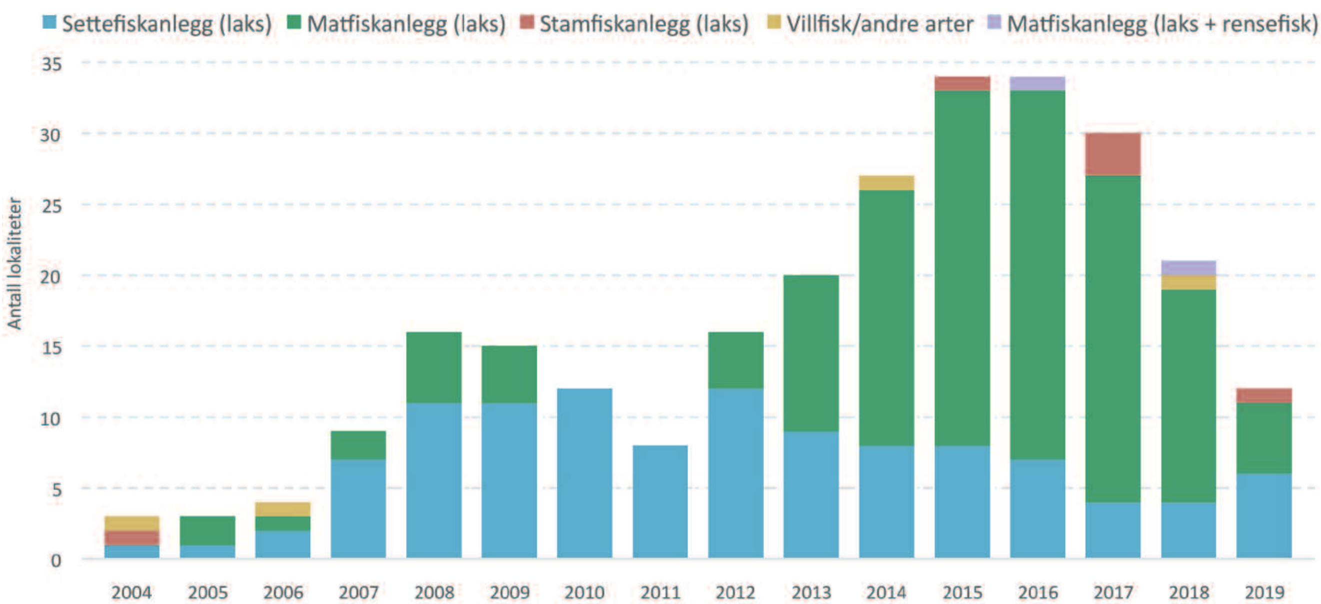


Figure 5.5.2: Distribution of *Y. ruckeri*-positive localities diagnosed by the Norwegian Veterinary Institute in recent years. Repeated diagnoses from the same locality are not included.

appear that the majority of producers along the whole coast, with the possible exception of Nordland, now vaccinate with a so-called ‘off-label’ injection with a *Y. ruckeri* bath vaccine, administered alongside a multi-component oil-adjuvanted vaccine. The gradual improvement in the situation (figure 5.5.2) probably reflects the steadily shrinking numbers of unvaccinated fish in the sea. As previously, some juvenile production facilities suffer recurring outbreaks during the freshwater period.

The Norwegian Veterinary Institute leads a current research FHF-financed project with the title ‘Yersiniosis: Investigation of the increased prevalence in Norwegian sea-farmed salmon’.

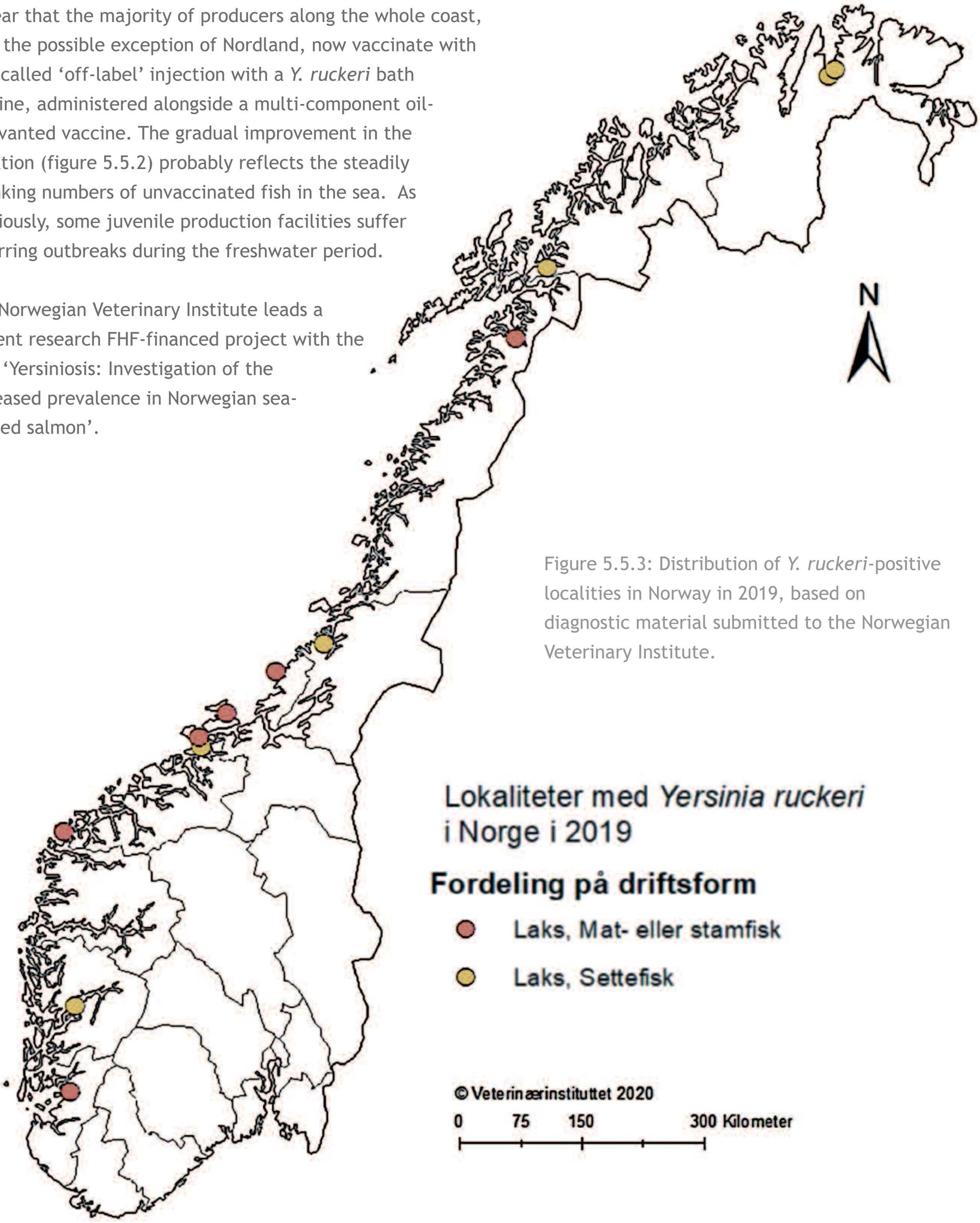


Figure 5.5.3: Distribution of *Y. ruckeri*-positive localities in Norway in 2019, based on diagnostic material submitted to the Norwegian Veterinary Institute.

5.6 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 best known are *M. marinum, M. chelonae, M. fortuitum* and *M. salmoniphilum*. Of these, *M. salmoniphilum* has been associated with disease in farmed fish in Norway.

Typically, mycobacteriosis in fish is a chronic disease with varying associated mortality. Visible signs of disease can include white nodules in internal organs and an enlarged spleen and kidney. Fish may also typically display skin lesions and appear emaciated. Histologically visible granuloma (inflammatory reactions) in inner organs are a typical finding in many fish species but are normally less pronounced in salmonids.

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

Mycobacteriosis in fish is difficult to treat with antibiotics due to the bacterium's impermeable cell-wall and granuloma formation. As the disease has a chronic course and affected fish display poor growth, the disease should be controlled by stamping out and disinfection of the farm. 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 situation in 2019

Data from the Norwegian Veterinary Institute

In 2019, mycobacteria were associated with granulomatous disease in seven localities, which was an increase from the previous year. The diagnoses were based on bacteriological culture or immunohistochemical analysis. *Mycobacterium salmoniphilum* was confirmed in one outbreak by culture and 16S sequencing. The same species was also identified in two farms in 2018.

Evaluation of the 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 also identified in one RAS hatchery and 2 ongrowing sites for salmon in 2018.

There are currently no indications that human consumption of mycobacteria infected fish represents a significant health risk, as most fish pathogenic bacteria including *M. salmoniphilum* do not grow at 37oC. It cannot be absolutely excluded that handling of non-processed fish may represent a zoonotic risk through contact infection involving a skin lesion.

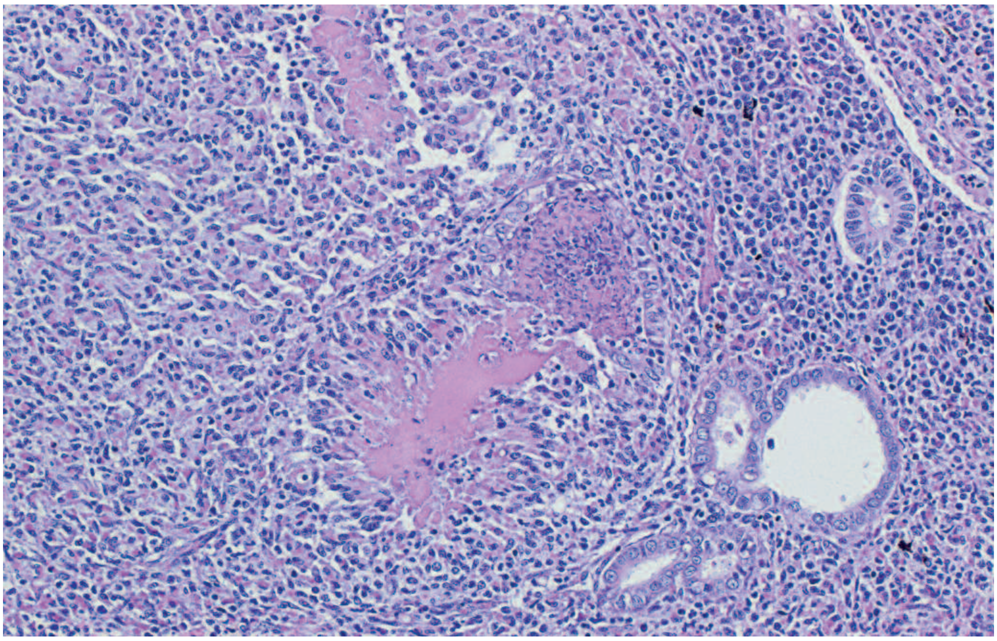


Figure 5.6.1. Kidney of mycobacteria infected salmon, displaying granulomatous inflammation and Splendore-Hoeppli reaction in the tissues. PAS staining. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

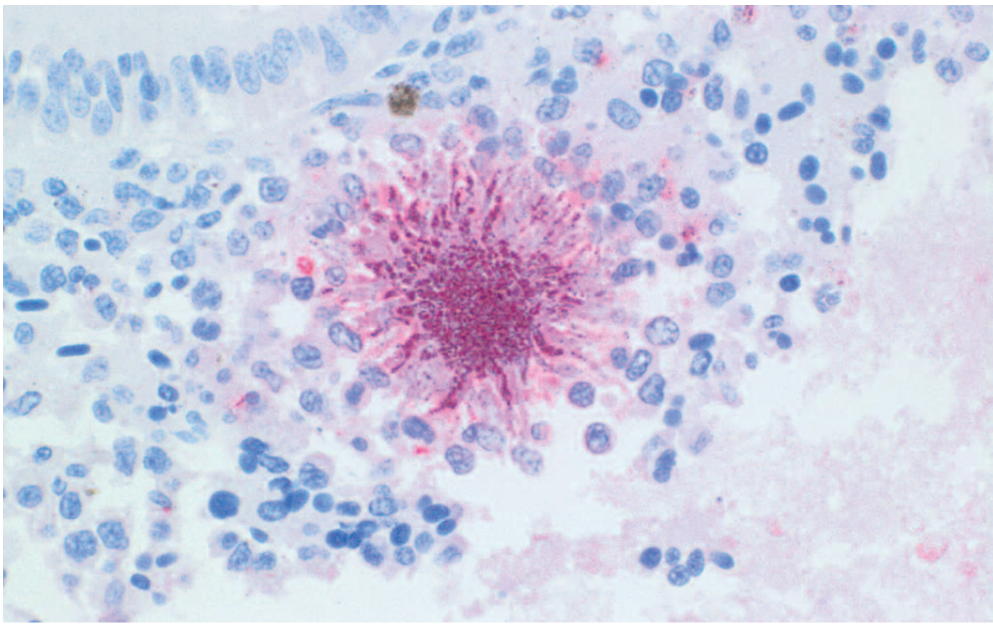


Figure 5.6.2. Kidney section from salmon displaying positive marking for mycobacteria. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

5.7 Pasteurellosis in salmon

By Hanne K. Nilsen

The disease

Pasteurellosis is caused by bacteria belonging to the genus Pasteurella. Pasteurellosis has since 2013 been recognised as one of the most serious threats to farmed lumpsucker. The disease was first diagnosed in Norwegian farmed salmon in Northern Norway as early as 1989. Pasteurellosis in salmon has since occurred irregularly in northern and southern Norway. The disease has, since the nineties, also been regularly diagnosed in Scottish farmed salmon. In 2017, severe mortalities were registered in association with this infection in a farm situated in Lewis.

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. Speciation of the Pasteurella strains involved which cause disease in salmon and lumpsucker remains undocumented, but considerable genetic and antigenic variations are known to exist.

Transmission of infection from cleaner fish to salmon cannot be excluded as investigations performed by the Norwegian Veterinary Institute show that the same genotype has been identified from both salmon and lumpsucker in a few farms. Outbreaks on geographically close neighbouring farms indicate that the infection transmits in a horizontal fashion.
There is a need for increased knowledge of the population structure of this bacterial group in order to assess whether polyculture represents a real risk of cross-species infection and whether there exists a marine reservoir.

Control

No commercial vaccines are currently available. The disease in non-notifiable.

Situation in 2019

Data from the Norwegian Veterinary Institute

The Norwegian Veterinary Institute registered an increase in the number of cases in salmon in 2019 (Fig. 5.7). Pasteurellosis was identified in 14 farming sites in western Norway. The disease was registered in neighbouring localities within a short period of time on a number of occasions and involved larger fish between 1.8 – 5kg.

The clinical picture varied between cases, from very low prevalence to mortalities of 150-200 fish per day. Typical symptoms include epicardial and peritoneal inflammation with skin lesions, particularly severe lesions in the proximity of the pectoral fins, musculature and inner organs. The bacterium may also be identified in the absence of obvious disease. Eye pathology has been identified in a few fish, but has not been a frequent finding in outbreaks in Norwegian salmon in 2019.

Evaluation of the pasteurellosis situation in salmon

Pasteurella infection in salmon is on the increase and represents an 'emerging' disease with a significant risk of becoming endemic.

Successful control of 'new' bacterial diseases in Norwegian aquaculture is dependent on close cooperation between the industry, fish health services, the Norwegian Food Safety Authority and research institutions.

The annual survey

5 of 72 (7%) respondents considered *Pasteurella* as one of the five most important diseases affecting mortality and welfare. 7 of 65 (11%) considered the disease to be on the increase. 1 of 67 (2) consider the disease to be related to poor growth. Comments were received indicating that *Pasteurellosis* is a serious challenge in salmon farming resulting in high mortality, reduced welfare and poor growth. Mixed infections including Pasteurella spp. appear to be a significant problem.

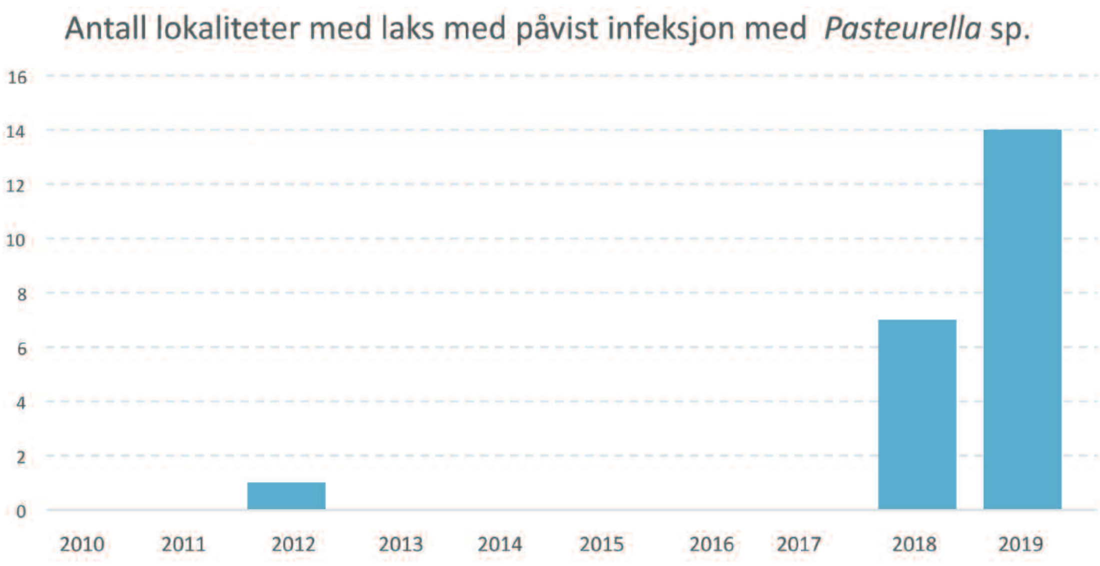


Fig. 5.7.1 Number of pasteurellosis affected farms (salmon) 2010-2019.

5.8 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.

The dramatic increase in number of pasteurellosis cases discussed previously (Section. 5.7, Pasteurellosis) probably represents the most important change i bacterial diseases of salmon in recent years. *Mycobacteria*, have, as in 2018, been diagnosed more commonly in 2019 than in previous years. (Section. 5.6, Mycobacteriosis).

Pseudomonas anguilliseptica, which causes disease in a wide spectrum of fish species worldwide is known primarily as a pathogen of lumpsucker in Norway, but was identified for the first time in sick Norwegian rainbow trout (~1kg) farmed in seawater (23-30ppt) at a water temperature of 8-11ºC. The fish had been transported and deloused some weeks prior to the outbreak.

Vibrio anguillarum serotype O1 was cultured from rainbow trout displaying classical signs of vibriosis during 2019. *Vibrio anguillarum* (which could not be serotyped using available antisera) was identified in two cases of complex infections in which *Flavobacterium psychrophilum* (rainbow trout) and pancreas disease (salmon) were also identified.

Coldwater vibriosis, caused by *Vibrio salmonicida*, was not identified in salmon in 2019.

Neither atypical *Aeromonas salmonicida* or *Aeromonas salmonicida* subsp salmonicida were identified in Norwegian farmed salmonids during 2019.

Piscirickettsiosis, caused by *Piscirickettsia salmonis*, was not identified in Norwegian farmed salmonids in 2019.

Norwegian Veterinary Institute Director, Gaute Lenvik (centre) visits the Institute's bacteriology laboratory in Bergen.
Photo: Eivind Senneset

5.9 Antibiotic sensitivity in Norwegian aquaculture

By Duncan J. Colquhoun and Hanne Nilsen

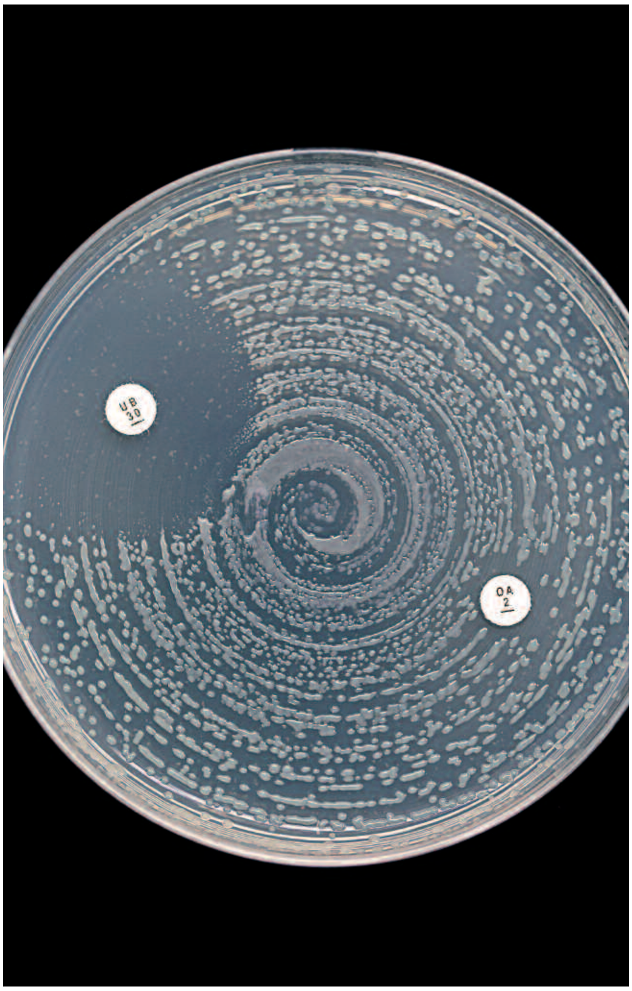
The Norwegian Veterinary Institute monitors antibiotic sensitivity in a large number of bacterial isolates cultured from diseased fish each year. A smaller number of isolates from wild fish are also tested, primarily from wild salmonids. The results of this surveillance reveal a favourable situation 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. It is important that use of antibiotics remains infrequent to avoid development of resistance in both environmental and fish-pathogenic bacteria.

As in previous years, we have again in 2019 identified reduced susceptibility to oxolinic acid in *Flavobacterium psychrophilum* isolated from diseased rainbow trout. Reduced sensitivity to oxolinic acid was also once more identified in *Aeromonas salmonicida* subsp. *salmonicida* isolated from two outbreaks of furunculosis in wild salmon. The river systems involved (Sandøla and Ferja) are situated in the same region in mid-Norway where this bacterial strain has been endemic for a number of years. The mechanism behind the reduced oxolinic acid sensitivity has previously been related to chromosomal mutation. The risk of transmission of this type of resistance is considered low.

