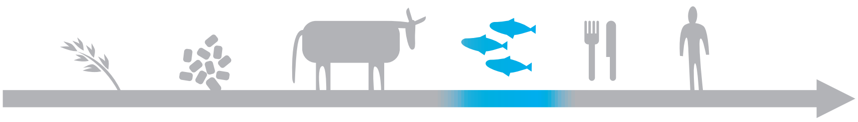
Report 6b - 2019

The Health Situation in Norwegian Aquaculture 2018

Ten week old lumpsucker juvenile (5mm) photographed using an electron microscope. Photo Jannicke Wiik-Nielsen, Norwegian veterinary Institute



Veterinærinstituttet
Norwegian Veterinary Institute

The Health Situation in Norwegian Aquaculture 2018

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Norwegian Veterinary Institute, annual summary of fish health in Norway

Authorship
Authors are credited for each chapter.
With the exception of chapter 8.3 on water quality, written by employees of the Norwegian Institute for Water Research (NIVA), all authors are employees of the Norwegian Veterinary Institute.

Editors
Brit Hjeltnes, Britt Bang-Jensen, Geir Bornø, Asle Haukaas and Cecilie S. Walde (Ed.)
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The Health Situation in Norwegian Aquaculture 2019

Contents

A common national effort for fish health is required

'The Health Situation in Norwegian Aquaculture 2018' is the sixteenth in an annual series of fish health reports first produced in 2003. Reactions received over the last few years indicate that there is significant interest in an annual report on the current status of fish health and welfare in Norway.

This year's report contains a risk evaluation of the health situation in Norwegian aquaculture including the status for individual diseases, welfare challenges and other health threats to farmed and wild fish.

New statistical analysis of mortality levels

High levels of mortality and other losses within the aquaculture industry have received much attention over the last two years. Dead fish represent the largest proportion of these losses, but escapes and other causes also represent significant 'losses' to the industry. Fifty three million fish were 'lost' from production in both 2016 and 2017, and losses of a similar level were experienced in 2018, with mortality accounting for 87.2% of this figure (Directorate for Fisheries statistics). These statistics are of concern for all involved parties concerned with the future of aquaculture in Norway.

There are many ways to present and analyse mortality statistics. The Norwegian Veterinary Institute considers it important that these figures are analysed in a standardised fashion and has therefore developed a novel standard analysis method. This method is utilised for the first time in the present report in chapter 2, Risk evaluation.

While analyses for 2018 appear to indicate a slight improvement in the situation at a national level, overall mortalities remain too high and large regional differences exist. Some areas, including Hordaland and Rogaland show a positive trend with lower mortality levels compared to the previous year.

The fatal effects of salmon louse treatment

Salmon-lice have been a problem for the aquaculture industry since its start in the seventies and control has been heavily dependent on chemical treatment. Frequent treatment has led to development of resistance to the chemotherapeutants utilised, which has led to extensive use of cleaner-fish and non-medicinal treatments. Non-medicinal treatments lead to stress and physical injury in the treated fish, which may lead to death. Fish already impaired by other health problems e.g. infectious disease, are particularly badly affected.

It is a paradox that while only a very few fish die due to salmon-lice infection, delousing is an important cause of direct and indirect mortality both for farmed salmon and cleaner-fish. The welfare challenges, particularly those involving non-medicinal delousing methodologies, are considerable. In some cases, fish health personnel may advise against treatment on fish welfare grounds.

The survey carried out in association with the present report indicates that non-medicinal delousing, despite the continued high associated mortality levels, is now considered somewhat less challenging in respect to welfare of the treated fish, than previously. Contributory factors may include increased experience by the operators regarding evaluation and handling of the treated fish, and improvements in the equipment utilised. Early, widespread adoption of novel delousing technologies prior to documentation of the animal welfare consequences has resulted in significant welfare problems.

Cleaner-fish (wrasse and lumpsucker) have become important tools in the fight against the salmon-louse. Use of wild-caught cleaner-fish will always represent a risk of infection transmission in addition to problems related to capture, transport and introduction to aquaculture surroundings. Import or transport of cleaner-fish over large geographical distances should be avoided. Farmed cleaner-fish represent a better solution in terms of infection hygiene.

In 2018, 40 million lumpsucker and 1.6 million ballan wrasse (Kontali Analyse AS) were produced for use in salmon-lice control. There continue to exist considerable disease problems in both wild-caught and farmed cleaner-fish. Despite use of very small volumes of antibiotics in Norwegian aquaculture, most antibiotic treatments are prescribed for use in cleaner-fish species.

Introduction of the traffic light system illustrates how decisive the salmon-louse is for the future of the industry. There are currently significant problems related to large-scale delousing and other methods for control of salmon-lice. Research efforts focussed on development of effective and sustainable methods of lice control should be increased.

The changing disease situation

PD has long been the most important virus disease in Norwegian farmed fish. In recent years, it has become clear that CMS increases its range and importance in Norway, Scotland and the Faroe Isles. Previously almost exclusively limited to large, harvest ready salmon, the disease now also occurs in younger fish. Respondents to this year's survey considered CMS as the second most important disease (after the salmon-louse) in Norwegian aquaculture. New research results indicate that this viral disease has the potential to transmit from parent to offspring.

Several serious fish diseases are known to have been introduced via import of live fish and other biological materials e.g. *Gyrodactylus salaris* and furunculosis in Norway. Furunculosis is now established in Norwegian fauna and has to be lived with. It has been shown that with extreme efforts and significant expenditure, it is possible to exterminate the parasite *G. salaris* from infected rivers. That several large river systems are now free of infection is a significant victory.

The viral disease IHN is now a real external threat. This extremely pathogenic virus has been identified in several areas in Finland, and we are familiar with reports of the disease in Russia. Wild pink salmon of unknown infection status, migrating southwards from northern Russia, represent a possible source of IHNV infection.

National Effort

New EU animal health legislation imposes stricter requirements regarding active eradication (not only control of) of serious diseases such as ISA and PD. The Norwegian Veterinary Institute believes that it is possible to drastically reduce the prevalence and range of these diseases provided the industry is willing to accept adoption of measures necessary to achieve this goal. This will require extensive planning of biosecurity and good cooperation between private and public institutions. The Norwegian Veterinary Institute is prepared to take an active role in this national effort aimed at eradication of serious disease in Norwegian aquaculture.

Disease currently costs the aquaculture industry enormous sums of money, results in poor fish-welfare, reflects poorly on the aquaculture industry and is environmentally unfriendly. More effective disease control will be costly, but profitable and will lead the industry in a more sustainable direction.

New technology, new challenges

Increasing numbers of fish are produced in recirculation (RAS) based farms. This is a more complicated technology than traditional through-flow based farming and recirculation of seawater is particularly challenging.

Through our diagnostic service and the annual survey, we have attempted to identify disease trends particularly associated with RAS. As yet there is no clear picture, but it does appear that pathogenic organisms when present within a RAS facility appear to cause more serious disease than in an equivalent through-flow system. Biosecurity is therefore a key factor in successful RAS operation.

It is important that the Norwegian Veterinary Institute maintains a high level of expertise in diseases associated with novel production methodologies such as RAS, enclosed, semi-enclosed and offshore farms. New production technologies create new possibilities, but may also create new disease and welfare challenges.

For nearly all areas touched upon in this year's report, the Norwegian Veterinary Institute focusses heavily on development of knowledge aimed at maintenance of a good state of national preparedness. The same knowledge also allows enlightened governmental management and supports a sustainable bio-industry. The institute has therefore, over the last two years, published a catalogue of active research projects in the field of aquaculture: 'Healthy fish and sustainability – Aquatic research and development projects at the Norwegian Veterinary Institute 2019' (In Norwegian)

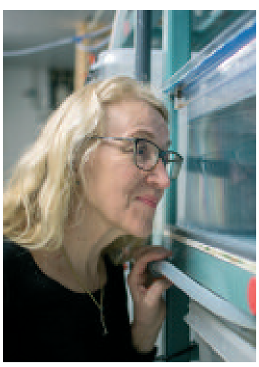
Changes in this year's report

The editorial committee would like to express its thanks to all who have contributed with text, data, photographs or other form of support.

The Norwegian Veterinary Institute has good oversight over the incidence of notifiable diseases, but we are completely dependent on information provided by private laboratories, fish health services and the Norwegian Food Health Authority to form a complete picture of the disease situation in Norway. We are extremely grateful for the willingness and interest from these sources to contribute to compilation of the present report. In this way, the combined efforts of fish health workers nationwide enable compilation of the world's best national report on farmed and wild fish health.

For the first time this year's report includes a section on water quality. Good water quality is fundamental for good fish health, and there have been several incidents involving acute mortality associated with poor water quality in recent years. We thank our colleagues at NIVA for their contribution to the section on water quality and health related problems.

We are also grateful for the positive feedback we receive to the annual 'Fish Health Report'. This shows that the report is both important and valuable. Please send constructive criticisms such that we can improve future reports and thereby continue to help develop an important industry as well as maintenance of good health in both domestic and wild fish.



Brit Hjeltnes,
Editor and Scientific Director Fish Health

Summary

Treatment against salmon-lice remained in 2018, as in previous years, the major fish-health related challenge in Norwegian aquaculture. The health- and welfare consequences of salmon-lice treatment relate mainly to the acute and often fatal injuries associated with the treatments themselves.

Besides the salmon louse, the viral diseases dominate the disease situation. Cardiomyopathy syndrome (CMS) appears to be of increased importance nationwide. In addition, pancreas disease (PD) is important in endemic areas. Infectious salmon anaemia (ISA) is catastrophic for infected farms. The bacterial disease yersiniosis, which has been particularly problematic in Mid-Norway, appears now to be under better control.

Changes in the salmon-louse situation

The salmon louse situation has not changed significantly between 2017 and 2018. Spring levels of adult female lice were, however, the lowest observed since 2013. Six of thirteen production areas experienced an increase in larval production, with reduced production recorded in the remaining seven areas. Four areas demonstrated higher larval production during the outward migration period for wild salmon smolts compared to 2017.

While 38% fewer prescriptions (n=295) were prescribed for anti-lice treatment in 2018 than in 2017, an increase of 21% was recorded (n=344) for non-chemical treatments. Of the non-chemical treatments, thermal methods represented the majority (685). Salmon louse control in Norway in 2018 was therefore dominated by non-medicinal treatments and other non-medicinal measures. Resistance to anti-louse chemicals/medicines remained widespread along the coast. Poor response to chemical treatment could therefore be expected.

Fish health workers reported that thermal and mechanical treatments more commonly resulted in increased post-treatment mortality than medicinal or freshwater-based treatments. According to this year's survey responses, the frequency of acute post-treatment mortality appears to have been less common in 2018 compared to 2017. This applied to all forms of treatment and may indicate that treatments were performed in a less physically injurious way.

Challenging virus diseases

In our annual survey, cardiomyopathy syndrome (CMS) was considered the second most serious disease in both ongrowing and broodstock farms in 2018. CMS was diagnosed in 101 localities in 2018, which represents a slight increase from the previous year. Private laboratories reported 125 diagnoses. Considered together with responses to the annual survey, this indicates an increase in number of diagnoses and impact of the disease. There are indications that the virus causing the disease (PMCV) may transmit from parent fish to offspring.

Pancreas disease (PD) remains a serious viral disease of sea-farmed salmonid fish in the endemic area in Norway. There are two epidemics in Norway, SAV3 in Western Norway and marine SAV2 North of Hustadvika in Møre og Romsdal and Trøndelag. In 2018, 163 new cases of PD were diagnosed. This was fewer than in the previous year, which was in turn a considerable increase from the year before. The increase in 2017 may have been due to early detection of the virus following introduction of mandatory screening. The impact and number of cases of PD appears to be increasing in the more northerly areas of its range.

Infectious salmon anaemia (ISA) was diagnosed in 13 farms in 2018 compared to 14 in 2017. Four additional cases were suspected. In contrast to earlier years, during which positive sites most commonly lay in physical close proximity to each other within endemic areas, the pattern has changed to a larger proportion of single outbreaks in geographically disparate locations.

Heart and skeletal muscle inflammation (HSMI) is one of the most common viral diseases of Norwegian farmed salmon. In 2018, the Norwegian Veterinary Institute and private laboratories diagnosed HSMI in 104 and 90 farms respectively. Although considerable uncertainty surrounding the real number of cases exists, the figures may indicate that HSMI remains at a level similar to previous years.

The Norwegian Veterinary Institute and private laboratories diagnosed IPN in 19 and 4 salmonid farms respectively. This indicates a prevalence similar to the previous year, but clearly lower than the peak year of 2009 when IPN was diagnosed in 223 farms. Use of QTL-roe is probably the most important factor in the reduction in number of cases. Increased focus on

eradication of 'house' strains has also contributed to the situation. A few cases of high mortality continue to occur and the Norwegian Veterinary Institute continues to monitor for eventual changes in the IPN-virus.

Other health challenges

Amoebic gill disease (AGD) is caused by the parasitic amoeba *Paramoeba perurans*. The amoeba was again identified throughout the year from Agder in the south to Nordland in the north, and the clinical situation followed the same pattern as 2016 and 2017. Despite the unusually warm and dry summer, AGD did not develop into the dramatic disease one might have feared under these conditions.

Poor gill-health in sea-farmed salmon is a significant and increasingly important problem, particularly in western Norway. Gill infections are complicated and often multifactorial, involving a number of infectious agents.

Skin lesions associated with bacterial infections remain on a level observed in previous years and are particularly prominent in northern Norway.

The impact of yersiniosis has increased in recent years, particularly in mid-Norway. In 2018, the number of outbreaks has decreased and the disease appears under control following introduction of vaccination.

According to Kontali analyse, approximately 41.6 million cleaner-fish (40 million lumpsucker and 1.6 million ballan wrasse) were produced in 2018. In addition, many wild-caught cleaner-fish were utilised. Mortality as a direct or indirect result of handling (particularly associated with sea-transfer and non-medicinal lice treatment), fin rot and several bacterial infections are the most important health and welfare challenges associated with cleaner-fish use in Norway.

Atypical furunculosis (caused by atypical *Aeromonas salmonicida)* is one of the most serious bacterial diseases of cleaner-fish, as are vibriosis and pasteurellosis (lumpsucker). Vaccination of cleaner-fish is increasingly practised. The most important virus infection is Flavivirus infection in lumpsucker, which causes occasional mortality levels >50%. Parasites are also problematic. Mortality is high and there are significant welfare concerns related to cleaner-fish use.

Preliminary figures from the Veterinary Medicine Register (VetReg), suggest that 931 kg (active substance) antibiotics were prescribed for Norwegian farmed fish in 2018. This is an increase from the 641 kg registered in 2017 but remains an insignificant amount in relation to historic levels and the quantity of salmon currently produced in Norway. The increase over the last two years was related to treatment of yersiniosis in relatively large salmon. While the total amount of antibiotic used is small, most fish prescriptions are related to cleaner-fish treatment (91 prescriptions).

Losses between sea-transfer and harvest of both salmon and rainbow trout remain high, and mortality accounts for the majority of losses. According to the Directorate for Fisheries, 53 million salmon and 3.1 million rainbow trout were lost in 2018. This indicates a situation similar to 2017.

In this year's report, we discuss various ways to calculate losses and mortality. On calculation of percent mortality, we identify clear regional differences, with the western regions displaying higher levels. A decrease in mortality was however, observed in Rogaland and Hordaland from 2017 to 2018.

The salmon parasite *Gyrodactylus salaris* has remained a serious threat to wild salmon in a number of Norwegian rivers since its introduction nearly 40 years ago. Comprehensive eradication programmes have involved several public institutions and local voluntary groups. The Norwegian Environment Agency has responsibility for administration and financing both the eradication programme and the Gene bank for wild salmon – a programme aimed at preserving the genetic basis of several endangered wild salmon populations, until the *G. salaris* threat is removed. Scientific responsibility for planning and practical execution of both programmes is delegated to the Norwegian Veterinary Institute. Following expenditure of between 0.5 and 1.0 billion kroner on parasite eradication and gene-bank programmes, 32 of the original 50 rivers infected are now declared free of infection, 11 are under surveillance following treatment and treatment is being planned for the remaining 7. Following declaration of freedom of infection, rivers are re-stocked with eggs from the original local genetic strain supplied by the gene-bank. Good stock development is now registered in these rivers.

During 2018, 1 253 000 tons of salmon, 64 000 tons of rainbow trout, 6000-6500-tons (estimate) of wild-caught, cage-held cod, 1900-2000 tons (estimate) halibut, 2-300 tons (estimate) turbot and 5-600 tons (estimate) arctic char were produced in Norway. In addition, 40 million individual lumpsucker and 1.6 million ballan wrasse were produced (Kontali analyse).

1 Statistical basis for the report

By Britt Bang Jensen

The statistics presented in the current report are, in the main, obtained from three different sources; official data, data from the Norwegian Veterinary Institute, 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 source/s 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.

These statistics include both diagnoses made by the Norwegian Veterinary Institute and diagnoses made by private laboratories (see under) which have been reported to the Norwegian Food Safety Authority. 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 diseases made by external laboratories.

The 'official statistics' in this report relate to the number

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

Disease	List	2011	2012	2013	2014	2015	2016	2017	2018
Farmed fish (salmonids)									
ISA	2	1	2	10	10	15	12	14	13
VHS	2	0	0	0	0	0	0	0	0
PD	3	89	137	100	142	137	138	176	163
Furunculosis	3	0	0	0	1	0	0	0	0
BKD	3	3	2	1	0	0	1	1	0
Farmed fish (marine species)									
Francisellosis (cod)	3	3	2	1	1	0	0	0	0
VNN/VER	3	0	1	1	0	0	0	0	0
Furunculose (lumpsucker)	3	0	0	0	0	1	4	0	0
Wild salmonids (freshwater)									
Gyrodactylus salaris	3	2	0	1	1	0	0	0	0
Furunculosis	3	1	0	0	0	2	1	2	0

of new diagnoses/positive sites following fallowing. As some farms may hold fish diagnosed the previous year, the actual number of affected sites may be higher.

Data from the Norwegian Veterinary Institute

The Norwegian Veterinary Institute receives samples for diagnostic investigation from a number of Fish Health Services. These samples are analysed in our laboratories in Harstad, Trondheim, Bergen and Oslo. All information generated from submitted 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 2017, so the statistics do not necessarily describe the number of new cases in 2018. The exception is for notifiable diseases (described above).

For non-notifiable diseases, Norwegian Veterinary Institute data alone does not provide a complete picture of the national situation. We have therefore asked several private diagnostic laboratories to provide data related to their own diagnostic investigations. Since the information collected is probably not complete, the statistics may represent an underestimate. On the other hand, some diagnoses made by private laboratories are also likely to 'overlap' cases diagnosed by the Norwegian Veterinary Institute.

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 and on various parameters relating to fish welfare.

The survey was sent to 116 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 16 individuals working for farming companies (total response 40 individuals). The survey was also sent to the Norwegian Food Safety Authority and we received responses from 15 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, Nils Toft (Toft Analytics), Lars Qviller, Mona Dverdal Jansen, Edgar Brun, Arve Nilsen, Haakon Hansen and Brit Hjeltnes

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 2018, 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

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, and preliminary sales figures for 2018 indicate a continuation of this trend (table 2.1). Biomass reported in the marine phase at the end of 2018, together with preliminary figures for sea-transfer of smolts and juveniles produced, indicate a similar total production in 2019.

Marine production of rainbow trout and other species e.g. halibut, turbot, and char remains comparatively stable. For 2018, approximately 3100 tons (preliminary statistics from Kontali analyse) were produced, which is around the same as the previous year. 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 for wild-caught cleaner-fish. Stocking of aquaculture facilities 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.

Almost 55 million cleaner-fish were stocked in salmon cages in 2018, 18 million more than the year before, which was in turn 11 million more than in 2015. 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 treatment of cleaner-fish. In 2018, all antibiotic prescriptions written for cleaner-fish 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 mortality 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 are based on reports from commercial ongrowing localities. Broodstock localities are not included (table 2.2).

The level of losses of fish within the Norwegian aquaculture industry has been relatively stable over the last three years following an increase from 45.8 million in 2014 to 53.3 million in 2016 and 52.4 million in 2017. In 2018, total losses of 53.0 million fish were registered, distributed between 87.2% mortality, 6.6% reject, 6% 'other' and 0.02% 'escaped' salmon.

The distribution between the four categories mentioned above are roughly the same from year to year. Five incidences of escaped fish were reported last year, two of which accounted for 90% of all escaped fish in 2018. For rainbow trout the total losses have varied between 2.8 million in 2017 and 3.4 million in 2015. In 2018, total losses of rainbow trout were registered as 3.1 million, distributed amongst 91% mortality, 4% reject, 5% 'other' and 0% 'escaped'. In table 2.1 only mortality is reported. In previous reports, we have reported the total losses. The figures for 2014-2017 in this report have therefore been limited to the respective mortality figures for each year.

Previously, several methods of calculating % loss of fish have been used. The challenge in calculation of this statistic is that both the number of dead fish and the number of live fish constantly change due to sea-transfer of new smolts and harvest of large fish. A method which

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

	2014	2015	2016	2017	2018
Number of farms					
Salmonid, Concessions, juvenile production	222	214	220	220	217
Salmonid, active sites, sea	994	990	978	986	1015
Marine fish, number of sites, sea	105	79	66	58	42
Biomass at end of year, tons					
Salmon	761 000	722 000	740 000	796 000	810 000
Rainbow trout	42 500	46 600	31 500	35 700	40 000
Harvested, tons					
Salmon	1 258 000	1 303 000	1 234 000	1 236 000	1 275 000
Rainbow trout	68 900	72 900	87 800	66 900	66 700
Marine species (halibut, char, cod, other)	3 140	1 713	2 473	2 683	3100*
Juvenile fish transferred to sea, millions					
Salmon	296	313	315	338	304
Rainbow trout	21,7	20,0	19,6	21,3	20
Cleaner-fish	24,5	26,4	37,4	54,6	41,6*
Post sea-transfer mortality. millions					
Salmon	40,9	41,3	44,8	45,8	46,2
Rainbow trout	2,7	2,6	2,4	2,4	2,8
Mortality in percent**					
Salmon	15,2	14,2	16,2	15,5	14,7
Rainbow trout	19,5	13,4	19,2	17,5	16,6

* Preliminary estimate, Kontali analyse, February 2019

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

considers both factors is required.

In this year's report, % mortality is calculated on the basis of rates, which allows the total number of fish (which can die), to change from month to month. In contrast to percent values, rates may be summed and thereafter converted to a percent which describes the probability that a salmon dies in the course of a given period. Calculation of monthly mortality rates for each locality allow the average monthly rate to be calculated for any given period. 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 method are provided. These figures do not include losses due to 'reject', escape or 'other'. As can be seen from the table, the proportion of dead fish increased from 2014-2015, then decreased for both salmon and rainbow trout over the last two years.

One may also choose to consider mortality on a generation or production cycle basis. It is possible to consider mortality from sea-transfer to harvest for all fish transferred to sea in any particular year, or calculate the total mortality for fish in localities that have been completely harvested during any particular year. We have chosen to utilise the latter format as we consider that it allows us to use the newest data. When mortality is calculated in this way for the period 2015 – 2018 (table 2.2), there is a visible increase in mortality from fish farmed in the sea between 2014 and 2015 and fish farmed in the sea between 2015 and 2016.

Treatment with new mechanical and thermal delousing technologies has led to an increase in mortality in recent years (see chapter 3, Fish welfare). Chemical bath treatments for lice and amoeba may also have caused increased mortality. Significant reduction in mortality from present levels must be a long-term goal.

Significant regional differences in losses continue to exist (Table 2.3). The figures for 2017 presented here are different from those presented in last year's report. This is due to adjustment of the figures to encompass mortality-based losses alone and not other categories of loss. Hordaland continues to have the highest mortality rate, but mortality based losses in this region have, however, according to our calculations, decreased from 25.4% in 2017 to 20.2 % in 2018, representing an almost 20% reduction. Sogn og Fjordane has experienced an increase in mortality with a rate nearly as high as Hordaland, both for salmon and rainbow trout. The largest increase in % mortality was identified in Nordland (increase from 9.6% to 12.8%) and levels have also increased in Troms and Møre og Romsdal. While lowest mortalities are experienced in the Agder-regions, these regions also have the lowest overall production.

The 'probable causes' of mortality based losses are not registered, but the large differences between geographical areas can indicate a variable regional disease/infection situation, which is discussed further throughout this report.

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

	2015	2016	2017	2018
Median mortality in percent for all sea-transferred salmon. cycle completed per year	12,3	15,7	16,1	15,0
1.- 3. quartile (50% of mortality % lies within this interval)	7,1 – 22,5	9,4 – 26,2	8,3 – 25,0	9,0 – 23,1

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 difficult to identify and there is always a risk that presumptively 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 2018 are not yet available, but for 2017, the total number of smolts transferred to sea in northern-Norway were 16.5 million greater than the number of smolts produced within the region, a situation similar to the year before. Figures for 2015 and 2014 were 11 and 13 million greater respectively. There is, therefore, a lack of 'self-sufficiency' within the region.

The situation in the remainder of the country appears quite stable with the exception of Møre og Romsdal and Sør-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. A newly published article based on data collected during 2016 identified the probability of spread of PD via well-boat activities. 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 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.

rainbow trout in 2018. Losses due to mortality are calculated as described in the text. The figures for 2017 are included, as they are calculated differently than in last year's report. The figures below should be used for any comparative purpose..

	2017		2018	
Region	% mortality salmon	% mortality Rainbow trout	% mortality salmon	% mortality Rainbow trout
Finnmark	13,4	-	11,6	-
Troms	7,5	-	8,8	-
Nordland	9,6	6,7	12,8	9,7
Trøndelag	14,9	3,2	12,0	8,9
Møre og Romsdal	15,5	14,0	17,5	17,4
Sogn og Fjordane	16,7	17,6	19,3	18,1
Hordaland	25,4	20,1	20,2	18,5
Rogaland	18,4	-	16,9	1,0
Vest-Agder	6,1	-	5,9	-
Aust-Agder	8,4	-	5,9	-

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 farmed Norwegian fish remains low and the increases observed during the previous two years were related to treatment of a few outbreak of yersiniosis in large sea-farmed salmon. This situation highlights the need for more intensive vaccination against yersiniosis in affected areas of the country.

Thirteen antibiotic treatments involving sea-farmed salmon were reported in 2018, nine in salmon in freshwater and three in rainbow trout in freshwater (table 2.6). Two of the treatments in the marine phase were due to Moritella viscosa infection. The ffreshwater treatments involving salmon were in response to Yersinia ruckeri infections. The remaining treatments were registered as due to 'general bacterial infections'.

Antibiotic treatment was prescribed 5 times for treatment of atypical furunculosis in halibut in the course of the year, 3 times for vibriosis and eight times against 'general bacterial infection'. Most antibiotic prescriptions were prescribed for cleaner-fish (91) and all involved lumpsucker. Of specific infections registered in relation to antibiotic treatment, vibriosis was diagnosed 11 times and atypical furunculosis four times, with the remaining infections diagnosed as unspecific bacterial infections.

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

RAS is a well-established technology, which saves both water and energy. Under optimal operation it can provide a more stable aquatic environment than is possible in traditional farming systems. There are an increasing number of RAS farms in Norway, with a varying degree of re-use of water. The majority of new juvenile production units for salmon are designed as RAS. RAS has been the sole method of smolt production on the Faroe Islands for many years and RAS technology is frequently used for production of juvenile marine fish and warm water species in other countries.

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 (CO2), H2S, ammonia (NH3), nitrite (NO2), total suspended solids (TTS), turbidity (NTU) and heavy metals (e.g. copper) is, however, paramount. H2S 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 in which short periods of elevated H2S have been suspected as the causative factor. Water quality related health problems are discussed later in this report.

On design of a RAS facility it is extremely important to avoid areas where organic material/sediment may be deposited. Periodical over-feeding and insufficient particle removal should be taken into account when planning the capacity of any particular system. Use of feed designed specifically for use in RAS systems is important.

Biofilters can be unstable during the start-up phase, prior to full establishment of the bacterial cultures. The biofilter community and activity in seawater RAS differs from that in freshwater RAS systems.

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 which are difficult to clean and disinfect without negatively affecting the function of the biofilter. 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.

To reduce the production period in traditional open cages, land-based seawater RAS farms have been established for production of ‘large smolts’ of up to 1 kg. In addition to the H2S 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 during 2017 and 2018. Knowledge relating to the aetiology of such infections and their management is currently lacking.

Production of larger smolts leads to handling related welfare challenges during transport and sea transfer. 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 and may be detected in many hatcheries.

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. It will be important to study whether RAS environments contribute to change in virulence status of potential pathogenic organisms entering and circulating within the system.

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	2014			2015			2016			2017			2018*
	Smolt prod	Smolt transf	Index	Smolt prod	Smolt transf	Index	Smolt prod	Smolt transf	Index	Smolt prod	Smolt transf	Index	Smolt transf
Finnmark og Troms	26,5	60,4	0,44	29,7	66,0	0,45	31,9	66,2	0,48	33,8	78,0	0,43	70,8
Nordland	78,7	57,8	1,36	83,3	57,6	1,45	83,4	66,0	1,26	92,0	64,3	1,43	62,5
Nord-Trøndelag	36,2	25,9	1,40	39,1	25,6	1,53	38,5	21,3	1,81	74,4	80,9	0,92	37,6
Sør-Trøndelag	32,4	16,1	2,01	33,4	53,2	0,63	32,6	19,6	1,66				
Møre og Romsdal	44,6	47,2	0,94	53,8	15,0	3,59	44,5	48,1	0,93	45,4	13,1	3,47	48,5
Sogn og Fjordane	15,1	23,8	0,63	15,8	24,2	0,65	15,6	25,2	0,62	17,2	25,9	0,66	22,6
Hordaland	57,4	41,0	1,40	54,9	45,9	1,20	56,3	44,9	1,25	57,0	50,0	1,14	41,2
Rogaland	13,2	19,1	0,69	15,1	19,4	0,78	13,5	20,7	0,65	14,4	19,3	0,74	21,2**
Sum	304,3	291,3		325,1	307,0		316,4	312,2		334,1	331,6		304,4

* Preliminary statistics, Directorate for Fisheries, January 2019

**Rogaland and Agder

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. The aim of these new concepts is to establish a more secure barrier between the captive fish and the external environment. 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.

Semi-enclosed farms are expected to reduce the risk of escapes and increase the opportunities for removal of waste products. In such farms, the water quality and the aquatic environment will be significantly influenced by water volume, current speed, temperature, biomass and feeding. There is 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. How health and biosecurity issues will be satisfactorily managed in these large oceanic farms is under testing and is not finally documented.

Rough weather and strong winds with the possibility of waves developing within the cages will be a challenge for such farms. Submersible cages have been developed which are less susceptible to high winds, but the design must allow the salmon access to air to allow the salmon to fill their swim bladders. Knowledge of the effects of these new offshore solutions on fish health and welfare is limited.

What developments can we expect?

Pancreas disease is notifiable within the OIE system and

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

Antibacterial substance	2013	2014	2015	2016	2017	2018
Florfenicol	300	403	194	138	270	858
Oxolinic acid	672	108	82	74	346	55
Oxytetracycline			(25)		10	20
Total antibiotics	972	511	276	212	626	933
Anti-salmon lice medication						
Azameziphos	3037	4630	3904	1269	204	160
Cypermethrin	211	162	85	48	8	
Deltametrin	136	158	115	43	14	10
Diflubenzuron	3264	5016	5896	4824	1803	378
Teflubenzuron	1704	2674	2509	4209	293	144
Emamectin	51	172	259	232	128	87
Hydrogen peroxide (tons)*	8262	31577	43246	26597	9277	6735
Anti-tapeworm						
Praziquantel	460	625	942	518	380	171

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

is a list 3 disease (national disease) in Norway together with the salmon louse and BKD. Farmed fish represent the main reservoir of infection, 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 new 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 also 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 until clinical signs of disease develop. The competent authority then decides upon control measures. The farmer may appeal against control measures, thus delaying their introduction. These procedures may therefore, result in significant 'leakage' of infectious virus particles prior to introduction of eventual counter measures. This situation increases the risk of northerly spread of pancreas disease.

The planned reform of PD legislation and PD-management raises expectations of improved PD control. PD is a disease that may be lived with in a favourable economic climate, but the industry should be prepared to take the necessary steps to reduce the impact of this disease via a targeted eradication programme. Eradication may be both economically and biologically possible.

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 than the year before and the clinical picture is commonly diffuse. The generally high infection pressure and increased degree of handling of

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	2013	2014	2015	2016	2017	2018
Salmon, ongrowing and brood stock	15	11	8	11	6	13
Salmon, juvenile fish	35	39	24	21	28	9
Rainbow trout and trout	1	5	0	1	1	3
Marine fish (cod, halibut etc.)	18	18	29	30	28	18
Cleaner-fish	38	59	108	126	115	91*
Sum	107	132	169	189	178	134

*All prescriptions for lumpsucker.

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 it is important to maintain a high state of awareness for this disease. ISA 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 transport of animals may occur via illegal import and/or illegal release.
Gyrodactylus salaris is a parasite that can travel easily with fish transported for stock enhancement purposes. The Norwegian Veterinary Institute is the OIE reference laboratory for *G. salaris* and shall confirm all diagnoses of this parasite.
In the border areas between Norway, Russia and Finland, shared watersheds represent a particular risk of cross border spread of *G. salaris*, as well as other infections. As the eradication programme for *G. salaris* has been so successful in Norway in recent years (see chapter 9.4), there is increasing concern, and increased focus, regarding the range and spread of *G. salaris* in Russia, Sweden and Finland. Several diagnoses have been made in previously infection free rivers on the Swedish west coast in recent years e.g. Kungsbackaån (2017) and Rolfsån (2015) in Hallands county. In 2018, the Norwegian Veterinary Institute identified *G. salaris* in the river Tuloma which runs through Murmansk. This is the first time this parasite has been identified in this area and means that the parasite is found closer to the Norwegian border and the important salmon rivers Pasvikelva and Tanaelva, than previously recognised. The parasite has also been identified in several rainbow trout farms situated on the Tuloma river and in an additional site. There are reasons to believe that the parasite has been spread via transport of infected rainbow trout.

The Norwegian Veterinary Institute has developed methodologies for detection of *G. salaris*, salmon and rainbow trout via water sampling, utilising so-called eDNA methodology. In cooperation with local researchers, the Norwegian Veterinary Institute has carried out eDNA investigations for the presence of *G. salaris* in several localities in north-western Russia and on the Swedish west coast. This work has been undertaken to increase our knowledge of the geographical range of the parasite and to demonstrate use of the technology to Russian and Swedish colleagues.

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. Over the last year, this fish species was more widely observed and in much larger numbers. This may indicate a natural spread in its range. Greater numbers of pink salmon juveniles will lead to greater numbers of returning adult fish. Pink salmon are a blacklisted species in Norway. As its numbers increase this species will constitute a greater risk of introduction of fish diseases and infectious hematopoietic necrosis (IHN) in particular. Few investigations relating to the disease status of pink salmon have been undertaken. 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.