Reduced antibiotic sensitivity has not been identified in any bacterial pathogen of cleaner-fish.

Reduced sensitivity to florfenicol was again identified in a single isolate of atypical *Aeromonas salmonicida* cultured from diseased halibut in 2019. Subsequent testing of later isolates of the same bacterium from the same fish population did not reveal reduced sensitivity.



Resistance testing. Photo: Eivind Senneset

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).

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.

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

The situation in 2019

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. In 2019, saprolegniosis was diagnosed in only two cases. There were two additional requests for advice outside the diagnostic service in which *saprolegnia* was related to high mortality in start-feeding fry and eggs. There were an additional four cases of oomycoses diagnosed in salmon, one in trout and four in lumpsucker.

Reports from the annual survey

Information from respondents to our annual survey indicate that the disease is considered more important in the industry than the statistics alone would suggest (See appendices A-C).

7. Parasite diseases in farmed salmonids

The salmon louse (*Lepeophtheirus salmonis*) continues to represent the most significant parasitic threat to salmonid production. Despite increased use of both medicinal and non-medicinal delousing, louse levels on a national basis were higher during the spring and autumn of 2019 than in the previous year. The lowest numbers of adult female and other motile stages were registered during the spring. Resistance to chemical based treatments was again widespread along the coast and again non-medicinal treatments and measures continued to dominate. In total, 2185 thermal and mechanical delousing treatments were performed in 2019, with thermal treatments dominating. Respondents to the survey informed that increased mortality was frequent following thermal and mechanical delousing. There are also strong indications that physical injuries resulting from these types of delousing are associated with reduced fish welfare.

Replies to the annual survey indicate that *Caligus elongatus* was also a greater problem in 2019 than in the previous year and that in some cases delousing against this parasite was necessary.

Parvicapsula pseudobranchicola is reported as particularly problematical in salmon farming in the regions of Troms and Finnmark. As in previous years, this parasite again proved challenging in 2019 in these regions in relation to mortality, growth and welfare.

The amoeba *Paramoeba perurans*, which causes AGD, was again detected throughout the year from Agder to Nordland with an increased number of cases recorded in Nordland in 2019. In cases of complex gill disease in sea-farmed salmon, the amoeba may be present alongside other parasites including *Desmozoon lepeophtherii* (*Paranucleospora theridion*).

There are other parasites commonly found in farmed salmon that may be problematical. Increased numbers of tapeworm have been registered since 2010 in sea-farmed salmon, particularly in western and mid-Norway. *Ichthyobodo necator* (salmon in freshwater), *I. salmonis* (salmon in freshwater and seawater) and *Trichodina* spp. are common single-cell parasites that can afffect both skin and gills. Such infections are normally diagnosed locally by fish health services. Responses to the survey indicate that these infections are considered a minor problem.

7.1 The salmon louse – *Lepeophtheirus salmonis*

Av Kari Olli Helgesen og Lars Qviller

The parasite

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.

The situation in 2019

Official data

All farmers are required by law to count and report lice numbers weekly. The average number of lice reported weekly for the country as a whole reveals a cyclical variation with the lowest lice counts in spring and the highest during the autumn (Figure 7.1.1). The highest numbers of adult female lice were recorded in September/October 2019 (week 40) and the highest numbers of other mobile stages (pre-adults and adult males) were observed in November (week 46).

The lowest numbers of adult female lice were recorded in May (week 20), while the lowest numbers of other mobile stages were recorded in April/May (week 18). Overall, louse numbers for 2019 were somewhat higher than those observed in 2018, for both minimum and maximum figures. The highest numbers of adult female lice were similar to those observed in 2016.

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 new salmon production areas (Figure 7.1.2) around the coast. Each area is considered separately in association with the so-called traffic light system regulating further expansion of the aquaculture industry.

Highest larval production occurred in production areas 2, 3 and 4 (Figure 7.1.3). With the exception of 1, 12 and 13 (in which louse larvae production decreased) all production areas experienced an increase in larval production from 2018 to 2019. Regarding lice numbers during the period of outward migration of wild salmon smolts (as described by Kristoffersen et al. 2018, Epidemics 23: 19-33) an increase in production was observed between 2018 and 2019 in production areas 5, 6, 7, 9, 10 and 11, while marginal increases were also observed in production areas 1, 4 and 12. This means that the production areas with the highest louse production (2, 3 and 4) displayed a reduction (2 and 3) or a marginal increase in louse production during the period of outward smolt migration in 2019 compared to 2018.

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 7.1.4)

The median value for average louse production per fish per week was highest in production zones 2, 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.

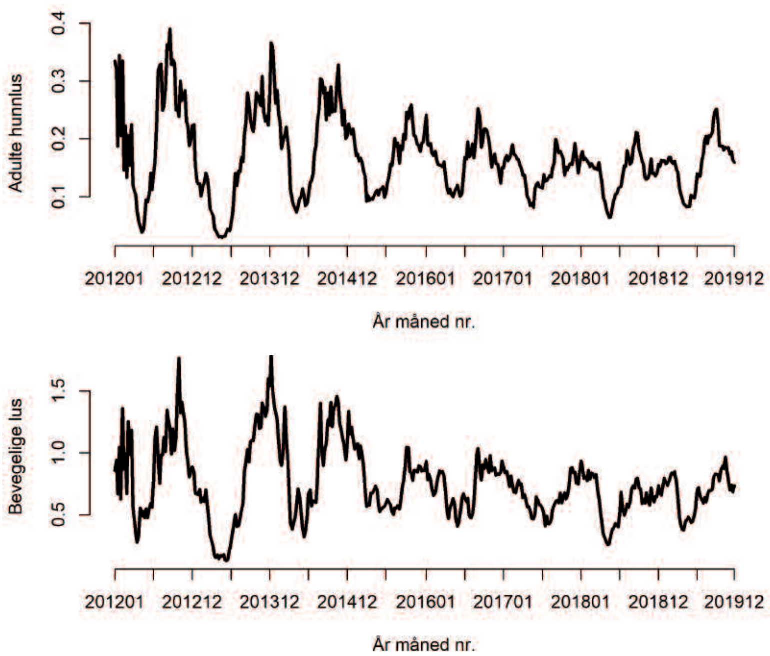


Figure 7.1.1. Average numbers of lice reported by all marine sites in Norway farming salmon or rainbow trout for the period January 2012 until December 2019. The upper panel describes the number of adult female lice and the lower panel other motile stages (pre-adults and adult males)

The number of anti-louse treatments in 2019 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 reveals that the drastic reduction in the number of prescriptions for medicinal treatment of salmon lice between 2016 and 2018, did not continue in 2019. Delousing prescriptions rose by 16% from 2018. Statistics describing prescription of individual active ingredients show an increase for all categories with the exception of hydrogen peroxide in this period.
The quantity of hydrogen peroxide presented in the table represents treatment of both salmon lice and AGD. Emamectin benzoate was the most frequently prescribed anti-louse pharmaceutical in 2019.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.

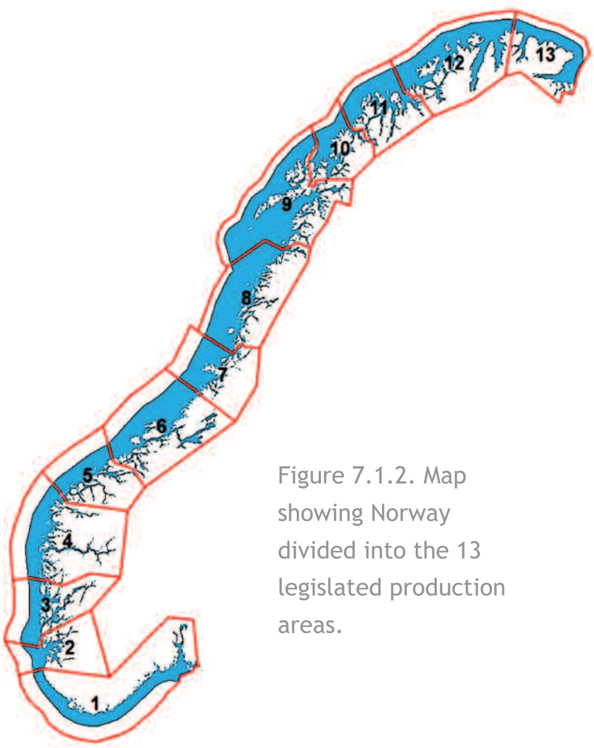


Figure 7.1.2. Map showing Norway divided into the 13 legislated production areas.

The number of reported non-medicinal delousing treatments has increased steadily since 2016 and continued to increase in 2019. The number of thermal-, mechanical- and freshwater- treatments registered again increased. The greatest increase was in the number of mechanical treatments (56% increase from 2018). Thermal treatments continued to be the most frequently used non-medicinal treatment in 2019 (representing 59% of all reported treatments). In addition to non-medicinal methods, various prophylactic measures, with cleaner-fish as the dominating form, have been widely used.

Figure 7.1.5 shows the results of the surveillance programme for salmon louse resistance performed by the Norwegian Veterinary Institute under contract from the Norwegian Food Safety Authority. This programme utilises bioassays (resistance testing in which live salmon lice are exposed to different levels of anti-louse substance) for the substances azamethiphos, deltamethrin (a pyrethroid), emamectin benzoate and hydrogen peroxide. The map indicates the geographical range of 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.

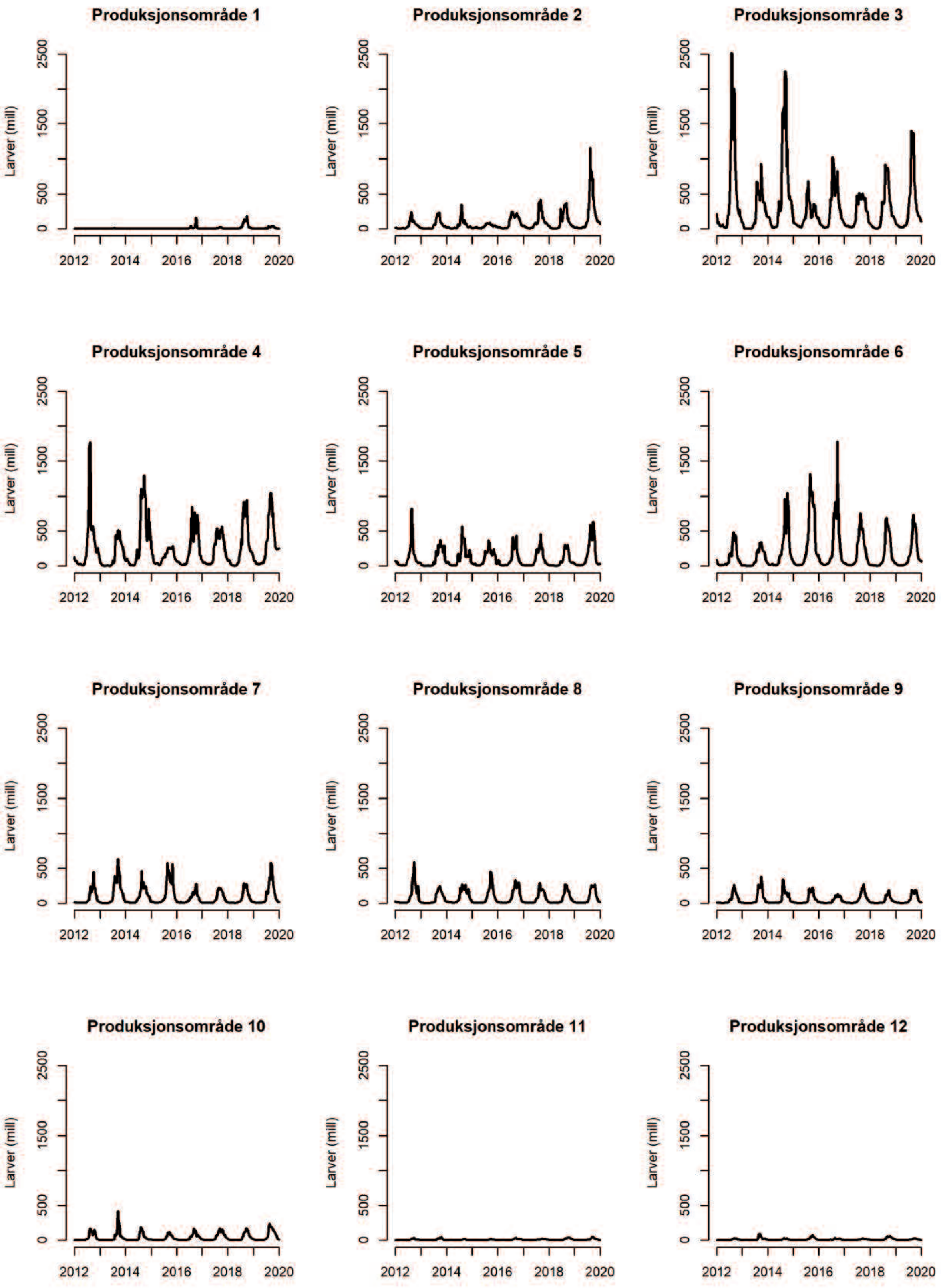


Figure 7.1.3. Calculated total production of louse larvae (in millions) per week per locality in each production area (Psone) for the period 2012-2019. Production area 13 is not included. This area had insignificant larval production throughout the whole period.

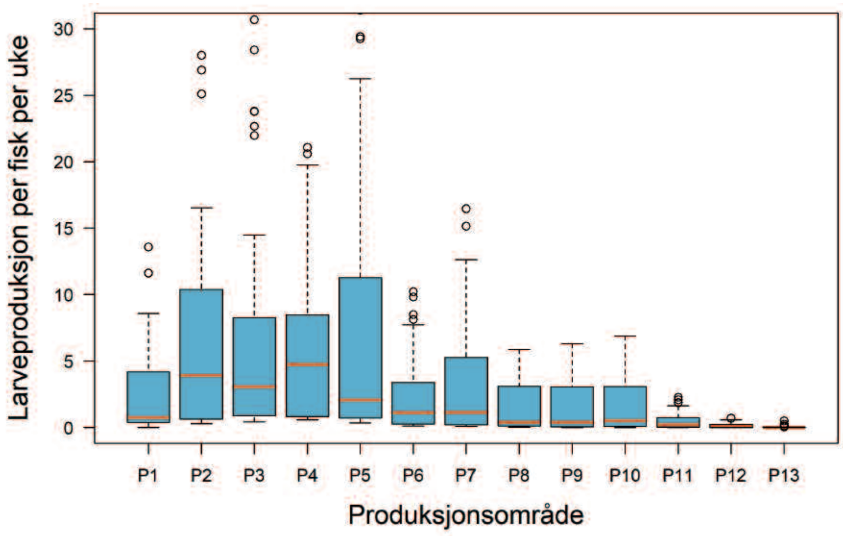


Figure 7.1.4. Calculated average louse larvae production per fish per week in each production area (P1-P13) in 2019. The red lines represent the median values, while 50% of the values are within the blue boxes.

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. N is the number of respondents replying to each individual query. When asked which diseases represent the most significant threat to ongrowing salmon in 2019, 12 selected the salmon louse as one of the most important, while 54 chose injuries resulting as a consequence of delousing (N=72). Of the causes of reduced growth, 14 chose the salmon louse as one of the most important causes, while 17 chose post-delousing injury (N=67). Forty seven and 59 respectively chose the salmon louse and post-delousing injury as one of the most important causes of reduced welfare (N=72), while 27 and 21 chose these two causes in regard to the most important increasing problem (N=65). In ongrowing rainbow trout, post-delousing injury was also commonly reported as one of the most important causes of reduced welfare, with the salmon louse itself close behind (N=11). See appendix B for details of diseases/conditions in the various categories.

In relation to scoring of treatment related mortality, a score of 1 = never or extremely rarely observed, while a score of 5 = observed on nearly every occasion. Increased acute mortality (over 0.2% mortality the first three days following delousing) was awarded a score of 3.9 for thermal delousing, 3.4 for flushing and/or brushing (N= 61) and 2.7 for use of freshwater (N=31).

The average scores for increased delayed mortality were 2.8, 2.7 and 2 for thermal, mechanical and freshwater delousing respectively. Both increased and delayed mortality were thereby observed more frequently following mechanical delousing and least commonly following freshwater delousing. A similar situation was reported in 2017 and 2018.

Specific welfare concerns, raised in the survey, surrounding non-medicinal louse treatments are also discussed in the Fish welfare section (Section 3) of this report.

Evaluation of the salmon louse situation

The salmon louse situation nationwide was worse than the year before, both in the spring and autumn, despite increased frequency of treatment with both medicinal and non-medicinal treatments (increases of 165 and 22% over the previous year). While the overall Spring numbers of lice were higher than observed during 2018, the weeks with the lowest prevalence of adult female and other motile stages were also observed during the spring outward migration period for wild salmon smolts. Nine of thirteen production areas experienced an increase in production of lice larvae, while the remaining three displayed reduced production. The three areas with reduced production were amongst those with lowest production (areas 1, 12 and 13). If only the period of wild smolt outward migration is considered, nine production areas displayed increased larvae production compared to the previous year.

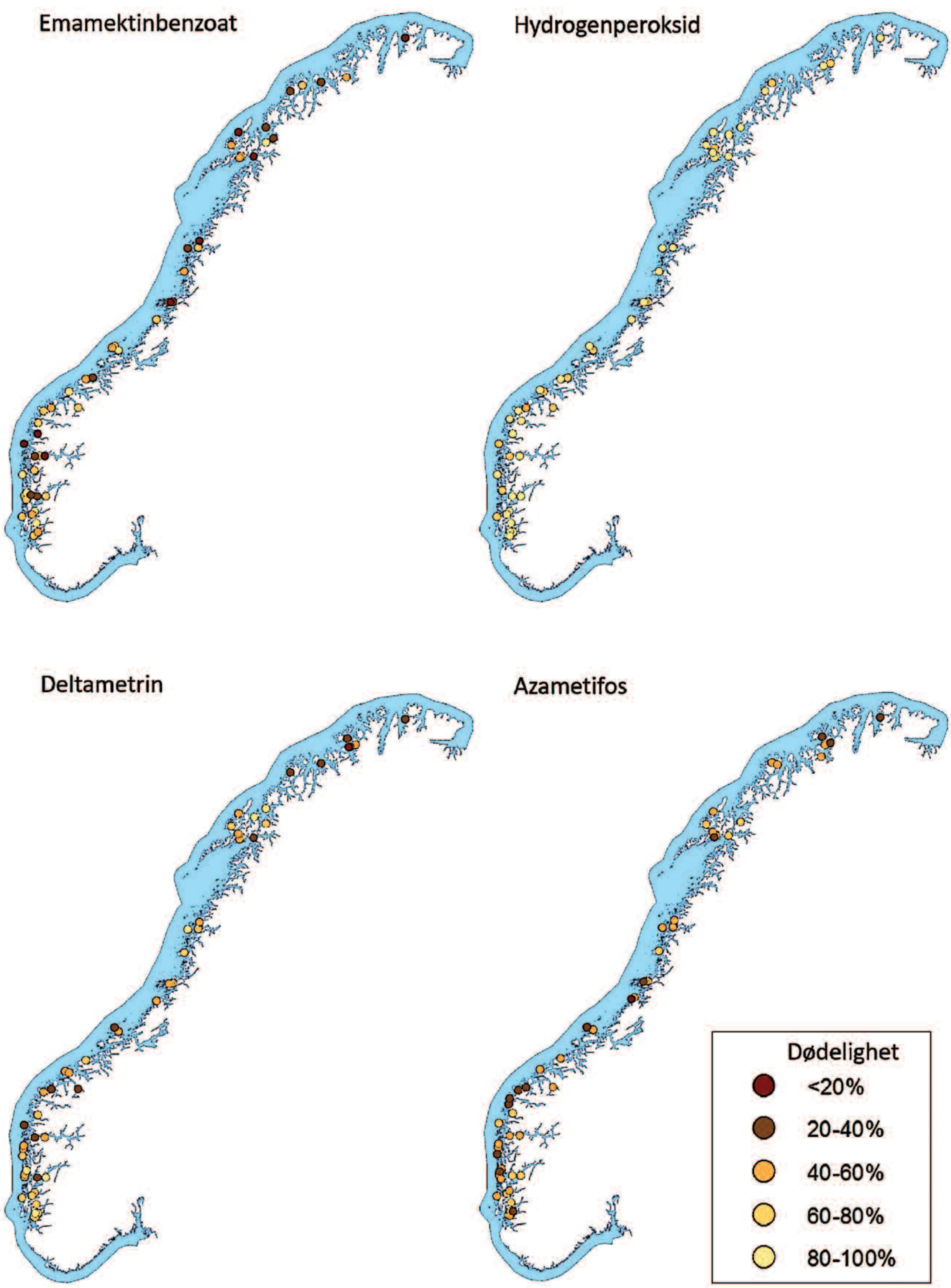


Figure 7.1.5: Mortality of lice in the simplified bioassay for emamectin benzoate, hydrogen peroxide, deltamethrin and azamethiphos, where darker colours represent lower mortality on exposure to a known concentration of active ingredient and therefore more resistant lice.

Delousing in Norway during 2019 was mainly based on non-medicinal treatments and other non-medicinal measures. 59% of the non-medicinal treatments comprised thermal delousing, compared to 68% of treatments the previous year. Although comprising a lower proportion, the number of treatments actually increased in 2019. Resistance to chemotherapeutants remained widespread along the coast. The effect of such treatment was considered poor. Nevertheless, the number of medicinal based treatment increased during 2019.

Reports from the field indicate that thermal and mechanical treatments often result in increased mortality in the treated fish. Considering that such treatments were performed more than 2000 times during 2019, these mortalities probably constitute a considerable proportion of overall salmon and rainbow trout losses experienced during the marine phase of culture. Post delousing injuries were also considered one of the most significant causes of reduced welfare in both salmon and rainbow trout in this year's survey, once again underlining the association between delousing and fish welfare.
til redusert velferd hos både laks og regnbueørret i årets spørreundersøkelse. Dette understreker ytterligere sammenhengen mellom lakselusbehandlinger og fiskevelferd.

Table 7.1.1. Number of prescriptions categorised by active ingredient, prescribed for treatment of salmon lice 2011-2019. Pyrethroids = deltamethrin and cypermethrin. Flubenzorones = teflubenzerone and diflubenzerone. The number of prescriptions was obtained from VetReg 13.01.20.

Active ingredient	2011	2012	2013	2014	2015	2016	2017	2018	2019
Azametiphos	418	695	483	752	621	262	59	39	82
Pyrethroids	460	1163	1130	1049	664	280	82	56	73
Emamectin benzoate	294	169	163	481	523	612	351	371	424
Flubenzurones	24	133	171	195	202	173	81	40	42
Hydrogen peroxide	179	110	255	1021	1284	629	214	96	77
Sum	1375	2270	2202	3498	3294	1956	787	602	698

Table 7.1.2. Number of reported non-medicinal treatments. Treatments relate to the number of individual weeks in which mechanical lice-treatments were reported to the Norwegian Food Safety Authority, as of 07.01.20. 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.

Category	2012	2013	2014	2015	2016	2017	2018	2019
Thermal	0	0	3	36	685	1247	1355	1451
Mechanical	4	2	38	34	331	279	471	734
Freshwater	0	1	1	28	88	96	104	172
Other	132	108	136	103	75	51	72	89
Sum weeks	136	111	178	201	1179	1673	2002	2446

7.2 *Caligus elongatus*

By Haakon Hansen, Geir Bornø and Øivind Øines

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 it 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 lumpsucker 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 lumpsucker used in control of salmon lice.

As does 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 lumpsucker can infect salmon and vice versa under farming conditions.

Cage held salmon and cleaner- fish within the same cage may be 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 readily be 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.

Control

nfestations have been reported which are so problematical that they have required treatment.

The situation in 2019

Annual survey

The survey ranked C. elongatus as the fifth most important increasing problem for ongrowing salmon in 2019 and was a greater problem in 2019 than in 2018. C. elongatus is not considered an important cause of mortality, reduced welfare, poor growth or as an increasing problem in rainbow trout farmed in ongrowing and broodstock farms.

7.3 *Parvicapsula pseudobranchicola* (parvicapsulose)

By Haakon Hansen, Lisa Furnesvik and Geir Bornø

The disease

Parvicapsulosis, caused by *Parvicapsula pseudobranchicola* 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 has been recognised in Norwegian farmed salmon since 2002 and is a normal finding in wild salmonids along the entire Norwegian coast.

Parvicapsula pseudobranchicola is reported as particularly problematical in salmon farming in the regions of Troms and Finnmark. The target organ for *P. pseudobranchicola* is the pseudobranch, which supplies oxygen-rich blood to the eye. Spores fill up large areas within the organ resulting in significant injury, which may result in reduced blood flow, which may in turn lead to reduced vision.

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

The situation in 2019

Data from the Norwegian Veterinary Institute

In 2019, the Norwegian veterinary Institute identified the parasite during histopathological investigation of 29 farming sites, compared with 37 in 2018. The diagnoses were limited to the two most northerly regions, Nordland and Troms and Finnmark.

Annual survey

The parasite was mentioned as a recurring and significant problem in affected regions, both in terms of overall mortality and growth as well as fish welfare.

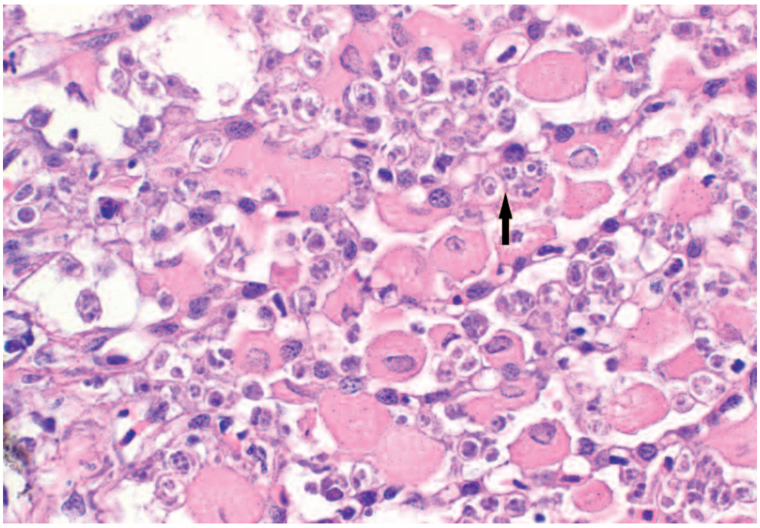


Figure 7.3.1. The pseudobranch of a salmon infected with *Parvicapsula pseudobranchicola* (arrow). Photo: Toni Erkinharju,

7.4 Amoebic Gill Disease (AGD) and *Paramoeba perurans*

By Sigurd Hytterød, Cecilie Walde 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.

Paramoeba 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. The amoeba occurs in seawater, primarily causing disease in Atlantic salmon, but has also been recorded in rainbow trout, turbot, lumpsucker and various wrasse 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 (H2O2) 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 H2O2.

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

Situation in 2019

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 2019, the Norwegian Veterinary Institute diagnosed AGD in 28 salmon and rainbow trout farms from Rogaland in the south to Nordland in the north. Although this is a reduction from the previous year (39), a slight increase in the number of cases was registered in Møre og Romsdal and Nordland compared to 2018. AGD has not yet been identified north of Nordland. There is, however, limited sampling for AGD in the north of the country.

Survey

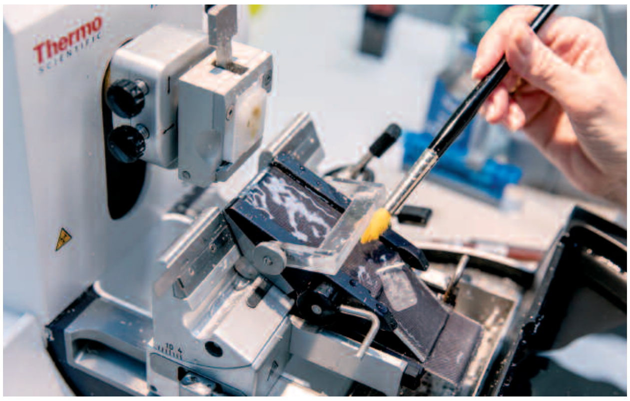
AGD is not considered an important cause of mortality in ongrowing farmed salmon. The disease is, however, considered a more important cause of reduced growth. AGD scores slightly over average regarding its effect on fish welfare and is considered an increasing problem. AGD appears to be a serious and increasing problem in ongrowing marine farmed rainbow trout and is considered one of the five most important conditions in this segment. For broodstock salmon, AGD scores lowly in all categories (mortality, reduced growth, reduced welfare and as an increasing problem), while it is considered an important cause of mortality in broodstock rainbow trout.

Evaluation of the AGD situation

AGD has established itself as 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.

Poor gill-health was a significant problem in 2019 as in 2018 and *P. perurans* was commonly identified as a component in complex cases of multiple aetiology.



Paraffin fixed tissues are sectioned, placed on an object glass, stained and examined using a light microscope or scanned for digital examination. Photo: Eivind Senneset

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.

Treatment

Eubothrium sp. are treated with praziquantel.

The situation in 2019

Data from the Norwegian veterinary Institute

The Norwegian Veterinary Institute identified tapeworm in ongrowing salmon in 10 farms compared to 33 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 most diagnoses are made locally by fish health services.

The annual survey

Of the 72 respondents, none replied that tapeworm represents one of the five most important causes (from a list of 25 alternatives) of mortality while it was rated as a ‘medium’ problem in relation to reduced growth, or as an increasing problem in ongrowing salmon. Tapeworms are not considered an important problem in rainbow trout farming (12 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.

In the period 2010-2015 there was a significant increase in sales of Praziquantel. There has been a reduction in sales of this medicament post 2016 and during 2018 sales levels were once again at a level similar to 2011. Responses to the survey indicate, however, that the tapeworm problem has not reduced, but that the reduced sales are due to development of resistance to praziquantel. In addition, permission must be applied for and granted by the Norwegian Medicines Agency for each treatment of fish, as this substance is not licensed for use in fish.

Figure 7.5.1. The tapeworm, *Eubothrium* sp. Photo: Jannicke Wiik Nielsen, Norwegian Veterinary Institute

8.0 Miscellaneous health problems in farmed salmonids

This chapter presents diverse non-infectious health problems in farmed fish including production related and environmentally based complaints. During the early summer of 2019, northern Nordland and southern Troms were severely affected by a bloom of the poisonous algae *Chrysochromulina leadbeaterii*. Approximately 8 million salmon were lost. The Fish Health Report 2019 includes, therefore, a separate chapter devoted to algae and fish health (See chapter 8.5). Of other health problems, gill disease is discussed in chapter 8.1, poor smolt quality and runt syndrome in chapter 8.2, nephrocalcinosis in chapter 8.3, water quality in chapter 8.4 and vaccine side effects in 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 which complex gill disease was ranked as the 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 and Norwegian Veterinary Institute data suggests that this was an increasing problem in 2019.

Nephrocalcinosis is a well known condition in farmed fish and is considered a production related disease. Based on the number of cases submitted to the Norwegian Veterinary Institute there would seem to have been a decline in the prevalence of this condition in 2019, with 118 farms diagnosed compared to 147 in 2018. The real number of cases is likely to be much higher however. In the annual survey, nephrocalcinosis was ranked as the most important of the five most important increasing health problems in juvenile salmon production.

The Norwegian Veterinary Institute occasionally identifies tissue damage associated with injection of oil-based vaccines. Few respondents to the survey considered vaccine side-effects to represent a serious problem compared to other conditions.

Photo: Rudolf Svensen, UW photo

8.1 Gill disease in farmed salmonids

By Brit Tørud, Cecilie Sviland Walde, Mona Gjessing and Anne Berit Olsen

The disease

The gills of fish have several critical physiological functions. They are responsible for gaseous exchange, osmoregulation, pH-regulation, hormone production and contain important immunological structures. The gills form a physical barrier against the environment and are therefore, exposed to any forms of insult present in the environment.

As only a thin epithelial cell layer separates the circulating blood from the environment, the gills are exposed to damage. Gill disease may be caused by several factors including unfavourable environmental conditions, pathogenic organisms, nutritional factors and management routines. Damaged gills may increase susceptibility to infection. Gill disease may affect farmed salmon at all stages of production.

Some cases involve only single infective agents but most involve a complex aetiology. It may therefore be difficult to establish the role of individual agents or environmental influences in development of the observed disease. Gill diseases represent a serious welfare challenge.

As there are very different environmental parameters in freshwater and seawater, gill diseases differ considerably between these two environments. Water quality plays a particularly important role in development of gill diseases in freshwater. Under non-optimal water treatment conditions in freshwater, there may be significant seasonal variation in water quality particularly related to metal content. Precipitation of iron and toxic aluminium compounds on the gills may result in high mortality. In marine farms precipitation of toxic aluminium compounds may also occur during freshwater treatment of amoebic gill disease (AGD) and salmon lice.

In recirculation (RAS) based farms, heavy particle loads and metal content may lead to irritated gills. For more information on water quality in land- and sea-based farms, see chapter 8.4 Water quality.

Bacterial infections or infection with *Saprolegnia* sp. in the gills of salmonids in freshwater are often considered secondary infections. These may be identified following episodes of low pH and e.g. metal precipitation, salmon pox virus infection (See Chapter 4.8 Salmon pox virus) or single celled parasite infestation.

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. Secondary infections with ubiquitous marine bacteria e.g. *Tenacibaculum* may often follow such events. For further details on the individual microorganisms see relevant chapters in this report.

An unambiguous nomenclature for gill diseases remains lacking. This can result in confusion and result in delayed identification of the cause of disease. Since many different factors may cause gill disease, which may manifest in different ways, clear diagnoses and treatment recommendations are challenging.

'Epitheliocystis' is a term used to describe disease conditions in where the bacteria which cause the epitheliocysts are considered responsible for the disease. In some cases the number of epitheliocysts (evaluated histopathologically) is so high that they probably result in pathological change. Under such circumstances, it is probably correct to use the term 'epitheliocystis'. The term 'epitheliocystis' is also used on identification of epitheliocysts alongside gill damage, although the relationship between the presence of the bacteria and the damage is unclear. 'Autumn disease', first described in 2008, is used to describe a condition in which inflammation and necrosis is observed in the gills. Systemic signs include haemorrhage, inflammation, necrosis and circulatory disturbance. The suspected cause is infection with the microsporidian *Desmozoon lepeophtherii*. This parasite is however, a normal finding and the causal relationship remains poorly understood.

Proliferative gill inflammation (PGI) was previously described based on a combination of histopathological findings alone. The term has to a degree become synonymous with the term 'epitheliocystis'.

Amoebic gill disease (AGD) is caused by the amoeba *Paramoeba perurans*, but is commonly found with other agents and injuries in the gills.

To aid diagnostics of gill disease the Norwegian Veterinary Institute has developed a multiplex PCR (gill package) which can detect four of the microoorganisms related to gill disease in the sea: *Paramoeba perurans, Desmozoon lepeophtherii, Branchiomonas cysticola* and Salmon gill poxvirus. Histopathological investigation combined with PCR results provide a good basis for diagnosis. This method can shed light on the agents present in the early stages of development of disease and allow an improved basis for informed management decisions. See the fact sheet for more information on chronic gill disease:
https://www.vetinst.no/sykdom-og-agens/kronisk-gjellebetennelse-hos-laks

Control

Formalin is commonly used in treatment of parasites such as *Ichthyobodo* spp. There are no vaccines currently available against the viruses or bacteria associated with gill disease. Treatment of AGD is discussed in chapter 7.4 Amoebic gill disease.

There are several indications that fish may already be infected with gill pathogenic agents on sea-transfer. Disinfection of incoming water is therefore of extreme importance in juvenile production facilities. Disinfection of biofilters in RAS facilities should be considered when recurring gill problems are experienced. On outbreak of gill-pox associated disease, feeding should be ceased, stress avoided and adequate oxygen levels maintained.

The situation in 2019

Data from the Norwegian Veterinary Institute

As gill-diseases are non-notifiable, estimation of the number of farms affected each year is extremely difficult. In 2019, the Norwegian Veterinary Institute diagnosed gill inflammation as the main- or partial-diagnosis on 109 marine farms and 21 juvenile production facilities. Most cases involved salmon but rainbow trout were also involved. This is an increase in the number of diagnoses in ongrowing fish from the previous year (81). Gill disease appears to be a recurring problem in some farms. The figures below illustrate the number of cases of gill disease diagnosed by the Norwegian Veterinary Institute. To illustrate the relationship between diagnoses and season, monthly figures are presented. In ongrowing fish, most submissions are received during the spring and early summer with a new peak in the late autumn. This may be related to newly sea-transferred 0+ and 1+ smolts. There are also two peaks in submission of gill samples from juvenile production facilities, which are difficult to relate to any particular production factor.

The annual survey

Gill disease does not appear to result in high mortality

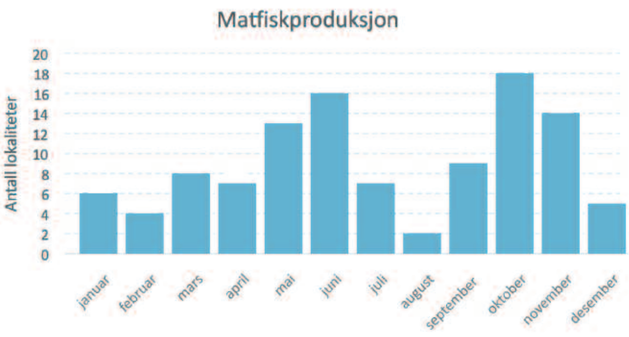


Figure 8.1.1 Total number of ongrowing sites in which gill inflammation was diagnosed as a main or contributory diagnosis throughout 2019. The diagnosis was awarded in a total of 109 different farming sites.

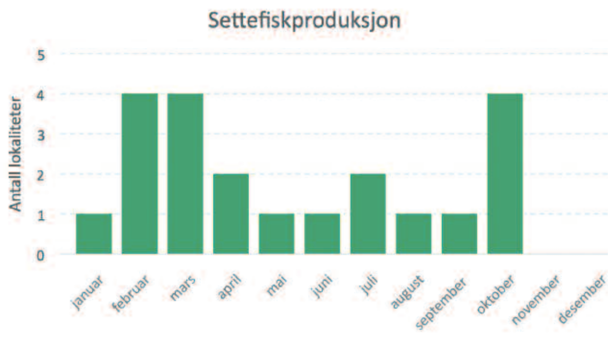


Figure 8.1.2 Total number of juvenile production sites in which gill inflammation was diagnosed as a main or contributory diagnosis throughout 2019. The diagnosis was awarded in a total of 21 different farming sites.

when considered at a national level, but is considered important in terms of reduced growth. Gill disease is not considered a serious welfare problem. Deformed and shortened opercula which result in exposed gills is however considered important in terms of mortality, reduced growth and reduced welfare. The importance of deformed opercula is considered by some to be increasing. Gill problems are also associated with farming of larger smolts related to technical difficulties in supplying these fish with the larger quantities of water required. There are also particular challenges related to RAS-farms.

Gill disease is considered an important cause of mortality and reduced welfare in ongrowing salmon. Complex multifactorial gill disease was ranged as the number one most important increasing disease in this type of fish.

Gill diseases are often complex. Gill haemorrhage is also commonly observed and is probably related to non-medicinal delousing. Sea-farmed rainbow trout appear to be less affected by gill disease than salmon. Gill-disease and gill-disease related mortality is not common in salmon broodstock. For details regarding ranking of health problems see appendices A-C.

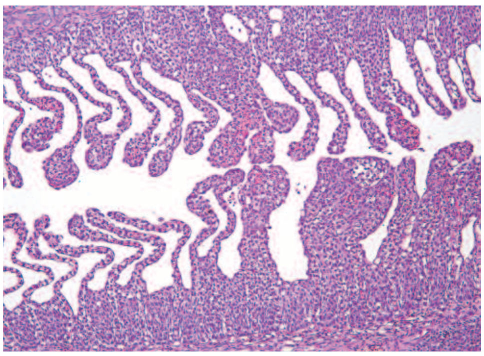


Figure 8.1.3. Normal findings on histopathological investigation of gills are thickened, fused lamellae and haemorrhage (histopathology). Photo: Anne Berit Olsen, Norwegian Veterinary Institute.

Figure 8.1.4. Example of gill injury. Photo: Brit Tørud, Norwegian Veterinary Institute.

8.2 Poor smolt quality and runt syndrome

By Synne Grønbech, Karoline Sveinsson and Jinni Gu

Optimal smoltification and correct timing of sea-transfer are important for normal development, growth and health of salmonids. Poor or variable smolt quality can increase the risk of runt development. Runt syndrome is a term used to describe a condition in which the affected fish presents as emaciated or does not grow normally. The term is normally restricted to marine farmed fish, although runts may also be observed during the freshwater phase.

Typical histological findings of runted fish include lack or absence of perivisceral fat and increased amount of melanised kidney tissues. Bacteriological and virological investigations are often negative.

The causes of runt development remain unknown and several possible factors may be involved. These include smoltification problems related to variation in fish size, tank capacity, uneven light regime, water quality etc. Disease, both infectious and environmental may disturb the smoltification process. Biased selection of fish may result in an inaccurate picture of smoltification status. During the sea-phase it has been observed that fish having survived IPN, PD and/or parvicapsulosis may be extremely emaciated. Stress and stress related situations probably contribute to runt development.

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 situation in 2019

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.

Submissions to the Norwegian Veterinary Institute in 2019 in which runted fish were mentioned in the disease history included 26 submissions from ongrowing farms, some of which reported long-term problems. This situation is similar to that experienced in 2018 in which 27 such submissions were received and a reduction from the level observed in 2017 and 2016 when 40 and 71 submissions were received. The diagnosis 'runted' was registered (VI statistics) in 9 ongrowing farms in 2019. This is a slight reduction from the thirteen affected farms identified in 2018. This was also a reduction from 2017 and 2016 when this diagnosis was awarded in 26 and 45 farms respectively. These statistics must be evaluated against a background of a falling number of diagnostic submissions to the Norwegian Veterinary Institute in recent years. Most diagnoses are awarded in farms in mid- and northern Norway a similar geographic pattern observed in recent years.

Annual survey

Runt syndrome scored highly for reduced growth in both ongrowing salmon and rainbow trout. Its importance as a factor related to mortality and reduced welfare was rated highly by fewer respondents (see appendix B).

Suboptimal smoltification appears to be a greater problem in in ongrowing salmon than in ongrowing rainbow trout. Smoltification problems were ranked as one of the seven most important causes of mortality and reduced growth in ongrowing salmon. Smoltification problems are considered a problem in only some ongrowing rainbow trout populations (see appendix B).

When asked to comment on smoltification problems during the juvenile production stage it would appear that there are greater problems associated with salmon compared to rainbow trout. This problem is considered the second most important cause of mortality and the third most important cause of reduced welfare (See appendix A). Respondents were also asked to comment on changes in mortality patterns during different production stages in recent years. For juvenile salmon, some respondents consider mortality to be increasing while some consider it to be reducing. Most consider the situation to be stable or don't have an opinion. The reasons for any increase are almost certainly complex with HSS (haemorrhagic smolt syndrome), skin conditions, nephrocalcinosis and yersiniosis mentioned.

Runt syndrome or smoltification problems do not appear to be increasing in frequency in ongrowing or during juvenile production and are mentioned by only a few respondents.

Comments received to the survey

Problems mentioned include challenges related to water quality, uneven growth and smoltification in large smolt production.

In ongrowing, poor smoltification, small size, poor quality smolts and/or poor timing of sea-transfer are mentioned. Skin lesions and mortality have been observed immediately following sea transfer, which indicates that poor smolt quality may be related to timing of sea-transfer and/or geography, particularly during periods of low water temperature. Some farms in Northern Norway experience cases of high mortality and runt development against a background of long transport and mixing of fish groups of varying smolt- and health- status.

Evaluation of the smolt quality and runt development situation

Smoltification problems and runt syndrome continue to be reported as serious problems, but based on data retrieved from the Norwegian Veterinary Institute and replies to the annual survey it does not appear to be increasing to any significant degree. The causes of poor smoltification and runting are often complex and difficult to define. These are important themes, however, and it would appear from comments from fish health personnel that the industry considers all smolts to be healthy. The reality under intensive farming conditions may be somewhat different.