IHN was again identified in rainbow trout in Finland in 2018. 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 is 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.

3 Fish welfare

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

Most researchers consider that fish have the ability to sense and thereby experience fear, pain and discomfort. Farmed fish are included in current animal welfare legislation, are subject to the same levels of protection as other domestic animals, and should have an environment and husbandry that ensures good welfare throughout the whole life cycle. Considerable changes are required, however, in both attitude and practice, before farmed fish in general are treated as individuals with specific 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 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). 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.

In introduction to this year's chapter on fish welfare we have chosen to focus on how attitudes to welfare may be reflected in choice of words, how welfare can be measured and the importance of registered data as means of creation of new knowledge. As in previous years, we identify various welfare challenges associated with different production platforms and new technologies, with contributions from Fish Health Personnel along the whole coast.

Intrinsic value begins with choice of words

Fish Health workers and research institutions have a particular responsibility to work towards improved fish welfare, communication of knowledge and promotion of good attitudes towards fish to the industry and to the general public.

To create positivity towards the intrinsic value of a fish life, we need to consciously focus on language use. If farmed salmon are referred to as a consumable product or 'biomass', financial considerations are naturally prioritised over fish welfare. The word 'Svinn' which in Norwegian is commonly used to describe non-specific losses in many industries, is routinely used in the Norwegian aquaculture industry to describe losses due to mortality, discarded fish, escapes, or fish which have disappeared from the system for unexplained reasons. Use of such terminology reduces fish life to a 'product' with 'losses' considered only in economic terms. 'Svinn' in aquaculture is actually loss of individual fish which may die due to disease or for some other reason do not survive to harvest. As only individual organisms can experience welfare, salmon must be considered as individuals. 'Svinn' is not a word used when an individual organism dies. It would be unnatural to say that 1600kg of cattle had died, on the death of three cows. For fish, however, mortality is commonly presented as dead weight in kilograms or tons. If 10 tons of fish die, the number of individuals will vary significantly dependent on the size of the fish concerned. Each fish life has its own intrinsic value, independent of size or economic worth. As it is misleading to discuss loss of fish life in terms of weight alone, mortality should be reported in terms of the number of individual fish and average weight.

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'.
In addition, better word-choice and definition of cause of death contribute to identification of the cause of the mortality. Current animal welfare legislation establishes the fact that individual fish have an intrinsic value independent of any financial value. Through a conscious choice of words we can contribute to general acceptance of this fact.

Welfare indicators

There are many occasions when one may need to measure animal welfare and for fish we use indirect welfare indicators. Welfare indicators are often categorised as environmentally based (such as water quality) or individual-based (e.g. scoring of external injuries). Good welfare indicators should provide important information regarding welfare and should be simple and easily interpreted. Biology is complex, different indicators may give contradictory indications, and we may lack knowledge of acceptable limits. It may therefore be difficult to identify the limits of what represents good or bad animal welfare when several indicators are used. It is in addition, difficult to identify (based on current knowledge) welfare indicators capable of documenting whether fish experience good welfare, not simply documenting the absence of obviously poor welfare. More knowledge on fish preferences is required along with methods for measuring the degree to which an individual fish thrives in any particular environment.

Through the project 'Fishwell', knowledge gathered on the welfare indicators identified for farmed salmon and how they 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 systematic further development of welfare indicators and welfare protocols for different farming situations. A handbook is under production for rainbow trout.

Only when systematic and objective measurements are recorded on a large scale and the data analysed can it be concluded which welfare indicators are most suitable for use as reference indicators. Development of good methods and technology for monitoring fish behaviour and welfare will contribute to rapid identification of any failure and 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 the 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 be considered to have the poorest welfare.

Smart use of data - a cloud of possibilities for increased fish welfare

Loss of fish life remains high in Norwegian fish farming despite long experience, better stock quality, improved technology and effective vaccines. There are however, changes in the way fish die. Runting, where fish stop growing and become emaciated after sea-transfer, is reduced compared to previous years (see chapter 8.3 poor smolt quality and runting). Larger fish die more frequently now due to the repeated handling experienced during lice treatment. There is a

Figure 3.1: 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.

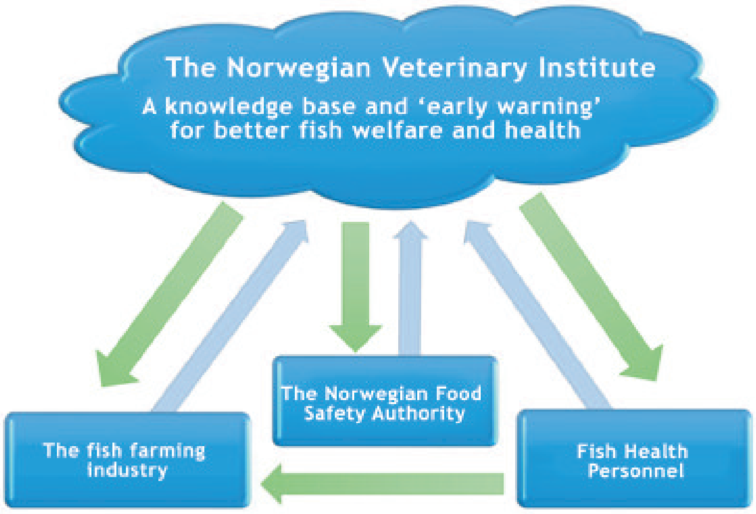


Figure 3.2: The Norwegian Veterinary Institute can, following collection of data (blue arrows) distribute knowledge (green arrows) on fish welfare and health, thereby contributing to increased knowledge sharing and research-based public management. Fish health personnel are central actors in this knowledge flow. Illustration: Kristine Gismervik.

considerable body of data gathered relating to fish populations, environment and disease in the hatchery phase and during ongrowing, which is not systematically analysed. Smart use of big-data could provide researchers, industry and public management with a much-improved understanding of the various processes involved. New relationships could be revealed and new tools for improvement of fish welfare developed. Such data must be registered in a uniform way and the various computer systems must be able to communicate with each other.

There are many demands for stricter public management, particularly in relation to disease management. Presently, we have a good overall view of notifiable diseases, but there are other diseases posing significant welfare consequences for which limited information is available. We need a better warning system to identify new diseases and a better understanding of how environmental factors, temperature, infection pressure, genetics and vaccine status influence the susceptibility of the fish to disease.

The Norwegian Veterinary Institute is working towards development of an improved tool for early identification and knowledge use in fish welfare and health and this requires extensive cooperation between the public authorities, other research institutions, fish health personnel and not least, the industry itself.

Welfare challenges and new technology

Technology aimed at optimization of production and handling of fish is under rapid and constant development. All new technologies must by law, be demonstrated as providing acceptable animal welfare before being taken into use. Although the general aquaculture legislation has, for many years required that new technology be documented in terms of acceptable animal welfare, this requirement has been followed up to a varying degree. Most Fish Health personnel responding to last year's survey were of the opinion that the requirement for welfare related documentation of new technologies should be more strictly enforced. Changes in legislation were introduced in 2018 relating to introduction and testing of new technologies, which include an increased requirement for approval of testing by the national experimental animal committee. Whether these changes in legislation will have the desired effect remains to be seen.

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 important. Further, it is extremely important that technologists and fish health personnel work closely together during the development and testing phases. New knowledge commonly results in a need for adjustment and optimisation following establishment of

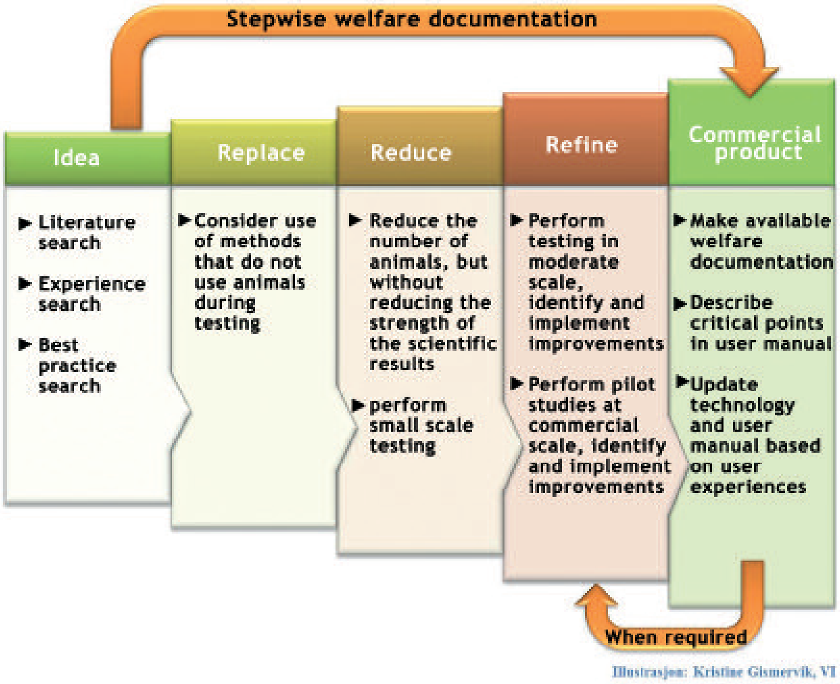


Figure 3.3. Stepwise welfare documentation from idea to commercial product on implementation of the «3R-s» (Replace, Reduce, Refine) during development of new technologies. Before a new technology is made commercially available, it is important that it is tested and found acceptable in terms of fish 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.

new technologies. Improvement is a continual process (see Figure 3.3). Norms relating to 'acceptable welfare' will also change as knowledge is gained.

Due to widespread resistance to medicinal delousing treatments, many new technologies have been directed at novel methods of louse removal from salmon. New technologies preventing louse infestation have also been introduced e.g. enclosed cages. Fish health and fish welfare in enclosed and semi-enclosed systems are important areas of current research.

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 by so doing decrease exposure to salmon lice. Production of large smolts (100-1000g) in enclosed or semi-enclosed

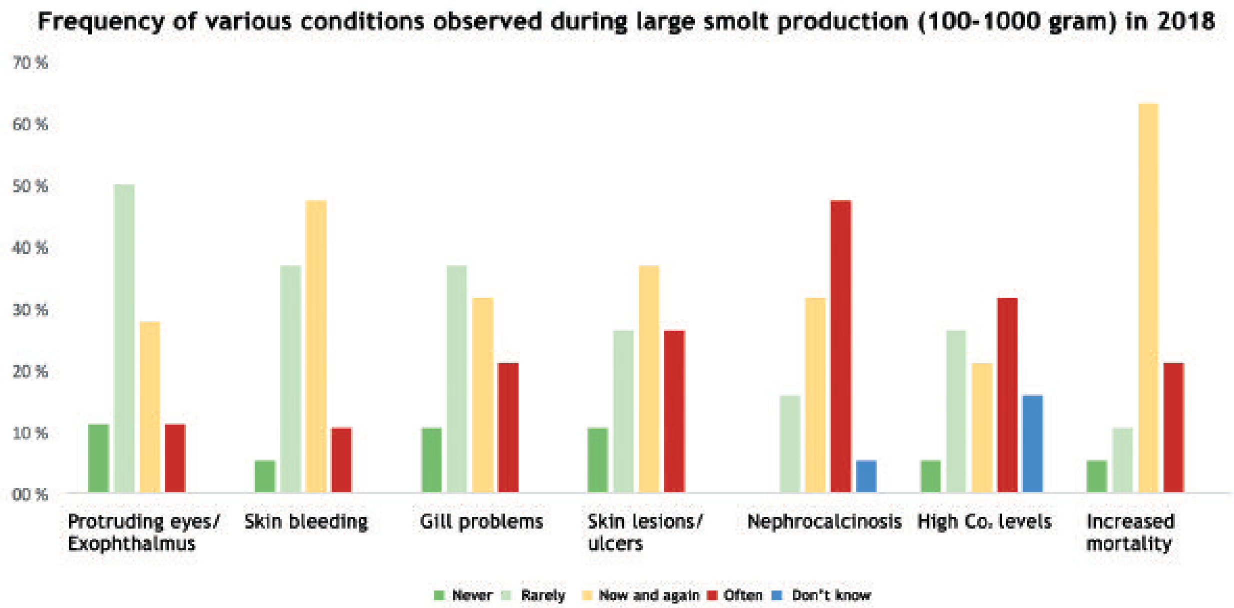
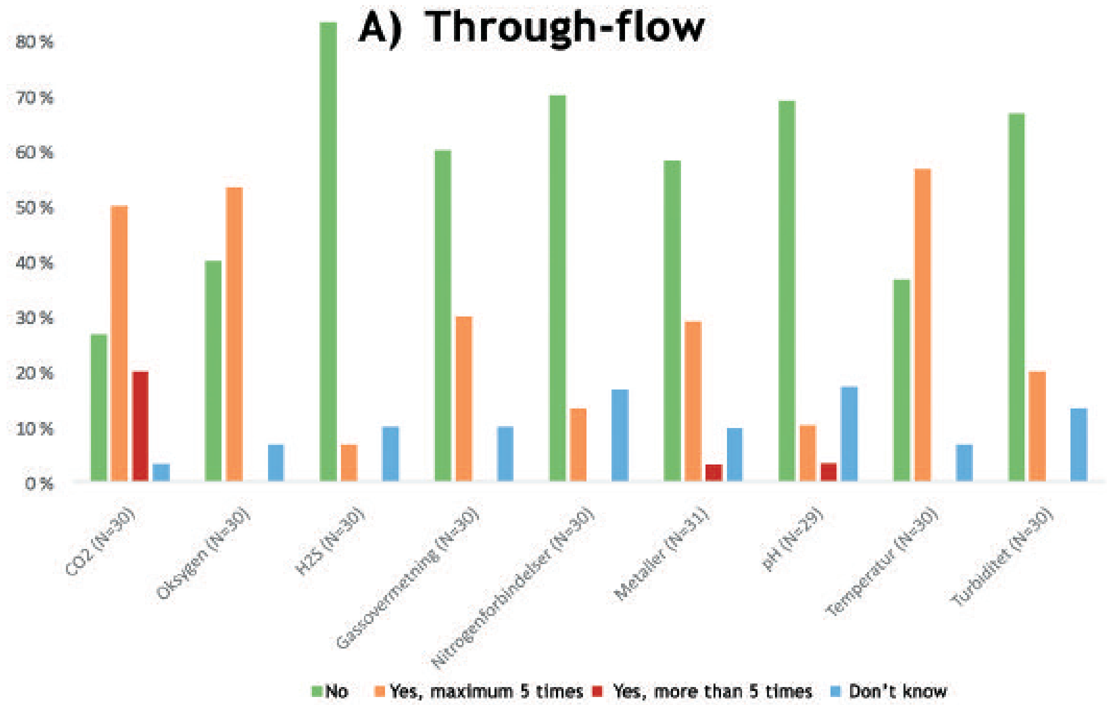
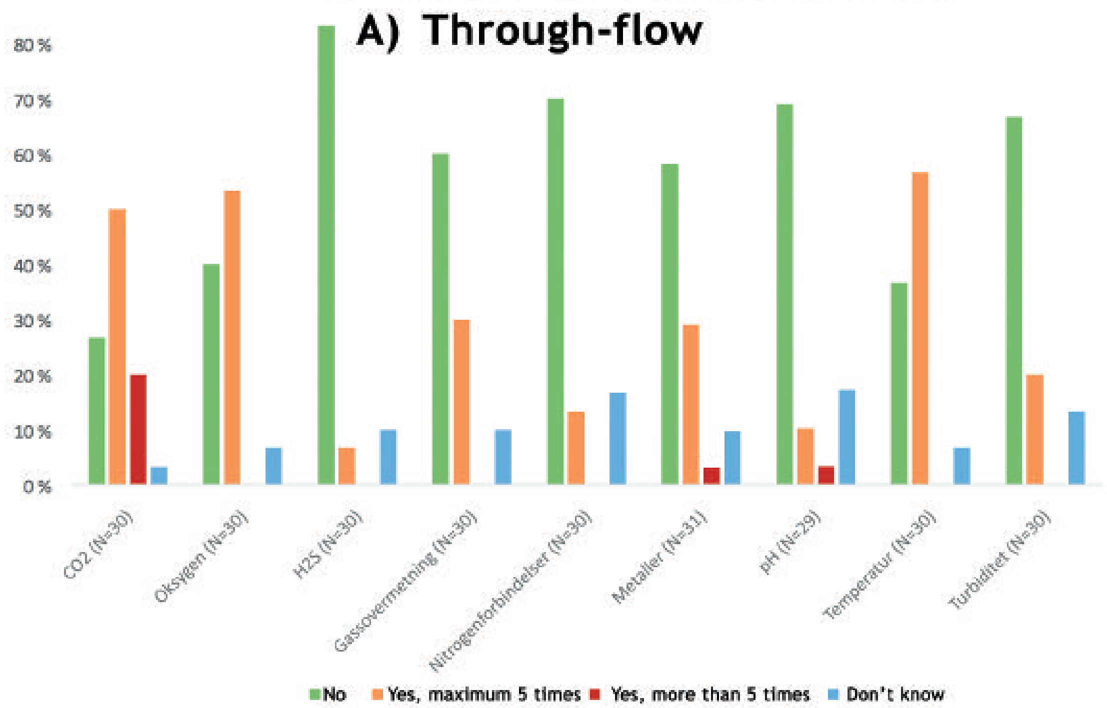


Figure 3.4: Frequency of various conditions observed during large smolt (100-1000 gram) production in enclosed/semi-enclosed units in 2018. The figures are based on 19 responses from Fish Health personnel (for protruding eyes N= 18) for different production principles (RAS and through-flow) with different degrees of seawater utilisation, as well as semi-enclosed marine farms.

units is increasing and 34.5% of fish health personnel responding to our survey had experience with this type of production in 2018. These experiences covered RAS-seawater facilities, freshwater through-flow facilities with supplementary seawater and semi-enclosed marine facilities. It is known that high CO_2 levels can be a

Figure 3.5: Fish Health personnel stated whether they had experienced water parameters negatively affecting fish welfare during 2018, and if so, how many times in A) through-flow farms (N=30) and B) Recirculation farms (N=19).





problem in RAS facilities with low replacement of water. When asked to supply the highest CO2 levels experienced, several replied that levels of 30 mg/L had been experienced. Development of nephrocalcinosis (calcium deposition in the kidney) has in some facilities, been related to high CO2 levels in the water. Several respondents in this year's survey noted that they had observed generally higher levels of nephrocalcinosis in 2018 than in 2017 (see chapter 8.4 on nephrocalcinosis). Large deposits of calcium in the kidneys can affect both kidney function and salt balance and result in reduced fish welfare and increased mortality, particularly in the period following seawater transfer. Several mentioned nephrocalcinosis and haemorrhagic smolt syndrome (HSS) as problems associated with large smolt production. Skin injury/ulcers and gill health were also mentioned, as were problems regarding disinfection of large water volumes. The frequencies of some clinical observations made during large smolt production are summarised in figure 3.4. These frequencies were reported by 19 fish health personnel from different forms of large smolt production and should therefore be interpreted with caution. Respondents were not questioned specifically on problems related to smoltification.

Welfare challenges related to water quality in juvenile salmon production
Water quality is particularly important for fish welfare. 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, the oxygen level in the water may be manipulated, while the concentrations of waste products like CO2 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). Fish Health Personnel consider that there is an increased requirement for knowledge on water quality in RAS-facilities and that particle removal is critical, particularly during start-feeding. An unfavourable aquatic environment will stress the fish and increase the susceptibility to disease.

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, algal blooms and reduced water flow. Several Fish Health Personnel reported that they had in 2018 experienced challenges related to low oxygen saturation when 'lice skirts' were used, particularly during the summer. It was also mentioned that water quality at the cage level may be insufficiently monitored and that low oxygen saturation may be related to poor appetite and growth. A combination of lice skirt use and net washing was also considered negative for water quality. Mortality episodes were also reported in association with algal blooms in the late summer.

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

Prevention of high levels of louse production is an important environmental target for the industry. In some cases, the number of lice in individual farms is so high that it represents a direct welfare challenge to the farmed fish. Such cases were observed in 2016. If the louse burden is held below the maximum treatment threshold of 0.5 adult female lice per fish (a limit set to hold infection pressure towards wild salmon low), there will be a low degree of direct impact on the welfare of farmed fish. Anti-lice treatment has, on the contrary, been identified to represent a considerable challenge to fish welfare, particularly if the fish are weakened by other infections. Special consideration must also be given to the welfare of cleaner-fish species during lice treatment. If ignored, these fish commonly die during lice-treatment.

Table 3.1 The number of weeks sites have reported delousing. Source:

Type delousing	2018	2017
Non-medicinal, farm complete and partial treatments	1949	1665
Non-medicinal, Whole farm	532	385
Non-medicinal, partial farm	1417	1280
Medicinal	739	1133
Total number of treatments (non-medicinal and medicinal)	2688	2798

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 2018, we have seen further increases in use of thermal and mechanical delousing in particular (Table 3.1). For further details, see chapter 7.1 on the salmon louse.

Thermal delousing requires transfer of the fish to a water bath (usually 29-34oC, dependent on seawater temperature, treatment effect and fish welfare) for approximately 30 seconds. Research has shown that such temperatures are painful to fish. There are two main systems used for thermal delousing, based on different methods of feeding the fish through the water bath. Since research on the effect of high water temperature on salmon is limited, the Norwegian Food Safety Authority contracted the Norwegian Veterinary Institute and the Institute for Marine Research to investigate this technology and a report should be available during 2019. From the literature we know that salmon par and smolts experimentally exposed to high temperatures, die within 10 minutes at 30-33oC. Mortality was described in wild salmon stocks as early as the 1940's in temperatures of approximately 29.5oC.

Fish health services have, during 2018 (as in 2017) observed salmon displaying brain haemorrhage following panic attacks in the treatment chamber during thermal delousing. Gas supersaturation, variable oxygen levels and poor water quality (particles and slime) are commonly identified in such treatment chambers.

Mechanical delousing represents various forms of physically flushing the 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. Information from the Norwegian Food Safety Authority indicates that the latter system has been improved during 2017 to ensure better fish welfare, and that the brushes now direct the salmon towards the water jets rather than physically brush the lice from the salmon. The manufacturer's homepage continues to state, however, that the technology 'brushes clean' the salmon. Injuries including scale loss and skin bleeding are particularly associated with the different forms of mechanical delousing using

The Fish Health service HaVet has observed serious haemorrhage in the brain, palate and eyes following thermal delousing of salmon (Photo: Kristin K.S. Ottesen, HaVet ©).

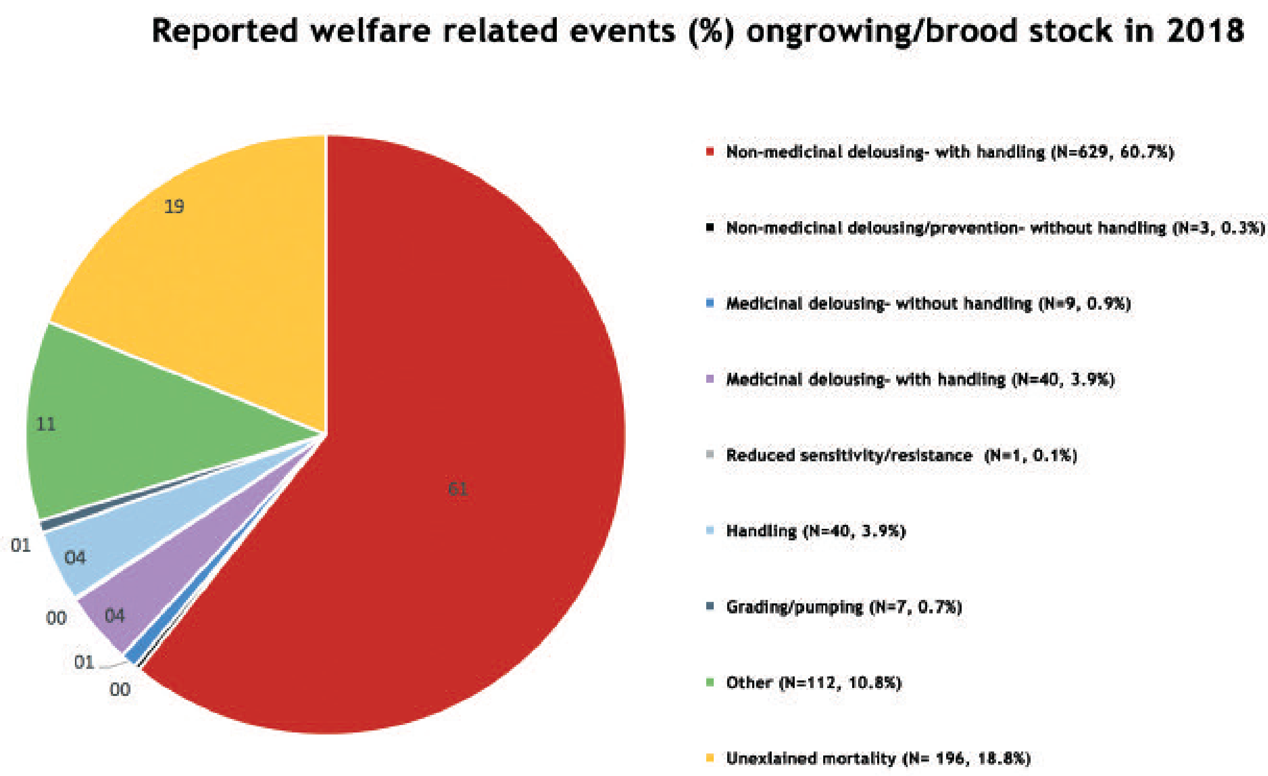
water jets.

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 known to represent a considerable welfare risk. Thermal, mechanical and freshwater treatments involve considerable handling and a series of stressful situations will occur as well as 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 (specifically mentioned in 2018), 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 what is 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. We continue to have limited knowledge of the extent of welfare problems and risk factors associated with mechanical delousing. Generally it would appear that mortalities were somewhat lower during 2018 (see discussion on mortality in chapter 2, change in infection risk). It is clear however, that frequent handling and mechanical delousing has a significantly negative effect on fish welfare.

During 2018, the Norwegian Food Safety Authority received 1036 reports of welfare related incidents in ongrowing sites for salmon, which represents an increase from 2017 when 963 reports were received. Of those reported in 2018, 629 (60.7%) were related to non-medicinal delousing treatments and handling (Figure 3.6). The severity and extent of the reported incidents varied, and different companies may have different thresholds for reporting of such incidents. It is extremely concerning that approximately 1/3 of all non-medicinal delousing treatments resulted in welfare challenges

Figure 3.6 shows distribution of welfare related incidents reported to the Norwegian Food Safety Authority in 2018, for each category. The reports (total N = 1036) relate to ongrowing fish. Data as registered in MATS. .



serious enough to warrant (compulsory) notification to the Norwegian Food Safety Authority. This trend cannot be allowed to continue, as non-medicinal delousing continues to increase in frequency.

Increased use of non-medicinal delousing methodologies reflects the continued decrease in use of medicinal treatments. Fish Health personnel also describe significant re-infection and a need for frequently repeated treatment when non-medicinal methodologies are used. We lack documentation of the effects of how frequency of treatment affect the fish. When several methods are used over a short peiod of time, the combined effect on the fish should be considered. Other routine work such as net changing, movement of fish from cage to cage or locality, transport of smolts or harvest ready fish should also be included in an overall evaluation. There are reasons to believe that the fish's stress tolerance is exceeded in many farms today. Changes in the pattern of outbreaks of infectious diseases may also indicate an increased overall burden. As an example, CMS was considered a significant problem in 2018 (see chapter 4.5 CMS).

Medicinal bath treatments utilising increased dosage and exposure times to achieve the desired effect may result in poisoning of the treated fish with significant welfare consequences. The extent of this problem is probably lower in recent times following the Norwegian Food Safety Authority campaign related to medicine use and focus on improved documentation of mixed treatments (combination treatments).

Fifty representatives from Fish Health services, farming companies and the Norwegian Food Safety Authority shared their experiences related to welfare and new delousing technologies. When asked whether they had experienced change in the number of lice treatments during 2018 on the farms on which they had responsibility for, 44% answered that there had been an increase, 28% that there had been fewer treatments and 22% answered that the number of treatments in 2018 was similar to the year before. Six percent answered 'don't know'.

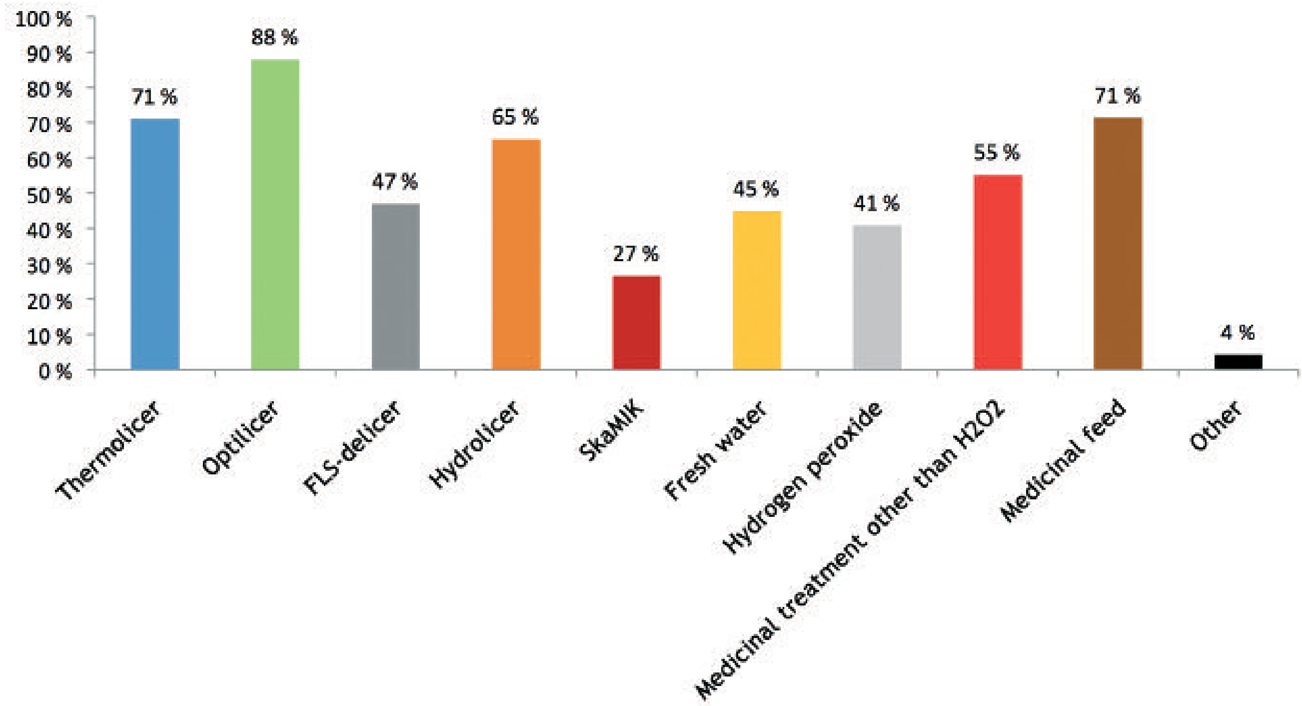


Figure 3.7. Presents a summary of the methods for which fish health personnel who responded to our survey had experience with in 2018. The Y-axis relates to % respondents who gave a positive reply (N=49).

A summary of the delousing methodologies respondents had experience with during 2018 is shown in Figure 3.7. While the number having experience with the two types of thermal treatment appears similar to 2017, there was an increase in the number having experience with mechanical delousing methodologies, particularly the FLS system. The number of medicinal treatments reduced further in 2018 (Table 3.1). Several respondents described having experience with chemical treatments other than hydrogen peroxide. This may be due to the fact that a larger proportion of respondents than previously are based in northern Norway, where resistance to medicinal treatments has been less common.

The efficiency of non-medicinal methods for removal of lice can depend on many factors including the basic principle behind each treatment method, how the machine is adjusted on the treatment day (e.g. water pressure in mechanical systems and temperature in thermal systems), exposure time (freshwater and thermal), model and eventual modifications to the original specification. Other factors such as crowding and the number of fish treated per hour also have an impact. The data must be interpreted with care as treatments are performed at extremely low infestation levels which make efficiency difficult to measure (this applies to all methods). The results appear to suggest that heated water displays (again) better treatment effect than the other two treatment principles. The effect of thermal treatment is, however, possibly lower in 2018 than it was in 2017. While this may be due to selection for more robust lice, changes in treatment temperature cannot be discounted. Several respondents report significant variation in the effect of the different methodologies and significant variation in degree of physical injury to the fish. The degree of physical injury may also vary between units, methods, personnel, localities and status of fish groups. Lice re-infection is also reported as a serious challenge. It was commented that thermal and mechanical delousing are poorly effective at removal of Caligus elongatus and that this parasite can represent a significant problem.

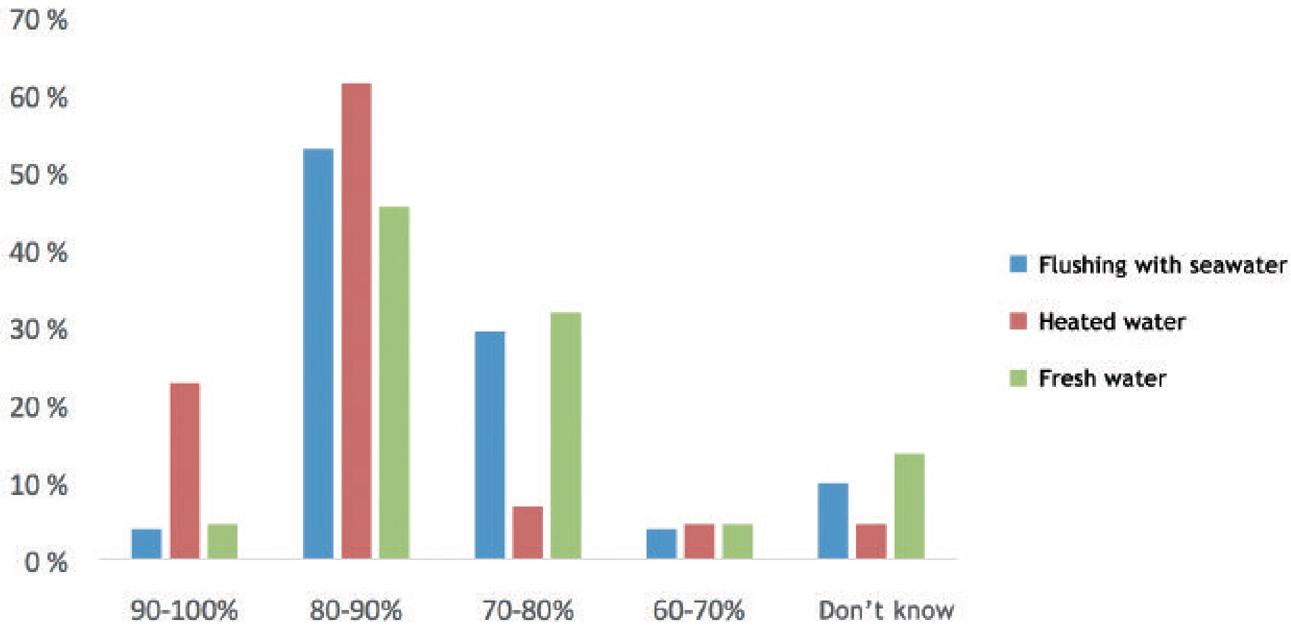


Figure 3.8. Presents a summary of the considered average reduction in number of motile and sexually mature salmon lice after treatment with the various flushing methods (three different types), thermal treatment (two different types) and freshwater treatment. The Y-axis displays % replies. The number of respondents who reported for each type of treatment were 39 for flushing-, 44 for thermal- and 22 for freshwater-.