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 farmed fish. Historically the disease has been associated mostly with rainbow trout, but 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 dilation and disruption of the tubules, with consequent fibrinous change and inflammatory reactions with occasional granulomatous changes in surrounding interstitial tissues. Calcium deposition in urinary tubules is often visible as longitudinal white stripes. The kidney may also be swollen and uneven. The changes may be extensive, such that the function of the kidney may be impaired.

Nephrocalcinosis may most probably be related to several different causes. Mineral deposits may display different consistencies, which may reflect different causes or represent different stages of the same condition. Some studies have shown that mineral imbalances in the feed can cause nephrocalcinosis, but the most frequent cause is most probably high CO_2 concentrations in the water, due to intensive culture under water-saving production forms. The mechanisms are not fully understood, but high levels of CO_2 results in changed blood values, which may lead to changed metabolic processes. The minerals then precipitate as crystals possibly during acidification of the urine. The highest recommended levels for CO_2 during the freshwater stages of salmon farming is 15mg/l, but recent research has shown that CO_2 may be injurious at lower concentrations.

Nephrocalcinosis is commonly identified in association with haemorrhagic smolt syndrome (HSS). HSS, also known as haemorrhagic diathesis (HD) is characterised by multi-organ haemorrhage typically including the tubules of the kidney, such that the fish has bloody urine. The mechanism/s behind precipitation of calcium containing deposits is/are unclear but it may be possible that damage to the kidney tubules associated with HSS results in a poorer reabsorption capacity.

Most cases are identified in pre-smolt, smolt and post-smolt. Affected fish normally recover without treatment. Extensive kidney damage does not heal and may be related to increased mortality.

Control

Nephrocalcinosis is considered an environmental problem. The risk of nephrocalcinosis development may be reduced by ensuring an adequate volume of good quality intake water and close monitoring of water quality in tanks and cages, including CO_2 and pH. Monitoring of water parameters and metabolic waste products like CO_2 must be performed with good quality equipment adapted to the tank and facility production conditions. Nephrocalcinosis may also be associated with mineral imbalances in the feed, therefore a feed adapted to the fish produced under different stages of growth and environmental conditions, may possibly reduce the chances of nephrocalcinosis development.

The situation in 2019

Norwegian Veterinary Institute data

In 2019, nephrocalcinosis was diagnosed in 118 salmonid farms by the Norwegian Veterinary Institute. Equivalent statistics for 2016, 2017 and 2018 were 107, 126 and 147 respectively. As in previous years most diagnoses were related to salmon farmed in the sea (76) with a minority in freshwater (37). Five cases were identified in broodstock.

The statistics for 2019 are an underestimate and the real prevalence is unknown. The disease is not notifiable and is diagnosed both in the field on the basis of visible clinical signs and in other laboratories. Histologically diagnosed nephrocalcinosis is often an additional finding identified during routine 'screening' investigations for notifiable diseases e.g. BKD which may result in similar clinical signs in the kidney.

Annual survey

Nephrocalcinosis in rainbow trout and salmon farmed in freshwater was considered an important cause of reduced growth, reduced welfare and mortality in this years survey. Nephrocalcinosis was ranked as the most important increasing problem in juvenile production (for details see appendix A).

Nephrocalcinosis in ongrowing farms is considered important in terms of poor growth and reduced welfare. It is considered more important in rainbow trout farming compared to salmon farming. In terms of mortality, there are a number of diseases ranked higher in ongrowing fish. Nephrocalcinosis is, nevertheless, one of the six most important diseases considered to be increasing in ongrowing production (for details see appendix B).

When asked to comment on the various water parameters considered important in relation to reduced welfare in juvenile production throughflow and RAS facilities, long term exposure to high CO_2 was considered to result in reduced welfare in both types of system by over 50% of respondents (see figure 3.4.1 and 3.5.1 in chapter 3, Fish welfare)

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 by the Norwegian Veterinary Institute throughout 2019, we have reason to believe there has been a steady increase in the prevalence of this disease in recent years, despite the slightly reduced number of cases registered in 2019. Nephrocalcinosis was considered the most important increasing disease and the second most important cause of reduced welfare in juvenile salmon production.

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 condition 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 may also be identified in large fish (1.5-4kg)

The Norwegian Veterinary Institute has registered an equivalent increase in the number of fish developing extensive, nephrocalcinosis-related chronic granulomatous inflammation in the kidney, both in freshwater and marine farms. Calcium deposition in other parts of the body e.g. stomach and pseudobranch is not uncommon.

The causes of the increasing frequency of nephrocalcinosis are uncertain, but suboptimal water quality is important for development of the disease. Increased use of RAS production systems and an increasing focus on large-smolt production, increasing louse-skirt use and increasing numbers of enclosed and semi-enclosed farms represent an increased risk of development of poor water quality and increased CO_2 levels. The influence of other factors including feed quality, should also be considered. Several new research projects focussing on nephrocalcinosis were initiated in 2019.

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. Photo: Silje Sveen, SalmoBreed

8.4 Water quality

By Åse Åtland, Paula Rojas-Tirado and Sondre Kvalsvik Stenberg, 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, however, complex and daily monitoring to a satisfactory level may be challenging. 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 second year in a row 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 were also observed in 2019. We will focus therefore 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 through-flow and RAS facilities in 2019. 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.

Hydrogen sulphide

Large scale mortality episodes in 2018 resulted in a focus on hydrogen sulphide.

Hydrogen sulphide is formed under anaerobic (absence of O2) conditions by bacterial degradation of sulphur-containing organic substances.   Seawater contains more than 1000 times more sulphate (SO4) than freshwater and the risk of hydrogen sulphide formation is therefore greater in seawater. Hydrogen sulphide related mortalities were observed in 2019 in RAS farms and in some through-flow farms. There are indications that this is related to feed and feed quality and that particle level in the farm has been a contributory factor. Effective particle control together with optimal design and sufficient water flow throughout the farm are important in eliminating the problem.

Research projects aimed at improving knowledge and identification of solutions to reduce the impact of hydrogen sulphide were initiated in 2019. The project 'Aquasulphate' (financed by the Research Council of Norway), led by NIVA with Enwa and Harding Smolt as industry partners, will investigate use of membrane filters as a means of reducing sulphate levels in intake seawater to a minimum. The results are very promising. The project has also identified the biofilter media to represent an unexpectedly significant potential for H_2S production under low oxygen conditions.

Based on the number of enquiries received by NIVA it would appear that there were fewer serious H_2S related events in RAS facilities in Norway in 2019 than in 2018. The same trend can be observed in replies to the annual survey. Only 31 % of respondents had experienced H_2S problems that had affected fish welfare negatively in 2019 compared to 57% in 2018. There is good reason, however, to maintain focus on this problem area and build more knowledge related to the acute and chronic effects on salmonids farmed in through-flow and RAS sites.

Aluminium

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. NIVA has

Figure 8.4.1. Semi-enclosed seafarm- Aquatraz cage at Kyrøyan near Rørvik (Midt-Norsk Havbruk AS). A comprehensive chemical and biological surveillance program is performed. Photo: Åse Åtland, NIVA..

observed several incidences of increased mortality and reduced appetite in relation to increased concentrations of aluminium in through-flow sites. Such events occur following heavy rainfall or snow melting, particularly after long dry periods.

In addition to problems related to toxic aluminium in freshwater through-flow sites, mixing of aluminium rich freshwater and seawater (between 1 and 10 ‰) is associated with a high risk of mobilisation of toxic aluminium. This is particularly so on use of humus rich freshwater in which aluminium is bound to organic matter. The mechanisms behind this phenomenon are well-known and were described in detail in last year's report. This type of event was also recorded in 2019.

The toxicity of aluminium in fresh- and seawater is a well-studied phenomenon and there are well documented strategies for reduction of toxicity in fish. Liquid silicate hydroxide binds aluminium and hinders mobilisation to the toxic form when mixed with seawater. The dose of silicate hydroxide must be adjusted according to the intake water quality in each farm and higher doses are required if seawater is to be mixed in. It is important to be prepared for periods of excessive water flow and to adjust the silicate dosage at the appropriate time. Increased calcium levels in the water also award the fish some protection. There is considerable room for improvement regarding such treatments, particularly in through-flow farms.

Problems with other metals

NIVA has also observed a number of cases involving increased copper concentrations which may be related to the freshwater source, from faeces, feed or from technical installations. Increased levels of zinc (Zn) during well boat transport were identified a number of times in 2019 and increased mortality has been associated with these events. 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.

Dialog between employees, fish health personnel, histologists and water chemists is a good basis for identification of preventative solutions.

Oxygenation

Lack of control of oxygen levels may lead to problems. Cases of over oxygenation last year, caused by technical failure, were associated with gill haemorrhage. This has been previously observed in land-based farms in other countries. This phenomenon is not well studied and the exact mechanisms are not understood. Oxidative stress and damage to lipid membranes is one possible explanation.

Marine farms

The opportunity for manipulation of water quality in marine farms is often limited, other than placement of cages in good sites, situated optimally in relation to prevailing currents etc. Mobilisation of toxic aluminium was again registered in 2019 in freshwater affected marine sites. Climate change and the greater risk of flooding may increase the risk of this type of event.

In response to the annual survey, it would appear that several farmers experience problems in marine sites related to use of lice-skirts involving poor water exchange and low oxygen levels. High mortality events have also been related to use of new net antifouling impregnation. There is a considerable requirement for knowledge and risk analysis prior to introduction of new antifouling substances. Use of lice-skirts increases the risk of eventual toxic events.

While introduction of new technologies and semi-enclosed farms result in new water quality challenges, these technologies have also the possibility to solve some of the water quality problems common in marine farms. Good surveillance of water quality is paramount in these farms and there remains much to learn.

Algal toxicity received significant focus in Northern Norway in 2019 and is discussed in chapter 8.5.

Summary

In summary, many of the same water quality problems observed in 2018 were again observed in 2019. A positive development was that several farms have now obtained ‘emergency water quality sampling packs’ which can be used during acute events (Figure 8.4.2). Several of the events described in the present chapter were documented following use of necessary sampling equipment which was available at the time. In this way it was possible to better establish the cause and not least gave the possibility to learn and prevent such events. Several investigations in the course of 2019 have involved cross-disciplinary cooperation between farmers, fish health personnel, pathologists, water chemists etc. This has been to the gain of all concerned and we are convinced that such cooperation is necessary to improve the water quality related health situation within the industry.

Figure 8.4.2. The 'emergency water quality sampling pack' to ensure collection of suitable samples on acute fish mortality. Such packs are present on many farms and have proven useful in resolving the water chemistry parameters responsible for fish mortality. Photo: Sondre Kvalsvik Stenberg, NIVA.

8.5 Algae and fish health

By Trine Dale (NIVA) and Geir Bornø (Norwegian Veterinary Institute)

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 to 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 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, which 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.

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*

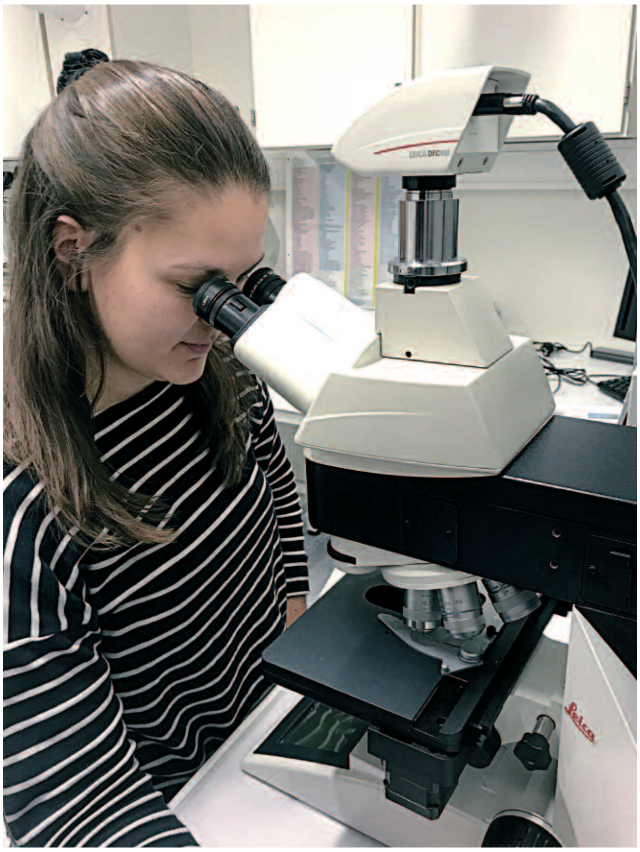


Fig. 8.5.1 Microscopy of algae at NIVA.
Photo: Sondre Kvalsvik Stenberg

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. Some time later, the same problem was 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. It is probable that many fish were saved in this manner. A continual algae surveillance program was also 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.

The photographs show boxes containing large numbers of salmon ready for transport to the destruction site following an algal bloom in Grovfjorden in Troms in May 2019. Photos: Northern Lights Salmon

8.6 Vaccine side effects

By Kristoffer Vale Nielsen, Siri Kristine Gåsnes and Ingunn Sommerset

Fish may be vaccinated by dip, bath, orally via feed and by injection. Both the effect of vaccination and the possible side effects vary according to method of administration. 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.

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 comes 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) IPN and yersiniosis.

From the 2019 survey, it would appear that vaccination against PD is normal from Rogaland in the south to (and including) Trøndelag in the north. Vaccination against ISA and other infectious diseases is performed more sporadically. The same is true for autogen vaccines. A limited number of vaccines are available for marine fish species.

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, as are iridocyclitis and autoimmune symptoms. Side effects can be painful for the fish and the degree of side-effects varies with vaccine type and variable factors including fish size at vaccination, misplaced injection, water temperature and hygiene. Vaccines against PD were until 2018 only available as oil-based injection vaccines but are now available as intramuscular DNA variants.

Figure 8.6.1 vaccinated farmed salmon in which a large number of vertebrae are deformed. Connective tissues are visible as a white 'halo' extending towards the musculature. Black spots on/in the spine in the affected area are probably melanin, which is not a normal finding in a healthy spine. Photo: Ingunn Sommerset, Norwegian Veterinary Institute

Side-effects associated with this type of vaccine are, according to the manufacturer 'temporary changes in swimming behaviour, pigmentation and loss of appetite are very common. Injury at the injection site are common'.

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 is that on balance, fish vaccines are positive for both the health and welfare of farmed fish. However, as vaccination does undoubtedly have a direct negative effect on fish welfare, there remains work to be done 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 2019

New data revealed through the Norwegian Veterinary Institute's annual survey of fish health personnel and the Norwegian Food Safety Authority, shows that a number of respondents consider that vaccine related injuries are an important welfare challenge in salmon farming. Vaccination results in reduced welfare and growth and to a lesser degree, increased mortality. As an example, 12 of 44 respondents consider vaccination to be amongst the five most important causes of reduced welfare in juvenile salmon production and 10 of 67 consider vaccination to be responsible for poor growth in ongrowing salmon (Table 8.8.1).

Nevertheless, vaccine related injuries are not considered to be increasing 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	4 of 45	4 of 35	12 of 44	0 of 32
Juvenile rainbow trout	0 of 11	0 of 8	3 of 10	0 of 6
Ongrowing salmon	1 of 72	10 of 67	8 of 72	2 of 65
Ongrowing rainbow trout	0 of 11	0 of 9	0 of 11	0 of 6

Table 8.6.2. In the table, free text replies (N=49 split into four categories):
1) Few problems with vaccines and vaccination 2) Moderate problems 3) significant problems and
4) Don't know/unclear answer.

N= 49	Total
Few problems associated with vaccines and vaccination	17
Moderate problems with vaccines and vaccination	20
Significant problems with vaccines and vaccination	5
Don't know/unclear answer	7

9 The health situation in wild salmonid fish

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

9.1 Introduction

2019 was the 'International year for wild salmon' and was an eventful year for all who are interested in wild salmonids. The program, organised by the North Atlantic Salmon Conservation Organisation (NASCO) and the North Pacific Anadromous Fish Commission (NPAFC) with participation from public authorities, research institutions and interest organisations, wild salmon were celebrated during a series of different events around the country. 2019 was a bad year in terms of escaped fish. According to Directorate of Fisheries statistics, 49 escapes were registered involving a total of 300,000 farmed salmon and rainbow trout. The primary threat from escaped salmon is cross-breeding with wild stocks, but escaped infected fish also pose a threat of transmission of disease to wild stocks.

The salmon louse is a significant threat to wild salmon, seatrout and sea-run arctic char. The red traffic light should have been turned on for the first time in the autumn of 2019 and there was significant interest in which production areas, if any, would receive this signal. The Ministry of Trade, Industry and Fisheries decision on this matter was, however delayed until 4. February 2020.

Spread of exotic species is one of the main causes of loss of international biodiversity. Such spread may result through removal and migratory barriers or changes in climate and/or habitat. The large movements are generally a result of transport of live fish, mussels or crustaceans for food, for release to the environment or for use in aquaculture. A changed biodiversity spectrum will also change the infection picture and infection dynamics in the affected ecosystem. A large influx of pink salmon was expected in 2019 and Statistics Norway (SSB) reported in January 2020 that capture of more than 19,000 pink salmon was registered in Norwegian rivers and sea during 2019.

Following declaration of freedom of infection in six rivers in the Rauma region, *G. salaris* represents less of a threat against wild salmon in Norway. However, identification of the parasite in Selvikvassdraget (river) in the Drammen infection region, the fifty-first infected river in Norway shows that the presence of the parasite in any particular river represents a threat of infection to neighbouring rivers. Norway aims to eradicate the infection from all Norwegian rivers. New introductions from abroad must also be avoided. Infections have been identified in Russian rivers near the Norwegian border in Troms and Finnmark, on the west coast of Sweden as far north as the Göta river and Klarä river which both rise in Norway (Trysil river). There has been expressed a desire to open up the migratory barriers which currently prevent Väner salmon from migrating up to Norwegian areas (the river Trysil).

Knowledge of the prevalence and importance of infectious agents and infectious diseases in wild populations is limited. Little research is carried out in this field and the little that is carried out 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 tact with this interest. Movement of fish from anadromous farming to inland farming involves the risk of introduction of new infectious agents to these ecosystems.

During the summer of 2019, dead and diseased wild salmon were found in the river Enningdalselva in Østfold. The salmon displayed 'rash'-like bleedings and skin lesions. In the course of the summer, fish displaying similar symptoms were examined from several Norwegian rivers and reports of a similar condition were received from Scotland, Ireland, Sweden and Denmark. In Sweden, Finland and Russia a similar condition has been registered over the last 4-5 years. In November 2019, researchers and animal health officials from Norway, Sweden, Denmark, Finland, Ireland, Scotland, England and Russia gathered in Oslo for a workshop on this theme. The aim of the workshop was to identify whether it is the same disease in all the countries involved and to discuss possible causes.

Several of the affected countries have carried out extensive investigations without identifying the cause. While an infectious aetiology cannot be completely ruled out, no recognised infectious disease has yet been identified. The workshop participants agreed to name the disease 'red skin disease' due to the diffuse skin lesions.

The Norwegian Veterinary Institute is the nationally responsible body for diagnosis of disease in wild fish. The Norwegian Veterinary Institute does not, however, possess the field personnel necessary to monitor the health situation in wild fish. We are therefore dependent on members of the public, councils, environmental authorities etc. to contribute both samples and information. On suspicion of notifiable, infectious, disease it is the Norwegian Food Safety Authority who have the responsibility and must be contacted. In cases of non-notifiable diseases there is a need for local coordination and collation of information to help in identification of the cause such that preventative or avoidance measures may be initiated. It is almost impossible for a layperson to evaluate whether a wild fish has died of a notifiable or non-notifiable disease. It is therefore recommended that the Norwegian Food Safety Authority or the Norwegian Veterinary Institute is contacted.

Salmon louse. Photo: Trygve Poppe.

9.2 News from the diagnostic service

Some examples from the Norwegian Veterinary Institute diagnostic service for wild fish in 2019.

Mortality amongst salmon returning to Enningdalselva (Berbyelva).

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. On the 22nd of May 2019, prior to the start of the angling season, sick and dying freshly sea-run salmon (5-15kg) were found. The first fish to arrive at the Norwegian Veterinary Institute for post-mortem was received on the 24th May (Figures 9.2.1 and 9.2.2).

Subcutaneous haemorrhages on the abdominal surfaces were observed in the absence of other symptoms. Extensive sampling and analyses for bacteria, virus and tissue changes (histology) were performed. Muscle and liver tissues were also taken for toxicological analysis. To ensure good quality samples, researchers from the Norwegian Veterinary Institute travelled to the affected river on the 31st May. Sick salmon held in tanks on the riverbank were sampled immediately after euthanisation. Microscopy of skin and gill mucus was performed on site. Unsurprisingly, some single celled parasites were identified as these are a normal finding in wild salmon. A total of nine salmon were examined without identification of the cause of disease. All the affected fish were in otherwise good condition and all were wild (according to scale and genetic testing). Possible causes include predation, poisoning and malnutrition in the sea.

Figure 9.2.1: salmon from Enningdalselva with skin lesions. Photo: Brit Tørud, Norwegian Veterinary Institute.

Figure 9.2.2. Post mortem examination of salmon from Enningdalselva. Photo: Brit Tørud, Norwegian Veterinary Institute.

As the summer progressed, the water level in the river decreased, the number of fish present in the river decreased and fewer spawning salmon were observed.

During the course of the season, 37 salmon and 8 seatrout were captured without any signs of skin disease while between 50 and 60 sick and dying spawning salmon were found. According to anglers reports, the dead fish displayed fungal infections. No dead or diseased juvenile salmon or diseased fish of any other species were observed. Salmon (30) caught at a commercial salmon netting station in the fjord into which the affected rivers runs, did not display signs of the disease.

The river Sandvikselva

Shortly after identification of sick and dying salmon in Enningdalselva, reports of sick salmon were received from the river Sandvikselva in Bærum. All fish ascending the river are videotaped and no abnormal fish were observed. Nevertheless, sick fish were subsequently observed in the river. As in the Enningsdalselva case, fish displaying skin pathologies did not display signs of disease in the inner organs, and no cause could be identified for the skin changes. Only naturally-occurring bacteria and fungi were identified. Seatrout with skin haemorrhages were identified in August and the number of such fish increased over the course of the autumn. This is an almost annual occurrence and the diagnosis 'ulcerative dermal necrosis' has been awarded previously.