Respondents were also asked to supply the temperatures normally used during thermal delousing. The results must be interpreted with care as treatment temperature, as mentioned previously, varies with sea temperature, which varies in different areas of the country. Most (47.4%) indicated temperatures between 31-32 ˚C, 34.1% answered 33-34 ˚C, 11.4 % answered 29-30 ˚C. One respondent (2.3%) answered that a temperature of 28oC was normal (total N = 44). When asked to estimate the highest temperatures utilised, several respondents answered > 34oC, with the highest registered at 36.1oC at a sea temperature of 12.4oC. When asked about the normal difference in temperature between seawater and treatment water (ΔT) during thermal treatments, figures between 15 and 24oC were supplied with most reporting temperatures between 22-22.5oC (14 of 33 respondents).

The upper temperature limit for thermal delousing is poorly scientifically documented. Given the relatively common occurrence of acute mortality episodes in association with thermal delousing, there must be a considerable question mark over whether this method, as it is currently used, represents an acceptable means of treating fish in terms of fish welfare.

The frequency of injury or mortality associated with the various means of delousing was also surveyed (see Figure 3.9). Compared to responses received in 2017 it would appear that both acute and delayed mortalities were reduced for both thermal and mechanical delousing in 2018. This may be due to improvement in the equipment used or the way in which the equipment was operated, but geographic factors may also play a role.

Reduction in the total mortality for 2018 (Chapter 2 changes in infection risk) may indicate that a more systematic approach to avoidance of losses associated with non-medicinal treatments has been utilised, but it is important to remember that good welfare is more than just a living fish. Thermal de-licers scored highest when evaluated in terms of acute mortality compared to other delousing methods. Flushing methods appear to cause the greatest degree of scale loss. In 2017, injuries including haemorrhage in the brain, nasal mucus membranes, palate and thymus were observed following thermal treatments and respondents were asked for their views regarding these types of injury in relation to thermal and mechanical treatments in 2018. Thermal treatment was awarded the highest score in this category, but given the

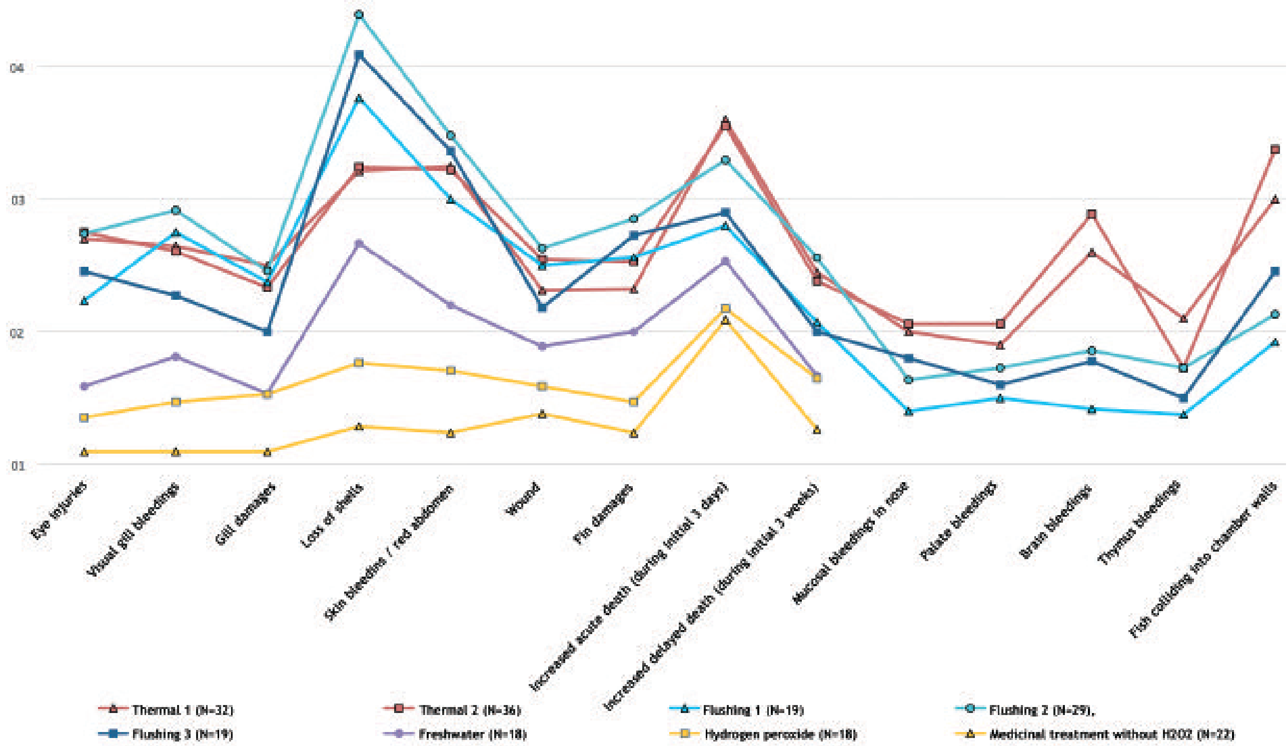


Figure 3.9. Displays the average frequency of injury or mortality each respondent experienced in relation to various methods of delousing in 2018, on a scale where 1 = never/extremely rare, to 5 = observed in nearly all fish. For the two questions related to mortality, 5 = nearly all delousing operations. 'Don't know' as a reply is not presented here. The red line relates to two different thermal methods, the blue line three different flushing methods. The question relating to haemorrhage in the nasal mucosa, palate and thymus was only asked in relation to thermal and mechanical methods. The number (N) of respondents who replied for each type of treatment is provided in the legend.

large number of 'don't know' replies, it is probable that thermal treatments are monitored more closely for this type of injury than other treatment forms. Experiences of this type of injury are so rare that average values should be interpreted with care.

Those respondents who had monitored both thermal and mechanical methods in this respect, wrote that bleeding is primarily observed in relation to thermal treatment. The information gathered also seems to indicate that collisions between fish and treatment chamber furniture happens more commonly during thermal treatment than during mechanical treatment. It may be speculated that the fish express a strong panic reaction on meeting the warm water. One respondent noted that fish treated with the thermal method show appetite depression for 2-4 days post treatment.

Other injuries reported as problematic in association with non-medicinal delousing included cuts and 'crushing' injuries, damaged opercula, skin ulceration (at cold temperatures), pressure injuries (due to blocked transport pipes) and loss of mucus.

The pre-treatment health status of the fish was considered decisive, as was the way the operation was performed and length of pre-treatment fasting. Fish with deformed opercula were considered more prone to develop gill problems in association with non-medicinal delousing. It was reported that repeated treatment over a short period makes evaluation of the injuries and mortalities associated with the various forms of treatment utilised difficult.

When asked whether scoring was performed on individual fish prior to/during/following non-medicinal delousing, 15% of respondents replied that such scoring is not common, while the remainder replied that fish health personnel or farm staff perform this type of scoring. The 'Fishwell' scoring system (or similar) was used actively by several respondents and 10-20 fish are normally examined before and after treatment and following any change in temperature or pressure during the treatment. Respondents were asked the degree to which external injuries of grade 2 and 3 (welfare poster) were observed following non-medicinal delousing (see Figure 3.10), and 35.6% chose the alternative 'often', which is a slight increase from the previous year.

In 2017, 76% of respondents stopped a non-medicinal treatment due to serious fish welfare concerns, and most (N=46) considered this necessary on a maximum of five occasions. Most (80%) found that farmers were willing to follow advice from fish health personnel on whether or not to perform a planned non-medicinal delousing, while 20 had experienced that a farmer had continued with the treatment despite advice to the contrary (an improvement from 2017). Additionally, 34% (compared to 41% last year) of fish health personnel had experience of farms performing non-medicinal delousing in the absence of fish health personnel.

In 2017, 85% of fish health personnel reported early harvest of fish on welfare grounds due to increasing lice numbers, on the supposition that the fish population concerned would not have tolerated the treatment. This was similar to previous years. Around 50% had observed poor biosecurity through unsatisfactory cleaning/disinfection of delousing barges. Such practices may indirectly lead to increased treatment associated mortality, via spread of infectious diseases. Cage-side harvesting continues to be an exceptional event with only

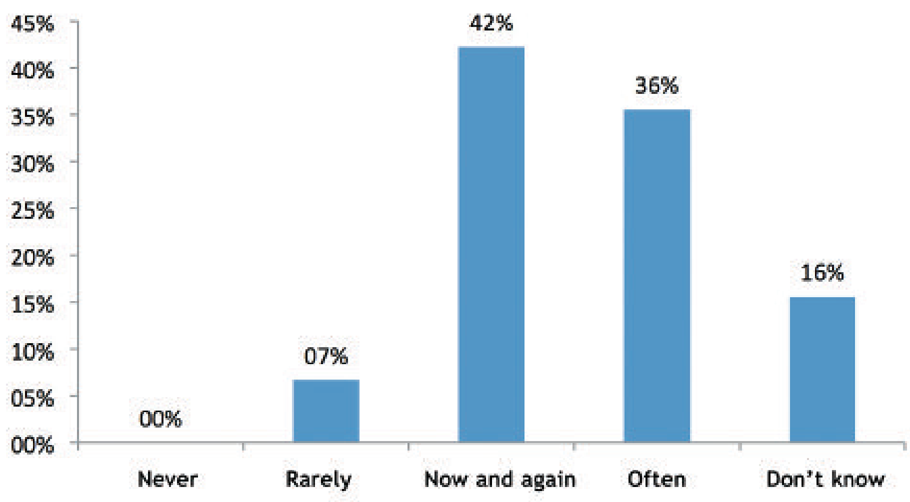


Figure 3.10. The degree to which external lesions of grade 2 and 3 are registered following non-medicinal delousing. The Y-axis displays the number of replies (N=45), while the X-axis describes the reply alternatives. For lesion grading, see 'The welfare poster'.

2% of respondents experiencing this type of event more than once in the course of 2018.

Half of respondents had registered outbreak of disease during the first two weeks post non-medicinal treatment, with most registering such events a maximum of five times during the year. Diagnoses included yersiniosis, HSMI, CMS, PD, ISA, systemic bacterial infection, various ulcerative conditions and gill diseases. Acute injuries caused during delousing may also provide a port of entry for both local and systemic infections. Vaccination does, however, seem to have had a positive effect on the yersiniosis situation (see chapter 5.5 Yersiniosis).

Thermal delousing and welfare- what does the Norwegian Veterinary Institute's Diagnostic Service say?

In 2018, 58 cases related to thermal delousing were submitted to the Norwegian Veterinary Institute for diagnostic investigation. Of these cases, 53 involved salmon, 3 involved rainbow trout and 2 involved lumpsucker. Increased mortality was described in most cases. The diagnoses registered are summarised in table 3.2. Viral diseases such as HSMI, CMS and PD weaken the fish and make them less able to tolerate non-medicinal delousing. The gill pathologies registered in many cases will also weaken the fish, but may also be caused by the treatment.

Repeated non-medicinal treatment may, with time, result in an accumulation of injuries and a weakened immune system in the fish. In ten cases, haemorrhage in or around the brain was found during post-mortem. Such injuries may occur after collision between the fish and the walls of the treatment chamber or during pumping. Ulcers, cuts and crush injuries are also described in fish after thermal delousing. In nine diagnostic cases, the Norwegian Veterinary Institute has identified a probable relationship between the pathological changes identified and thermal delousing and related handling. The Norwegian Veterinary Institute encourages submission of a comprehensive clinical history including information on the delousing methods used and pre-and post- treatment observations alongside the diagnostic samples themselves. This is important information that will allow active use of diagnostic resources in improving our knowledge base.

Welfare challenges associated with transport

Farmed fish are transported as smolts or as harvest ready fish. 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.

The Norwegian Food Safety Authority received six reports of 'welfare concern' in association with transport of fish in 2018 (five were reported as 'other', one as valve failure). Generally, it is important to produce a robust, disease-free smolt and subject it as far as possible to gentle production and handling methodologies. Stress during transport to the harvesting facility results in reduced product quality, particularly if fish are not allowed time to recover prior to harvest. Downgrading or customer complaints are indicators of poor welfare.

Wild-caught wrasse are a particular challenge. These fish are captured on a large scale by local fishermen along the southern coast from Østfold to Agder and are transported to salmon farms in the west and north of the country. Handling and transport can be rough, with extremely high associated mortalities (up to 40% has been recorded). Some wrasse species are also particularly sensitive to the poor water quality that may develop during transport.

Table 3.2. Diagnoses awarded in cases related to thermal delousing of salmon submitted to the Norwegian Veterinary Institute in 2018

Diagnosis	Number cases	Comments
CMS	8*	
HSMI	17*	
PD	2**	
Gill disease	22***	Includes both detection of gill-agents and other pathological conditions

* co-infection CMS and HSMI in two cases.
** co-infection PD and CMS in one case.
*** Diagnosed most commonly together with other disease conditions

Welfare challenges associated with harvesting

All harvesting processes involve a risk of suffering associated with handling, particularly during pre-harvest handling including crowding, pumping, chilling, time out of water, collision with harvesting furniture, sedation and bleeding. 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.

Sedation methods permitted for salmonids i.e. electricity or a physical blow to the head (or combination), are satisfactory on fish welfare grounds as long as the system is used and maintained properly. For sedation systems resulting in reversible loss of consciousness, it is essential that the fish are bled properly and quickly following sedation. Cutting a single gill-arch results in a slower bleed than cutting both gill arches.

Slaughter of fish is now highly automated. Small improvements and close surveillance are of real importance for both total fish welfare and product quality. All automated systems require human supervision and back-up systems. The legal training requirement for personnel involved, increases focus on animal welfare.

Welfare challenges associated with feed and feeding

Optimal nutrition is a precondition for normal development and growth for all animals. Nutritional requirements change throughout the life cycle, and can vary between individuals. Commercial feeds are developed to suit the majority of individuals within a population and the margins of error in relation to inclusion of optimal quantities of costly ingredients are small. Knowledge of the nutritional requirements of recently domesticated species is particularly limited. Change in the composition of feeds due to changes in ingredient price or environmental considerations e.g. increase in the proportion of vegetable matter in salmon feed, may result in health and welfare effects, and should be followed up closely over the short and long term. Feeding methods and amount of feed provided directly affect fish welfare e.g. competition for feed may lead to aggression. This may result in injury and individual undernourished fish. Farmed fish are routinely fasted prior to e.g. transport and handling. This is done to empty the intestine and reduce metabolism, such that the fish tolerate the stress of the subsequent management procedure. It is also performed on quality and hygienic grounds prior to harvest. There is, however, little knowledge of how fasting influences fish behaviour and how the desired effects of fasting may be achieved with the least negative effects on fish welfare.

Welfare challenges associated with new species

Domestication of new species inevitably results in new welfare challenges. Lack of knowledge in this respect is often a major challenge. In recent years in Norway, the huge increase in numbers of cleaner fish used has illustrated this situation regarding both health and welfare. Cleaner-fish i.e. wrasse and lumpsucker, are used in biological control of salmon-lice. Most lumpsucker used for this purpose are farmed while wrasse are mainly wild-caught. There are significant welfare challenges related to capture, storage and transport of wild-caught wrasse in addition to infection hygiene risks. The effect of removal of large numbers of wrasse from wild populations and ecosystems has been questioned, as have the eventual effects of escapees in the area of escape. Lumpsucker represent by far the majority of cleaner-fish farmed today and this species represents the second most numerous (30 million individuals in 2017) fish presently farmed in Norway. The advantages related to use of farmed cleaner-fish include stable quality and lower risk of transmission of disease between species and regions. Farmed fish also allow vaccination against important bacterial diseases, resulting in lower mortality and better welfare. The health challenges remain considerable however (as highlighted in other areas of this report (see chapter 10, the health situation for cleaner-fish). Knowledge related to cleaner-fish welfare and their particular needs has increased considerably in recent years. Surveillance during capture and transport, use of cover and improved feeding methods have contributed to better welfare, increased survival and better delousing effect. Several farmers have focussed on re-capture of cleaner-fish prior to delousing or harvest of salmon, which is positive for cleaner-fish welfare. Despite these positive developments, mortality levels remain high with some estimates indicating 100% mortality. Many cleaner-fish are killed during handling and delousing procedures, and despite introduction of legislation in 2018 requiring re-capture prior to such activities, the methodology to do so effectively remains inadequately developed. During freshwater treatment of salmon against AGD, all cleaner-fish not removed from the treated cage will die. Infestation with the sea-louse Caligus elongatus has also been identified as a welfare problem in lumpsucker in some areas in northern Norway.

Regulations related to fallowing and movement of fish make re-use of cleaner fish difficult, resulting in a limited 'window of use' for any particular cleaner-fish population. This is in itself a significant ethical and welfare challenge for which both the industry and the public authorities must find a solution. All fish species held in Norwegian fish farms are protected equally by animal welfare legislation. It is therefore a paradox that cleaner-fish used to improve welfare in farmed salmon are themselves subject to high mortality and a number of other health- and welfare- challenges. The Norwegian Food Safety Authority is presently conducting a policing campaign focussed on cleaner-fish. While the main principles behind evaluation of welfare are the same, it is necessary that evaluations are based on knowledge of the species biology and that specific welfare indicators other than mortality are developed. We lack today standardised welfare indicators for cleaner-fish.

Welfare challenges related to catch and release of wild fish

Catch and release of a proportion of fish caught by angling has a long tradition e.g. due to the fish being too small or belonging to a protected species etc. Catch and release as a general rule rather than an exception, despite being common in many areas of the world, is a relatively new phenomenon in Norway. This practice has however, increased considerably over the last 10-15 years and is integrated in some management plans. This is particularly common in management of salmon stocks in freshwater. Obligatory release of captured fish allows the riparian owner to continue to sell fishing licences and anglers may continue to fish, despite the fact that wild salmon stocks are threatened. Catch and release is also increasingly practised in sea-angling by e.g. foreign anglers continuing to fish after filling their legal quota. Catch and release has been debated in several fora. In 2018, the Norwegian Food Safety Authority arranged several meetings on the subject. There is a body of knowledge on how catch and release may be practised such that there is a reduced risk of the fish dying e.g. barbless hooks and fast rusting hooks, avoidance of handling the fish out of water, not fishing at high water temperatures etc. The fish welfare consequences of catch and release are however, more complicated than survival or death of the released fish. Animal welfare also relates to the fear and stress the fish are exposed to during hooking and fighting against capture, as well as direct injury caused by the hook/capture. Finally, this practice has an ethical aspect relating to the degree to which it may be defended when the sole aim is to provide excitement and fun for the angler. Such an ethical

Good fish welfare is biologically and technically challenging when different species with differing welfare requirements are held in the same cage. While predation is not the most common cause of mortality amongst cleaner-fish, this photograph demonstrates the welfare paradox. This wrasse died after being swallowed by the salmon, which in turn died because it choked on the wrasse. Photo: Kristine Gismervik, Norwegian Veterinary Institute evaluation is obligatory according to animal welfare legislation § 3, which states that animals shall be protected against unnecessary stresses and strains. As such, the benefit to the human population must be evaluated in relation to the welfare of the animal.

Overall evaluation of fish welfare in 2018

New production technologies and methods continue to challenge fish welfare in 2018. Experiences reported by Fish Health personnel indicate an increased prevalence of nephrocalcinosis associated with large-smolt production. This is in part due to water quality issues. Both CO2 and H2S are reported as having contributed to reduced welfare in 2018 and these problems appear to be particularly associated with recirculation based farms. Water quality problems in open cage farms in the sea were also reported, particularly low oxygen levels associated with use of 'louse skirts'. Problems with algae were also reported in several farms in 2018. Despite a reduction in overall mortality levels in the industry as a whole, increased mortality and injury continues to be experienced in association with handling and non-medicinal delousing. The welfare consequences of approximately 1/3 of all non-medicinal delousing procedures performed in 2018 were serious enough to trigger compulsory reporting to the Norwegian Food Safety Authority. We continue to lack documentation of the limits of tolerance related to repeated treatment and restitution time. While this makes maintenance of good welfare for farmed salmon extremely challenging, it is even more so for lumpsucker and wrasse farmed in systems not easily adapted to their biological requirements. Fish Health personnel report that thermal delousing can result in a strong panic reaction in treated salmon and that serious haemorrhage may be observed in the brain. Thermal treatment continues to cause higher mortality than mechanical delousing methodologies. The practice of use of increasing water temperatures has been registered, despite lack of knowledge regarding the upper limits of tolerance and experienced pain. Mechanical delousing continues to cause scale loss and bleeding skin lesions and crushing remains a considerable welfare risk during both mechanical and thermal delousing. It is also important to underline that diseased or sub-clinically infected fish poorly tolerate handling. Such populations should not be deloused with methodologies resulting in high levels of handling stress. Although many farmers are already working systematically towards better fish welfare, there is a general need for increased focus on this aspect of fish farming. Farmed salmon now have their own 'welfare encyclopedia', which was produced in 2017/18 as part of the FISHWELL project financed by the Norwegian Seafood Research Fund. This handbook documents the salmon's welfare requirements and how fish welfare can be measured and documented in practice. There is a need for further development of more standardised welfare protocols for several areas including testing of new technologies. To increase awareness of the importance of fish welfare it is important that we refer to fish as individual organisms. The industry needs concrete drivers and development of production systems that focus more on fish welfare and health. This applies to an equal degree to cleaner-fish production and use. gjelder i høyeste grad også rensefisk.

4 Viral diseases of farmed salmonids

A brief summary of the 2018 situation is provided in Table 4.1. Individual diseases are more closely described in subsequent disease-specific sections. The statistics stated for the notifiable diseases PD and ISA are the official statistics. For the remaining diseases, the provided statistics relate to the number of cases registered in the Norwegian Veterinary Institute system. Diagnoses made by private laboratories are not included in this table.

General evaluation of the viral disease situation

With the exception of the salmon louse, viral diseases have

the greatest effect on fish health in Norwegian aquaculture. For the first time, Fish Health personnel nationwide consider cardiomyopathy syndrome (CMS) to be the most important viral disease. Statistics from the Norwegian Veterinary Institute and other laboratories indicate that the number of farms affected continues to increase.

Pancreas Disease (PD) remains an important viral disease and the number of farms affected, although lower than last year, remains high (163). The number of SAV2 diagnoses in north-western (southern) Norway and in mid-Norway increased and both SAV2 and SAV3 were identified beyond their usual geographical limit at Hustadvika on the coast of Møre og Romsdal. SAV was not identified in the 3 most northerly regions in 2018.

The number of farms affected by infectious salmon anaemia (ISA) was similar to 2017 with 13 diagnoses and four suspected outbreaks. In contrast to previous years with a situation dominated by geographic clustering of outbreaks, the outbreaks identified in recent years covered a broader geographical area. A significant proportion of these outbreaks appear to represent epidemiologically independent events.
As in recent years there were few infectious pancreatic necrosis diagnoses made in 2018. Viral haemorrhagic necrosis (VHS) as in later years, was not identified in Norway.

For Heart and Skeletal Muscle Inflammation (HSMI) it is more difficult to conclude on whether the situation has changed over the last two years. The number of registered HSMI cases remains stably high and may be an underlying cause of high mortality associated with lice-treatment etc.

The status for each of these diseases and information on the causative viral agents involved are presented in specific chapters devoted to each disease.

Table 4.1 Prevalence of various viral diseases in farmed salmonids during the period 2001-2018. For non-notifiable diseases, the data is based solely on diagnoses made by the Norwegian Veterinary Institute.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ISA	21	12	8	16	11	4	7	17	10	7	1	2	10	10	15	12	14	13
PD	15	14	22	43	45	58	98	108	75	88	89	137	99	142	137	138	176	163
HSMI				54	83	94	162	144	139	131	162	142	134	181	135	101	93	104
IPN		174	178	172	208	207	165	158	223	198	154	119	56	48	30	27	23	19
CMS				88	71	80	68	66	62	49	74	89	100	107	105	90	100	101

4.1 Pancreas Disease (PD)

By Britt Bang Jensen, Jinni Gu and Hilde Sindre

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. Both types of infection lead to extended production times due to persistent reduced appetite, and losses due to reduced market quality are commonly experienced.

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

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. New legislation introduced in 2017 (2017-08-29 nr 1318), replaces previous legislation (2007-11-20 nr 1315 and 2012-11-06 nr 1056). In the new legislation, a PD zone is 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.

In response to outbreaks of PD in the surveillance zone north of Skjemta in Flatanger in Nord-Trøndelag (now Trøndelag) the Norwegian Food Safety Authority established a new control zone with the intention of prevention, hindering and eradication of pancreas disease (PD) in the council areas of Nærøy, Vikna, Leka, Bindal, Brønnøy and Sømna within the regions of Trøndelag and Nordland. This zone was extended in December 2017 to include Flatanger, Fosnes and Namsos in Trøndelag. All PD infected fish within the control-zone were harvested in the course of 2018, but as there remain fish stocked in the area where there was PD, the control-zone remains in force.

The largest reservoir of infection is infected farmed fish. Intensive health surveillance to identify early stage disease forms the basis for prevention of spread. 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. 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 into the control zone.

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. A new vaccine against PD, based on DNA-technology was released in 2018. It is too early to estimate the effect of this new vaccine in the field.

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 www.vetinst.no.

The 2018 situation

Official data

A total of 163 new cases of pancreas disease were registered in 2018. Following an increase from 84 to 121 SAV3 cases in western Norway from 2016-2017, a total of 98 cases were registered last year in the same area. The increase in 2017 was caused by the introduction of obligatory screening in that year which led to identification of a number of non-clinical SAV infections i.e. infections which do not always lead to outbreak of clinical PD. The number of SAV2 identifications in north-western (south) Norway and mid-Norway increased to 63 in 2018 compared to 55 in 2017 and 54 in 2016. The 'epicentre' appears to be Trøndelag, where 50 cases were registered. In 2018, one case of SAV3 was registered north of Hustadvika and one case of SAV2 was registered south of Hustavika (Gulen). Both genotypes were co-diagnosed in both localities. SAV was not identified in the three most northerly regions in 2018. The monthly distribution of PD cases was similar to previous years.

SAV3

PD caused by SAV3 is found primarily in Hordaland and Rogaland i.e. the southern part of

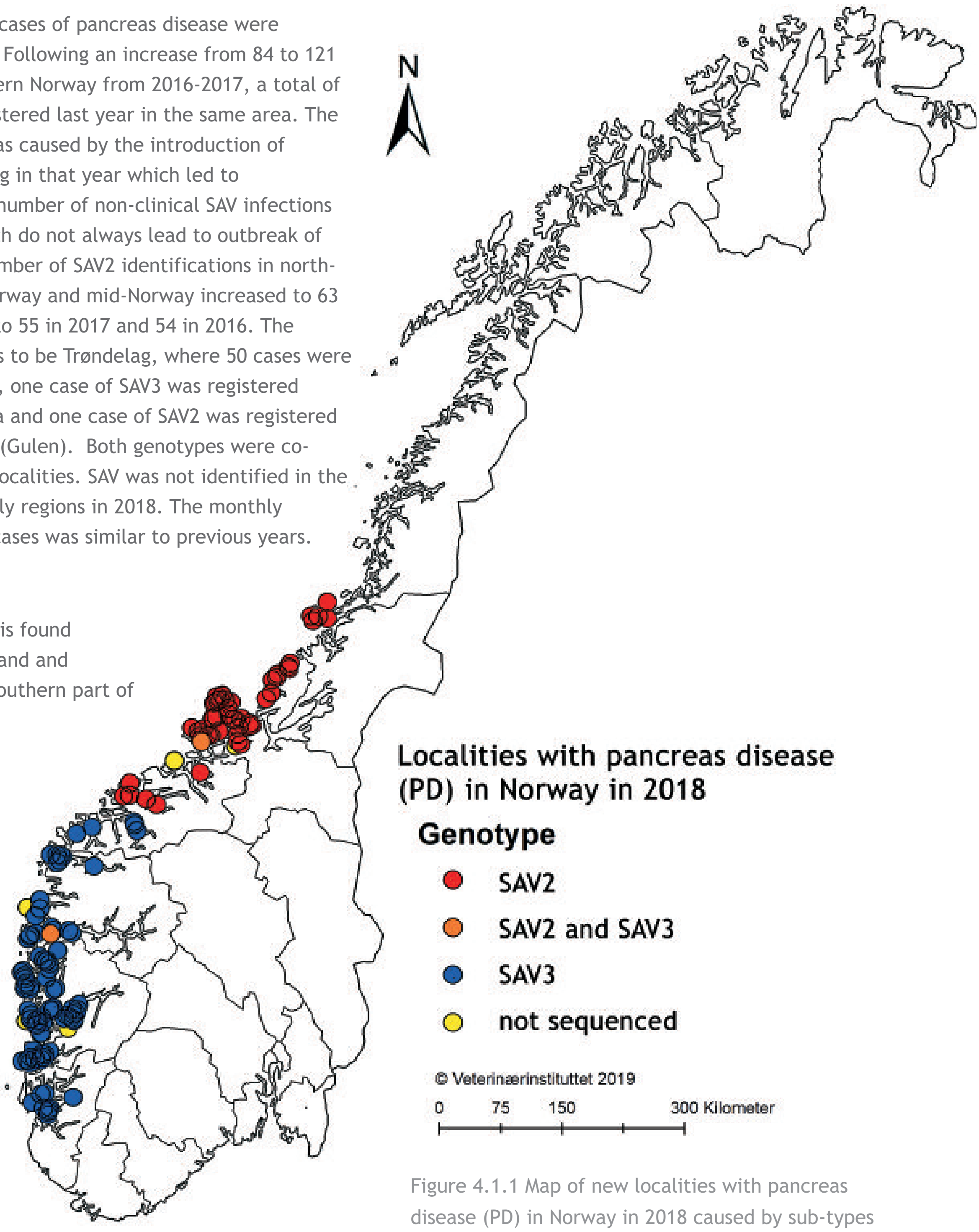


Figure 4.1.1 Map of new localities with pancreas disease (PD) in Norway in 2018 caused by sub-types SAV2 and SAV3

the PD zone. While the number of new cases in Hordaland in 2018 increased by approximately 10 compared to previous years (~50 cases), the number of new cases in Rogaland fell from 26 in 2017 to 10 (as in 2016). The number of cases in Sogn og Fjordane also fell from 31 in 2017 to 20 in 2018 (see Table for details). Following an increase in number of cases of SAV3 in Møre og Romsdal from 6 in 2016 to 10 in 2017, the number of cases in 2018 fell to 6 in 2018.

In October, PD caused by SAV3 and SAV2 co-infection was identified in 1.1kg salmon held in a farm in the Smøla council area in Møre og Romsdal region. The farm was harvested shortly after diagnosis in accordance with legislation which states 'Fish farmed north of Hustadvika diagnosed with SAV3 PD shall be harvested or destroyed'. Two months later SAV3 was identified by a private laboratory in a neighbouring farm. The Norwegian Veterinary Institute identified SAV2 associated PD in the same farm in January 2019.

SAV2

The number of new registrations of SAV2 increased from 55 in 2017 to 64 in 2018- the highest number recorded following introduction of this genotype to Norway. While the number of cases recorded in Møre og Romsdal fell from 21 to 14, the number in Trøndelag increased from 31-50 in 2018. SAV2 was also identified in a single farm in Sogn og Fjordane, which had previously been diagnosed with SAV3 PD.

Statistics and diagnoses

The statistics provided here represent the number of new positive farms, following a period of fallowing. This means that the real number of infected localities for any year is much higher, as some farms hold infected fish diagnosed the previous year.

Pancreas disease is defined as 1) histopathological findings consistent with PD and PD-virus detected in organs from the same fish (Diagnosis PD) or 2) histopathological findings consistent with PD in the absence of tissue samples suitable for virological investigation OR detection of SAV in the absence of histopathological findings consistent with PD (suspicion of PD). In some cases, a PD or SAV diagnosis has been made based on introduction of fish with diagnosed PD or SAV to the farm in question. In the statistics presented, diagnosed PD and suspected PD (few cases) are summed.