During the course of the summer, the Norwegian Veterinary Institute received reports of dead salmon

Photo 9.2.3. Salmon from Enningdalselva, probably bitten by a seal. Photo: Brit Tørud, Norwegian Veterinary Institute

Table 9.2.1.

River	Reported to Norwegian Food Safety Authority	Total reported	Received by VI	Resultats	Comments
Enningdalselva, Østfold	23.05	Ca. 50 dead, 37 salmon and 8 seatrout	9	No recognised disease identified	
Sandvikselva, Akershus	05.06	9	5. June: 1 morbid 17. July: 1 dead 4 September: 3 dead seatrout and 1 alive with skin haemorrhage	No recognised disease identified	
Tovdalselva, Aust Agder	07.06	few	1	No recognised disease identified	
Bjerkreimselva, Rogaland	10.06	few	4	No recognised disease identified	«Healthy» fish but displaying skin changes

displaying skin lesions from many rivers along the south coast of Norway. Only individual fish appeared to be affected. F0llowing encouragement from the Norwegian Food Safety Authority anglers sent in photographs of spawning salmon with skin lesions or skin haemorrhages. The Norwegian Veterinary Institute received photographs from many rivers. Four salmon subsequently sampled from the Bjerkreimselva, examined by the Norwegian Veterinary Institute, could not be diagnosed with any specific disease.

Furunculosis in the river Namsen

Furunculosis is a notifiable disease of salmon caused by the bacterium *Aeromonas salmonicida* subsp. salmonicida. The Norwegian Veterinary Institute receives submissions of wild salmon suffering furunculosis from Namdal in Trøndelag almost annually and the mortality levels can vary.

Outbreaks of furunculosis generally occur when water temperatures are high and water levels low during the summer when the fish are concentrated in pools or are stressed in some other way.
During the summer of 2019, as in the previous year, outbreaks of furunculosis were registered in the rivers Sandøla, Bogna, Ferga and Austerelva in Namdalen. Water temperatures of 23-25°C were registered. Around 550 dead salmon were retrieved from the rivers. Juvenile fish were also found dead but not submitted for investigation in the river Ferga.

Salmon submitted to the Norwegian Veterinary Institute for diagnosis displayed pathological changes in the skin and inner organs. A. salmonicida subsp. salmonicida was cultured from affected fish.

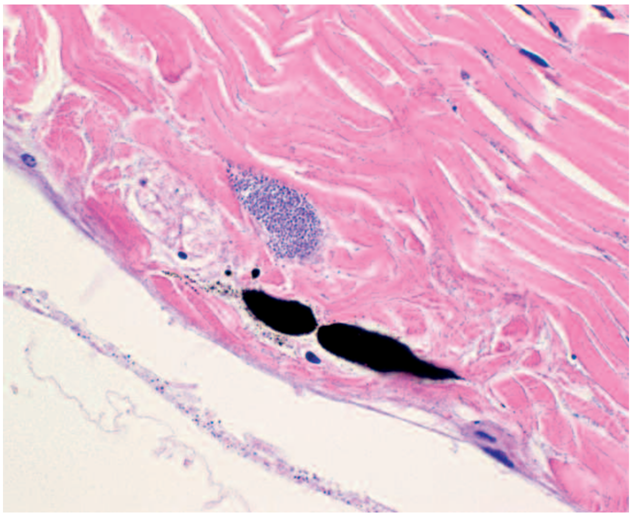


Figure 9.2.4 Microcolony of furunculosis bacteria in the skin of wild salmon.
Photo: Toni Erkinharju, Norwegian Veterinary Institute.

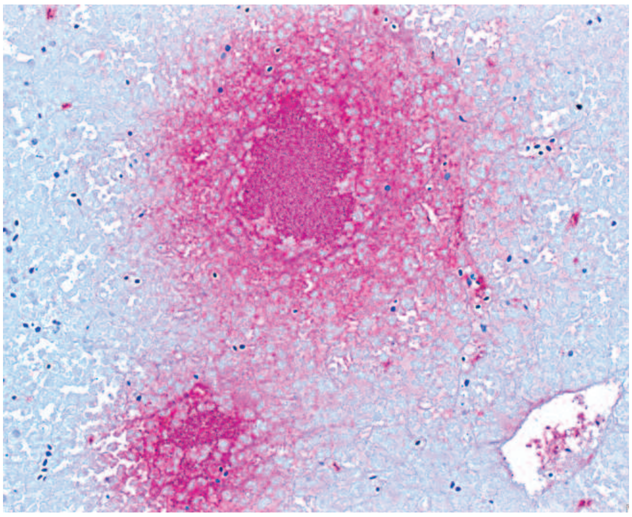


Figure 9.2.5 Positive immunohistochemical staining of *Aeromonas salmonicida* colonies in the liver of wild salmon. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

9.3 Health surveillance in wild salmonids

The Norwegian Food Safety Authority surveillance programme for the health status of wild anadromous salmonids aims to map the prevalence of infectious agents in wild anadromous salmonid fish populations (salmon, seatrout and arctic char).

Various viruses cause pathological changes in the heart of farmed salmonids, including piscine orthoreovirus 1 (PRV-1), which causes heart and skeletal muscle inflammation in salmon; piscine orthoreovirus 3 which causes HSMI-like disease in rainbow trout; piscine myocarditis virus which causes cardiomyopathy syndrome in salmon and salmonid alphavirus which causes pancreas disase in salmon, rainbow trout and char. Investigation of farmed fish has revealed that several types of virus may be present in individual fish, resulting in complicated pathologies. Atlantic calcivirus (ASCV) is little studied, but has been identified during diagnostic investigations of farmed fish. The absence or presence of this virus in wild fish could shed light on its epidemiology and importance for development of disease.

The health surveillance programme for 2019 aimed to map the occurrence of co-infections with ASCV, PRV-1, PRV-3, PMCV and SAV in wild-caught Atlantic salmon and seatrout. Recent invasions of pink salmon made inclusion of that species also relevant for this programme.

Multiplication and spread of infectious agents in farming can be of importance to wild fish. Escaped farmed fish, living in the same environment as wild fish represent potential sources of infection. Escapee farmed salmon and rainbow trout captured during health surveillance activities were included in this work. The material included fish caught in rivers and in netting stations in the sea, as well as brood stock from restocking hatcheries and the gene bank for wild salmon. PCR-analyses were generally performed by Patogen AS. Analysis for ASCV was performed by NMBU. Scale analyses were performed by the Norwegian Veterinary Institute and genetic analyses (speciation and genetic origins P(wild) of selected material) were performed by the Norwegian Institute for Nature Research (NINA). Table 9.3.1 summarises the results following investigation of sea-caught salmon along the whole coastline from Finnmark to Østfold in 2019.

Table 9.3.1. «The table shows the prevalence of PRV-1, PRV-3, PMCV, SAV and ASCV, amongst 163 wild, sea-caught salmonid fish in 2019.The material included one escaped rainbow trout and five farmed salmon, two of which had been identified by scale analysis and three by genetic testing.

Wild, sea-caught salmonifd fish		Number analysed	Positive				
			PRV-1	PRV-3	PMCV	SAV	ASCV
Salmon	Wild	136	2	1	0	0	0
	Restocking	7	0	0	1	0	0
	Farmed	5	2	0	0	0	0
Seatrout	Wild	14	0	6	0	0	0
Rainbow trout	Farmed	1	0	1	0	0	0
Total		163	4	8	1	0	0

* Two farmed fish identified by scale analysis and three by genetic testing. The latter have therefore a 'farmed' pedigree, but were spawned in a river.

The study did not reveal any viral co-infections in wild-caught fish and with the exception of PRV-3, the prevalence of viruses within the material was low. Six of 14 seatrout caught in the sea were, however, positive for PRV-3 as were one wild salmon and the single rainbow trout. PMCV was also identified in one wild salmon originally released from a restocking hatchery. PRV-1 was identified in two of 136 wild salmon and in two of five farmed salmon examined. Two of the farmed salmon were identified by scale analyses and can therefore be classified as escaped fish. Both were PRV-1 positive. Three salmon displayed scale growth rings consistent with wild salmon, but were confirmed to be of farmed origin by genetic testing. None of these fish carried virus. ASCV and SAV were not identified in the material. The results from the pink salmon are discussed in a section devoted to this species. For comprehensive summary of all investigations and results see the report which will be published and submitted to the Norwegian Food Safety Authority later in the year.

9.4 The health situation in the Gene bank for wild salmon

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

As part of the conservation work and collection for the gene bank for wild salmon, health controls are carried out on candidate broodstock. This control is based on post-mortem and testing for relevant infectious agents which may transmit from parent to offspring. 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. All wild salmon broodstock taken into the gene bank in 2019 were tested for the presence of infectious pancreatic necrosis virus (IPNV), *Renibacterium salmoninarum* (BKD) and *Piscine myocarditis* virus

Figure 9.4.1. Post mortem of wild broodstock salmon 2019. Photo Vegard P. Sollien, Norwegian Veterinary Institute

(PMCV) and *Piscine orthoreovirus* (PRV-1). All seatrout were tested for Piscine orthoreovirus (PRV-3). The three last agents are tested to avoid vertical transmission i.e. from parent to offspring via roe and milt.

In 2019, 346 salmon and 176 seatrout were examined. IPNV and *R. salmoninarum* were not detected. All salmon were confirmed to be of wild stock by scale testing (VI) and genetic testing (NINA).

Table 9.4.1. Results after PCR-analysis for *Renibacterium salmoninarum* (BKD), infectious pancreatic necrosis virus (IPNV), piscine myocarditis virus (PMCV) and Piscine orthoreovirus 1 (PRV-1, salmon) and 3 (sea-trout, PRV-3) performed on wild-caught broodstock destined for the gene bank for wild salmon and seatrout. Some analyses are not yet complete.

Region	Salmon	Seatrout	Comment
Nordland	17		1 salmon positive for PRV-1
Trøndelag	32		
Møre og Romsdal	160		28 salmon positive for PRV-1
Hordaland	53	176	2 salmon positive for PRV-1, 14 seatrout positive for PRV-3
Buskerud	84		
Total	346	176	

Parasites of wild caught broodstock

Gill lice (*Salmincola salmoneus*) and tapeworm (*Eubothrium* sp.) are normal findings in wild broodstock. The gill louse is a parasite on the gills of salmonid fish in freshwater. It is commonly registered in wild caught broodstock and may cause considerable damage (Figure 9.4.2)

Figure 9.4.2 Gill louse (*Salmincola salmoneus*) on wild caught broodstock. Photo: Jan Arne Holm

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.

The Rauma region- Declaration of freedom of infection

The infected Rauma region includes the river Rauma and its tributaries Istra, Isa and Glutra (Hensvassdraget), Breivikelva, Skorga, Innfjordelva and Måna. *G. salaris* was identified initially in the Hensvassdraget as early as 1978. The parasite then spread to the Rauma in 1980 and on to the other rivers in the watershed. The rivers in the Rauma region were rotenone treated in September 1993. *G. salaris* was again identified in 1996. Rotenone treatments were repeated in 2013 and 2014. In 2019, all rivers in the Rauma region were declared free of *G. salaris* infection.

Surveillance for *G. salaris* in Norway in 2019

The Norwegian Veterinary Institute coordinates two 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). See https://www.vetinst.no/overvaking for more detailed information (In Norwegian).

During the Ok-programme for *G. salaris* in 2019, 3095 salmon and rainbow trout from 94 farms and 2297 salmon from 71 rivers were examined. *G. salaris* was detected for the first time in one river, the Selviksvassdraget in Vestfold region. The parasite was not identified in any hatchery or restocking hatchery in 2019.

During the FM-programme, 1452 juvenile salmon were examined from 11 rivers, originating from the infected regions Vefsna (one river), Rauma (six rivers), Skibotn (three rivers) and Rana (one river). G. salaris was not identified in any of these rivers.

Infection status

Of the originally 51 infected rivers, 8 remain infected at the start of 2020. Six rivers are currently under post treatment surveillance.

Eradication and method development 2019

No eradication operations were performed in 2019. Work

Figure 9.5.1 Inger Mette Hogstad of the Norwegian Food Safety Authority, presents the 'Freedom of infection' report for the Rauma region to Minister for the Environment Ola Elvestuen. Photo: Mari Press, Norwegian Veterinary Institute.

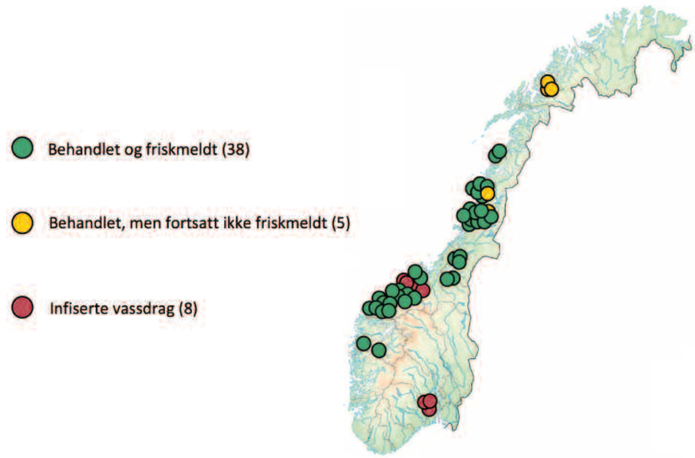


Figure 9.5.2. Current distribution of *Gyrodactylus salaris* in Norway January 2020.

related to preservation, planning and surveillance continues in the remaining two infected regions.

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 will be present above the barrier. After this time treatment may be performed below the barrier in the knowledge that the area above the barrier is free for salmon (and *G. salaris*). The barrier was completed in 2017 and chemical treatment is planned for 2023 and 2024. The method of treatment has not yet been decided upon. Hydrological surveys were started in 2019 as part of the pre-treatment planning.

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.

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 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. The Norwegian Veterinary Institute has, since 2016, collected salmon from this area for the Gene bank for wild salmon. In 2019, the salmon ladder at Hellefoss was closed and the traditional restocking program for wild salmon cancelled.

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 were performed in the Driva in 2019 to investigate the toxicity of chlorine at concentrations and exposure times relevant for *G. salaris* treatment. New dosage equipment for chlorine treatment was also tested on a large scale. Chlorine, as monochloramine, was administered to the river using river flow-managed dosing pumps over a six-day period. The chemicals were administered at the migratory barrier in the river Driva and the chlorine concentrations in the water measured at several sampling stations downstream. Preliminary results indicate that the dosing equipment worked well and that the trial could be considered successful.

9.6 The traffic light system and wild salmonid fish

Salmon lice infestations in wild salmon smolts as a sustainability indicator

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 for the risk of mortality in wild salmon resulting from salmon lice infection originating in farmed salmon.
Figure 9.6.1 summarises the expert group's conclusions for the 13 production areas for the period 2016-2019.

Based on the expert group's evaluation in 2018 and 2019, a steering group consisting of representatives from NONA, the Institute for Marine Research and the Norwegian Veterinary Institute has advised the Industry, Trade and Fisheries Department (NFD). The NFD's final decision, based on scientific advice from the steering group, short-term trends in lice numbers and a socio-economic analysis, was published on 04.02.2020. PO3, which the steering group considered to represent a risk of over 30% mortality amongst wild salmon smolts, was awarded 'amber' status. Two areas considered to represent a risk of between 10 and 30% wild smolt mortality were awarded 'green' status.

Areas awarded 'green' status are now given the opportunity to expand production by 6% (around 33,000 tons), while areas awarded 'red' status must cut production by 6% (around 9,000 tons). 'Amber' areas remain at current production levels. Production legislation § 12, provides the possibility for increase in production (or dispensation from reduction) independent of traffic light colour. This is on condition that no more than one medicinal delousing treatment has been performed on a particular farm during the previous production cycle and that the number of lice has been held under a defined level for a defined period. This dispensation scheme is considered to be a driver for increased use of non-medicinal delousing and as a means of avoiding production decrease or allow production increase.

All non-medicinal delousing methodologies pose welfare challenges for the treated fish (See chapter 3. Fish Welfare). There are also grounds to question the degree to which repeated stressful non-medicinal delousing affects shedding of infectious agents and thereby increasing the infection pressure within the local environment. There is a requirement for establishment of a battery of sustainability indicators, which together, will provide the best steering system for the authorities.

Photo: Siw Larsen, Norwegian Veterinary Institute.

Figure 9.6.1 Low risk = <10% salmon louse induced mortality in wild salmon smolts, moderate risk = 10-30% salmon louse induced mortality in wild salmon smolts

Production area	2016	2017	2018	2019
1.Swedish border - Jæren	Low risk	Low risk	Low risk	Low risk
2. Ryfylke	Moderate risk	Low risk	Moderate risk	Low risk
3. Område Karmøy to Sotra	Low risk	Low risk	Low risk	Moderate risk
4. North- Hordaland to Stadt	Moderatee risk	Low risk	Moderate risk	Low risk
5. Stadt to Hustadvika	Moderate risk	Moderate risk	Moderate risk	Low risk
6 Nordmøre - Sør-Trøndelag	Moderate risk	Low risk	Low risk	Low risk
7 Nord-Trøndelag to Bindal	Moderate risk	Low risk	Moderate risk	Low risk
8 Helgeland - Bodø	Low risk	Low risk	Low risk	Low risk
9 Vestfjorden and Vesterålen	Low risk	Low risk	Low risk	Low risk
10 Andøya - Senja	Low risk	Low risk	Low risk	Moderate risk
11 Kvaløya - Loppa	Low risk	Low risk	Low risk	Low risk
12 West-Finnmark	Low risk	Low risk	Low risk	Low risk
13 East-Finnmark	Low risk	Low risk	Low risk	Low risk

Salmon lice infestation in seatrout as a sustainability indicator

The salmon louse is a considerable threat to seatrout. Seatrout migrate only short distances from their river mouth of origin, often in close proximity to salmon farms and are thereby exposed to salmon louse infection. The marine phase of their lifecycle is important in terms of nutrition, development and reproduction. Both acute mortality and early return to freshwater as an avoidance tactic (to remove the lice) have an important detrimental effect on seatrout populations. The Department for trade, industry and fisheries has asked the expert group to evaluate the effect of salmon lice on seatrout as a new sustainability indicator in the traffic light system. The expert group has stated that it is natural that the effect of salmon lice on seatrout be included in the system and are now evaluating methodology for calculation of the two factors ‘reduced marine range’ and ‘reduced marine period’ in seatrout in relation to salmon louse infections of farm origin.

The Scientific Commission for Atlantic salmon management (VRL) evaluated the state of 430 seatrout populations in 2019. Of these, 91% were affected by salmon lice. Other important threats include factors limiting seatrout production areas, including hydro electrical developments, agriculture and transport amongst others. Overfishing was also a problem in several populations.

Salmon lice and sea-run arctic char

In southern Norway, arctic char for the most part, complete their lifecycle in freshwater. In northern Norway, they perform short migrations to seawater to build energy stores prior to maturation, spawning and overwintering in freshwater. Sea-run arctic char can double their weight in the course of a one-month sojourn to sea. Increased farming activity in open cages in Troms and Finnmark can increase the salmon louse infection pressure on sea-run arctic char. Sea-run arctic char are a susceptible host for the salmon louse, but the extent to which this type of fish is damaged by salmon louse infection is less well studied.

The Institute for Marine Research published an experimental study in 2019 utilising farmed arctic char. The study showed that, as in salmon and seatrout, an increasing louse burden caused osmotic balance problems in the seawater-held char, which led to death. The study also revealed that even low salmon louse burdens led to reduced growth in infested char. Increased louse burdens almost certainly reduce the advantages of sea-migration through osmotic balance disturbance, growth, survival and reproduction.
(For details see: https://doi.org/10.1093/conphys/coz072).

9.7 Topical

Pink salmon

Pink salmon are not native to Norway but are now present in several Norwegian rivers following their release in Russia. Pink salmon are black-listed by the Norwegian Biodiversity Information Centre. Their release in Russian rivers running into the White- and Barent –seas ceased in 2000. The species has a two-year life cycle, which leads to the existence of two separate genetic populations, one of which spawns in even years and the other in odd years. Since the odd year population is most numerous in Norway, a new invasion was expected in 2019.

The Norwegian Scientific Committee for Food and Environment (VKM) has evaluated the risks related to the pink salmon invasion on behalf of the Norwegian Food Safety Authority and The Environment Agency. The main conclusions were that the invasion of pink salmon will have negative consequences related to biodiversity, productivity of local salmonid fish populations and aquaculture. They also conclude that a broad regional and international effort is required to reduce the impact and range of pink salmon. Pink salmon were included in Norwegian angling statistics for the first time in 2019. Statistics Norway report that over 19,000 pink salmon were registered last year with 13912 (21 tons) and 5710 (11 tons) captured in the sea and in freshwater respectively. According to the Scientific Committee the majority of fish are now captured further west and south compared to 2017, such that the area now includes west-Finnmark and northerly areas of the region formerly known as Troms region.

Little is known of the possible effects of pink salmon on the health of farmed and wild salmonid species. It is feared that pink salmon may introduce and spread infectious diseases to farmed and/or wild salmonids, contracted in nature or following their migration pathways past Russian or Norwegian fish farms. To contribute to the knowledge base, the Norwegian Veterinary Institute sampled pink salmon from the river Karpelva in Finnmark. This location was chosen to increase the probability of including eventual infected individuals originating from Russian rivers. 1314 pink salmon were reported caught in the river Karpelva between 6 July and 28 August 2019. An additional 98 Atlantic salmon, 94 seatrout and 40 sea-run arctic char were caught and released. Similar statistics are reported from neighbouring rivers in East-Finnmark.

As shown in Table 9.7.1 notifiable infectious agents were not identified (VHS, IHN, ILAV, *R. salmoninarum*). Piscine orthoreovirus-1 (PRV-1) was identified in 4 individuals, traces of *Desmozoon lepeotheirii* in 2 and nematodes in a few.