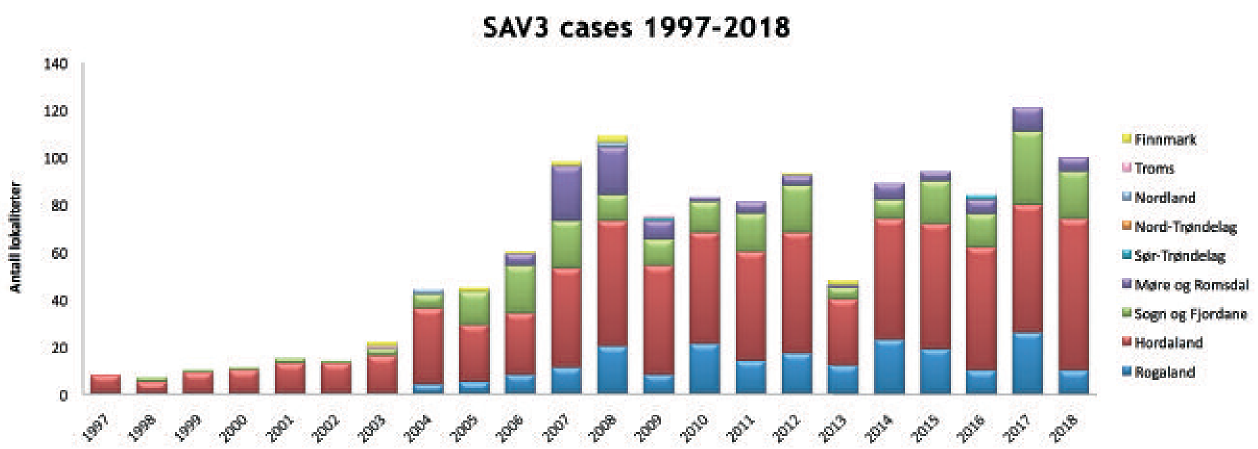


Figure 4.1.2 Regional distribution of new PD-cases per year 1997 – 2018, sub-type SAV3

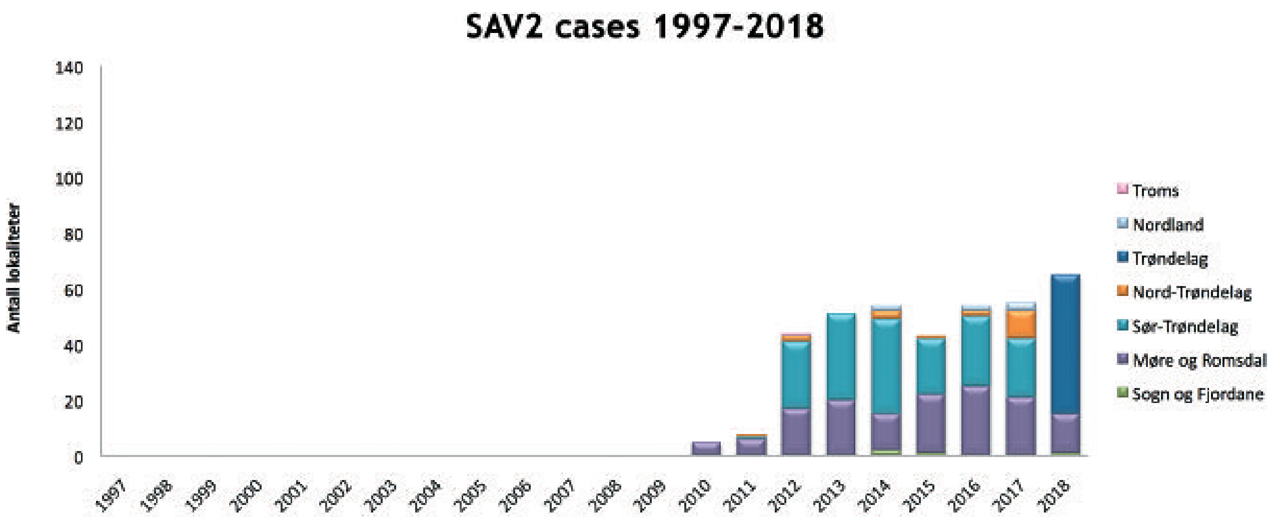


Figure 4.1.3 Regional distribution of new PD-cases per year 1997 – 2018, sub-type SAV2

The survey

The Norwegian Veterinary Institute has again carried out a survey of Fish Health Services and the Norwegian Food Safety Authority. This year's survey reveals that respondents from Hordaland and further south consider PD together with CMS as the most important infectious diseases of sea-farmed salmon. Both diseases scored 4.3-4.5 on a scale of 1-5 (with the salmon louse scoring highest). In northwest (southern) Norway PD scores higher than CMS, as does gill disease (4.2-4.3). In mid-Norway, PD is considered a significant problem by the Norwegian Food Safety authority (5), but not as serious by Fish Health personnel (4.1). In the north, PD is not considered a significant problem by either group. PD is considered a less serious problem in ongrowing rainbow trout, generally scoring between 2.5 and 3, with a lower score in the north (0-1). Just under half of respondents inform that fish in their areas are vaccinated against PD to a greater or lesser degree. While most of these respondents work in the PD-zone, a third work in the three most northerly regions and report vaccination of a proportion of fish. Forty three percent of respondents state that PD QTL-roe is used to lesser or greater degree in their areas. This applies particularly within the PD-endemic zone. Three respondents report experiencing outbreak of PD in single localities, despite use of PD QTL smolts.

Evaluation of the PD situation

The high prevalence of PD is a challenge to the industry and causes significant financial loss. (See Norwegian Veterinary Institute report 2015 nr. 5 Pancreas disease in salmonid fish- a review with focus on prevention, control and eradication, ISSN 1890-3290, in Norwegian). PD is an extremely infectious disease that can manifest in a 'sneaking' manner. The fish may be infected long before they become clinically diseased. Frequent screening is therefore important to reveal infection at an early stage, although a farm may be infected despite negative screening results. The infection spreads in the sea via transport and movement of infected stocks between farms. PD is a typical stress related disease, and latent infections may develop into serious outbreaks following e.g. delousing. The number of new diagnoses increased dramatically following implementation of new legislation requiring monthly screening for SAV. Without this screening, a number of SAV infections would have gone unnoticed and possibly remained latent. It is, however, equally likely that these infections would have developed into active clinical disease which would have been diagnosed at a later date.

Since the border of the PD-zone was moved north in 2017, there have been 5 cases in the area approaching Buholmråsa, an area previously free of PD. PD legislation introduced in 2017 allows that farms with SAV2 outside the PD-zone, following an evaluation of the situation, may continue to hold fish in the sea until harvest. This will most probably result in further northerly spread of the disease.

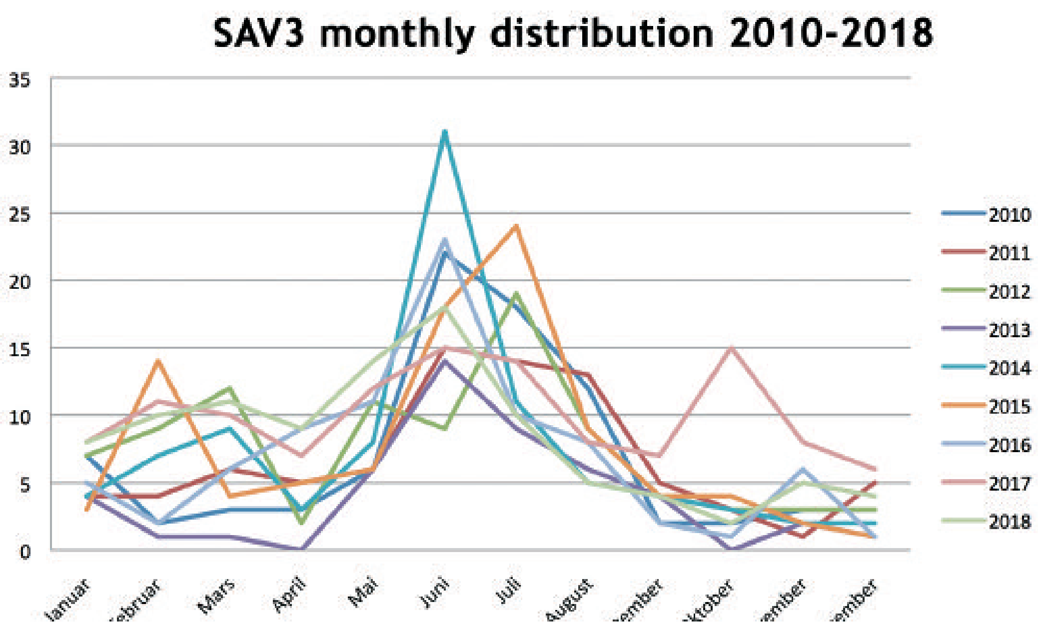


Figure 4.1.4 Monthly incidence rate of localities with PD SAV3 2010 – 2018

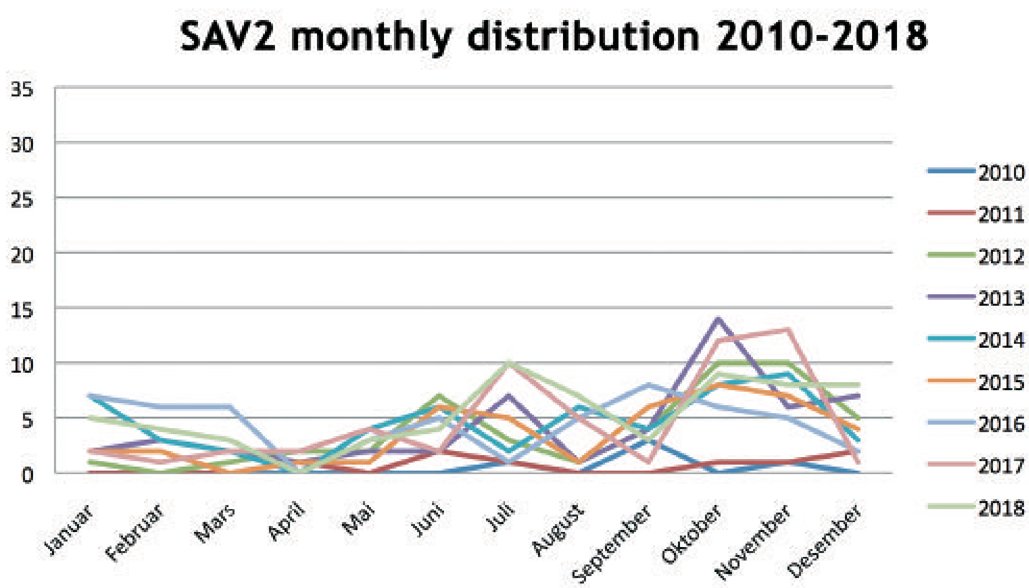


Figure 4.1.5 Monthly incidence rate of localities with PD SAV2 2010 - 2018

4.2 Infectious salmon anaemia (ISA)

By Mona Dverdal Jansen, Maria Aamelfot, 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.

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

Situation in 2018

Official data

In 2018, ISA was diagnosed in 13 localities; 1 in Rogaland, 5 in Hordaland, 1 in Sogn of Fjordane, 1 in Møre og Romsdal, 3 in Nordland and 2 in Troms. Late in the year, there were an additional four suspected cases in Hordaland (1), Trøndelag (1) and Troms (2).

Evaluation of the ISA situation

The 13 outbreaks were distributed amongst 6 regions from Rogaland in the south to Troms in the north. Since 1993, Norway has experienced between 1 – 20 outbreaks annually (see Figures 4.2.1 and 4.2.2). Over the last few years, the majority of outbreaks have occurred in Northern-Norway, but as far back as 2003-2006, outbreaks were distributed along the whole coastline. The geographic distribution of confirmed ISA outbreaks in Norway from 2015 – 2018 is shown in Figure 4.2.3.

The outbreak in Møre og Romsdal involved a broodstock population, while the remaining outbreaks involved marine ongrowing sites. There were no ISA diagnoses made in freshwater farms in 2018.

Phylogenetic analyses performed by the Norwegian Veterinary Institute revealed that the majority of ISA virus from outbreaks in 2018 were not closely related and thereby represent isolated occurrences of unknown infection source. Such outbreaks may be explained by mutation of ISAV HPR0 to ISAV HPR-del. One such occurrence was described in a new publication from the Faroe Isles (Christiansen et al., 2017). Recent research has generated results supporting the hypothesis that spontaneous ISA-outbreaks may be related to poor biosecurity and stress (FHF project nr. 901051). Little is known of possible reservoirs and infection routes for HPR0-ISAV. Arguments have been made for the existence of a marine reservoir of HPR0-ISAV and/or that HPR0-ISAV circulates mainly in populations of farmed salmon. These views are supported by information published in Norway, The Faroe Isles and Scotland.

Phylogenetic analyses and geographical proximity suggest that the outbreak in Rogaland was related to an

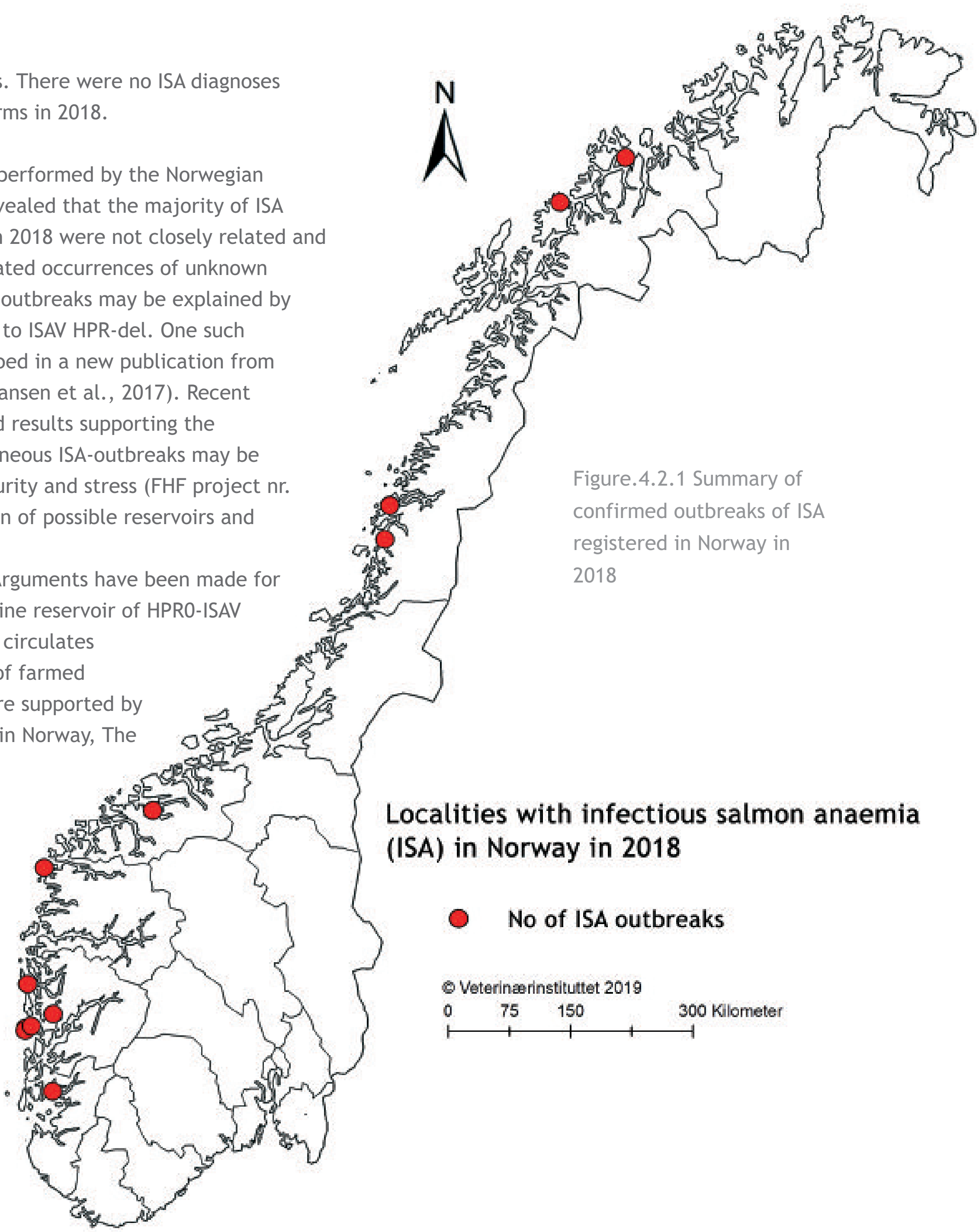


Figure.4.2.1 Summary of confirmed outbreaks of ISA registered in Norway in 2018

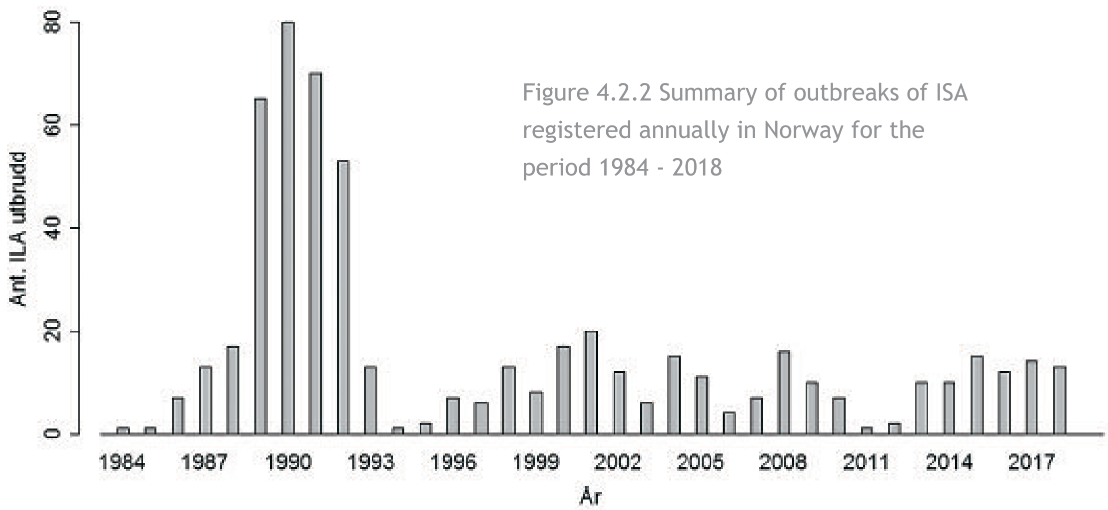


Figure 4.2.2 Summary of outbreaks of ISA registered annually in Norway for the period 1984 - 2018

outbreak in a nearby farm in August 2017. This means that horizontal transmission of infection in this case is probable. Four of five outbreaks in Hordaland have, most probably, a common but unknown source of infection. The phylogenetic analyses support horizontal transmission of infection between sites. Several variants of ISA-virus were identified on a broodstock farm in Møre og Romsdal during the autumn of 2018. While ISAV was also identified in this farm in 2017, the 2017 variant was not closely related to the variants identified in 2018.

The remaining outbreaks and sequences recovered from the non-confirmed suspected outbreak cannot be related to any previous known outbreak.

In light of the Norwegian Veterinary Institute's responsibilities as an international and national reference laboratory for ISA, it was decided during the autumn of 2018 that ISAV sequences for gene segments 5 and 6 recovered during confirmatory investigations shall be published on GenBank. This is performed as soon as sequences of satisfactory quality are recovered. Sequences for all outbreaks from 2018, together with all available sequences from previous years related to our reference function will be deposited. The 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.

There is no official surveillance of ISAV HPR0 in Norway, but its widespread presence is revealed though surveillance for ISAV-HPR-del and other diagnostic

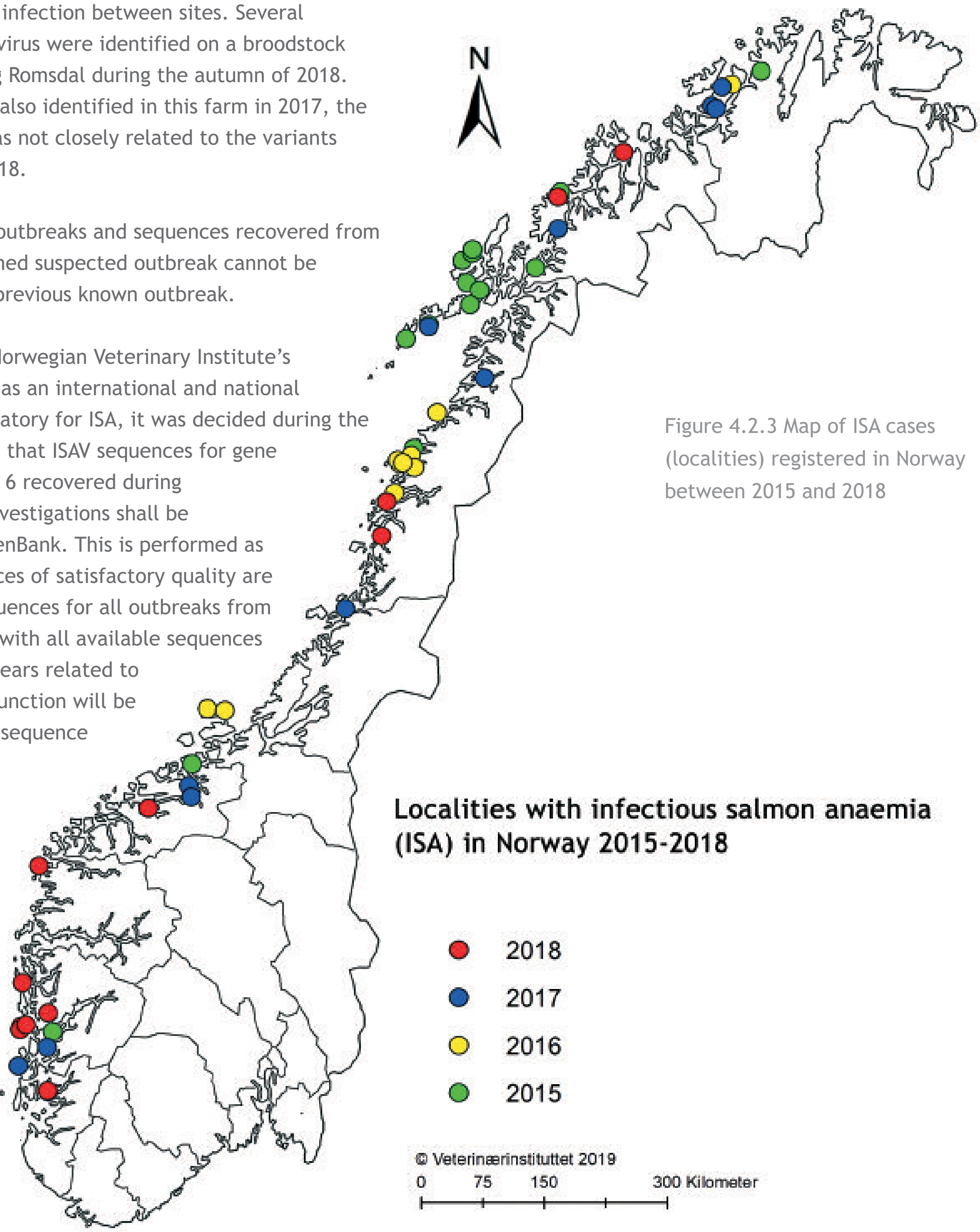


Figure 4.2.3 Map of ISA cases (localities) registered in Norway between 2015 and 2018

investigations. Preliminary data which the Norwegian Veterinary Institute has access to, suggests that at ISAV HPR0 was detected on at least 40 sites in 2018. ISA was diagnosed on three of these localities in 2018. Final figures will be reported when the surveillance programme for ISA is published.

Successful control of ISA is based on prevention of spread through early diagnosis and rapid removal of diseased fish from the affected farm. The industry, Fish Health Services and the Norwegian Food Safety Authority have, since 2015, worked together on systematic surveillance within ISA control zones. Surveillance includes monthly 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 underline the importance of effective counter measures against ISA in Norway (Xiao et al., 2018).

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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.

Figur 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, strain of fish 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.

Situation in 2018

Data from the Norwegian Veterinary Institute

In 2018, IPN or IPN-virus was identified in 19 salmonid farming localities, of which 8 were juvenile production units and 11 were marine ongrowing sites. An outbreak was also suspected in a juvenile rainbow trout production facility. As in 2017, IPN was not diagnosed in ongrowing rainbow trout. The total number of outbreaks represents a slight reduction from 2017 when IPN was diagnosed in 23 farms. The reduction relates to the number of cases in ongrowing salmon and hatchery rainbow trout while the number of outbreaks in hatchery salmon increased

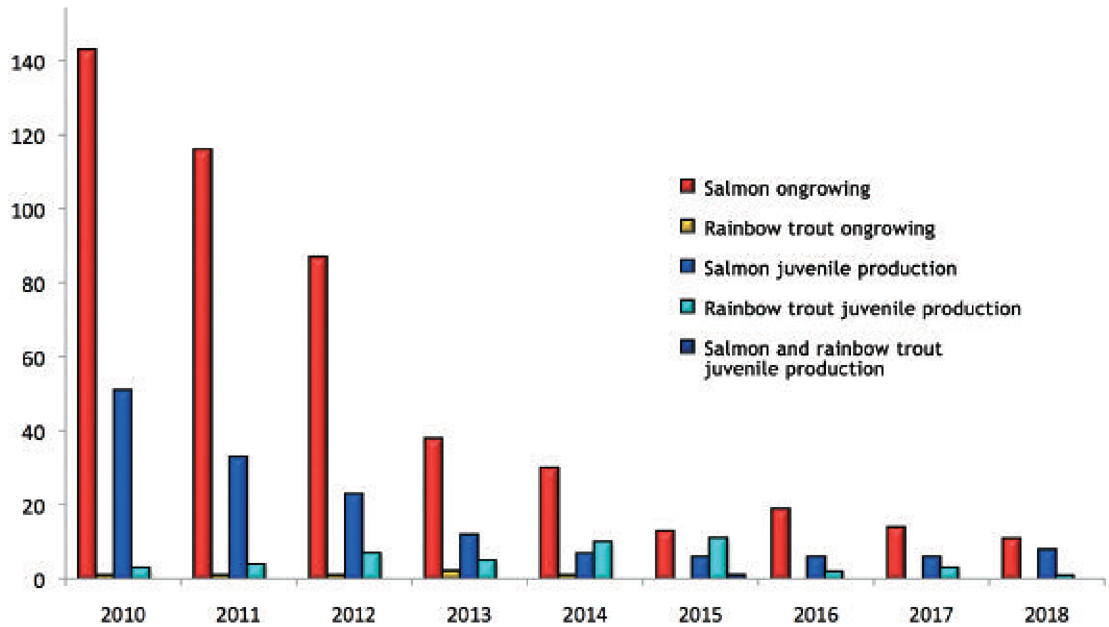


Figure 4.3.1: Number of registered IPN-outbreaks 2010-2018

slightly. Fifteen of the 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.

Evaluation of the IPN situation

One private laboratory diagnosed four cases based on histopathology and immunohistochemistry, all freshwater facilities, one farming rainbow trout and three salmon. As IPN is non-notifiable and diagnoses do not require confirmation by the Norwegian Veterinary Institute, the actual number of cases is likely to be higher. Whether cases diagnosed by the Norwegian Veterinary Institute and private laboratories wholly or partly overlap is unknown. There is good reason to believe that the number of cases continues to remain relatively low.

Read more: www.vetinst.no/sykdom-og-agens/infeksiøs-pankreasnekrose-ipn

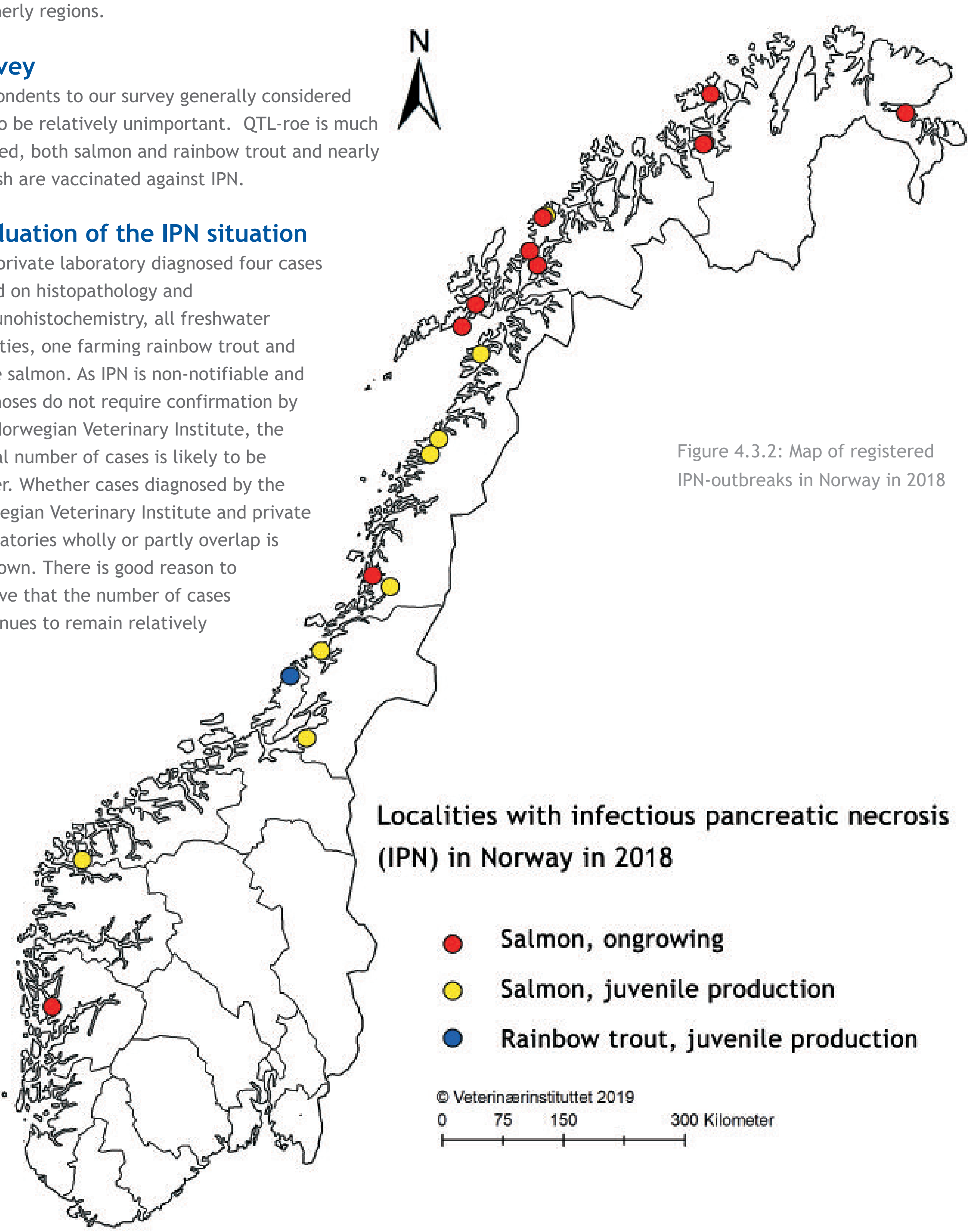


Figure 4.3.2: Map of registered IPN-outbreaks in Norway in 2018

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 salmon in 1999, and in 2014 an HSMI-like disease was identified in rainbow trout. In salmon, the disease is primarily identified during the first year in seawater, but outbreaks may also occur in freshwater. Outbreaks of HSMI-like disease in rainbow trout are identified in freshwater and in fish transferred to sea from infected freshwater farms. The disease primarily affects the heart. On histological investigation, sparse to gradually more advanced levels of inflammation may be observed in the heart, prior to clinical outbreak of disease. Outbreaks may last several weeks. Inflammation of the red skeletal musculature is also a relatively common finding in salmon with HSMI.

HSMI may result in a variable degree of mortality, and losses are often associated with stressful management routines. While affected rainbow trout commonly display anaemia, this is not common in salmon. Salmon dying with HSMI often display signs of circulatory disturbances.

Piscine orthoreovirus (PRV) was identified in HSMI-affected salmon in 2010 (PRV1). Another type of this virus was identified in rainbow trout suffering a clinically similar disease in 2015 (PRV3, also called virus Y or PRVOm). The evidence indicates that the PRV-subtypes are relatively fish-species specific, but may spread to a degree between species. PRV1 from salmon and PRV3 from rainbow trout have a genetic similarity of around 80%. The aetiological relationship between PRV1 and HSMI in salmon and PRV-3 and HSMI-like disease in rainbow trout has been confirmed following experimental challenge experiments performed in 2017 and 2019.

While PRV1 is widespread and has been identified in wild and farmed salmon, infected salmon do not necessarily develop HSMI. HSMI has not been identified in infected 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. Fish developing HSMI can have a high viral load in heart and muscle cells.

For more information on HSMI, see: www.vetinst.no/faktabank/HSMB

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, and is also associated with non-clinical infections. There are no vaccines available on the market, but experimental vaccine testing carried out in 2018 identified moderate levels of protection against HSMI. Treatment of HSMI with anti-inflammatory components is reported to have some effect.

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.

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 probably to be found in the marine environment. There are indications that many farms suffer repeated outbreaks, which may indicate persistent infection. 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.

The situation in 2018

Data from the Norwegian Veterinary Institute

In 2018, HSMI was diagnosed by the Norwegian Veterinary Institute in 104 salmon farms, 96 ongrowing sites, 2 broodstock farms and 6 hatcheries. HSMI-like disease was not diagnosed in rainbow trout during 2018.

Data from other laboratories

HSMI was diagnosed by private laboratories in 90 farms during 2018. 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.

Annual survey

Both Fish Health Services and field officers of the Norwegian Food Safety Authority consider HSMI in salmon to represent a significant problem. On a scale of 1-5

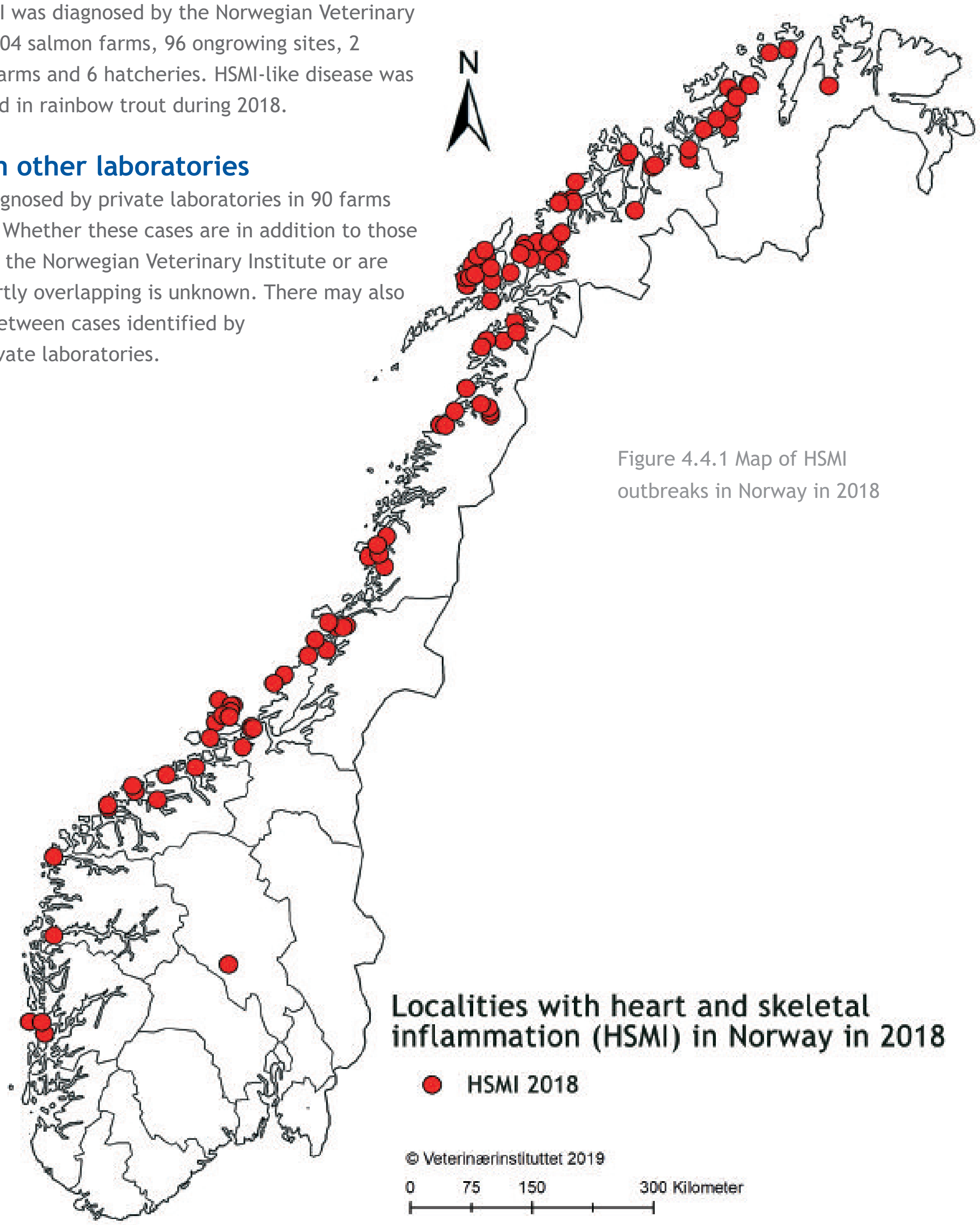


Figure 4.4.1 Map of HSMI outbreaks in Norway in 2018

where 5 = maximal significance, HSMI was graded to 3.74 and is thereby considered the third most important disease of farmed salmon. Fish Health Services in Northern- Norway consider HSMI to be a greater problem than the remainder of the country. It is considered less of a problem in juvenile production facilities, scoring an average of 1.7 for through-flow facilities and 2.2 for recycling facilities. Some individual farms seem to have much greater problems than others. It would appear that HSMI is a more significant problem in through-flow facilities (score 2.0) and recycling facilities in Northern-Norway than in the rest of the country.

PRV3 in rainbow trout has, according to responses received greatest impact in through-flow hatcheries (score 2.0) with slightly less impact in through-flow farms (score 1.56). The significance of PRV-3 in broodstock farms and ongrowing sites has reduced markedly (score 1.57 and 1.71 in 2018 compared to 3.8 and 2.7 in 2017). This is almost certainly related to the absence of diagnoses in Norway in recent years.

Evaluation of the HSMI situation

HSMI appears to continue to be a significant problem in salmon farming. Fish Health Services covering the whole country report problems with HSMI, with the situation being most severe in northern –Norway. The fall in number of cases identified by the Norwegian Veterinary Institute in ongrowing sites does not, in all probability, reflect an actual fall in number of outbreaks, but is more probably related to the now non-notifiable status (since

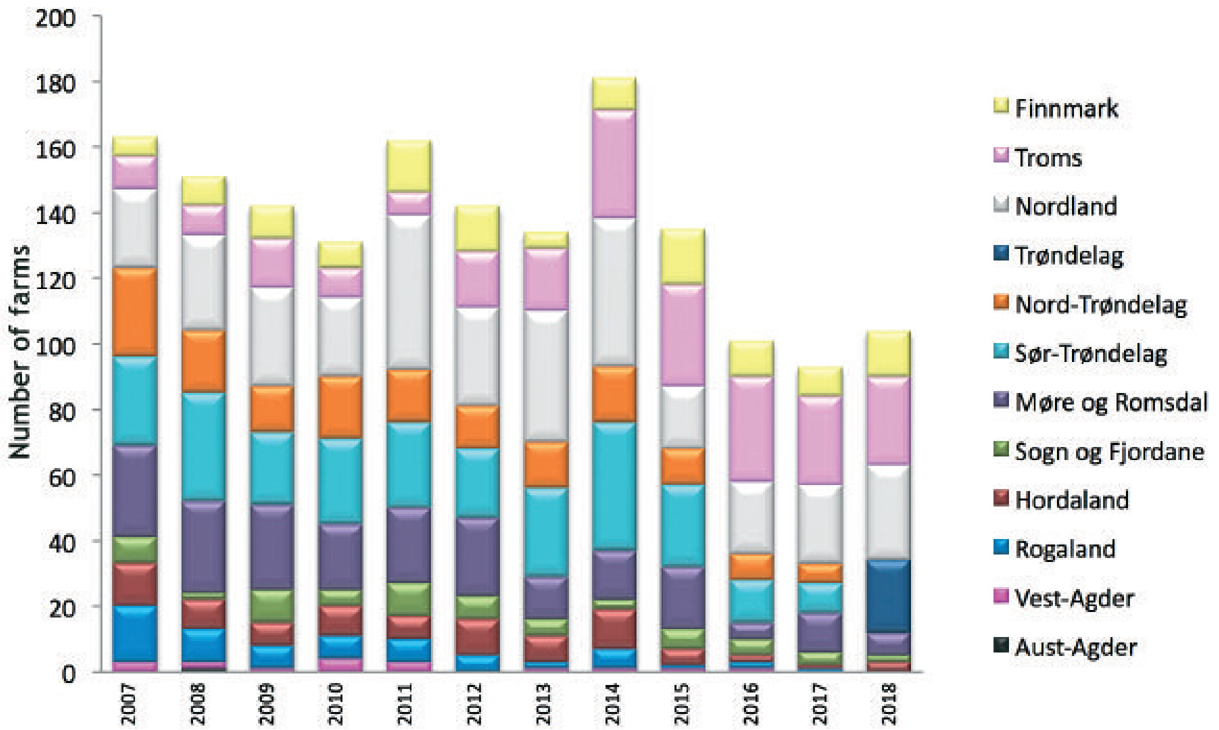


Figure 4.4.2 Regional distribution of HSMI outbreaks 2007 - 2018

2014) of the disease. HSMI outbreaks diagnosed by private laboratories are not included in official statistics due to the risk of overlapping investigations.

The survey indicates that the HSMI situation is comparable to that experienced in 2017. HSMI appears to be an important factor related to mortality episodes following delousing or other handling routines. HSMI affected fish have a low tolerance for treatment and handling, and high levels of mortality may result. The significance of HSMI in juvenile production units seems to vary, but severity does not seem particularly related to geography or production system. This indicates that while individual farms can have serious problems, others only experience minor or no effects of infection. The significant cases may be due to persistent infections.

HSMI-like disease was not identified in rainbow trout during 2018, and the importance of the disease during the sea phase of culture has reduced dramatically. PRV-3 is, however, considered to impact juvenile production in freshwater.

HSMI and associated diseases mediated by PRV are of increasing international importance and diseases other than HSMI are reported to be associated with PRV infection. PRV-1 in particular has been associated with liver necrosis in Chinook salmon in Canada and PRV-2 with anaemia in Coho salmon in Japan. PRV3 has been associated with disease in rainbow trout and has been identified in wild brown trout in several European countries.

Table 4.4.1. Relationships between PRV-genotypes and disease in salmonids

PRV genotype	Species	Disease
PRV-1	Atlantic salmon	HSMI
	Chinook-salmon (Canada)	Liver necrosis («jaundice syndrome»)
PRV-2	Coho-salmon (Japan)	Anaemia («Erythrocyte Inclusion body syndrome»)
PRV-3	Rainbow trout	cerebral inflammation with anaemia
	Seatrout/brown trout	?

4.5 diomyopathy syndrome (CMS)

By Camilla Fritsvold and Britt Bang Jensen

The disease

Cardiomyopathy syndrome (CMS) is a serious cardiac complaint affecting sea-farmed salmon. The disease 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.

Typically, fish are affected during their second year at sea, but the number of cases affecting younger fish is increasing. Recent research has revealed that smolts transferred to sea during the autumn have around double the risk of development of the disease compared to spring transferred smolts.

The disease is caused by the totivirus-like Piscine myocarditis virus (PMCV), a naked double stranded RNA-virus with a relatively small genome of around 8800 basepairs. Clinical 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 and HSMI, but moribund fish are not commonly observed. CMS does not normally result in changes in the exocrine pancreas or skeletal muscle tissues. Waterborne fish-to-fish transmission is known to occur, and the most important reservoir of infection is farmed salmon.

A newly completed FHF-financed research project 'CMS-EPI', found that PMCV is probably more widespread than previously thought, and that salmon may be infected with PMCV on or immediately following sea-transfer. Fish in half of the 12 farms studied did not develop clinical CMS, despite the fact that fish on all localities became infected shortly (between 3 and 7 months) after sea transfer. The period between PMCV infection and outbreak of disease varied between 3 and 13 months. There are indications that PMCV may be transmitted under normal farming conditions from parent to offspring, but no positive findings have been made at start feeding.

In 2017 PMCV was again identified in corkwing and ballan wrasse from a salmon farm in Ireland.

For more information on CMS, see: http://www.vetinst.no/sykdom-og-agens/kardiomyopatisyndrom-cms (updated February 2019)

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.

It is known that stress during e.g. delousing, transport etc. may trigger outbreaks and associated mortality in fish displaying clinical CMS changes. Following a CMS diagnosis, all stressful management routines should be reduced to a minimum.

The virus's biophysical characteristics are poorly understood. Choice of a biosecurity strategy is therefore challenging. General control of the health status of incoming fish and water, as well as generally high levels of infection hygiene during the whole production cycle are important risk reducing elements. There are no available vaccines against CMS, but CMS-QTL smolts are available on the market.

The situation in 2018

Data from the Norwegian Veterinary Institute

Diagnosis of CMS requires histopathological investigation. The Norwegian Veterinary Institute diagnosed CMS in 101 localities during 2018. All were ongrowing sites or broodstock farms. This represents a slight increase in prevalence compared to the previous year when the disease was identified in 90 farms.

Data from other laboratories

CMS was identified by other laboratories in 125 localities during 2018. A degree of overlap in cases identified by the Norwegian Veterinary Institute and private laboratories is likely. 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.

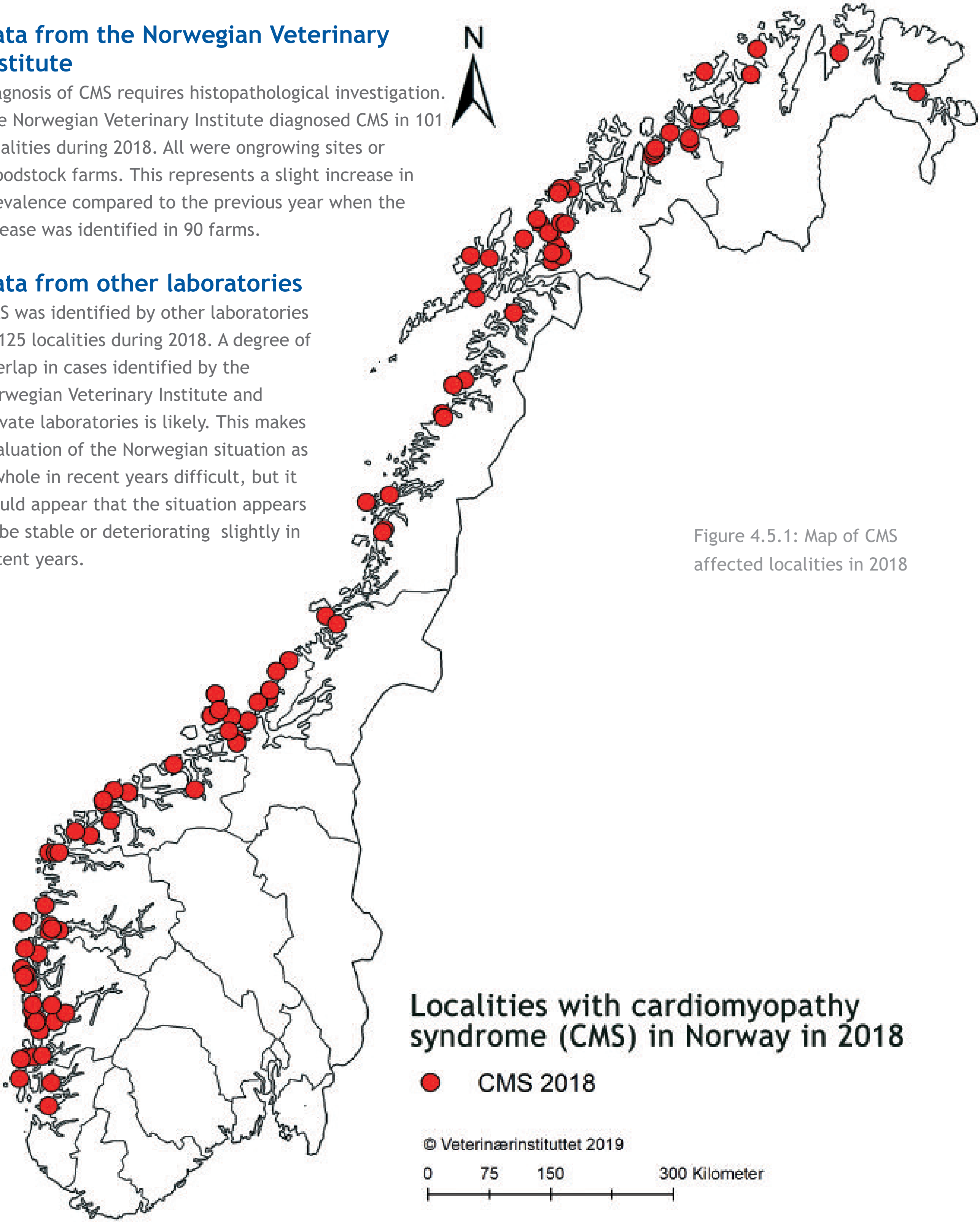


Figure 4.5.1: Map of CMS affected localities in 2018

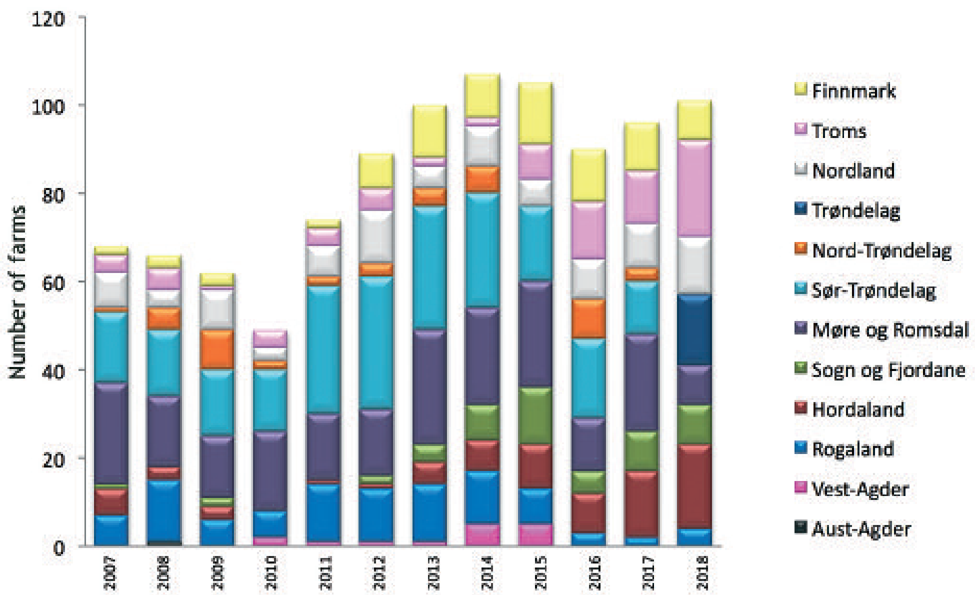


Figure 4.5.2: Summary of CMS affected localities 2007– 2018, distributed by year and region. The data is based on material submitted to the Norwegian Veterinary Institute (illustration Britt Bang Jensen, Norwegian Veterinary Institute)

Geographical distribution of CMS cases identified by the Norwegian Veterinary Institute

In 2017, approximately one third of CMS diagnoses made by the Norwegian Veterinary Institute were made in Nordland, Troms and Finnmark and this increased to nearly half of all cases identified in 2018. The proportion in Trøndelag and Møre og Romsdal decreased from 36% in 2017 to around 25% in 2018, while cases from west and south-western Norway increased from a quarter to a third of the national statistic. The largest regional changes in number of CMS cases were the increase in Troms from 12 to 22 registered outbreaks and the decrease in Møre og Romsdal from 22 cases to 9. A slightly increasing trend has been observed in Hordaland over the last 10 years, and with 19 diagnoses in 2018, this region dominated Norwegian Veterinary Institute CMS statistics. Whether this reflects the true situation is difficult to say, but the changes in Møre og Romsdal may be due in part to the fact that Fish Health Services in this region have largely utilised private laboratories for diagnostic purposes in 2018.

Evaluation of the CMS situation in 2018

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 would appear, however, that the situation is stable or deteriorating slightly in recent years.

CMS was considered the second most important disease problem in both ongrowing and broodstock fish in the annual fish-health survey after the salmon louse and related louse-injuries. The disease is thereby the most important infectious disease in both categories in 2018. A total of 55 Fish Health Service-, farming company- and Norwegian Food Safety Authority-employees geographically well-spread across the country, responded in 2018.

As salmon with CMS tolerate stress and handling poorly, salmon lice and salmon lice treatments have contributed indirectly to development of CMS as the serious disease it now is in Norwegian salmon farming. Salmon with CMS can, despite serious pathological changes in the heart, perform relatively satisfactorily provided they are protected from stressful management techniques. Modern lice treatments, and probably the mechanical treatments in particular, result in mortality due to mechanical injury, but also cause massive stress and an ‘escape reaction’ in the treated fish. Fish with advanced CMS heart pathologies do not tolerate such stress and die abruptly. This CMS-related mortality contributes therefore to ‘treatment mortality’ which may be significant. Other latent infections such as yersiniosis may be activated by such stress and result in mortality in the period following treatment. This is a serious welfare problem and should motivate increased research into CMS.

While the louse situation and lice treatments contribute significantly there are other factors which also contribute to the current importance of CMS. Several respondents to the survey confirmed an observed trend that both the presence of the PMC-virus and clinical CMS is becoming more common in younger, smaller sea-farmed fish than previously.

Of the 34 respondents who commented use of CMS-QTL-fish, 17.6% stated that this type of fish was utilised to a significant degree and 23.5% that they were utilised to 'some degree' on farms for which they had responsibility. Six respondents had experienced CMS in this type of fish.

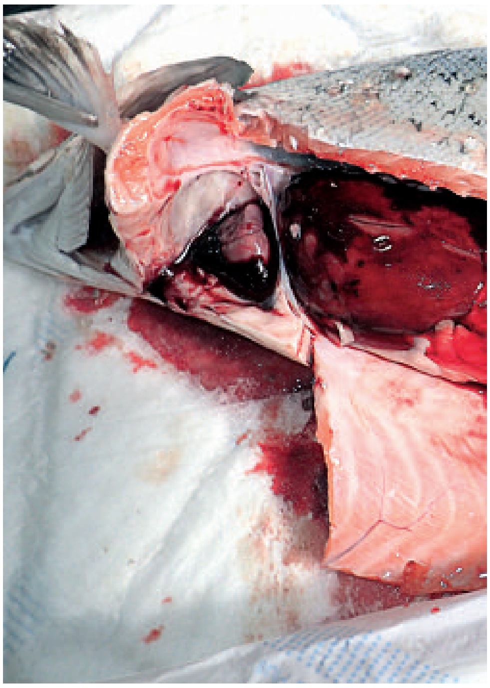


Figure 4.5.3 CMS-affected salmon dying due to cardiac tamponade i.e. ruptured atrium with coagulated blood in the cardiac chamber. Photo: Mattias Bendiksen Lind, Havet AS.

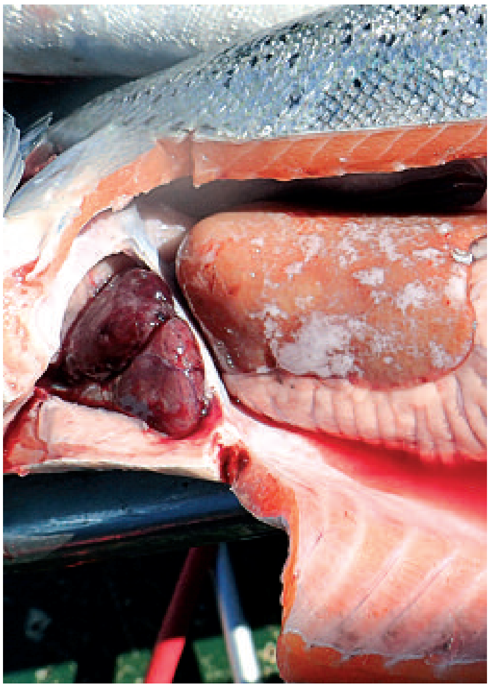


Figure 4.5.4 Post-mortem findings in salmon with chronic CMS: The atrium is enlarged and severely distended due to weakening of the atrium wall and an inability to withstand the pressure generated by the heart pumping. Chronic circulatory failure leads to a white fibrinous deposition on the liver and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

Figure 4.5.5 Photo: Per Anton Sæther, MarinHelse AS

4.6 Viral haemorrhagic septicaemia (VHS)

By Torfinn Moldal

The disease

Viral hemoragisk septikemi (VHS) er 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 haemorrhaging 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.

The situation in 2018

Official data

VHS was not identified in 2018 in Norway. The last Norwegian outbreak occurred in rainbow trout farmed in Storfjorden in 2007-2008.

Evaluation of the VHS situation

No outbreaks of VHS were reported in neighbouring countries during 2018, but 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 evaluated the risk (probability x consequence) for transmission of disease between wild cleaner-fish and farmed fish to be high. Given the serious consequences of a VHS outbreak, surveillance for VHS is important 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.

Read more: www.vetinst.no/sykdom-og-agens/viral-hemoragisk-septikemi-vhs

4.7 Infectious Hematopoietic Necrosis (IHN)

By Torfinn Moldal and Ole Bendik Dale

The disease

Infectious hematopoietic necrosis (IHN) is a viral disease that affects primarily salmonid fish. IHN-virus belongs to the genus Novirhabdovirus in the Family Rhabdoviridae. Juvenile fish are most susceptible. Outbreaks occur most commonly during the spring and autumn at temperatures between 8 and 15oC. High mortality rates are reported in large sea-farmed salmon in British Columbia. Externally, exophthalmos is common. Internally, haemorrhage in internal organs, swollen kidney and ascites are commonly observed. Histologically, disruption of hematopoietic tissues can be observed 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). IHN was first identified in China in 1985 and is now endemic in that country. The majority of Chinese outbreaks can be traced back to a single introduction of genotype J.

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 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. The infections were identified during a surveillance programme for IHN and VHS. Infection was spread from state-owned broodstock farms and hatcheries that had delivered fish to ongrowing farms in Bottenviken.

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. Several effective vaccines have been developed, but vaccination is not relevant for the Norwegian situation.

The situation in 2018

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 Russia, Italy, France, Germany, Austria, Switzerland, Poland and the Netherlands. IHN was diagnosed for the first time in Finland in 2017.

Spread of infection is related to a significant degree to trade of infected eggs or juvenile salmonids. Infected fish do not always display signs of disease. The Norwegian Veterinary Institute has recently developed a typing system for the bacterium Yersinia ruckeri and typing of isolates from rainbow trout provide a strong indication that Norway lies outside the international trade in rainbow trout, which has been central in spread of IHN-virus. 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 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.

Read more: www.vetinst.no/sykdom-og-agens/infeksiøs-hematopoetisk-nekrose-ihn

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, Pasific Biological Station, BC, Canada.

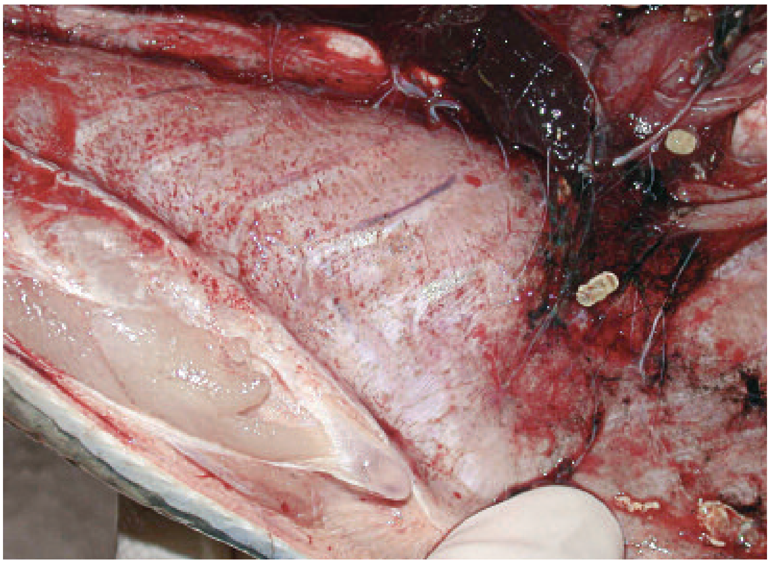


Figure 4.7.2 cutaneous haemorrhage can also be observed in fish with IHN Photo: Kyle Garver, Pasific Biological Station, BC, Canada.

4.8 Salmon pox

By Ole Bendik Dale 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 is lacking. Affected hatcheries reduce the risk of mass mortality by stopping feeding, increasing oxygen levels and avoidance of stress. A study of gene expression during outbreaks of salmon pox revealed that infection resulted in a shift to the freshwater-isotype of ATPase. This may explain why sea-transfer during particular phases of the infection can lead to unfortunate results.

Situation in 2018

Data from the Norwegian Veterinary Institute

In 2018 as in 2017, salmon poxvirus was identified in the gill tissues of sick salmon in 8 ongrowing sites and 8 hatcheries. The whole coastline from Troms in the north to Hordaland in the south was represented. In thirteen cases, salmon pox virus was a contributing factor in multifactorial gill disease in various combinations with *Paramoeba perurans*, *Desmozoon lepeophtherii* and *Branchiomonas cysticola*, identified using the Norwegian Veterinary Institutes newly developed multi-plex PCR method.

Annual survey

Variable responses were received from respondents with salmon pox being considered of between very low and extremely high importance. Salmon pox was considered most severe by respondents in mid-Norway in both through-flow (score 3.4) and recirculation (score 4.0) based farms.

Data from private laboratories

Private laboratories reported 29 diagnoses of salmon pox/SGPV. The cases originate from more or less the same geographic area as those reported by the Norwegian Veterinary Institute, in addition to Rogaland and Telemark. Approximately 50% of cases were identified in Hordaland.

Evaluation of the salmon pox situation

Data generated during 2018 confirm findings from 2017, which suggested that salmon pox is an important component of complex gill disease in both hatcheries and ongrowing sites, and that seawater outbreaks are commonly related to freshwater outbreaks. Whether this situation is new or been previously overlooked, is difficult to conclude.

Salmon pox involved in complex gill diseases may be overlooked unless molecular biological analyses e.g. PCR are utilised. Following PCR confirmation of infection, infection tracing may be performed utilising a newly developed typing assay, such that scenarios including the existence of 'house strains' or the presence of particularly virulent strains etc. may be evaluated.

Although complex and multifactorial diseases are most common, we continue to identify cases of single infection with poxvirus which lead to extremely high acute mortality levels. Salmon pox also occurs in the Faroe Isles and Scotland where a clinical picture similar to that seen in Norway is observed.

A related but genetically distinct poxvirus has been identified in wild Atlantic salmon on the east coast of Canada. This virus has not been associated with disease in the fish in which it has been detected. PCR investigations have only identified infrequent positives amongst other fish.

Read more- https://www.vetinst.no/sykdom-og-agens/laksepox#sthash.LDI1QT0c.dpuf

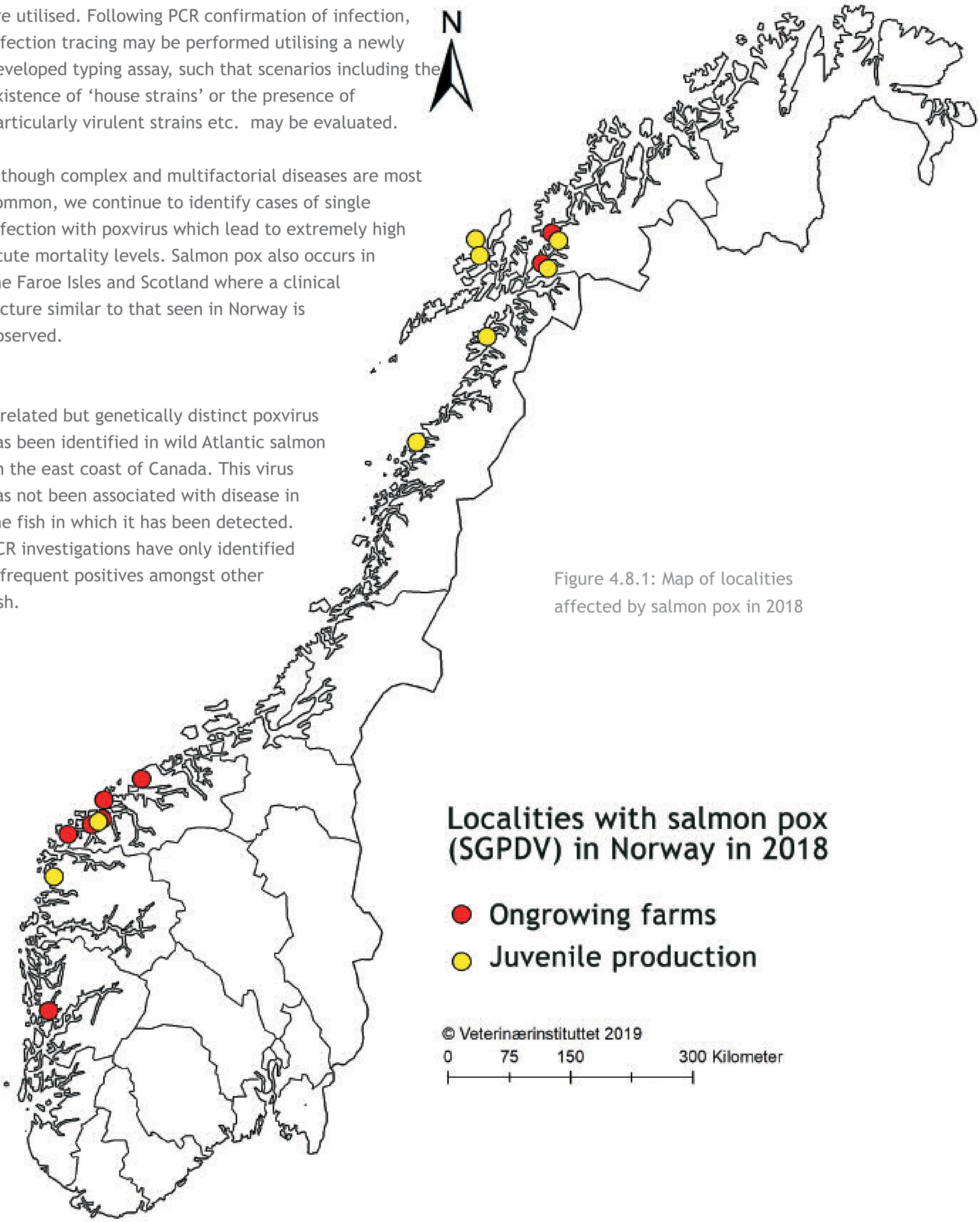


Figure 4.8.1: Map of localities affected by salmon pox in 2018

5 Bacterial diseases of farmed salmonids

Overall, the situation regarding bacterial diseases of farmed salmonids is relatively favourable and stable. In 2018, systemic infection with *Flavobacterium psychrophilum* was diagnosed in four rainbow trout farms. Systemic *F. psychrophilum* infection in rainbow trout is a notifiable disease in Norway. Important diseases including vibriosis, furunculosis and coldwater vibriosis, which in earlier years caused huge losses, are now under control, thanks to extensive vaccination. Previously, vaccination against these diseases was compulsory. This is not now the case, but vaccination against these diseases remains extensively practised. While the general situation is good, winter ulcer continues to cause concerns and is a serious welfare problem. Yersiniosis has been increasingly registered in mid-Norway, particularly in ongrowing fish in the sea. Vaccination is increasingly practiced against yersiniosis and appears to be improving the situation. Consumption of antibiotics remains at an extremely modest level both in terms of previous quantities used and in relation to current levels of salmon production.

Individual disease situations are described in specific chapters below. Figures for notifiable diseases are the official statistics. For the remaining diseases, the figures presented represent in the main, findings registered by the Norwegian Veterinary Institute. Available information from private laboratories is included.

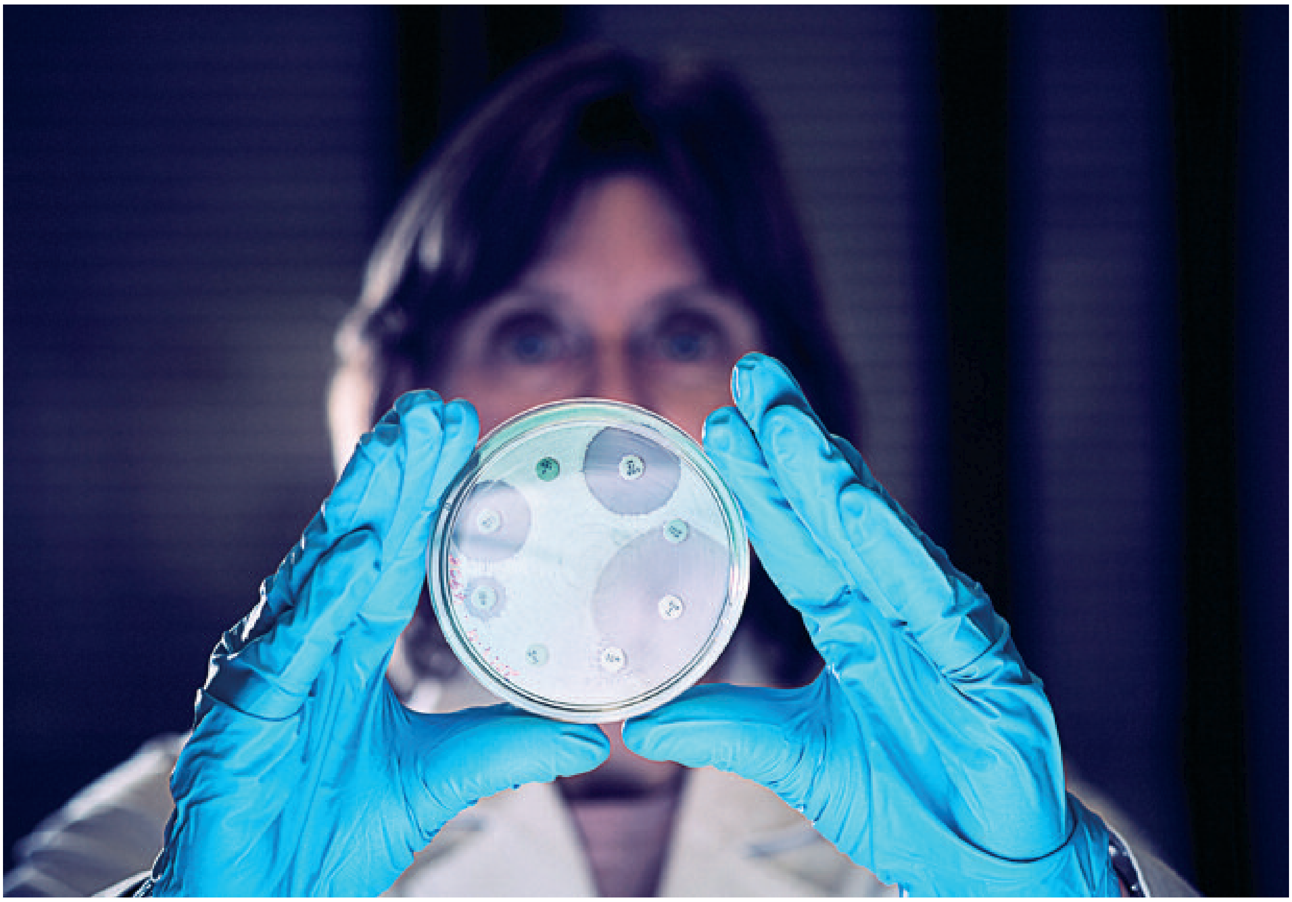


Foto: Eivind Røhne

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 and in Norway* F. psychrophilum *has previously caused large losses during the hatchery phase of culture of this fish species. In recent years, the disease has primarily occurred in larger rainbow trout farmed in brackish water. The bacterium is a relatively normal finding associated with skin conditions in salmon and brown trout in freshwater. MLST (multi-locus sequence typing) has become a standard method for typing* F. psychrophilum. *Several studies have demonstrated that a group of closely related sequence types (CC-ST10) are responsible for most severe outbreaks*

Control

Flavobacterium psychrophilum *transmits horizontally from fish to fish. It is also thought to transmit vertically from broodstock to eggs. This may be related to the bacterium's ability to form biofilm. Basic hygiene such as disinfection of equipment, personnel and eggs is important for prevention of outbreaks. There are no commercially available vaccines. Systemic infection with F. psychrophilum in rainbow trout is a notifiable disease in Norway (List 3).*

The situation in 2018

Official data

Rainbow trout

Systemic infection with *F. psychrophilum* was identified in 4 rainbow trout farms in 2018. Two outbreaks occurred during the summer affecting fish of 400-800g and 4-5kg respectively. In both cases, ulceration and scale loss were obvious. In a third case in the same fjord system the fish displayed clinical signs consistent with systemic infection, but *F. psychrophilum* was not cultured. Isolates cultured from the first two outbreaks were typed to ST2, a variant of the bacterium internationally associated with systemic infection and high mortality in rainbow trout. As is typical of this strain, it displayed reduced sensitivity to quinolone antibiotics. At the end of the year a fourth case, again in the same fjord affecting rainbow trout of 3.5kg was associated with ST2.