Agents	# positive (Ct-verdi)	Comments
Viral hemorrhagic septicaemia (VHS)	0	Norwegian Food Safety Authority surveillance program for VHS/IHN PCR analyses performed on kidney/ myocardium*/ spleen of Norwegian Veterinary Institute
Infectious hematopoietic necrosis (IHN)	0	
Piscine myocarditis virus (PMCV)	0	Norwegian Food Safety Authority surveillance program for wild salmonids PCR-analyses x 3 for SAV, PRV-1, PRV-3 and PMCV performed on myocard* by Patogen AS
Piscine orthoreovirus-1 (PRV-1)	4 (24,2-35,2)	
Piscine orthoreovirus-3 (PRV-3)	0	
Salmonid alphavirus (SAV)	0	NMBU performed
Atlantic salmon calicivirus (ASCV)	0	PCR-analysis for ASCV
Infectious salmon anaemia virus (ISAV)	0	PCR performed on kidney/ myocard* /spleen by Norwegian Veterinary Institute (project/ Emerging diseases)
Renibacterium salmoninarum	0	
Parvicapsula pseudobranchicola	0	
Salmon gill poxvirus (SGPV)	0	PCR analysis performed on gill by Norwegian Veterinary Institute (project Emerging diseases)
Desmozoon lepeophtherii	2 (Ct-32,5-36,3**)	
Paramoeba perurans	0	
Branchiomonas cysticola	0	

*Sample material from a pink salmon lacked myocard (kidney used in survellance-wild fish)

** Analyses repeated in triplicate when Ct-values lay between 32.5-36.3.

The Norwegian Veterinary Institute received samples from 60 mature pink salmon of which 19 were females and 41 males. The material was included in the Norwegian Food Safety Authority surveillance and control programs for infectious hematopoietic necrosis virus (IHNV) and viral haemorrhagic septicaemia (VHSV) and the health surveillance program for wild anadromous salmonid fish. The pink salmon were also investigated for the presence of other relevant infectious agents.

As shown in Table 9.7.1 no notifiable infectious agents (VHS, IHN, ILAV, R. salmoninarum) were identified. Piscine orthoreovirus-1 (PRV-1) was, however, identified in four individuals , traces of Desmozoon lepeotheirii in two individuals and nematodes in a few individuals.

Marte Andrea Fjær, an MSc student at the University of Bergen, published in 2019, an extensive survey of infection status in 80 pink salmon caught in 3 rivers in Hordaland in 2017. *Parvicapsula pseudobranchicola* was detected by PCR in pseudobranch samples and *Desmozoon lepeophteirii* was identified in the gills. Viral infections (IPNV, ISAV, PMCV, SAV, IHNV, PRV-1) were not identified. A number of macroparasites were identified at similar prevalence in all three rivers and at a similar level as reported from pink salmon in Russia.

Transmission of disease by escaped farmed fish?

According to the Directorate for Fisheries statistics, 49 escapes were reported in 2019 involving 290,000 farmed salmon, 2,000 rainbow trout and 7,500 cod. This is a serious blow to the industries 'zero-tolerance' vision regarding escapes.
The challenge with escaped farmed salmon is primarily related to cross-breeding with wild salmon and interference in their genetic integrity. Rainbow trout is an exotic species to Norway and can potentially establish reproducing populations in nature. Both species represent a risk for spread of infection. Research performed by The Institute for Marine Research and the Norwegian Veterinary Institute show that escaped farmed fish carry disease to a greater degree than wild salmon. Several escapes in the autumn of 2019 involved sick and infected stocks of fish. Strategic barriers and intensive fishing efforts were initiated, but what happens to the fish that were not recaptured?

Figures 9.7.1 - 9.7.3 show an escapee farmed salmon that has survived a considerable period in nature following its escape. This fish was captured in the upper reaches of the river Eira and was at the time of capture, visibly sick. It was observed swimming in circles and scale pocket oedema, a sign of circulatory disturbance, was observed. Both scale analysis and genetic testing confirmed that this was an escaped farmed fish. Scale analysis also confirmed that this fish was a serial spawner and had spawned several times previously. The fish was frozen before post-mortem investigation and was therefore not suitable for histopathological analysis. The post-mortem investigation confirmed vaccine related side-effects in the peritoneal cavity, circulatory disturbance and that the salmon was sexually mature. Piscine myocarditis virus (PMCV) was identified, but the diagnosis cardiomyopathy syndrome could not be confirmed as this diagnosis is dependent on histopathological analysis. The question remains as to when and where this salmon became infected with PMCV? Has it transmitted the infection to wild salmon in the river or to its own offspring? How many offspring are there and how many ex-farmed fish live such a life?

Figure 9.7.1: An escaped farmed fish from the river Eira at a weight of 16 kg and length 111 cm. Photo. Theodor Isaksson

Figure 9.7.2. Scale pocket oedema i.e. gathering of fluid in the scale pocket due to circulatory disturbance. Photo: Theodor Isaksson

Figure 9.7.3 Post mortem examination of escaped farmed fish from the river Eira revealed vaccine related side-effects in the peritoneal cavity, swollen spleen and visible gonads. Photo: Mona C. Gjessing. Norwegian Veterinary Institute.

10 The health situation in cleaner-fish

By Toni Erkinharju, Geir Bornø, Synne Grønbech, Snorre Gulla and Haakon Hansen

Large numbers of wild-caught and farmed cleaner-fish have been used in recent years in the fight against the salmon louse. In Norway in 2019, a total of 49.1 million cleaner-fish were utilised of which 22.6 million were lumpsucker, according to the Directorate for Fisheries. All lumpsucker used as cleaner-fish are of farmed origin, while most of the wrasse species used are wild caught.

The most commonly used wrasse species are goldsinny, corkwing, Ballan and to a lesser degree rockcook. Lumpsucker are considered easier to farm and have a much faster developmental cycle compared to the wrasse species. Wrasse are also less active and thereby eat fewer lice at lower water temperatures. Lumpsucker are therefore more commonly used in the north of the country.

Wrasse fisheries are regulated and based on fyke netting or fish traps 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 involve 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 which result directly or indirectly as a result of handling, skin lesion development and several bacterial diseases. Lumpsucker in particular appear susceptible to a number of pathogenic agents often present in mixed infections, which may make identification of the primary cause difficult.

Figure 10.1. Lumpsucker (*Cyclopterus lumpus L.*). Photo: Rudolf Svendsen, UW

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., *Pseudomonas anguilliseptica* and *Vibrio ordalii*. 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. *A. salmonicida* infection commonly manifests as a chronic disease with multi-organ granuloma and ulcer development. Two genetic variants of the bacterium dominate amongst Norwegian cleaner fish (A-layer types V and VI). The notifiable infection caused by *A. salmonicida* subsp. *salmonicida* was diagnosed in lumpsucker used as cleaner-fish in Trøndelag in 2015 and 2016, but has not been identified since.

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 lumpsucker. More than 20 serotypes have been described but serotypes O1 and O2 (including sub-types of O2) are most common in Norway.

Pasteurella sp. (as yet undescribed to species level) is a pathogen of lumpsucker in Norway and Scotland. Pasteurellosis is a systemic infection and macroscopic signs include caudal fin erosion, skin lesions (white spots), gill haemorrhage, haemorrhage at fin bases and

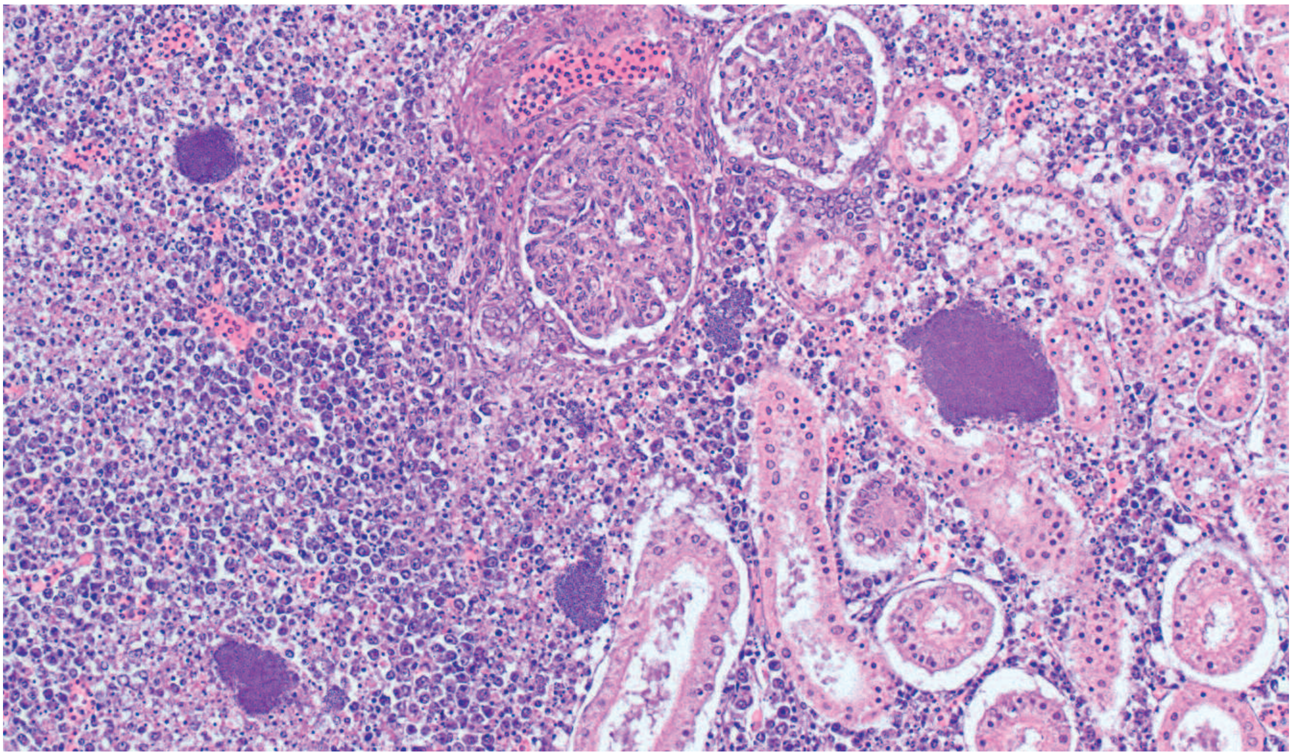


Figure 10.2. Necrosis and micro-colonies of rod-shaped bacteria in the kidney of lumpsucker with atypical furunculosis. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

ascites. Outbreaks may occur during the hatchery and marine phases and mortality can be extremely high, occasionally approaching 100%.

Pseudomonas anguilliseptica is an opportunistic fish pathogen and was identified for the first time in Norway in lumpsucker in 2011. The number of affected localities has increased significantly in later years. The infection manifests normally as a haemorrhagic septicaemia.

Vibrio ordalii causes atypical vibriosis which 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 lumpsucker. *Tenacibaculum* sp. has been isolated from several cases of 'Crater disease' in lumpsucker but it has not been confirmed as the aetiological agent.

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.

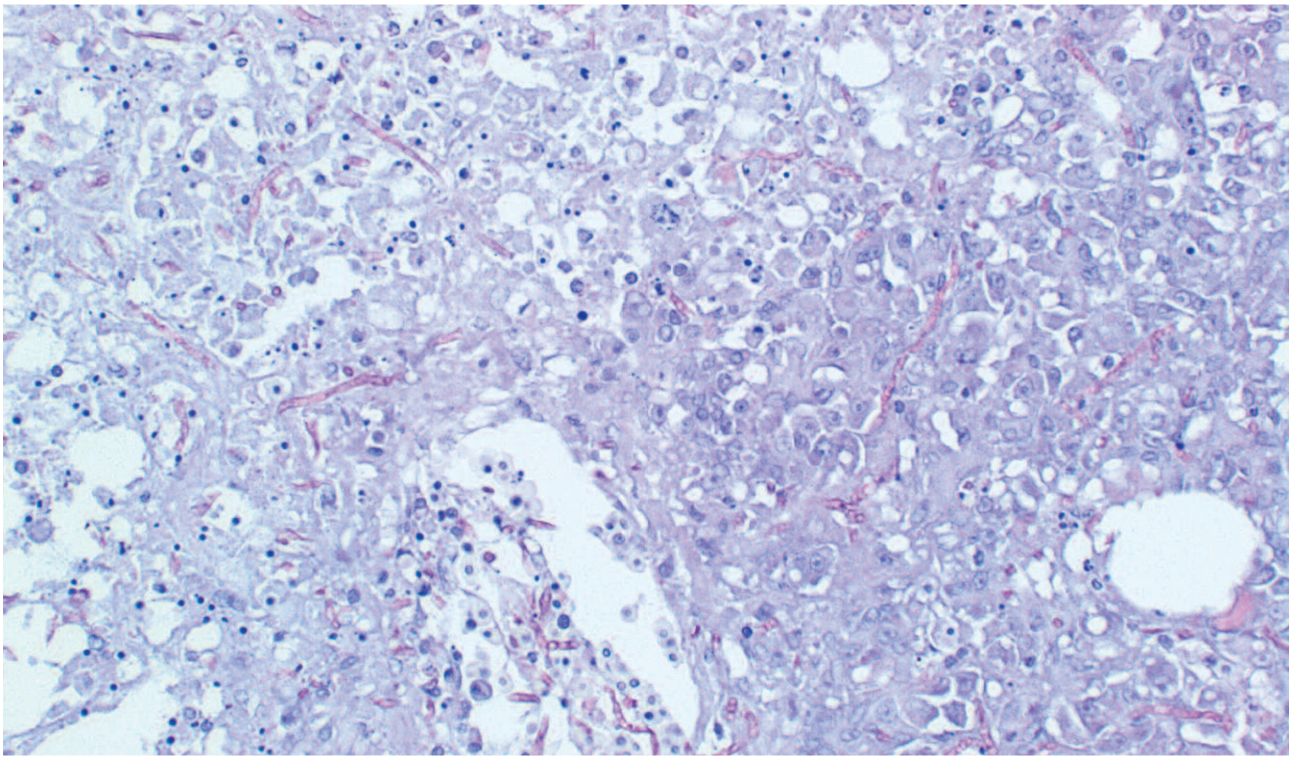


Figure 10.3. Fungus infected liver in lumpsucker. PAS staining. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

Fungal infections

Fungal disease occurs sporadically in cleaner fish. Increased mortality has been reported in lumpsucker 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 lumpsucker in Norway.

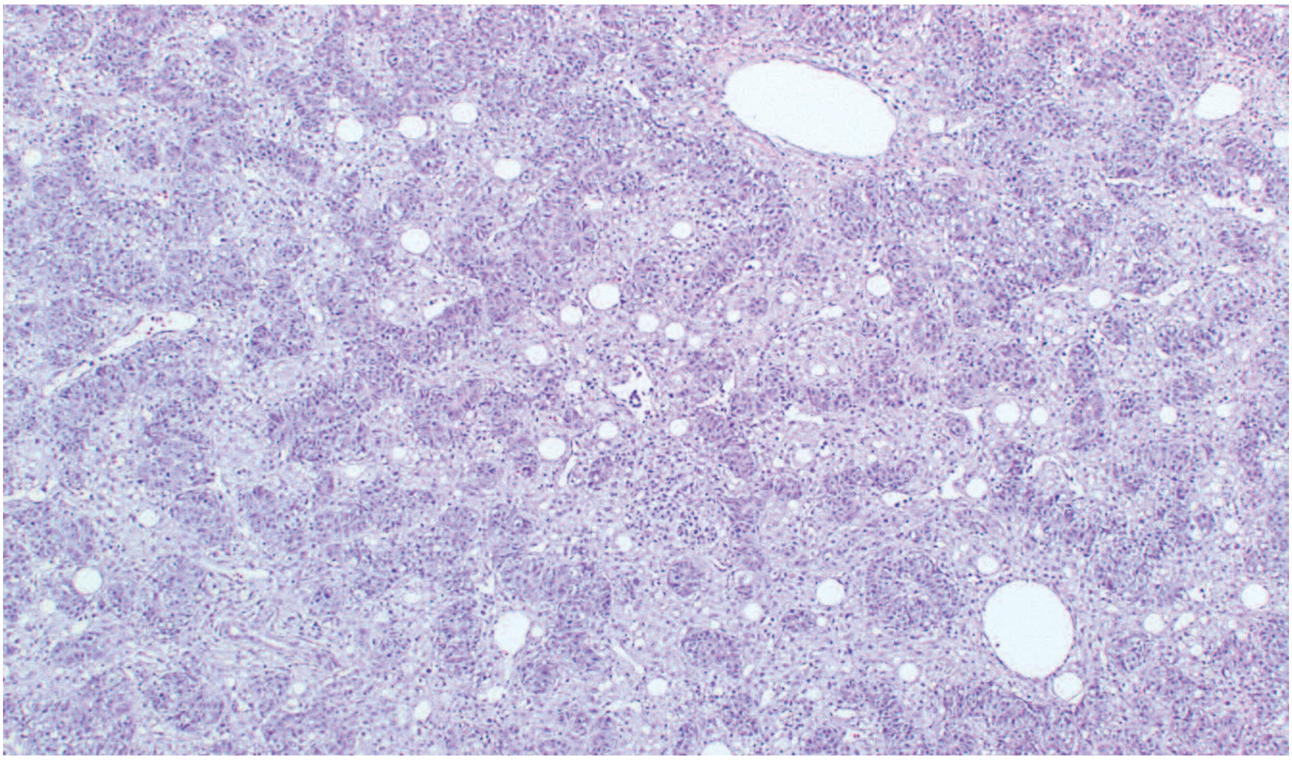
Virus

A virus belonging to the family Flaviviridae, called cyclopterus lumpus virus (CLuV) or lumpsucker flavivirus, has been reported widely since 2016, with a gradual reduction this last year. On a national level, the virus has posed one of the most significant health threats to farmed lumpsucker, particularly during the hatchery stage. High associated mortalities have been reported.

The liver appears to particularly affected with massive necrosis of hepatocytes associated with the infection. In chronically infected fish, the liver appears more cirrhosis-like. The virus is present along the entire Norwegian coastline. The Norwegian Veterinary Institute does not currently have diagnostic capability for this disease.

Other types of virus have been recently reported from lumpsucker, including a new ranavirus in Ireland, Scotland, the Faroe Isles and Iceland. 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 lumpsucker. The virus has not been identified in Norway. In 2018, two new viruses were described from sick lumpsucker 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 lumpsucker farming is unknown.

It has been shown experimentally that lumpsucker may be infected with nodavirus and that lumpsucker and



Figur 10.4. Nekroser i lever hos rognkjeks med flavivirusmistanke. Bilde: toni Erkinharju, Veterinærinstituttet.

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 lumpsucker 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. None of these viruses have been reported in lumpsucker.

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 lumpsucker. 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 lumpsucker farmed on land in tanks. AGD has not been diagnosed in cleaner fish in the most northerly areas of the country.

Microsporidea are single-celled parasites. Infections with the intracellular microsporidea *Nucleospora cyclopteri* and *Tetramicra brevifilum*, which infect white blood cells and probably weaken the immune system of the affected fish are particularly important for lumpsucker. Infected fish often develop a pale and enlarged kidney, with or without the presence of white nodules. *Nucleospora cyclopteri* is considered an important pathogen of lumpsucker and is a normal finding in wild lumpsucker in both Icelandic and Norwegian seas. The lumpsucker is the only known host for this parasite. A recently completed Norwegian Veterinary Institute project concluded that current routine histopathologically based diagnostic routines are not sensitive enough to detect infections with *N. cyclopteri*. Newly developed in situ hybridisation techniques were found capable of visualising the parasite in tissue sections which were difficult to detect by histology alone. The parasite is therefore most probably underreported.

Tetramicra brevifilum has been reported in wild caught lumpsucker in Ireland. It is unknown whether this parasite is present in Norway.

A *myxosporidian, Kudoa* sp., probably *K. islandica*, is occasionally identified in the skeletal musculature of lumpsucker. This species was described in wild caught lumpsucker 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.

The monogeneans *Gyrodactylus sp./G. cyclopteri* have been recorded on the skin and gills of lumpsucker. It is possible that *Gyrodactylus* may become a problem in farming of this fish species, but the prevalence and ability to cause damage has not been studied.
Caligus elongatus infestation is considered a problem in

lumpsucker 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. Lumpsucker 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.

Fish coccidia (*Eimerias p.*) have been identified in the intestine of both wild and farmed lumpsucker. They appear to be extremely common in wild lumpsucker. Coccidia can create problems in unnaturally dense populations of fish, as in a salmon cage. Coccidia related disease and mortality has been registered in lumpsucker. It may also be speculated upon the extent to which coccidian infection affects the fish's appetite and louse eating ability. Coccidia infections were recently identified in two different farming localities in wild caught corkwing and Ballan wrasse in Rogaland and Sør-Trøndelag.

Ichthyophonus sp. has been diagnosed in a few cases involving Norwegian cleaner-fish. *Ichthyophonus hoferi* causes disease in rainbow trout. It is a fungus-like parasite which may lead to serious systemic granulomatous infection in affected fish. The parasite has been described from more than 80 marine species of fish and can potentially transmit from infected cleaner fish to salmon. It was identified in Ballan wrasse in one farm in 2018 and has also been identified in lumpsucker.