Early in 2018, *F. psychrophilum* infection was identified in 100g rainbow trout displaying ulcers and fin-rot in a freshwater farm. Sequence typing identified the isolate involved as a non-CC-ST10 isolate which displayed a high degree of sensitivity to quinolone antibiotics. In the late autumn, ulcers were observed in juvenile fish in an inland farm. The affected fish developed typical 'boils' and ulcers with varying mortality. Several variants of F. psychrophilum were identified with two belonging to CC-ST-10 and one presumably environmental strain.

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 2018, such findings were made on 10 farms, often in association with other pathological changes such as nephrocalcinosis, which may indicate a role for sub-optimal water quality in the observed disease. The position of the observed ulcers varied, but the dorsal fin area was affected in some cases. In two cases the bacterium could be observed in association with degeneration of the musculature around the ulcers. Two cases involved triploid fish. ST70, previously identified in salmon in Norway, was identified in one case in 2018.

For more information on the disease see: http://www.vetinst.no/sykdom-og-agens/flavobacterium-psycrophilum

Evaluation of the flavobacteriosis situation

The disease was once again identified in the fjord system in which *F. psychrophilum* ST2 has been previously identified. The clinical picture appears to be more variable than in previous years. Other variants of *F. psychrophilum* have also been identified in rainbow trout exhibiting skin ulcers, but in the absence of systemic infection. For salmon, the impact of flavobacteriosis is less certain.

Sequence typing of the bacterium, which can give much valuable knowledge is dependent on culture on special agar. Respondents report that the disease is important in rainbow trout farming in South-West Norway and in mid-Norway. It is considered less of a problem in salmon farming, although considered quite important in recirculation based hatcheries in Mid-Norway.

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 have contributed to the effective disappearance of the disease from Norwegian aquaculture. The disease is currently under extremely good control, and very few outbreaks are registered.

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

The situation in 2018

Official data

Furunculosis was not identified in farmed salmon or lumpsucker in 2018, but *A. salmonicida* subsp. salmonicida was again isolated from dead wild salmon found in the river Namsen and during stripping in the river Bognaelva and in wild brown trout sampled from the river Årgårdsvassdraget, all in Nord-Trøndelag. All three 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. In later years, outbreaks in northern Norway have been related to smolts imported from Iceland.

*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 2018

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. Commercial salmon vaccines contain components of the 'typical' variety.*

'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.

Such cases are associated in the main with infections involving diverse strains of Tenacibaculum spp. *which may be identified in pure culture. 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. There is a high degree of genetic variation amongst the* Tenacibaculum *bacteria identified from skin disease in Norwegian farmed salmon, with several species involved (some as yet undescribed). There are no commercial vaccines available.*

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.*

The situation in 2018

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 2018. 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.

Survey

Responses to the annual survey sent to Fish Health Services and the Norwegian Food Safety Authority indicate that winter-ulcer is considered important along the whole coastline. Fish Health Services in Northern-Norway consider the problem more serious than their colleagues in western Norway. Tenacibaculosis or 'atypical winter-ulcer' is considered most serious in the north of the country.

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. *M. viscosa* is relatively easily identified on agar culture due to its colony viscosity, and *Tenacibaculum* spp. are relatively easily identified due to their typical cell morphology i.e. long, thin, hair-like cells, when studied in the light microscope either from marine agar cultured colonies or in direct scrapes from damaged tissues.

Diagnostic experience suggests that both *M. viscosa* and *Tenacibaculum* spp. may, in some cases, be difficult to culture and that the total prevalence of infections involving these bacteria may be under estimated.

It has been shown that *M. viscosa* may be more effectively isolated on blood agar containing 2% NaCl with an additional antibiotic (vibriostat) which inhibits growth of fast-growing Vibrio species. *Tenacibaculum* spp. require sea-salts for growth and marine agar is a therefore a suitable medium.

Information received from the field indicates that winter ulcer is often associated with delousing and other management routines requiring handling or stress. Avoidance of production factors that may predispose to ulcer development is therefore important. The winter ulcer situation in the industry as a whole is considered relatively stable.

The Norwegian Veterinary Institute has active research projects on both *Moritella viscosa* and *Tenacibaculum* epidemiology.

Figure 5.4.1 Classical winter-ulcer in salmon. Photo Aoife Wastgård, Aqua kompetanse

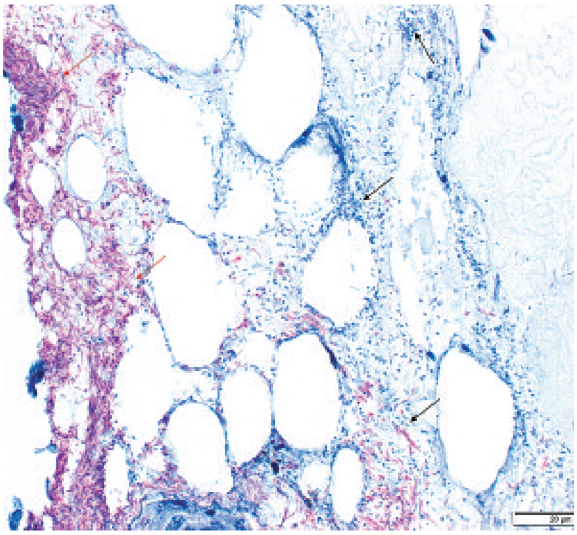


Figure 5.4.2 Immunohistochemistry for *Tenacibaculum sp*. Positively stained filamentous bacteria, *Tenacibaculum sp*. (red arrows) in necrotised surface tissues and other rod-shaped bacteria lying in deeper tissues (black arrow). Photo Lisa Furnesvik, Norwegian Veterinary Institute.

5.5 Yersiniosis

By Snorre Gulla, Jinni Gu and Anne Berit Olsen

The disease

Yersiniosis, caused by the bacterium Yersinia 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.

Recent 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. Intraperitoneal vaccination with water-based vaccines is increasingly used.

The situation in 2018

Official data

The diagnostic service of the Norwegian Veterinary Institute diagnosed 31 cases involving 21 farming localities in 2018 involving 21 salmon farms (4 freshwater hatcheries and 16 marine ongrowing sites) and one arctic char farm in freshwater. This represents a considerable reduction in number of cases from 2017 (54 cases/30 sites Figure 5.5.2). *Yersinia ruckeri* serotype O1 was cultured or identified using immunohistochemistry in all affected farms, with the exception of one farm in which serotype O2 was identified. As in 2017, most of the diagnoses were made in large salmon (>1kg) farmed in the sea and in several cases outbreaks occurred following delousing/handling. During 2018, *Y. ruckeri* was cultured from a single lumpsucker held in a cage of salmon, which were diagnosed with the infection several weeks later.

Most cases in 2018 again occurred in mid-Norway, although the number of cases identified in the north and western parts of the country did increase from the previous year (Figure 5.5.3).

Survey

The responses received to the annual survey support our diagnostic statistics in that yersiniosis scores slightly lower than in 2018 compared to 2017. The disease is reported to be a significant problem in mid-Norway and it is considered that stress and/or mechanical injury related to non-medicinal lice treatments are most probably an underlying cause of outbreaks in large sea-farmed salmon.

Increased vaccine use (indicated by survey responses) may be the main reason for the reduction in number of cases in 2018. The number of farms using intraperitoneal vaccines appears to be increasing.

Evaluation of the situation

The degree to which the Norwegian Veterinary Institute's diagnostic statistics reflect the true situation is uncertain as we do not have direct access to similar statistics produced by private diagnostic laboratories. We do know

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.

that yersiniosis has been diagnosed by several private laboratories during 2018. In light of the responses to the annual survey it seems reasonable to conclude, however, that the situation was somewhat improved in 2018 compared to 2017 and that increasing use of vaccination (particularly intraperitoneal vaccination) has contributed to this situation. The effect of vaccination is expected to increase as the proportion of vaccinated fish transferred to sea in affected areas continues to increase.

One possible cause for concern is the recent discovery of a small number of *Y. ruckeri* biotype 2 (non-motile, non-lipase producing) isolates in Norwegian salmon.

An increased prevalence of this biotype in other countries has been related to vaccination against *Y. ruckeri*. Development of biotype 2 has been hypothesised (but not proven) as resulting in reduced vaccine efficiency. This speculation is based upon the fact that biotype 2 does not have a flagella, an important antigenic structure which the immune response of the salmon may react against. The new Norwegian biotype 2 isolates all belong to the same genetic clone of serotype O1 which dominates all clinical outbreaks in Norway.

A relatively newly discovered histopathological manifestation of *Y. ruckeri* infection in salmon, first observed by the Norwegian Veterinary Institute in 2017 and retrospectively identified in archived tissues are a type of granulomatous inflammation termed 'Splendore-Hoeppli-like bodies'. These pathological changes, almost exclusively identified in sea-farmed fish, can indicate

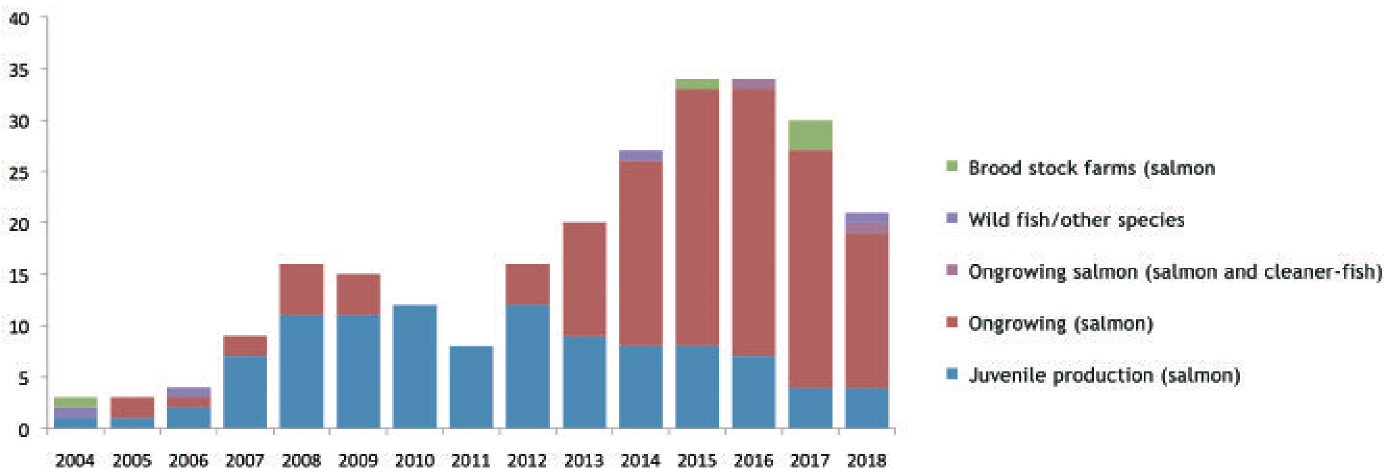


Figure 5.5.2: Distribution of Y. ruckeri-positive localities diagnosed by the Norwegian Veterinary Institute in recent years. Repeated diagnoses from the same locality are not included.

that *Y. ruckeri* may cause chronic latent infection. Such latent infections represent a risk of repeated outbreak of disease following stress events.

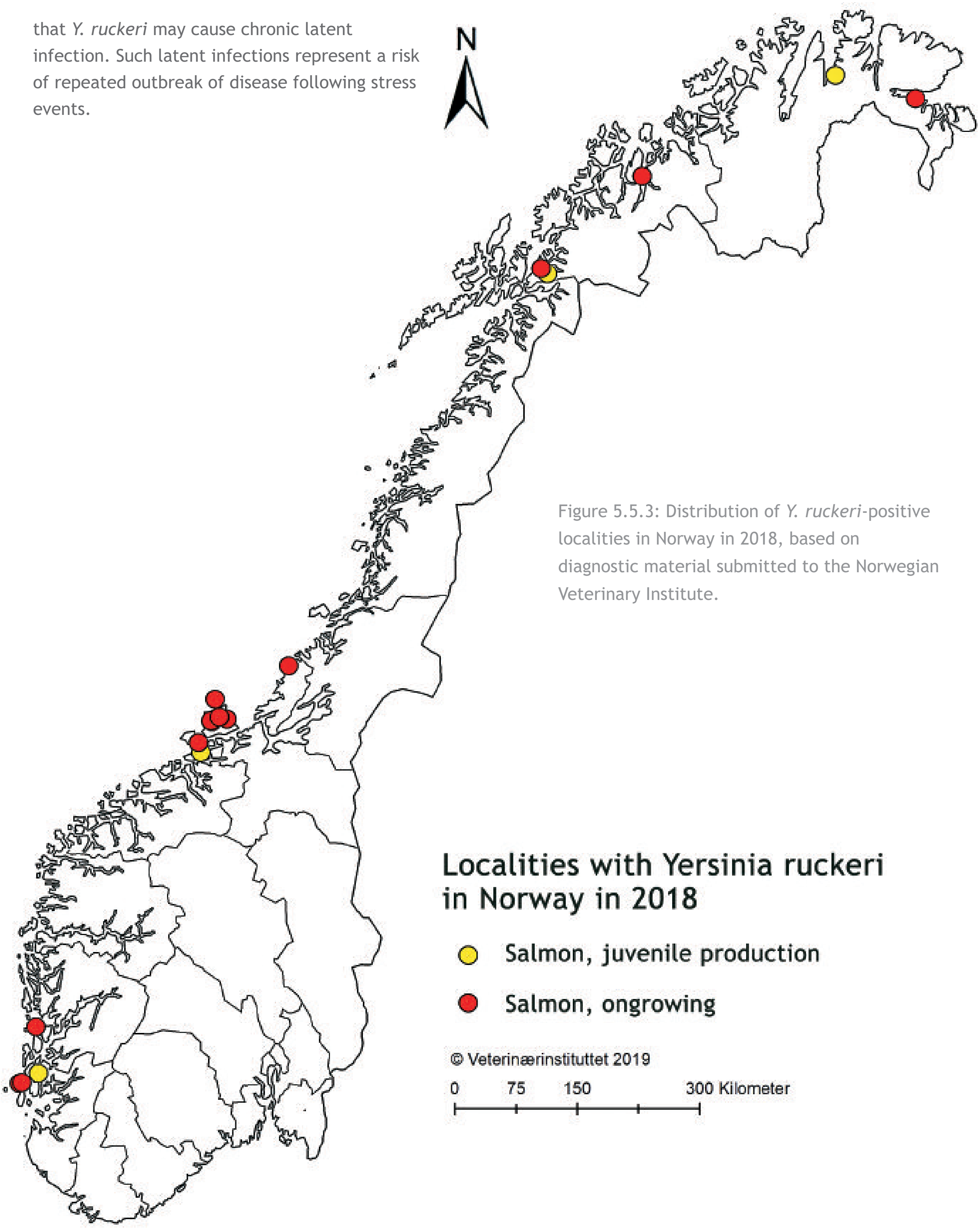


Figure 5.5.3: Distribution of *Y. ruckeri*-positive localities in Norway in 2018, based on diagnostic material submitted to the Norwegian Veterinary Institute.

5.6 Mycobacteriosis in salmonids

Adam Mulualem Zerihun, Jinni Gu, Lisa Furnesvik, Toni Erkinharju, Hanne Nilsen, Stefanie C. Wüstner

The disease

Mycobacteria are widely present in the environment and a large number of species have been described of which some are pathogens of humans and animals. Mycobacteriosis in fish is most commonly associated with rapidly growing Mycobacteria. Pasteurisation of fish feed has drastically reduced the frequency of mycobacteriosis in farmed fish and this disease is now rare.

Typically, mycobacteriosis in fish is a chronic disease with varying associated mortality although up to 80% of fish in a population may be infected. 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. (Fig. 5.6.1)

Mycobacteriosis usually has a long incubation time and the fish may be asymptomatic carriers for several years following infection. Due to the chronic course of infection, the disease may be under-diagnosed.

Horizontal waterborne or contact transmission is considered the most common route of infection. Vertical transmission (parent to offspring) has been documented, but is not considered an important factor in the cases observed.

Mycobacteria are acid-fast and may be stained in tissue samples using e.g. Ziehl Neelsen staining, or using immunohistochemical (specific antibody) techniques. Conventional and real-time PCR methods with subsequent DNA sequencing are also available for detection and species identification. Culture of mycobacterium is best performed on mycobacteria-selective media e.g. Middlebrook 7H10 agar, but experiences from the laboratory show that CHAB-agar (cysteine heart with blood) is also suitable for culture of some fast-growing mycobacteria species. Some fast-growing species may also be cultured on blood agar.

Mycobacterium *spp. known to cause disease in fish include* M. marinum, M. chelonae *and the relatively newly described* M. shottsii *and* M. salmoniphilum *but other species may also be found in association with disease in fish.*

Mycobacteriosis is often found in combination with other diseases. Whether mycobacteriosis represents a primary or secondary infection in fish remains unclear, but there are many indications that mycobacteria may represent the primary pathogen, which by weakening the immune defences of the affected fish then allows 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 situation in 2018

Official data

Between July and December 2018, the Norwegian Veterinary Institute diagnosed mycobacteriosis in salmon in one RAS hatchery and in two marine ongrowing sites (A and B). The marine farmed salmon had been recently transferred to sea from the affected RAS hatchery.

On submission of samples from site A, significant mortalities were reported following transfer to sea. The mortality was then considered due to poorly smoltified smolts and sub-optimal environmental conditions at the hatchery. *Moritella viscosa* and *Vibrio spp*. were identified in addition to mycobacteriosis as were haemorrhagic smolt syndrome (HSS) and renal fungal infection. Heart and skeletal muscle inflammation (HSMI) was also suspected. Post-mortem findings of fish from both hatchery and ongrowing sites included swollen kidneys, granuloma and nephrocalcinosis (Calcium deposition in the kidneys). Fish from site B displayed a white deposit on the surface of the liver.

Histological investigation of individuals from the hatchery and site A revealed chronic inflammatory reactions with multi-focal granuloma, giant cells and Splendore-Hoeppli bodies in the kidney (Fig 5.6.2A) and less frequently in the heart, gills, pseudobranch and skeletal musculature. Individuals from ongrowing site B displayed a more sub-acute clinical picture with massive prevalence of aggregates of long, thin acid-fast bacteria in the inner organs and peritoneum (Fig 5.6.2B). Bacterial aggregates were also identified in blood vessels within the gills. A variable degree of inflammatory response was observed, but granuloma were absent.

In some individuals, acid-fast bacteria were observed, as was positive marking for mycobacteria following immunohistochemical staining (Fig 5.6.3), while other individuals were only positively marked by immunohistochemistry. Bacterial isolates cultured from both ongrowing sites were identified as *M. salmoniphilum* by gene sequencing.

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 reasons for the 2018 outbreaks are not clear and there may be several contributing factors. The warm summer and high water temperatures may have favourised the bacterium. Other factors including stress levels in the fish, susceptibility of the fish etc. may have played a role. Mycobacteriosis may become more of a problem in RAS sites as it may be difficult to remove from the system. The 2018 cases involved RAS fish or fish that had previously been held in the RAS site. RAS technology is still quite new in Norwegian aquaculture and there is a requirement for further study to identify whether these farms are more prone to this type of disease. It is also possible that the increasing incidence of nephrocalcinosis is of importance for predisposition to infections such as mycobacteriosis. During routine diagnostic investigations, we have identified several cases in which bacteria and/or fungus were diagnosed concurrently with nephrocalcinosis, but have been unable to conclude on whether these infections are primary or secondary.

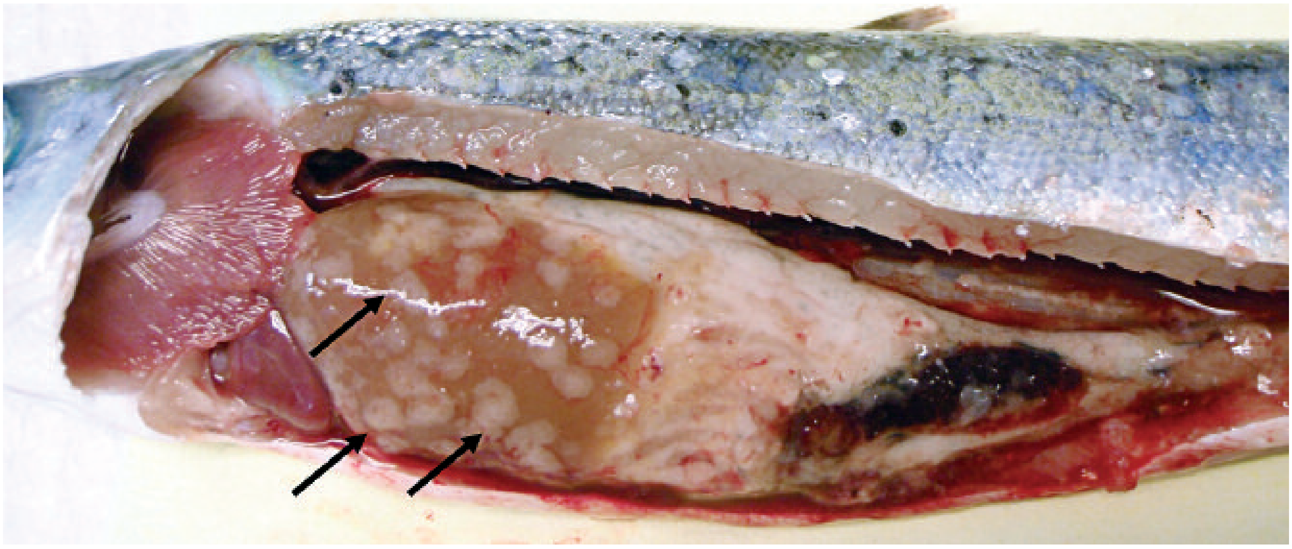


Figure 5.6.1. Macroscopically visible granuloma (black arrows) in the liver of salmon with mycobacteriosis. Photo: Adam Mulualem Zerihun, Norwegian Veterinary Institute

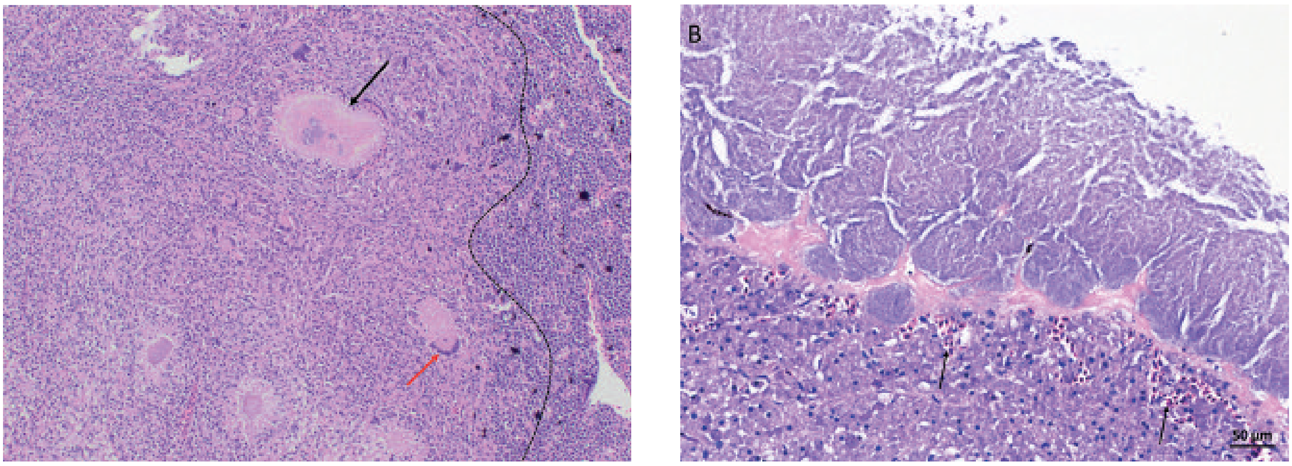


Figure 5.6.2. A. Histopathological section of kidney (A) and liver (B) from salmon chronically infected with *M. salmoniphilum*. A) dotted line (---) shows demarcation of normal kidney tissues (right side) and granuloma (left side). The black arrow indicates Splendore-Hoeppli bodies and the red arrow indicates a giant cell. Scale-bar = 50 µm. Photo: Lisa Furnesvik. B) Massive prevalence of *M. salmoniphilum* on the surface of the liver with associated sub-capsular haemorrhage (black arrow). Scale-bar = 50 µm. Photo: Jinni Gu

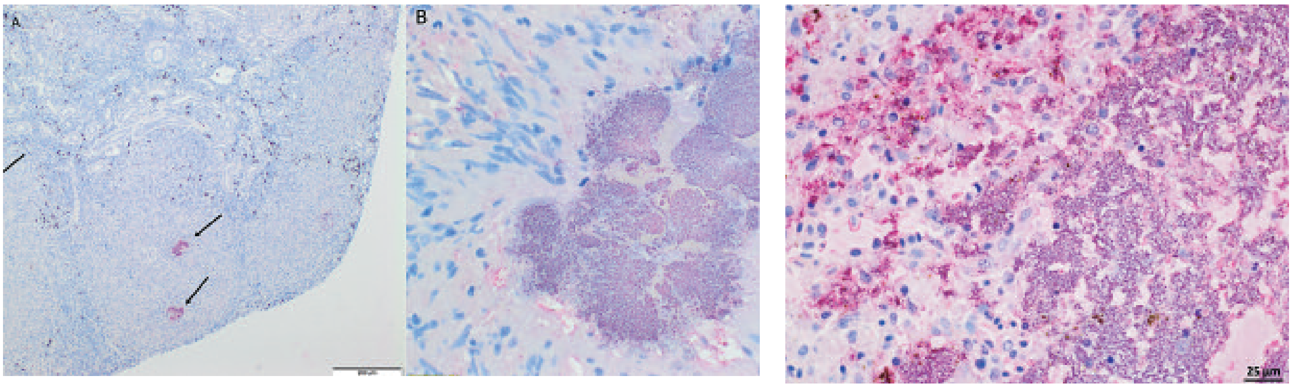


Figure 5.6.3. Immunhistochemical analysis showing positive marking of *Mycobacterium salmoniphilum* surrounded by granuloma (black arrow) (A), in Splendore-Hoeppli bodies (B) and in interstitial tissues (C) in the kidney. Scale-bar = 200 µm (A), 20 µm (B) and 25 µm (C). Photos: Lisa Furnesvik (A and B) and Jinni Gu (C).

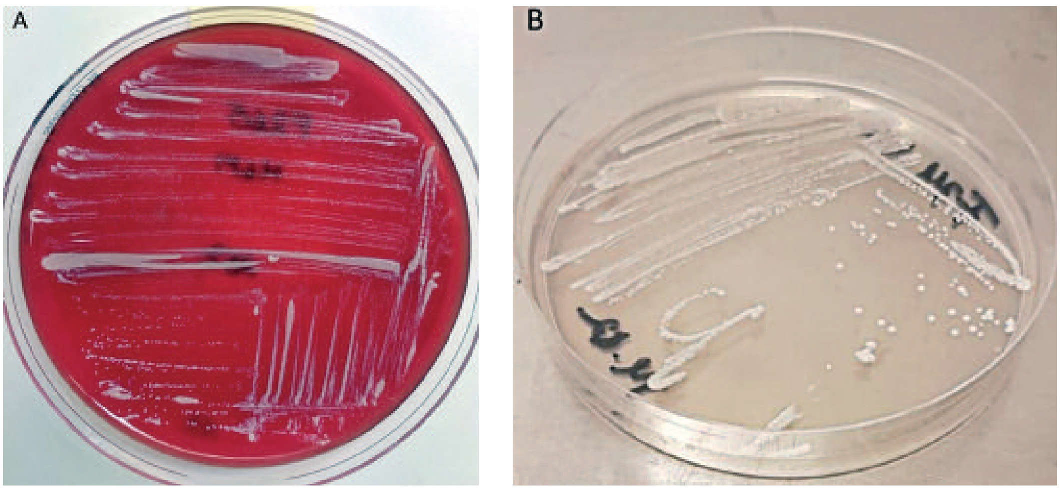


Figure 5.6.4: Cream-white bacterial colonies (0.5-1 mm) cultured on blood agar incubated at 25oC and Middlebrook 7H10-agar cultured at 22 °C. Photos: Jinni Gu (A) and Lisa Furnesvik (B).

References may be obtained from the authors.

5.7 Other bacterial infections

By Duncan J. Colquhoun

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. Bacteriological investigations performed during 2018 have identified isolates belonging to the genera *Vibrio, Photobacterium, Alteromonas, Pseudoalteromonas, Psychrobacter, Polaribacter* amongst others. Trends in culture–based bacteriology are continually monitored such that new pathogenic bacteria and bacterial diseases may be discovered as quickly as possible.

Pasteurellosis was first described in farmed Atlantic salmon in 1991. The disease is identified intermittently in ongrowing salmon in north- and south-west Norway and is associated with variable but generally low mortality. The Pasteurella species pathogenic for salmon is closely related to, but different from the Pasteurella species that usually causes disease in lumpsucker.

In 2018 pasteurellosis was identified in seven different ongrowing salmon farms within a relatively limited geographic area in Hordaland/Rogaland.The affected salmon were 1.5 – 4kg in weight. Mortality varied as did the clinical signs of disease. Ulceration, exophthalmos, cardiac and peritoneal inflammation were observed. Two of the diagnoses were considered incidental findings as the sampled fish were initially suspected of suffering from a different disease.   For the first time in 2018, the same genotype (in this case a genotype normally associated with salmon) was identified in both clinically diseased salmon and clinically diseased lumpsucker held on the same farm.

Carnobacterium maltoaromaticum (previously. *Lactobacillus piscicola*) is identified fairly regularly during diagnostic fish work, and this bacteria was isolated several times in the course of 2018. This bacterium can be found in the environment and as a member of the normal intestinal flora in several fish species. While we generally consider this bacterium to be poorly pathogenic, it has been associated with systemic infections and amongst other findings, fibrinous epicarditis and peritonitis in a few cases during the year.

Coldwater vibriosis, caused by *Vibrio salmonicida*, was not identified in salmon in 2018.

Atypical *Aeromonas salmonicida* infection (atypical furunculosis) was identified in a mixed infection with Yersinia ruckeri in large sea-farmed salmon in mid-Norway.

Piscirickettsiosis caused by *Piscirickettsia salmonis* is a relatively rare disease in Norway and was last identified in 2017. This bacterium continues to cause significant losses in salmon farming in Chile. There are considerable genetic differences between Norwegian and Chilean strains of the bacterium. Infectious challenge experiments have demonstrated that Norwegian isolates are much less virulent for Atlantic salmon than Chilean isolates.

5.8 Antibiotic sensitivity in bacterial pathogens of salmonids

By Duncan J. Colquhoun and Hanne Nilsen

The Norwegian Veterinary Institute monitors antibiotic sensitivity in a large number of bacterial isolates cultured from diseased farmed fish each year. Smaller numbers of isolates from wild fish, mainly salmonids, are also tested each year. The total consumption of antibiotics in Norwegian aquaculture remains modest and despite occasional identification of decreased susceptibility to individual antibiotics, our results indicate that the situation is favourable, with a very low frequency of antibiotic resistance amongst relevant fish pathogenic bacteria in Norway.

Antibiotic treatment (mainly oxolinic acid and florfenicol) is occasionally necessary in farmed fish, but there is good reason to maintain a low antibiotic consumption in Norwegian aquaculture, as this will hinder development of resistance in both environmental and fish pathogenic bacteria.

As in previous years, we have in 2018, identified reduced sensitivity for oxolinic acid in *Flavobacterium psychrophilum* isolated from sick rainbow trout. We have also in the course of the year identified reduced sensitivity to oxolinic acid in *Yersinia ruckeri* in one salmon farm and in three isolates of *Aeromonas salmonicida* subsp. *salmonicida* from wild salmon and brown trout originating from three different rivers in the same geographical area in mid-Norway where this bacterium has been endemic for several years. The mechanism behind the reduced sensitivity to oxolinic acid in these bacteria has been related to chromosomal mutations. The danger of transfer of such resistance to other bacteria is therefore, considered low.
Reduced antibiotic sensitivity was not identified in fish pathogenic bacteria isolated from cleaner-fish in 2018. Reduced sensitivity to florfenicol was identified in atypical *Aeromonas salmonicida* isolated from 100-200g halibut following florfenicol treatment. The underlying genetic mechanism for the reduced sensitivity identified is now under investigation. Later testing of atypical *A. salmonicida* from the same farm did not identify reduced susceptibility to florfenicol.