Other parasites identified sporadically in cleaner fish include *Trichodina* and other ciliates on the skin and gills and endoparasites e.g. nematodes and flatworms in the intestine. Recently cases of infection with scuticociliates have been identified in lumpsucker. These organisms are

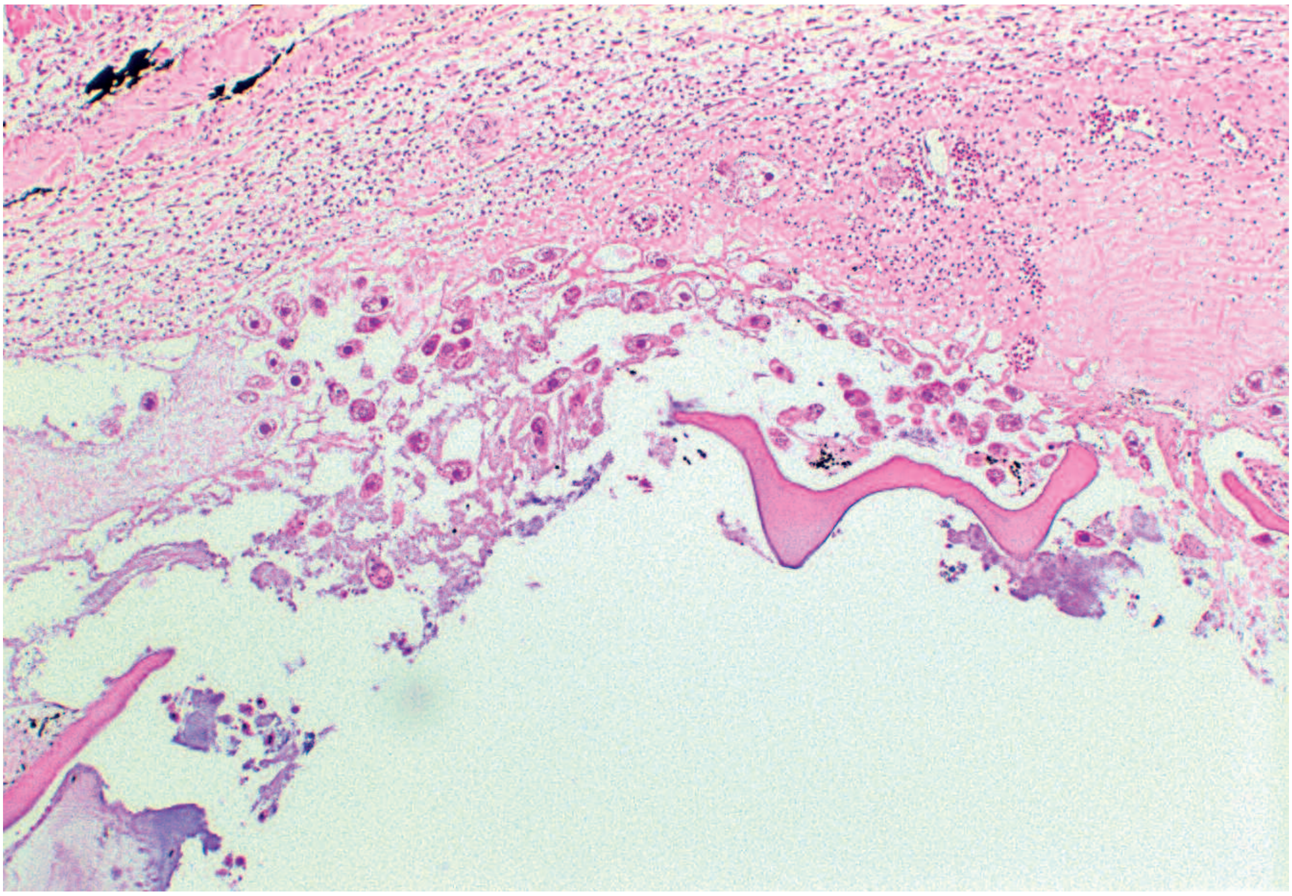


Figure 10.5. Skin lesion infected with scuticociliates in lumpsucker. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

free-living in marine environments and can parasitize fish, lobsters and other aquatic animals. They are described as secondary pathogens, and have been reported in association with skin lesions in lumpsucker in Ireland.

The health status of farmed Norwegian cleaner-fish in 2019 is described below. Cleaner-fish welfare is discussed in chapter 3. Fish welfare. Sensitivity to antibiotics in bacterial pathogens of cleaner-fish is discussed in chapter 5.9. Antibiotic sensitivity in Norwegian aquaculture. No evidence of antibiotic resistance was identified amongst bacterial pathogens of cleaner-fish by the Norwegian Veterinary Institute in 2019.

The health situation in 2019

Data from the Norwegian Veterinary Institute

The main findings for 2019 and previous years are presented in Table 10.1. The statistics reflect the situation in both farmed and wild-caught cleaner-fish. In some cases, there may be some confusion in the field surrounding the individual species identity amongst the various wrasse species, and a number of submissions are therefore categorised as 'wrasse'. The various species of wrasse are not specified in this summary.

Table 10.1: Frequency (number of farms diagnosed) of selected diseases/agents of cleaner-fish diagnosed by the Norwegian Veterinary Institute between 2012 and 2019.

Fish species	Disease/agent	Number positive farms per year							
		2012	2013	2014	2015	2016	2017	2018	2019
Lumpsucker	Atypical *Aeromonas salmonicida*	1	8	5	51	27	24	20	27
	Typical *Aeromonas salmonicida*	0	0	0	1	4	0	0	0
	Pasteurella sp.	1	16	8	14	28	23	14	10
	Pseudomonas anguilliseptica	0	0	1	4	8	15	17	7
	Vibro anguillarum	7	6	8	12	12	7	7	3
	Vibrio ordalii	3	4	1	3	1	6	3	2
	AGD	0	0	2	2	8	2	4	0
Wrasse	Atypical *Aeromonas salmonicida*	12	13	16	32	18	14	13	15
	Vibro anguillarum	6	6	6	2	2	2	3	0
	Pseudomonas anguilliseptica	0	0	0	0	0	1	0	0
	AGD	0	5	2	2	1	1	0	2

Bacteria

Problems with atypical furunculosis continued in 2019 (27 and 15 farms respectively) in lumpsucker and wrasse. This is an increase from the previous year. The diagnoses are spread throughout the year. Private laboratories have also diagnosed considerable numbers of atypical furunculosis cases, particularly in lumpsucker. *A. salmonicida* subsp. *salmonicida* was not identified in cleaner-fish by the Norwegian Veterinary Institute in 2019.

Pasteurella sp. has also been a problem in lumpsucker, although the number of positive localities has fallen considerably from 28 in 2016 to 10 in 2019. The 2019 outbreaks were spread throughout the year and all were identified post sea-transfer. Private laboratories have also diagnosed a number of pasteurellosis cases in lumpsucker in 2019.

The number of lumpsucker localities affected by *Pseudomonas anguilliseptica* which increased steadily in recent years, fell in 2019 to 7 affected farms. Outbreaks were spread throughout the year. *P. anguilliseptica* was not identified in wrasse in 2019.

V. anguillarum was identified in sick lumpsucker (primarily serotype O2, but also O2a) in three farms. The detections were made between August and November. V. *anguillarum* infection was not diagnosed in wrasse in 2019.

V. ordalii infection was identified in two lumpsucker populations during 2019.

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.

Virus

No viral disease or viral agent was identified in the diagnostic material submitted from cleaner-fish to the Norwegian Veterinary Institute in 2019. The Norwegian Veterinary Institute does not presently have diagnostic tools capable of detection of Lumpsucker flavivirus.

Statistics from private laboratories reveal a total of 45 identifications of virus in 2018, a reduction from the 75 diagnoses made in 2018. It should be emphasized that the statistics for 2018 relate to the number of positive detections and not the number of affected localities. Thus, the statistics may include several detections from the same farming locality.

Parasites

AGD was identified in two populations of Ballan wrasse in 2019. AGD was not identified by the Norwegian Veterinary Institute in lumpsucker in 2019.

Nucleospora cyclopteri was not identified by the Norwegian Veterinary Institute in lumpsucker in 2019. As described previously it is probable that *N. cyclopteri* is underdiagnosed as it is difficult to detect in routine histopathological investigations.

Kudoa sp. were identified in the skeletal musculature of lumpsucker from one farm in 2019. In this case relatively few spores were identified and only minor pathological change was observed.

Coccidiosis was identified in lumpsucker in one farm in 2019 and was associated with emaciation.

Flagellates (probably *Cryptobia* sp.) were identified in the stomach of lumpsucker in a few sites. These probably reflect harmless infections. Sporadic identification of ectoparasites including *Trichodina* sp. and other gill-related ciliates, with the exception of a single case, could not be related to significant health problems. Nematodes (probably Hysterothylacium aduncum) within the peritoneum and internal organs were identified in goldsinny wrasse in two locations.

Fungal agents

The yeast *Exophiala psychrophila* was identified from two populations of lumpsucker in 2019, one of which involved a systemic mycosis. An additional case of systemic mycosis (unspeciated) was also diagnosed in lumpsucker.

Other diseases

Calcification in the kidney (nephrocalcinosis) is diagnosed sporadically and to a varying extent in cleaner-fish, but the significance of this condition remains unclear.

Response to the survey

Significant levels of mortality in cleaner-fish continue to be related to bacterial infections, handling, delousing, sub-optimal husbandry, skin lesions, and emaciation (see also chapter 3. Fish welfare). The period following sea-transfer to the salmon cages appears to be particularly perilous. Lumpsucker appear to be more susceptible during this period than wrasse.

There appear to be fewer problems (relatively) during the hatchery phase, but fin erosion and fin-rot are considered problematical. Atypical Aeromonas salmonicida, independent of fish species or stage of production, is considered the single most deadly infectious disease in cleaner fish. The sea-louse Caligus elongatus is considered an increasing problem for lumpsucker in marine sites.

From replies to the survey it would appear that there remains considerable uncertainty around actual mortality levels in Norwegian cleaner-fish. Of those respondents who commented on overall mortality in 2019 compared to the previous year, most reported a similar situation. This should be considered in light of the fact that several, both last year and this year, used the 'free text' area of the survey to comment that mortality was almost total and several reported that mortality was difficult to estimate. Many also mention that mortality can vary significantly from farm to farm and that this is reflected in the attitudes of individual farmers regarding husbandry and use of cleaner-fish. Overall, the majority of this year's comments are more negative than last year and many respondents consider the health situation for

Figure 10.6. Lumpsucker juvenile with fin-rot. Photo: Mattias Bendiksen Lind, Havet.

cleaner fish unacceptable. The situation for lumpsucker and wild-caught wrasse (particularly corkwing) in salmon cages is of particular concern.

Regarding the specific causative factors mentioned in relation to poor cleaner-fish health, the lack of good technical solutions for removal of cleaner-fish in advance of delousing, non-optimal feeds, lack of knowledge of nutritional requirements and effective vaccines are commonly mentioned. Some infectious diseases, primarily in lumpsucker, not asked specifically about in the survey (e.g. crater disease in lumpsucker), were mentioned by several respondents as particularly problematical. Several respondents also mentioned strong currents as a problem for lumpsucker. Significant seasonal differences in mortality between the different species are also mentioned. Several respondents consider cleaner-fish relevant legislation has become clearer, more knowledge based and to somewhat stricter. They also feel that the authorities should monitor the situation more closely.

It is worth mentioning that replies to the survey are considered on a national basis and that there are likely to be significant geographical differences in how the cleaner-fish health situation is perceived.

Evaluation of the cleaner-fish health situation

Despite the fact that cleaner-fish health has been the subject of much debate in recent years, the situation does not appear to have improved, and may have worsened, which gives grounds for concern. Many farmers undoubtedly strive to provide conditions that as far as possible support good cleaner-fish health, but mortality levels on a national level remain too high. That precise mortality levels cannot be identified is a problem. The necessary knowledge and technical solutions necessary to make cleaner fish use sustainable under conditions of good welfare, are lacking. Fish health personnel consider legislative change is required.

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. 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.

11 The health situation in farmed marine fish

By Hanne K. Nilsen

Marine species in aquaculture

Farming of marine fish species is performed in both land-based farms and in sea-cages. The most commonly farmed marine fish species in Norway are halibut, turbot, spotted wolffish and cod.

There is currently a focus on farming and selective breeding of halibut. 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 remain. Cod farming met significant challenges related to juvenile production and early maturation.

The situation in 2019

Official data

Halibut and turbot

In 2019, 23 submissions involving halibut (22) and turbot (1) were received, which was an increase from the previous year. Atypical *Aeromonas salmonicida* is one of the most commonly diagnosed bacteria in these fish species. Vibrio species including *Vibrio (Allivibrio) logei*, *Vibrio splendidus* and *Vibrio tapetis* are also diagnosed regularly in these fish, alone or as mixed infections with atypical *A. salmonicida*.

Carnobacterium maltoaromaticum was identified in association with epicarditis and gonads of mature broodstock halibut. It is not unusual that this bacteria is identified in association with inflammation in serous membranes in various fish species.

As in previous years, *Tenacibaculum-like* bacteria were identified in lesions and inflamed eyes of large halibut. Material for culture was not submitted in these cases. Nephrocalcinosis (calcium deposition) was suspected in some cases and in one instance included deposition of calcium in the choroid of the eye.

Thickening and necrosis of gill filaments were registered in halibut with shortened opercula. '*Costiasis*' (infection with *Icthyobodo* sp.) is a not unusual finding as are epitheliocysts in the gills.

A case of acute mortality in halibut was associated with kidney necrosis following treatment with a disinfectant. Nodavirus infection was not suspected or diagnosed in halibut in 2019.

Cod

Four submissions were received in 2019 involving cod. The material represented wild-caught cod and commercial production. Problems associated with emaciation were reported in 'live stored' wild-caught cod. In two submissions *Trichodina* sp. were identified. *Aeromonas salmonicida* was identified in two localities (Fig. 11). Material for bacteriological culture was not submitted.

Francisellosis, caused by *Francisella noatunensis* subsp. noatunensis, was not identified in 2019.

Nodavirus infection was not suspected or diagnosed in cod in 2019.

Spotted wolffish

Four submissions involving spotted wolffish were submitted in 2019. The material originated from wild caught and aquarium held fish.

In one submission, histopathological findings consistent with *Kudoa* sp. were identified in wolffish (Fig 11.2). *Kudoa* is a myxosporidean that infects the musculature and can lead to histolysis of the tissues. The species *K. islandica* has been a particular problem in wild-caught wolffish in Iceland and the species *K. thyrsites* is a problem in Canadian salmon farming. In Norway, *Kudoa* has been previously found in farmed grey wolffish, but does not appear to be a common parasite of wolffish in Norwegian aquaculture.

Annual survey 2019

Eye injury and parasites are reported in halibut. In farms previously affected by aquareovirus after stamping out of affected stocks. Bacterial infections during the early life stages are challenging.

Poor welfare, capture related injury, gas bubble formation in the eyes and emaciation are problems in 'live storage' of cod. Atypical furunculosis, deformities,

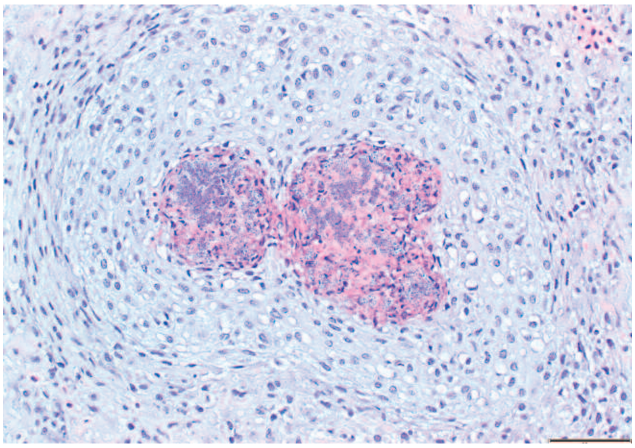


Figure 11.1 Encapsulated bacteria (consistent with *Aeromonas salmonicida*) associated with reddish discolouration of the skin in Atlantic cod. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

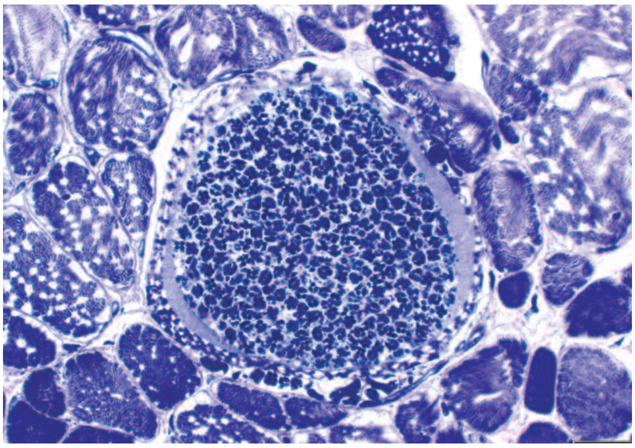


Figure 11.2 Plasmodia, consistent with *Kudoa* sp. (Myxozoa) in the skeletal musculature of wolffish. Giemsa staining. Photo: Toni Erkinharju, Norwegian Veterinary Institute.

sunburn, and unexplained mortality are reported after transfer to sea.

Trichodina and *Tenacibaculum* sp. infections are reported to be a problem in wolffish. There is a need for more knowledge related to notifiable virus infections in marine fish species.

12 Koi herpesvirus (KHV)

By Ingunn Sommerset and Hanne Nilsen

The disease

Koi herpesvirus (KHV) is an extremely infectious virus that causes high mortality in common carp (*Cyrinus carpio*). Common carp are cultivated as a food fish in many countries, but are also cultivated as an ornamental fish termed 'koi-carp'.
Disease caused by KHV, first described in England in 1996, is now recognised in a number of countries where carp farming is performed. KHV is not infectious in humans.

Disease caused by KHV often results in 80-100% mortality at water temperatures of 16-25ºC. Surviving fish typically continue to carry the virus, a recognised feature of other herpesvirus infections. Transmission occurs via direct fish to fish contact, via waterborne infection or contact with contaminated sediment or other vector.
Clinical signs of KHV-infection are often diffuse, but white spots (necrosis) on the gills, sunken eyes, skin lesions and abnormal swimming are commonly observed.

Control

There is no treatment for KHV and as a list 2 notifiable disease, it is controlled by stamping out of infected fish and introduction of transport restrictions etc.
See the fact sheet for more information on KHV: https://www.vetinst.no/sykdom-og-agens/koi-herpesvirus-sykdom-khv

The situation in 2019

Official data

KHV has been a cause for concern to the aquarium industry for several years and the disease was identified in Norway for the first time in 2019 in a private collection in Hordaland. Tissue samples from a koi-carp displaying clinical signs consistent with KHV were submitted to the Norwegian Veterinary Institute where the virus was detected using specific PCR and sequencing. All the fish in the affected population were rapidly destroyed, which meant that access to material for further study was limited. It was therefore not possible to identify whether the disease originated from newly introduced koi or from a persistent sub-clinical infection in older fish present in the collection.

According to the OIE, 31 outbreaks of KHV were registered globally in 2019. Fourteen of these were registered in Iraq. Prior to the 2019 diagnosis in Norway in 2019, there have been no Scandinavian cases since the last case in Sweden in 2012.

Evaluation of the KHV situation

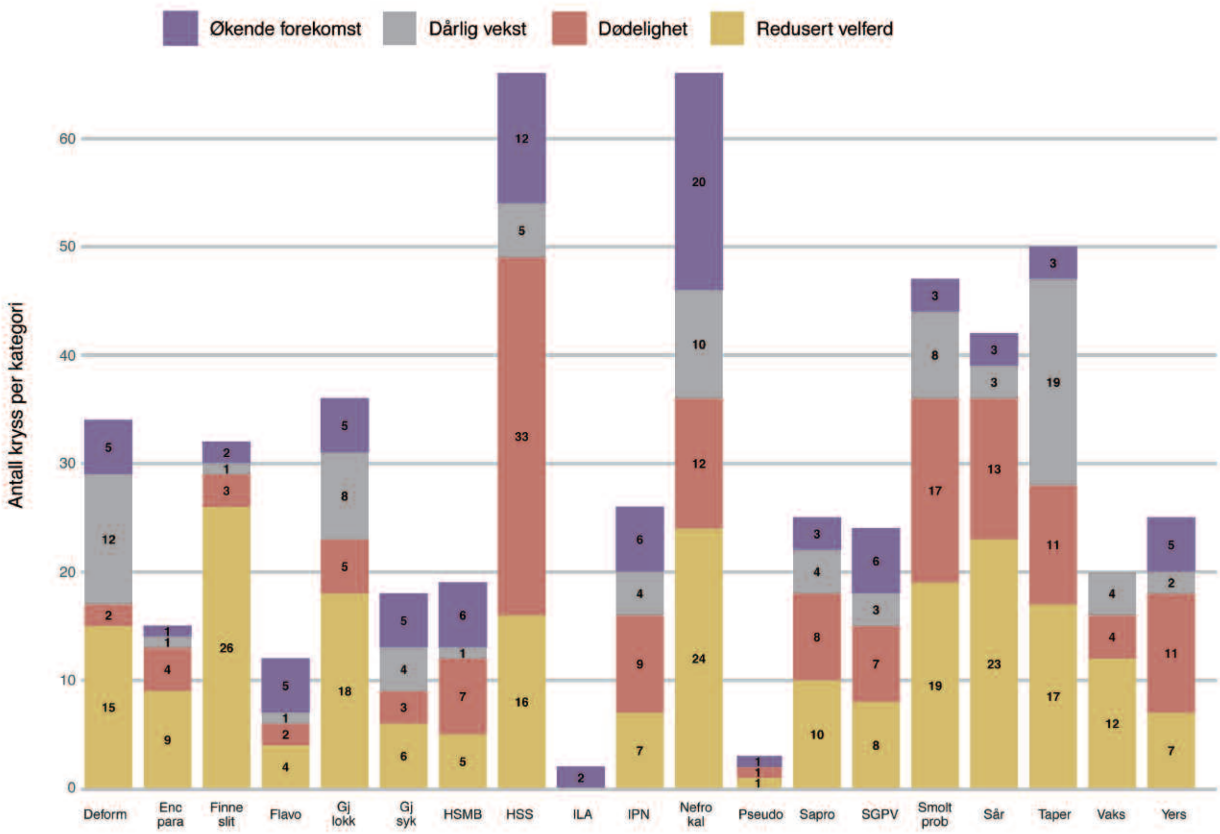
Only a single case of KHV has been identified in Norway. The owner of the affected population destroyed the infected fish shortly after the diagnosis was made and all tanks, hoses etc. were thoroughly disinfected. No diagnoses of KHV have been made in koi subsequently stocked in the system following a fallowing period.

Figure. 12.1 The clinical signs associated with KHV-disease are commonly diffuse, but white spots on the gills, sunken eyes (photo) and skin lesions associated with increased mortality at temperatures over 16^{o}C can give grounds for suspicion. Photo: Norwegian Veterinary Institute

Appendix A:

Health problems in juvenile production of salmon and rainbow trout

Resultat fra spørreundersøkelsen 2019 der Results from the annual survey in which respondents were asked to list the top 5 problems (from a list of 20), based on mortality, poor growth, reduced welfare or considered to be an increasing problem (increasing prevalence)

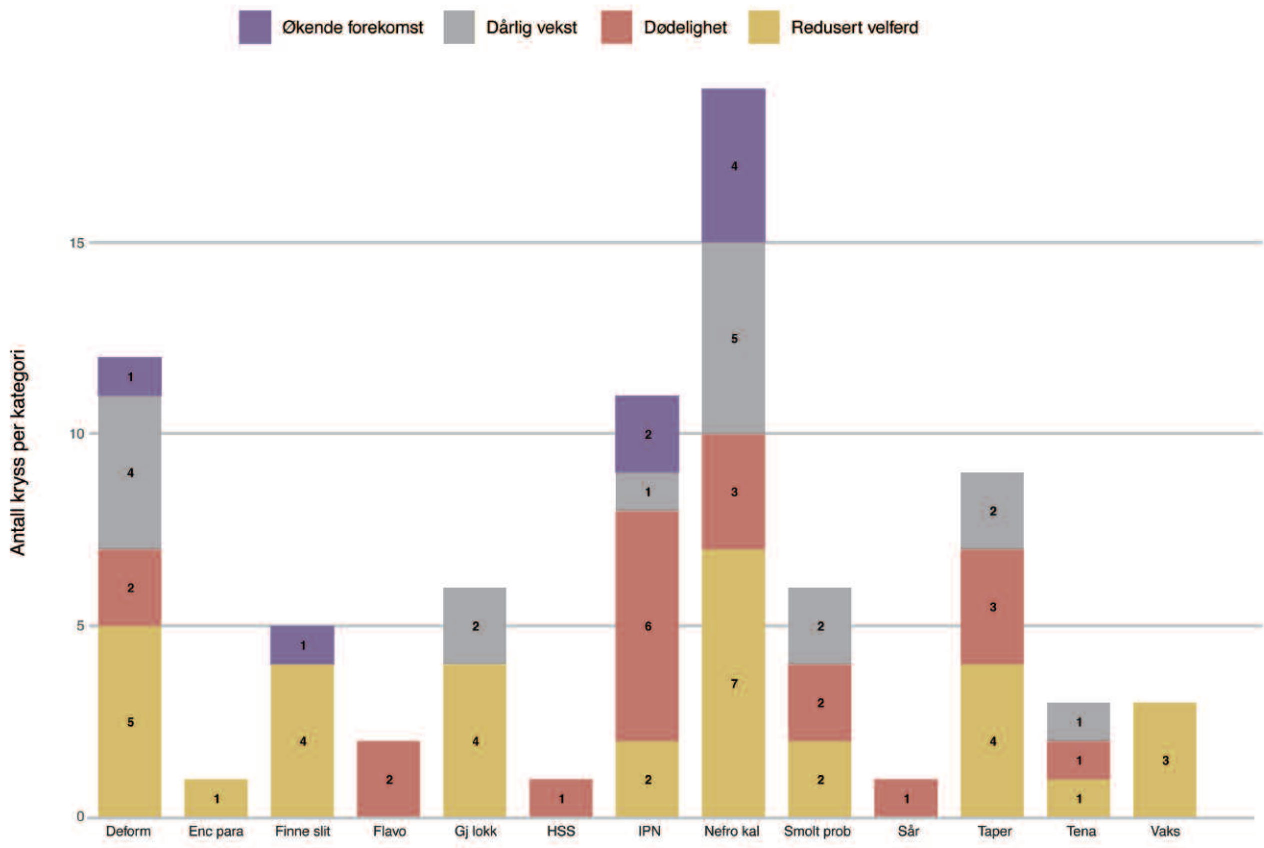


Juvenile production salmon A1:

Total N= 45 respondents, respectively N= 45 (mortality), N= 35 (poor growth), N= 44 (reduced welfare) and N= 32 (increasing prevalence).

Abbreviations:

Deform =	deformities
Enc.para =	single-cell parasites on gills/skin
Finneslit =	fin ereosion
Flavo =	infection with *Flavobacterium psychrophilum*
Gj.lokk =	Shortened opercula
Gj.syk =	complex/multifactorial gill disease
HSMB =	heart and skeletal muscle inflammation
HSS=	Haemorrhagic smolt syndrome
ILA =	infectious salmon anaemia
IPN =	Infectious pancreatic necrosis
Nefrokal =	nephrocalconosis
Pseudo =	Infection with *Pseudomonas* sp.
Sapro =	*Saprolegnia* sp
SGPV =	salmon gill poxvirus (gill disease caused by salmon pox)
Smoltprob =	smoltification problems
Sår =	skin lesion
Taper =	runted fish, emaciation
Tena =	Infection with *Tenacibaculum* spp. (atypical winter ulcer)
Vaks =	Vaccine side effect
Yers =	infection with *Yersinia ruckeri* (yersinosis)

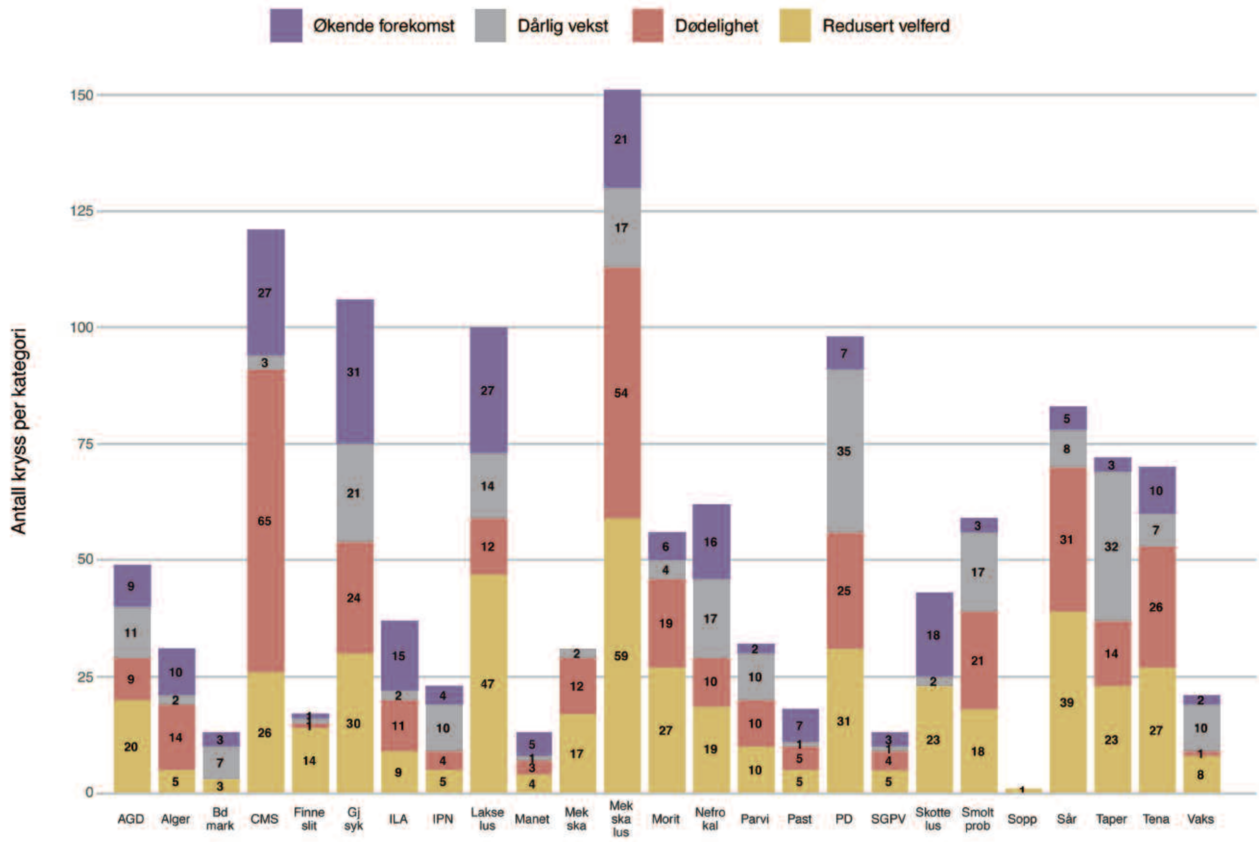


Juvenile production rainbow trout A2:
Total N= 11 respondents, respectively N= 11 (mortality), N= 8 (poor growth), N= 10 (reduced welfare) and N= 6 (increasing prevalence).

Appendix B:

Health problems in ongrowing salmon and rainbow trout

Results from the annual survey in which respondents were asked to list the top 5 problems (from a list of 25 for salmon, 26 for rainbow trout), based on mortality, poor growth, reduced welfare or considered to be an increasing problem (increasing prevalence). Due to a technical problem, HSMI was not included as a possible cause for ongrowing salmon.

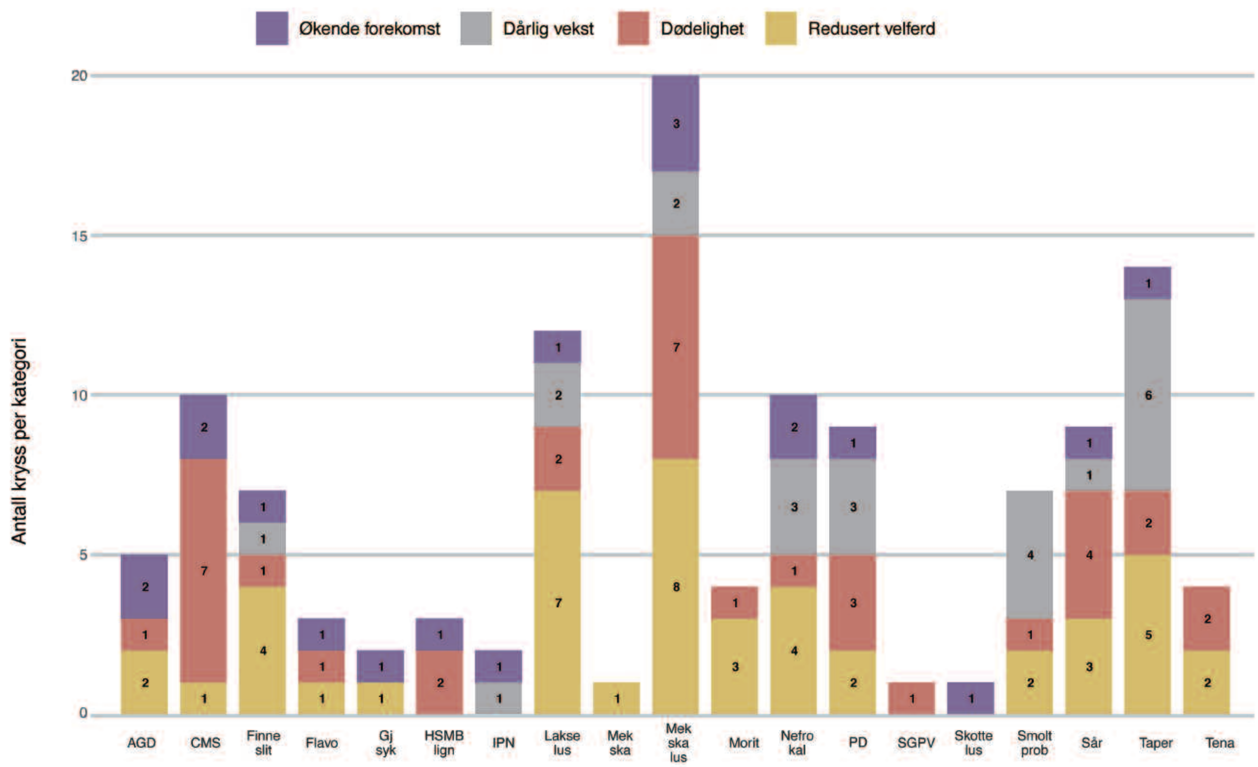


Ongrowing salmon B1:

Total N= 7245 respondents, respectively N= 72 (mortality), N= 67 (poor growth), N= 72 (reduced welfare) and N= 65 (increasing prevalence).

Forkortelser:

AGD = amoebic gill disease
Alger = algae
Bd.mark = tapeworm
CMS = Cardiomyopathy syndrome
Finneslit = fin erosion
Flavo = infection with *Flavobacterium psychrophilum*
Gj.syk = Complex/multifactorial gill disease
HSMB lign. = PRV3/HSM)-like disease
ILA = infectious salmon anaemia
IPN = infectious pancreatic necrosis
Lakselus= salmon louse
Manet = jellyfish
Mek.ska = mechanical injuries not related to salmon lice
Mek.ska.lus = Mechanical injuries associated with delousing
Moritel = infection with *Moritella viscosa* (classical winter-ulcer)
Nefrokal = nephrocalcinosis
Parvi = infection with Parvicapsula pseudobranchicola (parvicapsulosis)
Past = infection with Pasteurella sp. (pasteurellose)
PD = pancreas disease
SGPV = salmon gill poxvirus (gill disease caused by salmon pox)
Skottelus = Caligus elongatus
Smoltprob = smoltification problems
Sopp = fungus
Sår = skin lesions
Taper = runted fish, emaciation
Tena = infection with *Tenacibaculum* spp (atypical winter-ulcer)
Vaks = vaccine side effects
Yers = infection with *Yersinia ruckeri* (yersinosis)

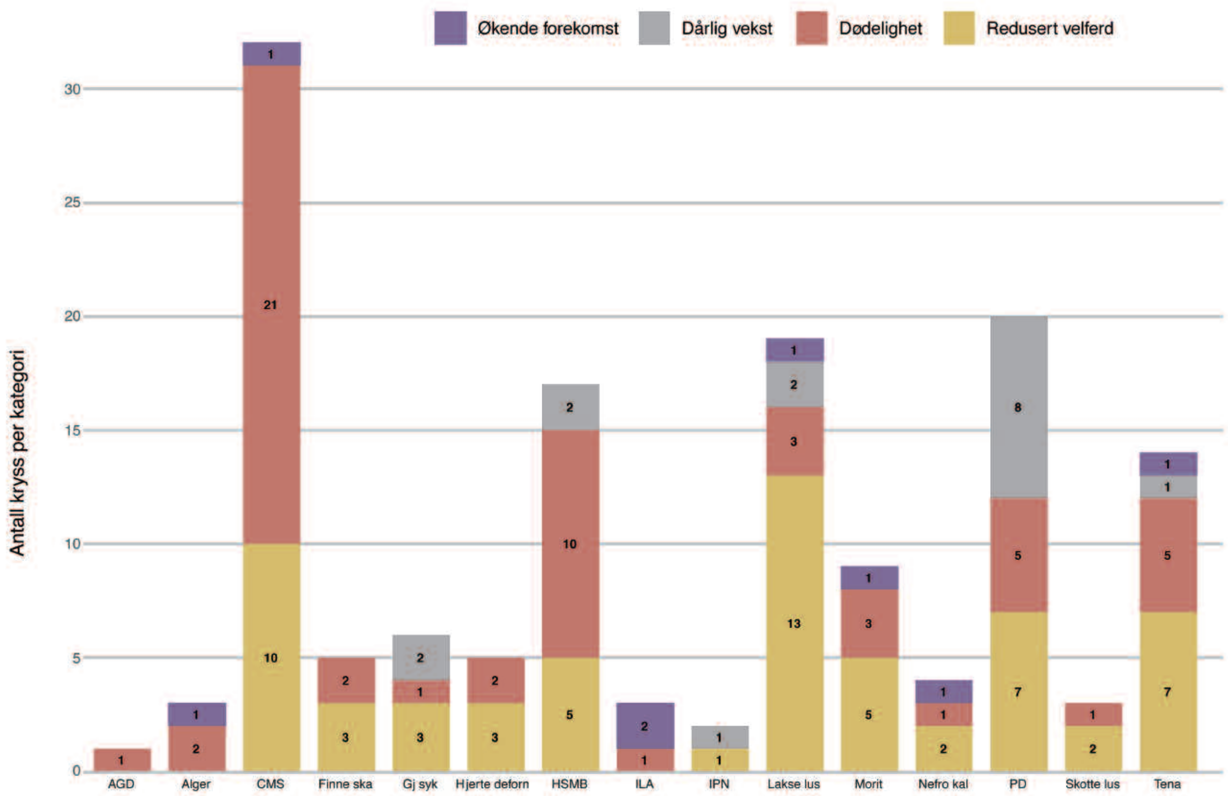


Ongrowing rainbow trout B2:
Total N= 11 respondents, respectively N= 11 (mortality), N= 9 (poor growth), N= 11 (reduced welfare) and N= 6 (increasing prevalence).

Appendix C:

Health problems in broodstock salmon and rainbow trout

Results from the annual survey in which respondents were asked to list the top 5 problems (from a list of 19), based on mortality, poor growth, reduced welfare or considered to be an increasing problem (increasing prevalence). Due to a technical problem, HSMI was not included as a possible cause for ongrowing salmon

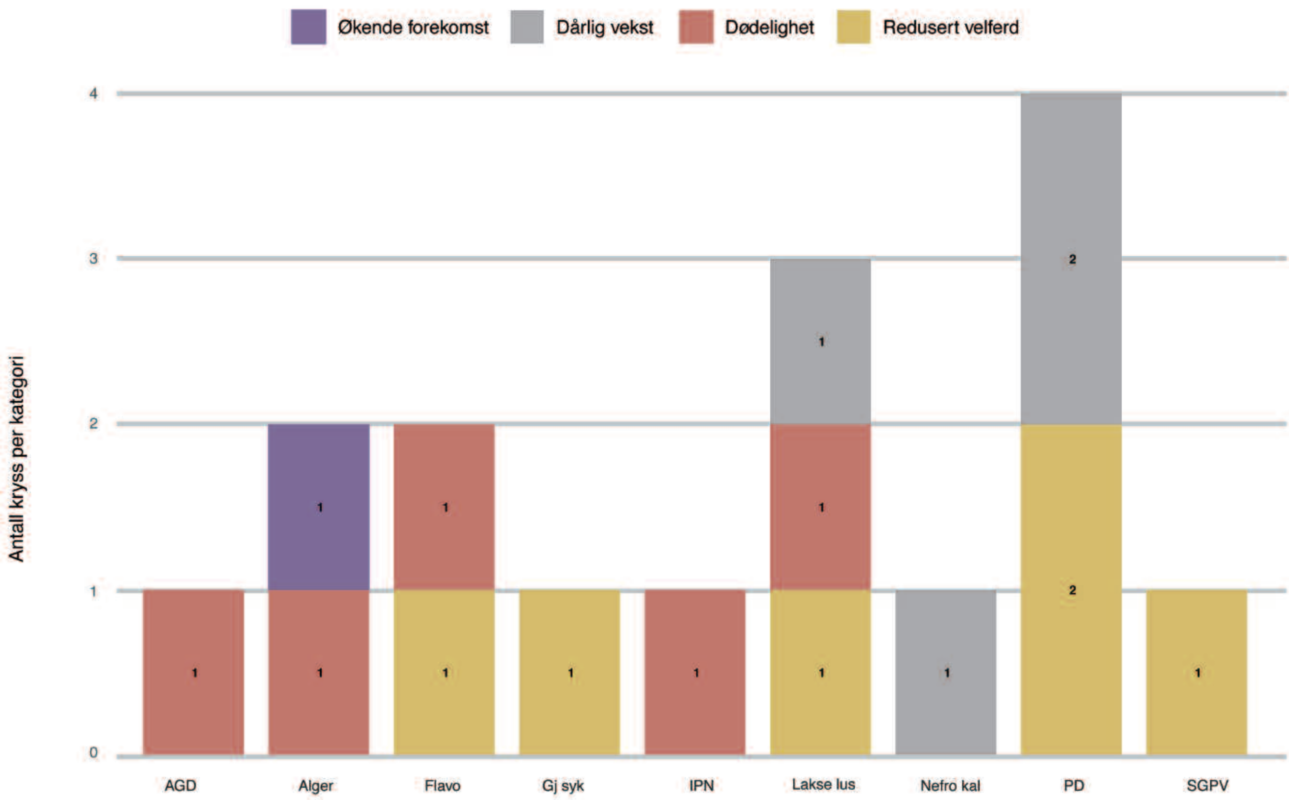


Broodstock salmon C1:

Total N= 22 respondents, respectively N= 22 (mortality), N= 11 (poor growth), N= 19 (reduced welfare) and N= 4 (increasing prevalence).

Forkortelser:

AGD = amoebic gill disease
Alger = algae
CMS= Cardiomyopathy syndrome
Finneska = fin injury
Flavo = infection with *Flavobacterium psychrophilum*
Gj.syk = complex/multifactorial gill disease
Hjerte.deform = Heart deformity
HSMB = heart and skeletal muscle inflammation
ILA = infectious salmon anaemia
IPN = infectious pancreatic necrosis
Lakselus = salmon lice
Morit = infection with *Moritella viscosa* (classical winter-ulcer)
Nefrokal = nephrocalcinosis
PD = pancreas disease
SGPV = salmon gill pox virus (gill disease caused by salmon pox)
Skottelus = Caligus elongatus
Tena = infection with *Tenacibaculum* spp. (atypical winter-ulcer)



Broodstock rainbow trout C2:

Total N= 4 respondents, respectively N= 4 (mortality), N= 3 (poor growth), N= 3 (reduced welfare) and N= 1 (increasing prevalence).

Photo: Colourbox.

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The Norwegian Veterinary Institute is a national research institution in the fields of animal health, fish health, food safety and feed hygiene providing independent research-based knowledge to the authorities as its primary function.

Preparedness, diagnostics, surveillance, reference functions, consultancy and risk evaluations are important areas of work. Products include results and reports from research, analyses, diagnostics and advice.
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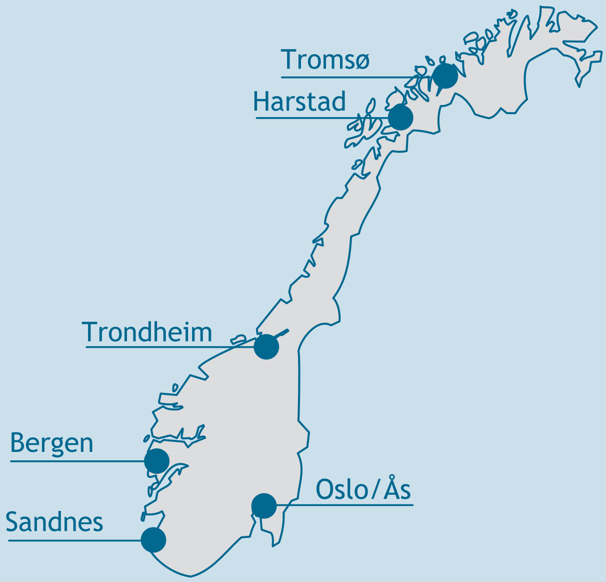
The Norwegian Veterinary Institute collaborates with a number of institutions, both in Norway and abroad.



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