Photo: Colourbox.

6. Fungal diseases of salmon

By Even Thoen

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.
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 2018, saprolegniosis was diagnosed in only eight cases. There were two additional requests for advice outside the diagnostic service in which saprolegnia was related to high mortality in start-feeding fry.

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.
Saprolegniosis also appears to be considered a greater problem in RAS facilities than in through-flow systems.

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. Systemic mycoses were diagnosed in six localities in 2018.*

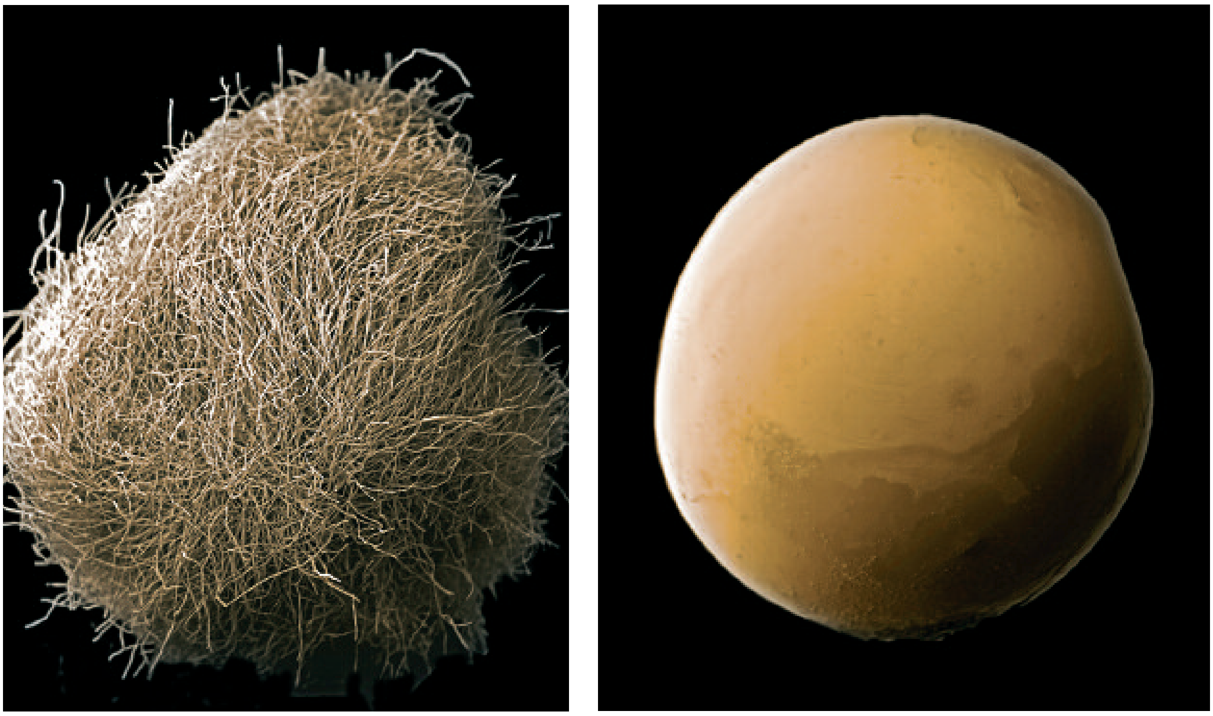


Figure 6.1 Fish eggs with and without saprolegnia, which is an oomycete. The species *Saprolegnia parasitica* and *saprolegnia declina* are most commonly associated with disease in fish in freshwater, although other Saprolegnia species may be isolated sporadically from diseased fish. Oomycetes are normally only pathogenic when the affected fish have a depressed immune system caused by e.g. high stress levels, or that the fish have damaged skin or mucus layer. (coloured scanning electron photomicrograph, magnified 10x). Photo Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

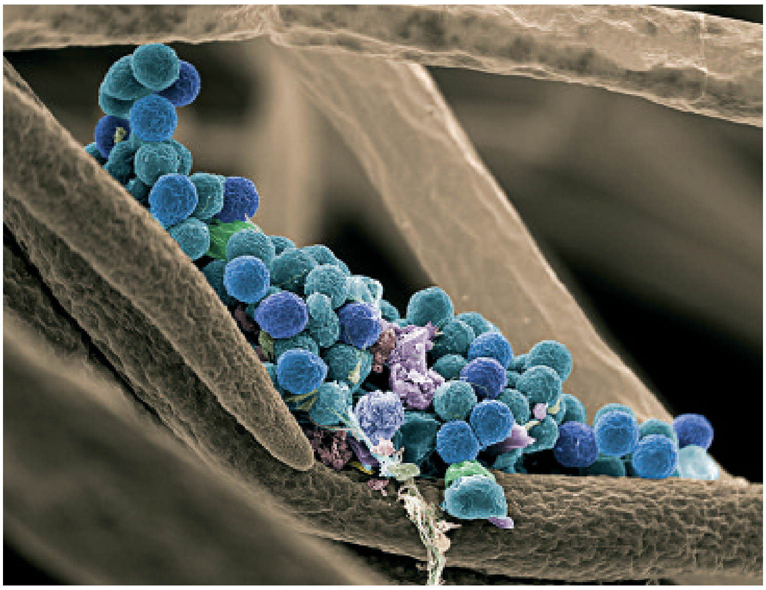


Figure 6.2
Saprolegnia spores in colour. Saprolegnia is a normal finding in freshwater and produces motile spores (see photograph). Hatcheries and juvenile production units are colonised via the intake water. *Saprolegnia* spp. are present in biofilms within pipes and tanks, use organic material as nutrition and can produce spores without obvious effects on fish or eggs. (coloured scanning electron photomicrograph, magnified 10x) Photo Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

7. Parasite diseases in farmed salmonids

*The salmon louse (*Lepeophtheirus salmonis*), as in 2017, continued to represent the most significant parasitic threat to salmonid production in 2018. The situation has not changed significantly although the spring levels of female lice were the lowest observed since 2013. Lice control in Norway was largely dependent on non-medicinal treatments. Resistance to chemical treatments remains widespread along the coast.*

The amoeba *Paramoeba perurans*, which causes AGD, was again detected throughout the year from Agder to Nordland and developments showed the same pattern as in 2016 and 2017. Despite the unusually warm and dry summer in 2018, the incidence or severity of the disease did not develop to the degree feared. In cases of complex gill disease in sea-farmed salmon, the amoeba may be present alongside other parasites including *Desmozoon lepeophtherii (Paranucleospora theridion)*.

Parvicapsula pseudobranchicola is reported as particularly problematical in salmon farming in the regions of Troms and Finnmark. Responses to the 2018 survey indicate that *P. pseudobranchicola* is a recurring problem that has caused significant losses with considerable welfare consequences for salmon farmed in the sea.

A detailed evaluation of each agent is provided in specific sections below.

Photo: Colourbox

7.1 The salmon louse – *Lepeophtheirus salmonis*

By Kari Olli Helgesen and 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 exoskeleton 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. Louse numbers are monitored and reported weekly from all farms holding salmon or rainbow trout.
The main control measures have traditionally been pharmaceutically based, but increasing levels of resistance have led to a situation in which alternative methods now dominate. Farmers commonly now use a combination of preventative measures including continual delousing (mainly cleaner-fish) and both pharmaceutical and non-pharmaceutical methods.

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

For more information, see the Norwegian Veterinary Institute factsheet on the salmon louse

The situation in 2018

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 2018 (week 38) and the highest numbers of other mobile stages (pre-adults and adult males) were observed in January (week 1).

Overall, louse numbers for 2018 were somewhat lower than those observed for the period 2012-2017, the period for which comparable data is available. The lowest numbers of lice were observed in May (week 20) and this was the lowest weekly count reported since spring 2013. Numbers of motile lice in the spring of 2018 were also the lowest recorded since 2013.

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 zones (Figure 7.1.2) around the coast. Each zone is considered separately regarding further expansion of the aquaculture industry.

Highest larval production occurred in production areas 3, 4 and 6 (Figure 7.1.3). Production areas 1, 3, 4, 7, 11 and 12 experienced an increase in larval production from 2017 to 2018. The remaining production areas experienced a fall in larval production. On examination of the figures in relation to the outward migration period of wild salmon smolts (migration period based on Kristoffersen et al. 2018 Epidemics 23: 19-33) an increase in larval production can be identified in production areas 1, 2, 7 and 13 from 2017 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 zone 4 and decreased with increasing and decreasing latitude.
This shows that the effect on numbers of lice produced by eventual expansion of the aquaculture industry will depend on where in the country the expansion occurs.

The number of anti-louse treatments in 2018 are summarised in Table 7.1.1. and 7.1.2. The number of medicinal treatments relates 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

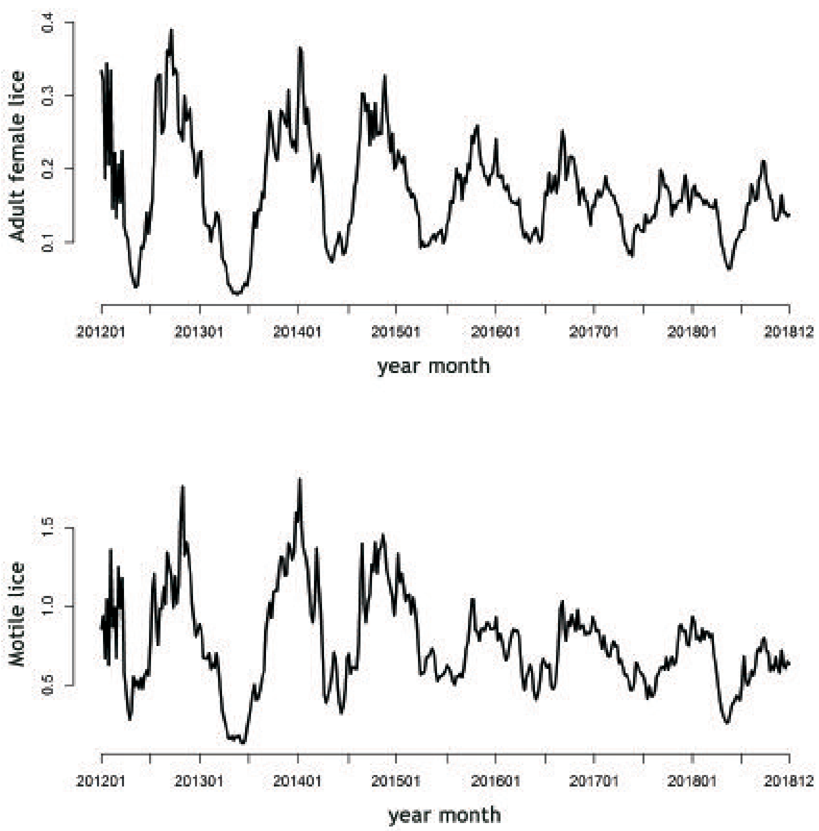


Figure 7.1.1. Average numbers of lice reported by all marine sites in Norway farming salmon or rainbow trout for the period January 2012 until December 2018. The upper panel describes the number of adult female lice and the lower panel other motile stages (pre-adults and adult males)

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, which started in 2016, continued in 2018. From 2016 to 2017, the number of pharmaceutical prescriptions issued for treatment of salmon lice fell by 61% and this figure fell by a further 38% from 2017 to 2018. At the active constituent level, the figures for 2018 show a significant reduction in prescription of all categories of anti-louse pharmaceuticals. 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 2018.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.

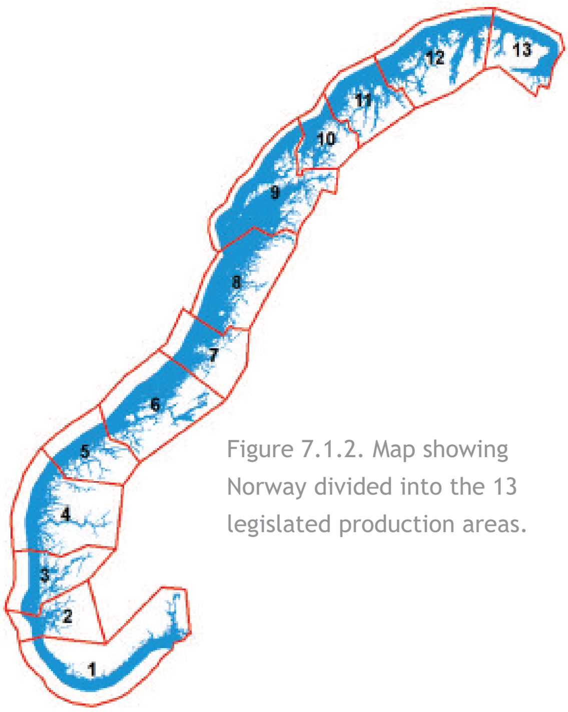


Figure 7.1.2. Map showing Norway divided into the 13 legislated production areas.

The number of reported non-medicinal delousing treatments has increased steadily since 2016 and continued to increase in 2018. The number of thermal-, mechanical- and freshwater- treatments was the highest ever registered. The greatest increase was in the number of mechanical treatments (68% increase from 2017). Thermal treatments continued to be the most frequently used non-medicinal treatment in 2018 (representing 68% 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.

Survey

In our annual survey of Fish Health Services, the Norwegian Food Safety Authority and farming companies, the salmon louse was considered to represent the most significant threat to salmon and rainbow trout farmed in the sea. The salmon louse scored 4.5 (of maximum 5.0) in

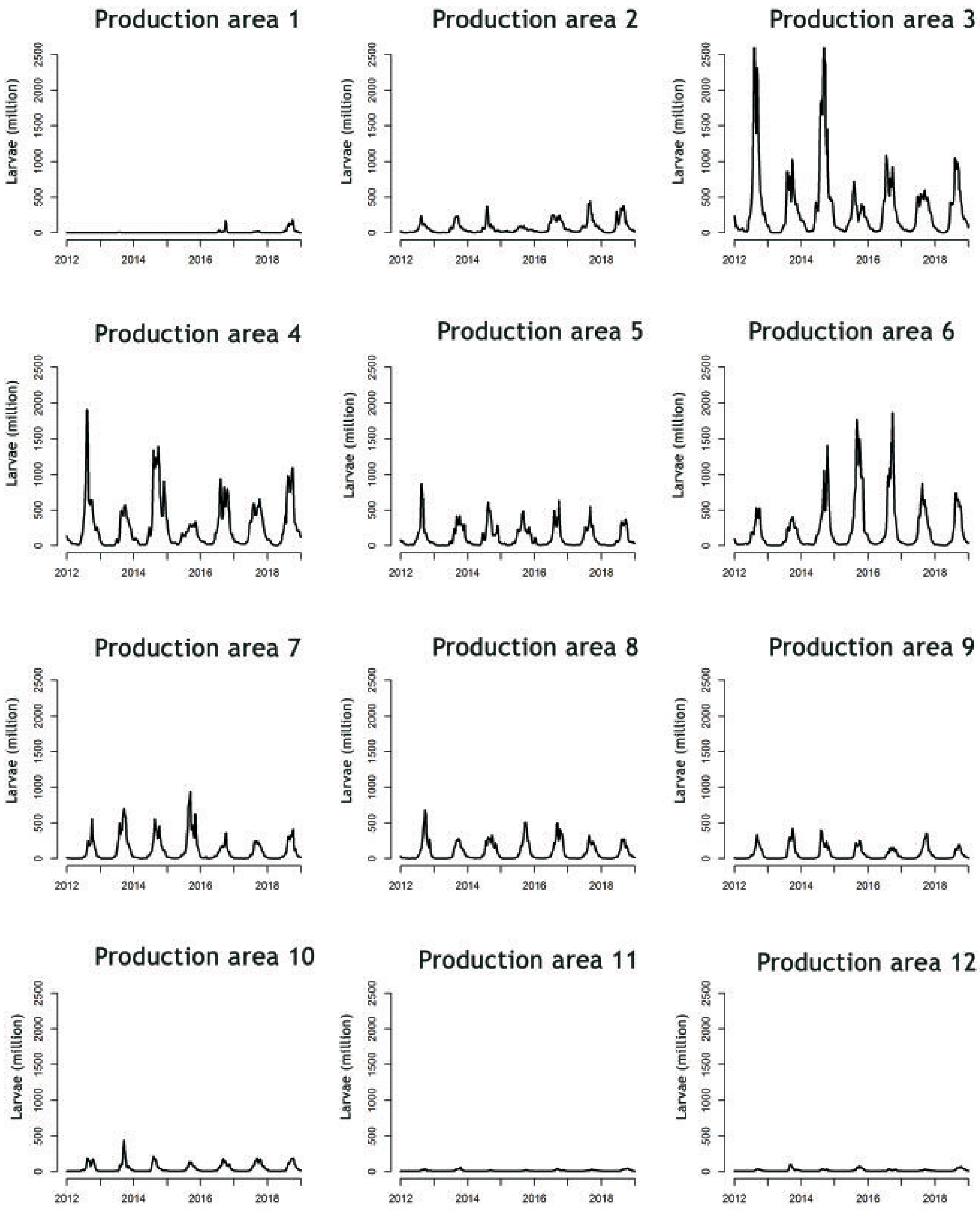


Figure 7.1.3. Calculated total production of louse larvae (in millions) per week per locality in each production area (Psone) for the period 2012-2018. Production area 13 is not included. This area had insignificant larval production throughout the whole period.

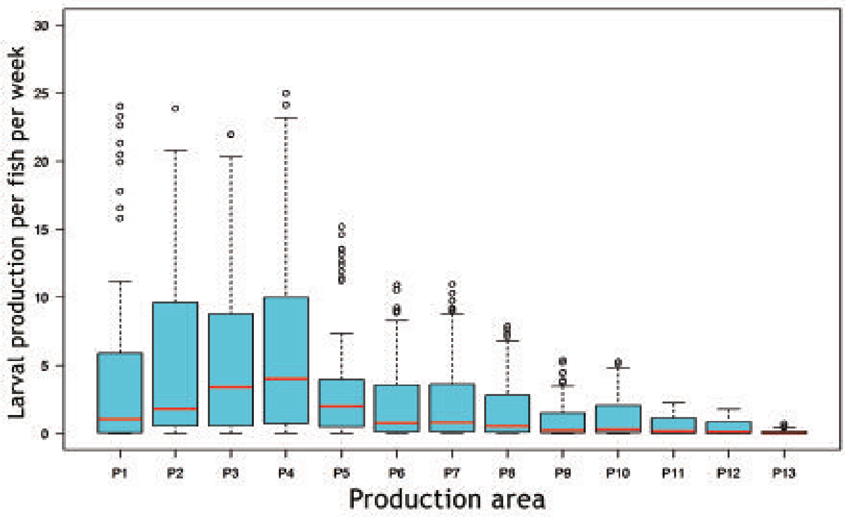


Figure 7.1.4. Calculated average louse larvae production per fish per week in each production area (P1-P13) in 2018. The red lines represent the median values, while 50% of the values are within the blue boxes.

relation to salmon (n=54) and 3.9 in relation to rainbow trout (n=15). Mechanical injury following delousing was considered the second and third most important health problem for rainbow trout and salmon respectively (scores of 3.9 and 3.1; n=54 and n=15). For broodstock of both salmon and rainbow trout, the salmon louse was also considered the most important health challenge (scores of 3.8 and 3.3 respectively; n=14 and n=6).

When questioned on mortality in relation to delousing (score 1=seldom/never, score 5=nearly always), the category ‘increased mortality exceeding 0.2% over the first three days post treatment’ was awarded a score of between 2.8 and 3.6 for the various non-medicinal methods. Medicinal and freshwater treatment for the same category scored 2.1 and 2.5 (n= between 13 and 38). Scores for ‘delayed mortality’ were 2.0-2.6 for non-medicinal delousing and 1.3-1.7 for non-medicinal and freshwater (n= between 13 and 36). Thus, increased acute and delayed mortality were observed more commonly following the various methods of mechanical and thermal delousing compared to medicinal or freshwater treatment.

All mortality scores for the different methods were lower than reported for 2017. The average score for acute mortality lay 0.5 lower in 2018 than 2017, with delayed mortality scoring 0.4 lower than in 2017.

Specific welfare concerns surrounding non-medicinal louse treatment are discussed in the Fish welfare chapter of this report.

Evaluation of the salmon louse situation

The salmon louse situation nationwide did not change significantly between 2017 and 2018. Spring numbers of female lice were the lowest observed since 2013. Six of thirteen production areas experienced an increase in larvae production, with the remaining areas reporting a decrease in larvae production. If only lice larvae production during the outward migration period for wild salmon is considered, only 4 areas displayed increased larvae production compared to the previous year.

The total number of louse-related prescriptions for medicinal treatment fell by 38% from 2017 to 2018 (295 prescriptions). The number of non-medicinal treatments increased during the same period by 21% (n=344). Thermal treatments represented 68% of all non-medicinal treatments. Salmon louse control in Norway in 2018 was, therefore, mainly dependent on non-medicinal treatments and other non-medicinal prophylactic measures. Resistance to chemotherapeutants remains widespread along the coast and suggests that eventual treatment using these substances would have poor effect.

Reports from the field indicate that thermal and mechanical treatments often result in increased mortality in the treated fish compared to medicinal or freshwater treatments. Reports of treatment related mortalities were however, less frequently reported in 2018 compared to 2017. This applied to all types of treatment, which may suggest that treatments are performed in a gentler manner.

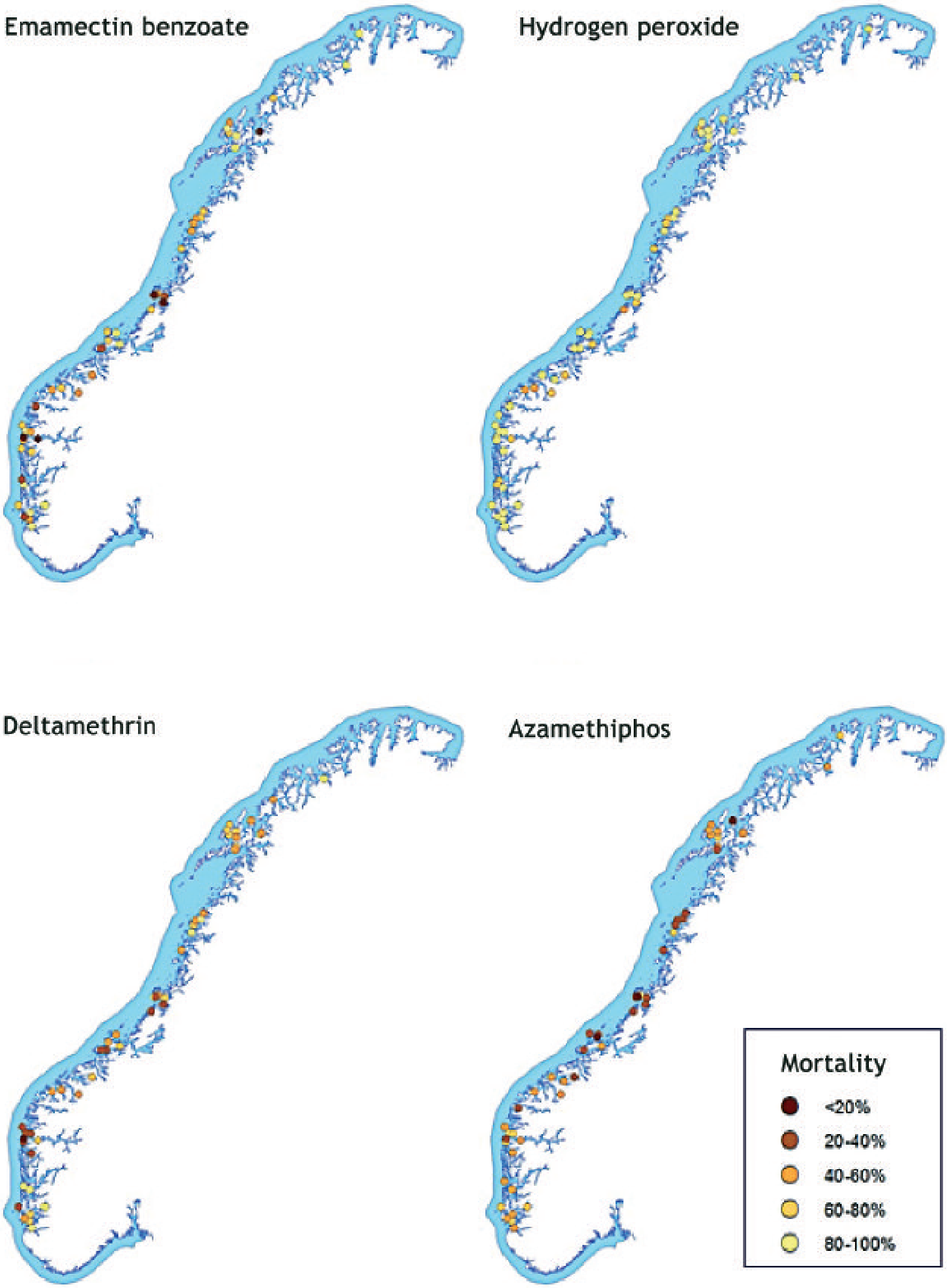


Figure 7.1.5: Mortality of lice in the simplified bioassay for emamectin benzoate, hydrogen peroxide, deltamethrin and azamethiphos, where darker colours represent lower mortality on exposure to a known concentration of active ingredient and therefore more resistant lice.

Table 7.1.1. Number of prescriptions categorised by active ingredient, prescribed for treatment of salmon lice 2011-2018. The number of prescriptions was obtained from VetReg 14.01.19.

Active ingredient category	2011	2012	2013	2014	2015	2016	2017	2018
Azamethiphos	409	691	480	749	619	257	58	38
Pyrethroids	456	1155	1123	1043	662	276	80	55
Emamectin benzoate	288	164	162	481	523	608	348	274
Flubenzurones	23	129	170	195	201	173	79	27
Hydrogen peroxide	172	110	250	1009	1279	629	214	90
Sum	1348	2249	2185	3477	3284	1943	779	484

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 10.01.19. 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
Thermal	0	0	3	36	683	1244	1370
Mechanical	4	2	38	34	331	279	469
Freshwater	0	1	1	28	88	95	102
Other	132	108	136	103	77	55	76
Sum weeks	136	111	178	201	1179	1673	2017

Salmon louse. Photo: Labora

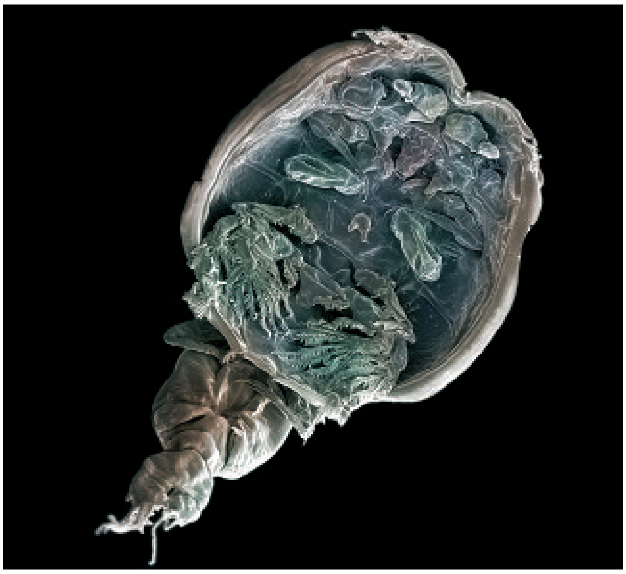


Photo: Jannicke Wiik Nielsen, Norwegian Veterinary Institute

7.2 Amoebic Gill Disease (AGD) and Paramoeba perurans

By Sigurd Hytterød 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 was first identified in Norwegian farmed salmon in 2006, but was not found again until 2012. It has since caused considerable losses. AGD affects fish farmed in seawater, primarily Atlantic salmon but also other farmed species such as rainbow trout, turbot, lumpsucker and various wrasse spp. may be affected.*

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 difficult 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

Figure 7.2.1 Damaged gill filament due to infection with the amoeba *Paramoeba* (coloured photograph taken with a scanning electron microscope, enlarged x 130). Photo Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

The situation in 2018

Official statistics

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. To supplement our own data, the Norwegian Veterinary Institute obtained situation reports from several Fish Health Services (Åkerblå AS, FoMas – Fiskehelse og Miljø AS, PatoGen AS, Labora AS and Pharmaq Analytiq).

In 2018, *P. perurans* was identified by RT-PCR from Vest-Agder to Trøndelag. No outbreaks have so far been described north of Nordland. There is limited sampling performed in this part of the country, but farms exposed to high levels of salinity are tested to some degree.

The general trend for AGD during 2018 was that in most areas the disease appeared rather later in the year than previously, particularly in mid-Norway where the disease also caused fewer losses compared to previous years. Fewer treatments were recorded in this area, presumably due to the later appearance of the disease and the shorter duration of the AGD season due to falling water temperatures in November and December. In Rogaland, the first cases of AGD were registered in July, with initial cases in Hordaland not appearing until the autumn. In Rogaland, the prevalence of AGD was similar to that experienced in 2017, but the number of treatments fell somewhat. In some areas of Rogaland the disease was, however, reportedly more severe in 2018 compared to 2017. Both freshwater and hydrogen peroxide are used in treatment of AGD, with freshwater most commonly used to good effect in several areas.

Survey

AGD is considered an extremely important disease of farmed salmon in southern- and mid-Norway (score 4.0 and 3.3). It is considered less important further North (score 1.3 in region North). It is also considered more important in rainbow trout farming in the south of the country. A few respondents considered the disease extremely important in this species.

Evaluation of the AGD situation

AGD has established itself as a serious fish disease in Norway, particularly in south- and mid-Norway. The number of outbreaks and the degree of severity varies from year to year and this appears to be related to climatic conditions. Reports suggest that AGD outbreaks may be more severe, with more rapid progression, in semi-enclosed farms compared to open cages. These are interesting observations that should be followed up closely in the future. 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. This has led to treatment of the disease at a higher gill-score than has been normal in outbreaks not-expected to die out naturally. Poor gill-health remains a significant problem particularly in south-western Norway. The amoeba *P. perurans* is often one component of a complex and multifactorial disease situation involving several infectious agents.

7.3 Other parasite infections

By Haakon Hansen and Geir Bornø

Desmozoon lepeophtherii (syn.*Paranucleospora theridion*)

Desmozoon lepeophtherii is a microsporidian first identified as a parasite of the salmon louse, but later associated with 'autumn disease' in farmed salmon. The significance of the infection remains uncertain, but recent research indicates that this parasite may cause pathological changes in the gills and intestine of infected fish. The various life-stages of this organism are extremely small and may be easily overlooked in histological sections. The parasite is extremely prevalent, but is generally considered of little importance by respondents to our annual survey. It is however, considered slightly more significant in ongrowing and broodstock production than in other phases of the culture cycle.

Parvicapsula pseudobranchicola (parvicapsulose)

Parvicapsulosis, caused by *Parvicapsula pseudobranchicola* may result in high mortality in ongrowing salmon. The parasite has a broad geographical range, is highly prevalent in wild salmonids and is reported to be a problem in farmed salmon in Troms and Finnmark. *Parvicapsula pseudobranchicola* has a complicated life cycle with a polychaete worm as its main host and fish as the intermediate host. The main host for *P. pseudobranchicola* remains unknown.
In 2018, the Norwegian Veterinary Institute identified the parasite (mainly via histological investigation) in 37 salmon farms, which compares with 38 in 2017. Diagnoses were mainly made in the three most northerly regions, with 22 in Finnmark, 7 in Troms and 7 in Nordland. The parasite was also identified in 1 farm in Sør-Trøndelag. This parasite was mentioned, in the 2018 survey, as a recurring problem which leads to significant losses and considerable welfare consequences.

Ichthyobodo spp. («Costia»)

At least two species of this parasite can be found in salmon in Norwegian aquaculture; *Ichthyobodo necator* in salmon in freshwater and *I. salmonis* in salmon farmed both in freshwater and the sea.
These parasites have a wide geographical range, are common and can damage both skin and gills.
Most diagnoses are made locally by Fish Health Services. The Norwegian Veterinary Institute diagnosed *Ichthyobodo* spp. in 26 submissions in 2018. Most diagnoses are associated with salmon, both in juvenile production sites and in ongrowing farms. *Ichthyobodo* spp. were also identified in arctic char, rainbow trout and halibut.

Single celled parasites of the gills and skin *(Ichthyobodo* spp. and *Trichodina* spp. etc.) scored comparatively lowly in the annual survey for both recirculation and through-flow based salmon and rainbow trout farming. This type of infection is however, considered more important irrespective of technology, in the north-western and middle parts of the coastline (scoring 2-3 on a scale of 1-5, in which 5 is extremely significant).

Tapeworm – *Eubothrium* sp.

An increasing prevalence of intestinal tapeworms in sea-farmed salmon has been reported in recent years. Most diagnoses are made locally by Fish Health Services and the organisms concerned are not identified to species level, but it is considered likely that most cases involve *Eubothrium* spp. Tapeworm infestations may lead to increased feed consumption and decreased growth in affected fish.

Eubothrium spp. are treated with praziquantel and there has been a significant increase in the quantity of this drug sold since 2010. Several Fish Health Services report treatment failure and there are concerns regarding development of resistance. Most diagnoses are made locally. The Norwegian Veterinary Institute identified tapeworm in 36 farming sites in 2017. No diagnoses were made north of Nord-Trøndelag. The Norwegian Veterinary Institute diagnosed tapeworm in salmon on 35 farms with ongrowing salmon in 2018, a level similar to the previous year (36 farms). Most of the affected farms lie in south-west and middle areas of the coastline, with a few north of Trøndelag.

Forty-one percent of respondents to the annual survey had experienced problems with tapeworm, while 43% had not experienced problems with tapeworm in 2018.

On the basis of the survey and Norwegian Veterinary Institute data, the tapeworm problem seems to be most serious in salmon farmed in the sea, particularly in western and mid-Norway. The tapeworm situation in sea-farmed salmon scored 3 in the south-west, 2.8 in north-west and 2.1 in mid-Norway.

Eubothrium spp. are treated with praziquantel. In the period 2010-2015 there was a significant increase in sales of this medicament. There has been a reduction in sales of praziquantel post 2016. Responses to the survey indicate 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.

Of respondents to the survey, approximately 23% replied that they treat for tapeworm and 13% reported treatment failure.

The Norwegian Veterinary Institute leads a project that shall document the prevalence of *Eubothrium* spp. in Norwegian aquaculture and its effect on farmed salmon.

Runted fish with parvicapsulosis. Photo: Per Anton Sæther, Marin Helse AS.

8.0 Miscellaneous health problems in farmed salmonids

This chapter presents diverse health problems in farmed fish, including gill diseases and water quality, poor smolt quality and runt syndrome as well as nephrocalcinosis and vaccine side-effects. Gill disease continues to be a significant, complex and increasing problem in salmon farmed in the sea, but can also pose problems in some freshwater farms. The survey shows that gill disease appears to be most serious in north-western (southern) Norway and in mid-Norway.

Good water quality is absolutely necessary for good fish health. In 2018 a number of health related problems were related to water quality. Significant mortality events related to hydrogen sulphide were registered in a number of RAS farms. The survey identified three major water quality challenges: 1) problems related to oxygen saturation in sea-farms utilising lice-skirts, 2) problems with algal blooms in the late summer/autumn and 3) problems with gill health related to net cleaning. Lack of systematic registration of problems related to smoltification, smolt quality and runt syndrome make compilation of reliable statistics related to the frequency of these problems in Norwegian aquaculture difficult. Data from the Norwegian Veterinary Institute and responses to the survey indicate quite clearly that these problems are significant.

Based on diagnostic material submitted to the Norwegian Veterinary Institute in 2018 we have reason to believe that the number of cases involving nephrocalcinosis has increased in recent years. This is in accordance with views expressed in the annual survey.

Data from the aquaculture industry as revealed in the annual survey of Fish Health personnel and the Norwegian Food Safety Authority indicates that vaccine side-effects are not considered a significant problem when compared to other health problems. This applies to both ongrowing and juvenile production systems.

Photo: Rudolf Svensen, UW photo

8.1 Gill disease in farmed salmonids

By Mona Gjessing, Cecilie Sviland Walde and Ole Bendik Dale

The disease

The gills of fish have several critical physiological functions. They are responsible for gaseous exchange, osmoregulation, pH-regulation, and 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.
Gill disease causes changes in the cells of the gills, which weaken or destroy their functional capabilities. Gill disease may be caused by several factors and unfavourable environmental conditions, pathogenic organisms, nutrition and management routines may be central. Gill disease may be caused by a single insult or following a combination of insults occurring simultaneously. Manifestation of disease may therefore be complex and difficult to interpret. Gill disease may affect farmed salmon at all stages of production. In the sea-phase the disease may be particularly serious, lengthy and cause severe losses. Affected fish generally show poor growth and treatment is costly.

Organic and inorganic substances in the water may also have a negative effect on gill health and increase susceptibility to infection. Precipitation of toxic iron and aluminium compounds, low levels of calcium and poisonous hydrogen sulphide all lead to poor water quality and may cause high, acute mortality. Precipitation of poisonous aluminium compounds may also occur in seawater during freshwater treatment of amoebic gill disease (AGD) and sea-lice infections.

For more information on water quality in land and sea-based farms see chapter 8.2 Water quality.

Microorganisms that may result in gill health issues include Paramoeba perurans, *which causes AGD, the microsporidian* Desmozoon lepeophtherii, *the bacterium ‘Ca.* Branchiomonas cysticola, *salmon poxvirus and single celled parasites such as ‘Costia’ (*Ichthyobodo spp.*) and* Trichodina spp. *Several agents may cause gill disease in both fresh- and seawater. Various bacteria may cause epitheliocystis in farmed salmonids and some appear to cause more gill damage than others.*
‘Ca’ Branchiomonas cysticola *is one such bacterium. It has been shown that* B. cysticola *and salmon pox virus may be transmitted from fish to fish in freshwater. Microsporidians may cause a generalised infection resulting in changes in the inner organs and peritoneal cavity as well as gill disease. Bacterial gill disease in salmonids in freshwater is commonly secondary to other gill injury e.g. metal precipitation, infection with salmon pox virus or fungal infection. Bacteria belonging to the* Tenacibaculum *group may cause gill problems in seawater. Algal and jellyfish blooms may also cause gill injury, as do fouling organisms e.g. hydroids released during net cleaning. Secondary bacterial infections may commonly occur after such events. For more details on individual organisms, see individual chapters within this report.*

For more information on gill disease see: Chronic gill inflammation in salmon and salmon pox under diseases and agents at http://www.vetinst.no/dyr/oppdrettsfisk

The Norwegian Veterinary Institute has now established a PCR method for simultaneous detection of several gill pathogens. Interested parties are encouraged to submit gill tissues fixed in RNAlater as well as normal organ samples in formalin. This will enable development of a better understanding of the contribution of individual agents to the observed pathological changes.

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 7.2 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 2018

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 2018, the Norwegian Veterinary Institute diagnosed gill inflammation as the main- or partial-diagnosis on 101 farms farming salmon and/or rainbow trout. Most of the affected farms were situated in western Norway. Twenty affected farms were in freshwater and the remaining in seawater, with salmon most commonly affected. Gill inflammation was noted in 350 cases, which indicates that the disease has an extended course on many farms. Submissions were distributed throughout the year, with a larger number received in January and October. Many cases of complex gill disease, involving several infectious agents were identified. Comparison of multi-plex PCR results with histological investigation will help us understand the relationship between certain infections and particular pathological changes.

Gill disease was also identified in cleaner-fish, mainly lumpsucker, in 9 localities. The diagnoses in these cases were dominated by bacterial infections, but parasites including amoeba and Trichodina were also observed.

The annual survey

Gill disease in salmon farmed in the sea is considered extremely important in the north-western and mid-Norway regions (4.2 and 4.1) (see Table 8.1) and less so in the south-west and north (2.9 and 2.7).

As far as gill problems in the freshwater phase of culture are concerned, B. cysticola infection in both through-flow and RAS facilities is considered more of a problem in the north-western and middle areas of the country. It is also considered a more significant problem in RAS facilities than in through-flow systems in mid-Norway. Pox-virus infections in RAS facilities are considered a greater problem in mid-Norway (4.0) than in the remainder of the country (average score for the whole country 2.48). *Desmozoon lepeophtherii* is not considered a serious problem in through-flow or recirculation based farms.

On a countrywide basis non-specific gill problems in salmon scored 2 (where 5 is the most serious score). Salmon farmed in RAS facilities scored slightly higher (2.55) than in through-flow systems. This type of problem scored generally higher in both through-flow and RAS farms in mid-Norway.

In marine ongrowing farms for salmon, 39% of respondents considered gill problems (excluding AGD) to be at the same level as the previous year, almost 17% consider problems during 2018 to have been fewer and 17% higher. The remainder replied that they did not know.

Evaluation of the gill disease situation

The majority of gill disease diagnoses made by the Norwegian Veterinary Institute involve salmon farmed in the sea. Respondents to the survey considered the problem greatest in the north-west and in mid-Norway. Gill disease remains a significant problem for salmon farmed in the sea, particularly in western- and mid-Norway. Complex cases involving several infectious agents are relatively common.

Non-specific gill problems are also considered important in freshwater juvenile production farms, particularly in mid-Norway. Problems involving *B. cysticola*, *Desmozoon lepeophtherii*, pox-virus and non-specific problems generally score higher in RAS facilities than in through-flow systems. The gill pox problem in mid-Norway is considered particularly serious.

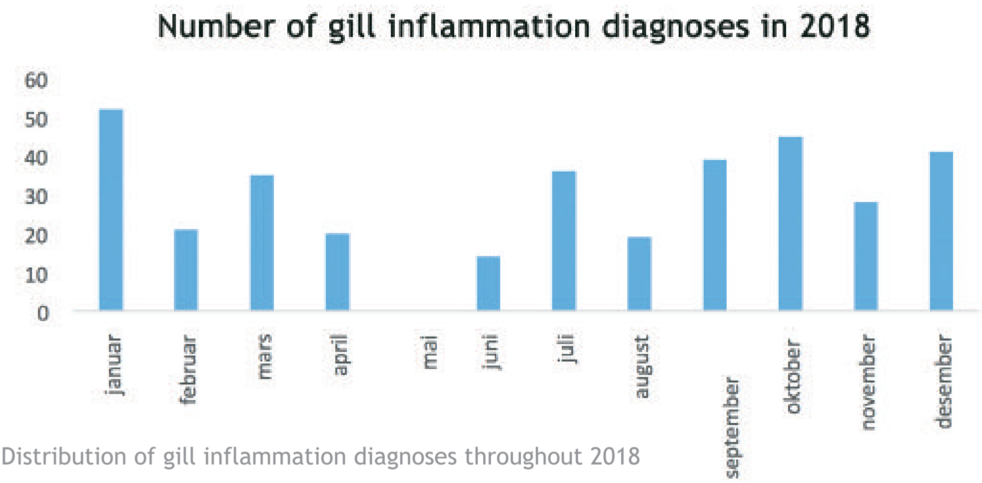


Figure 8.1 Distribution of gill inflammation diagnoses throughout 2018

Figure 8.2 Sampling of gills for detection of *P. perurans*, *P. theridion*, Ca. *B.cysticola* and SGPV during establishment of a macroscopic gill-scoring scheme for AGD. Photo: David A Strand, Norwegian Veterinary Institute

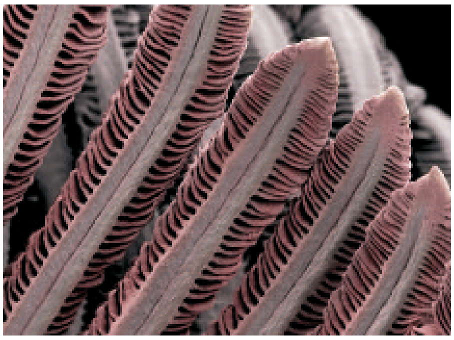


Figure 8.3 Normal gill filament in salmon (coloured scanning electron microscopy image, enlarged 100x) Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

Table 8.1 Scoring of gill related diseases in freshwater juvenile production facilities for salmon in 2018.

			Fish Health Services Number Respondents	Average
Through-flow facilities	*'Ca' Branchiomonas cysticola*	South-west	5	1,0
		North-west	4	2,5
		Mid-	5	2,0
		North	13	1,3
	Desmozoon lepeophtherii	South-west	5	1,0
		North-west	4	2,0
		Mid-	5	1,0
		North	13	1,0
	pox-virus	South-west	5	1,2
		North-west	4	2,3
		Mid-	5	3,4
		North	13	2,1
	Non-specific gill problems	South-west	5	1,0
		North-west	4	2,0
		Mid-	5	2,6
		North	13	2,0
Recirculation based facilities	*'Ca' Branchiomonas cysticola*	South-west	2	1,0
		North-west	2	2,5
		Mid-	3	3,3
		North	10	1,8
	Desmozoon lepeophtherii	South-west	2	1,0
		North-west	2	1,0
		Mid-	3	1,0
		North	10	1,0
	pox-virus	South-west	2	1,0
		North-west	2	2,5
		Mid-	3	4,0
		North	10	1,9
	Non-specific gill problems	South-west	2	1,5
		North-west	2	2,5
		Mid-	3	3,3
		North	10	2,3
Sea	Gill disease	South-west	7	2,9
		North-west	6	4,2
		Mid-	7	4,1
		North	23	2,7

8.2 Water quality

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

Good water quality is decisive for good fish health and improved water quality will lead to reduced disease related losses. Acute mortality episodes related to water quality are experienced every year. The number of enquiries received by NIVA and responses to the annual survey indicate that this type of problem has increased in recent years. There is a clear need to increase knowledge levels related to water chemistry amongst fish farmers, in aquaculture education and in the public authorities.

Land-based facilities

Events related to poor water quality have occurred in both through-flow and recirculation based farms. Some of these problems have been related to poor quality intake water (both chronic and episodic) and some have been related to development of poor water quality within the farm.

Inadequate calcium levels

Acid-rain has been a significant problem in Norway. A number of remedial measures have been initiated to reduce this problem with considerable success. Acid-rain and the effects of previous acid-rain remains a problem in some areas of southern Norway. Low pH, ion-poor intake water with a low calcium level has been identified in several freshwater production sites. Many are familiar with the negative impacts of low pH and remedy this problem with silicate hydroxide, but few are familiar with the importance of sufficient calcium for fish health. NIVA has registered calcium levels well under 1mg/l in several through-flow farms. Such low levels of dissolved calcium result in poor ion regulation in the farmed fish and make the fish extremely susceptible to metal related gill damage.

Seawater use and aluminium mobilisation

Mixing of aluminium rich freshwater with seawater poses a risk of mobilisation of poisonous aluminium. This is especially risky if humus rich freshwater, containing organically bound metals is used and one should be particularly aware of this problem in mid-Norway where humus rich intake water is common.

Humus is commonly considered a ‘magnet’ for metals. These metals are not particularly poisonous when bound to humus, but mixing with seawater can lead to release of free poisonous aluminium. Based on observation and experimental trials it has been documented that the dangers are greatest in salinities of 1 - 10 ‰. This is despite the fact that increasing salinity results in a reduced total concentration of aluminium (seawater contains very low levels or no aluminium). The increased toxic effect is due to the metal changing from ‘gill non-reactive’ to ‘gill reactive’ (Figure 8.2.2). This toxicity, chemical transformation and consequent aluminium deposition on the gills has been demonstrated in a number of experiments.

A previous study (Figure 8.2.1) from the river Tangedalselva in Hordaland showed clear mobilisation of aluminium following mixing of seawater to a salinity of 4.5‰ and that the aluminium precipitated on the gills of the fish causing distress. A similar situation will occur if salt (NaCl) rather than seawater is utilised. In this study the effect of silicate application in advance of seawater mixing was investigated. This prevented aluminium deposition on the gills.

This type of toxicity has been observed in smolt farms mixing seawater with freshwater and during freshwater treatment of salmon lice or AGD in the sea where mixing of seawater and freshwater was either intentional or unintentional.

Mortalities and injuries have resulted as a result of inappropriate silicate dosage or failure of the silicate dosing apparatus.

Other metals may also be mobilised, but the toxic properties of aluminium are well known and this metal is present in potentially toxic concentrations in many areas

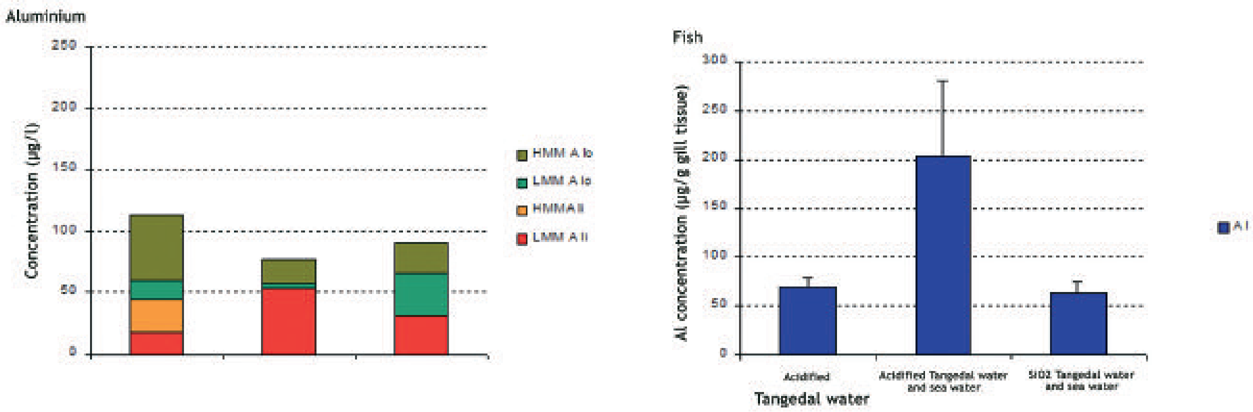


Figure 8.2.1. Proportion toxic aluminium (marked red) in acidic freshwater (above on the left), following addition of seawater to 4.5‰ (above, centre) and after pre-treatment with silicate (above right). Below- equivalent levels of gill aluminium in acidic water (left), following addition of seawater (centre) and following pre-treatment with silicate (right) (Åtland et al. 2004).

along the coast. Seawater/freshwater mixing has the opposite effect on iron i.e. toxicity decreases.

The problem with aluminium may be overcome if the farmer has knowledge of the humus content and aluminium levels in the relevant freshwater supply. For treatment in the sea, one should avoid humus and aluminium rich freshwater. In freshwater farms, should no alternative supply be available, keep the salinity below 1‰ or higher than 10‰. Pre-treatment of the water with silicate can also represent a good solution. There is also a requirement for good surveillance routines and technical back-up systems to ensure that silicate application and dosage remains reliable.

There is little focus on removal of humus in Norwegian aquaculture. This process could have significant potential, as humus rich water reduces UV-transmission and thereby reduces the effect of UV-treatment.

Other metal related problems

NIVA has registered a number of cases of increased copper levels, which could be related to the intake water, feed and/or faeces or from technical installations. It has been documented that both salt and calcium products used in smolt production can contain significant amounts of copper. Documentation is again the key to improvement. Systematic surveillance of the farm including analysis of both filtered and unfiltered water samples can lead to identification of the source of the problem and allow application of remedial measures. It is important that the farmer demands delivery of quality assured products from suppliers in respect to salt and calcium levels.

RAS-related problems

Extensive mortality episodes involving hydrogen sulphide have received much attention in 2018. Episodes involving high levels of ammonia, nitrite and CO2 have also been reported during this period. There may be several possible underlying causes but examples include incomplete biofilter maturation and/or incorrect calculation of biofilter capacity. Levels of knowledge relating to water quality vary considerably between farmers and some would benefit from increased knowledge.

Hydrogen sulphide is formed under anaerobic (O2 is absent) 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

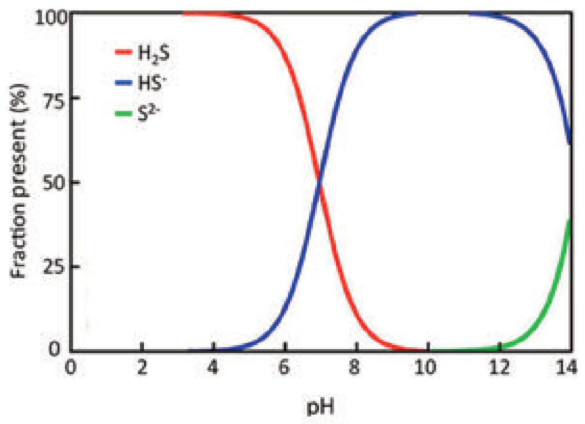


Figure 8.2.2. Relationship between pH and the various forms of sulphide. Hydrogen sulphide, which is the most toxic form, is highlighted in red.

greater on use of increasing amounts of seawater during e.g. post-smolt production. Sulphate reducing bacteria use SO42- to form H2S. In lay terms one could say that the bacteria 'breathe' sulphate and form hydrogen sulphide rather than water as the end product.

The toxic effect on the fish is almost exclusively related to H2S, which occurs mainly at pH of 6-8 (see figure 8.2.2). HS is almost non-toxic, while H2S is toxic, but not pH relevant in an aquaculture setting. H2S is extremely soluble and thereby significantly more difficult to eradicate via aeration than Co2.

H2S reacts further with metal ions in the water and forms metal sulphides. These metal sulphides e.g. iron- and manganese sulphides, are characteristically observed as black/brown precipitates. Lessons are being learned however, and new data loggers capable of monitoring even low levels of H2S are being utilised. There is a need for increased knowledge of where and how H2S is formed within individual farms, to allow introduction of appropriate remedial measures. The interplay with other water quality parameters such as nitrate and pH needs further study. Further reduction in sedimentation and levels of suspended solids in RAS farms will undoubtedly be of importance in establishing control of these problems.

Responses to the survey- land-based farms

Responses to the survey were generally consistent with the enquiries received by NIVA throughout the year, but also highlighted other problems related to water quality. The most commonly commented water quality parameter in the survey was increased levels of dissolved CO2 with 60-70% of respondents considering this a problem. This indicates that there remains much to be done to understand better the capacity of individual farms in terms of water treatment, fish density and water consumption before good fish welfare may be assured. It would appear that most respondents consider water quality more challenging in RAS systems compared to through-flow farms. As expected, problems related to hydrogen sulphide were identified much more commonly in RAS systems compared to through-flow farms. Only 6.75% of respondents reported this type of problem in through-flow farms while 57.2% had experienced H2S associated problems in RAS farms.

Marine farms

There are normally few opportunities to manage water quality in marine farms other than favourable hydrological siting of the farm. A number of occurrences of toxicity due to mobilisation of aluminium have been registered in association with freshwater treatment of

Photo: Mari M. Press, Norwegian Veterinary Institute

salmon-lice and/or AGD when humus rich freshwater has been used. Such events could be avoided by pre-treatment analysis of the freshwater to be utilised. Some marine sites are also influenced by freshwater run-off and in these cases, there are few mitigating strategies other than avoidance of stress in the fish. Anything that encourages the fish to seek deeper, less toxic water e.g. strategic feeding, may benefit the situation.

New technological solutions and semi-enclosed farms present new water quality related challenges. Adequate surveillance of water quality parameters is extremely important, as is surveillance for algal blooms. There is much to be learned regarding optimisation of such aquaculture environments.

In the annual survey, a number of commonalities relating to water quality in marine farms were noted. These fell into three categories: 1) challenges related to oxygen saturation in relation to louse-skirt use, 2) algal blooms during the late summer/early autumn and 3) gill health challenges related to net cleaning. This underlines the need for systematic studies related to the interplay of cage environment and fish health.

Summary

We are of the opinion that many water quality related events could be avoided and that it is important that lessons are learned and knowledge disseminated. Many farms participated in the so-called VK (water quality)-investigations between 1999-2009, and much research has since been done on development of good water treatment methods. With introduction of new aquaculture technologies and a new generation of fish farmer there is a clear need to 'dust off' this knowledge to combat modern challenges. Based on both NIVA's experience and survey responses it is clear that there is a requirement for an increased focus on water quality in RAS farms.

8.3 Poor smolt quality and runt syndrome

By Jinni Gu

Good control of smoltification and exact evaluation of smolt status are important factors in ensuring good smolt quality. Poor or varying smolt quality is probably a major contributing factor to unsatisfactory development, growth and health following sea-transfer i.e. development of runt syndrome.

Challenges related to smoltification in freshwater farms lead to significant variation in fish size etc. Diseases, both infectious and environmental will influence the smoltification process. Biased selection of fish for analysis may also lead to a misleading conclusion regarding smolt status.

Runt syndrome is a condition in which the fish become emaciated or do not grow normally after sea-transfer. A typical histological picture in runts includes a lack of perivisceral fat and increased melanisation in the kidney, but with an intact pancreas. Bacteriological and virological investigations are often negative. Runts may be observed in freshwater, but the term is normally associated with sea-farmed fish.

The cause/s of runt syndrome remain/s unclear and may be complex. Smoltification problems may be involved. Observations made during the sea phase indicate that fish surviving IPN, PD or parvicapsulosis may become severely emaciated. It is considered likely that runt syndrome may be related to stress and stress-related situations. Optimal smoltification, transfer to sea at the correct time and a good feeding strategy are important for normal development, growth and health of salmonid fish.

Runted fish may survive for considerable periods and undoubtedly represent a significant welfare challenge. These fish are considered to carry a higher burden of infectious agents than fish in normal condition. Tapeworms are a normal finding in runted fish. Runts should therefore, be removed from the population to reduce transmission of infection.

The situation in 2018

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.

In 2018, approximately 27 farms appear to have experienced runt syndrome. This represents a continued reduction compared with 2017 and 2016 when 40 and 71 farms were affected respectively. Considerably fewer farms have been registered as suffering from ‘emaciation’ by the Norwegian Veterinary Institute since 2016 as the diagnosis was made on 13 farms in 2018 compared to 26 and 45 farms in 2017 and 2016 respectively. As in previous years, large regional differences were identified. Most farms diagnosed with ‘emaciation’ in 2018 were situated in mid- and northern Norway.

Annual survey

Runt syndrome in ongrowing farms scored 2.5 for salmon and 2.4 for rainbow trout, but the significance of runting was considered higher in rainbow trout than in salmon. Poor smoltification status on sea transfer scored 2.4 for salmon and 1.7 for rainbow trout.

Respondents were asked for their evaluation of the smoltification process in freshwater farms. Problems with salmon scored 2.6 and 2.8 for through-flow and recirculation based farms respectively and these problems were ranked as third and second most important for each respective technology. For rainbow trout, smoltification is reported to be a less significant problem overall, but as for salmon it seems to be more of a problem in RAS facilities (2.1) than in through-flow farms (1.5).

Evaluation of smolt quality and runt syndrome

The trend towards increasing production of large smolts continued in 2018 and the largest farms producing large smolts are recirculation based. Some have established good routines for production of smolts up to 300g in weight. Several workers report HSS and nephrocalcinosis as challenging in production of large smolts. Production of spring smolts can be more challenging in comparison to autumn smolts, which may be related to cold winters and fluctuating water quality. Serious ulcer and gill problems leading to osmoregulatory problems and timing of smoltification have been associated with increased use of seawater.

A number of ongrowing farms have reported reception of smolts of poor or varied quality. These populations are either poorly smoltified, resmoltified, are leaving the smoltification window, have a high prevalence of precocious males or are deformed.

Poor smolt quality represents a greater risk of secondary skin infection, e.g. winter-ulcer and subsequent high mortality in fish sea-transferred in early spring. Some farms have experienced extended welfare challenges related to sea transfer of poor quality smolts. Some observers note significant quality differences in smolt from different producers.

Runt development post sea transfer is reported to be a problem along the whole coastline but results in the greatest health challenges in Northern Norway. While whole farms may be affected, in some farms the problem appears to be related to single batches of fish or individual cages. Some farms report increases in mortality related to runted fish. The overall situation does appear, however, to have improved in recent years.

Photo: Colourbox.

8.4 Nephrocalcinosis

By Jinni Gu and Anne Berit Olsen

The disease

Nephrocalcinosis (calcium deposition in the kidney, kidney stones) is a normal finding in farmed fish. The disease is not infectious. Nephrocalcinosis related mortalities are generally low, but the condition can lead to reduced growth. Nephrocalcinosis is an important welfare indicator in farmed fish.

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 tubuli, 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. Both high Co2 levels and an incorrect mineral balance in the feed e.g. low magnesium levels, are associated with the disease. Experimentally, high doses of selenium in the feed have also caused nephrocalcinosis. The most common cause in an aquaculture setting are the high levels of dissolved CO2 experienced over extended periods in modern intensive aquaculture facilities. The mechanisms are not fully understood, but high levels of CO2 results in respiratory acidosis in the fish, which may lead to increased excretion and reduced reabsorption of calcium and other minerals in the kidney. The minerals then precipitate as crystals possibly during acidification of the urine. The highest recommended levels for CO2 during the freshwater stages of salmon farming is 15mg/l. In full strength seawater (through-flow) there is a risk of development of nephrocalcinosis in salmon at pH levels under 7-7.1 (CO2 >15 mg/l).

Nephrocalcinosis is commonly identified in association with haemorrhagic smolt syndrome (HSS). HSS, also known as haemorrhagic diatese (HD) is characterised by multi-organ haemorrhage typically including the tubuli 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 tubuli associated with HSS results in a poorer reabsorption capacity.

Nephrocalcinosis can occur in all sizes of fish in both hatcheries and ongrowing sites. Most cases are identified in pre-smolt, smolt and post-smolt. Affected fish normally recover without treatment.

Om bekjempelse

Nephrocalcinosis is considered an environment related problem. The risk of nephrocalcinosis development may be reduced by ensuring good quality intake water, good monitoring of water quality in tanks and cages, including CO2 and pH, and stocking to an appropriate fish density.

The situation in 2018

Norwegian Veterinary Institute data

In 2018, nephrocalcinosis was diagnosed on 147 salmonid farms by the Norwegian Veterinary Institute, which represents an increase from 2017 and 2016, when this condition was diagnosed in 126 and 107 farms respectively. The increase is generally related to salmon in the sea as nephrocalcinosis was identified in 80 marine sites compared to 63 in 2017 and 36 in 2016.

As far as rainbow trout are concerned, nephrocalcinosis was diagnosed in four hatcheries and 11 ongrowing sites in 2018 which is a similar level to 2017 and 2016. As in previous years, nephrocalcinosis was also identified in broodstock (salmon and rainbow trout) in a few land-based farms.

Annual survey

Several Fish Health personnel consider nephrocalcinosis a more significant disease in 2018 than in previous years, in both ongrowing and juvenile production, particularly in salmon. Nephrocalcinosis scores highest

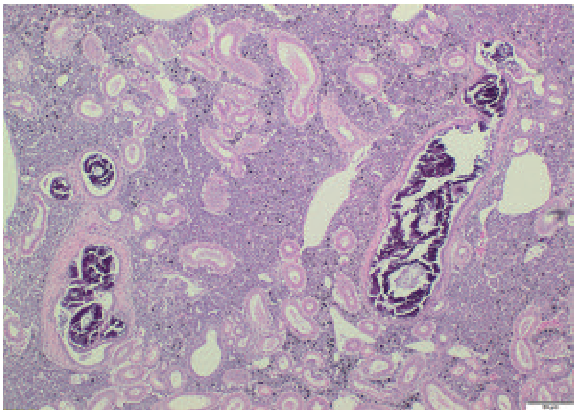


Figure 8.4.1 Histological photograph of kidney tubules with calcium deposition. Damaged epithelium may be seen in places. Such deposition can lead to blockage of the urine excretory system. photo: Toni Erkinharju, Norwegian Veterinary Institute.

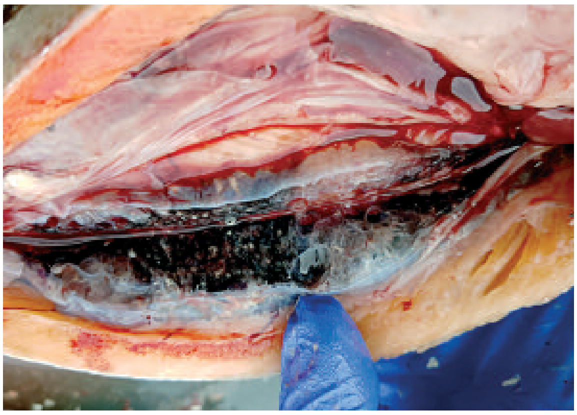


Figure 8.4.2 Salmon with advanced nephrocalcinosis. Photo: Marianne Elnæs, Mowi ASA

for large-smolt production (3.3), while high levels of CO2 scored 2.9. In ongrowing farms, nephrocalcinosis scored on average 2.5 for salmon and 2.4 for rainbow trout. Nephrocalcinosis was considered only a minor problem in broodstock farming of both salmon and rainbow trout.

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 2018, we have reason to believe there has been a worsening in the situation since 2016. This is in accordance with experiences reported in the annual survey.

In hatcheries, nephrocalcinosis was most commonly diagnosed in pre-smolts and smolts with sub-clinical disease in the absence of raised mortality. A number of affected fish were also diagnosed with HSS or had survived an earlier HSS outbreak.

RAS technology is considered a risk factor for development of nephrocalcinosis. There is a general feeling in the industry that nephrocalcinosis is a greater problem in RAS farms than in through-flow farms, but there is a need for more systematic registration of the condition before valid comparisons can be made.

In ongrowing farms, 58% of investigated cases involving nephrocalcinosis involved smaller fish transferred to sea during the previous 3 months. It is considered likely that a large proportion of the cases involved in marine sites originated in the freshwater hatchery. Some farms have experienced episodes of high mortality in nephrocalcinosis-affected fish shortly after sea transfer.

Approximately 14% of investigated cases involved large fish (1.5-4kg) or chronic nephrocalcinosis, as long as 7 months post sea transfer.

The Norwegian Veterinary Institute has also registered an increase during 2018 of incidences of extensive nephrocalcinosis-related chronic granulomatous kidney inflammation in both freshwater and marine farms. In one marine farm, calcium deposition and granulomatous inflammation was identified not only in the kidney, but also in the peritoneum and several organs including the liver and eyes.

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 CO2 levels. The mineral content of feeds should also be considered. There is a need for increased knowledge related to development of nephrocalcinosis.

8.5 Vaccine side effects

By Kristoffer Vale Nielsen and Siri Kristine Gåsnes

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.

New aquaculture legislation introduced in April 2018 (FOR-2018-04-19-673) repealed previous legislation (paragraph 63) requiring Atlantic salmon to be vaccinated against particular infectious diseases. Vaccination of fish is now regulated according to aquaculture legislation (Akvakulturdriftsforskriften, §§ 11 and 28) and chapter 13 of 'Trade and disease in aquatic animals' legislation. The new regulations are more general and place responsibility on the producer to perform relevant prophylactic measures, including vaccination. Farmed salmon in Norway are normally vaccinated against furunculosis, vibriosis, coldwater vibriosis, winter-ulcer (*M. viscosa*) and IPN.
In some areas vaccination against PD (western Norway and northern west-Norway) and yersiniosis is common. Vaccination against ISA and other diseases including use of autogen vaccines, occurs more sporadically. A limited number of vaccines are available for marine fish species.

Vaccine side-effects following injection vaccination 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 growth, increased frequency of deformity, iridocyclitis and autoimmune symptoms. Some of these side effects must be painful to the fish.

The degree of side effects varies with vaccine type and conditions related to the vaccination process e.g. fish size, water temperature and hygiene. Vaccine side effects are commonly graded according to the Speilberg scale, which is based on the degree of adherence and melanin deposition within the peritoneal cavity. The scale starts at 0, which is equivalent to no visible changes, and ends at 6, which represents huge change. Grade 3 and above in the Speilberg scale represent injuries that are considered unacceptable in terms of fish welfare. Since introduction of the first oil-based vaccines to the market in the early 90's, there has been a general reduction in the degree of vaccine side effects registered. This is a result of increased knowledge of the risk factors, improved administration procedures and changes in vaccine formulation and dosage volume.

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.

Given the extensive use of vaccination in Norwegian aquaculture and negative welfare aspects of vaccination, it is important that a focus be maintained on reduction of vaccine related side effects. Vaccine formulations must be continually improved upon, vaccine administration must be performed under optimal conditions and vaccine side effects should be monitored in all fish groups.

Annual survey

Fish Health Service personnel and inspectors of the Norwegian Food Safety Authority continue to feel that vaccination does not constitute a significant health or welfare problem compared to other diseases. This applies to farming of salmonids in both fresh and seawater.

When asked on their views regarding whether vaccination represents a welfare problem for ongrowing salmon, 30 % of respondents answered ‘No, not at all’, 40% replied ‘Yes, to a minor degree’, 15% ‘to a dergree’, 4% answered ‘yes, to a significant degree’ and 11% answered ‘don’t know’. Vaccine side-effects of over 3 on the Speilberg scale were registered ‘not at all’ by 16 % of respondents, ‘to a minor degree’ by 44%, ‘to a degree’ by 15%, ‘to a significant degree’ by 0%, while 25% answered ‘don’t know’.

When asked ‘Do you have any further comments on welfare challenges related to vaccines or vaccination?’ several comments related to a possible association between vaccination against PD and development of spinal deformities. Other comments included a possible change and increase in side-effects following vaccination or combinations of several vaccines.

Figure 8.5.1 Minor adhesions and melanin deposition around the injection site.
Photo: Kristoffer Vale Nielsen, Norwegian Veterinary Institute.

9 The health situation in wild salmonid fish

By Åse Helen Garseth, Siri K. Gåsnes Sigurd Hytterød, Asle Moen, Haakon Hansen and Anne Berit Olsen

9.1 Introduction

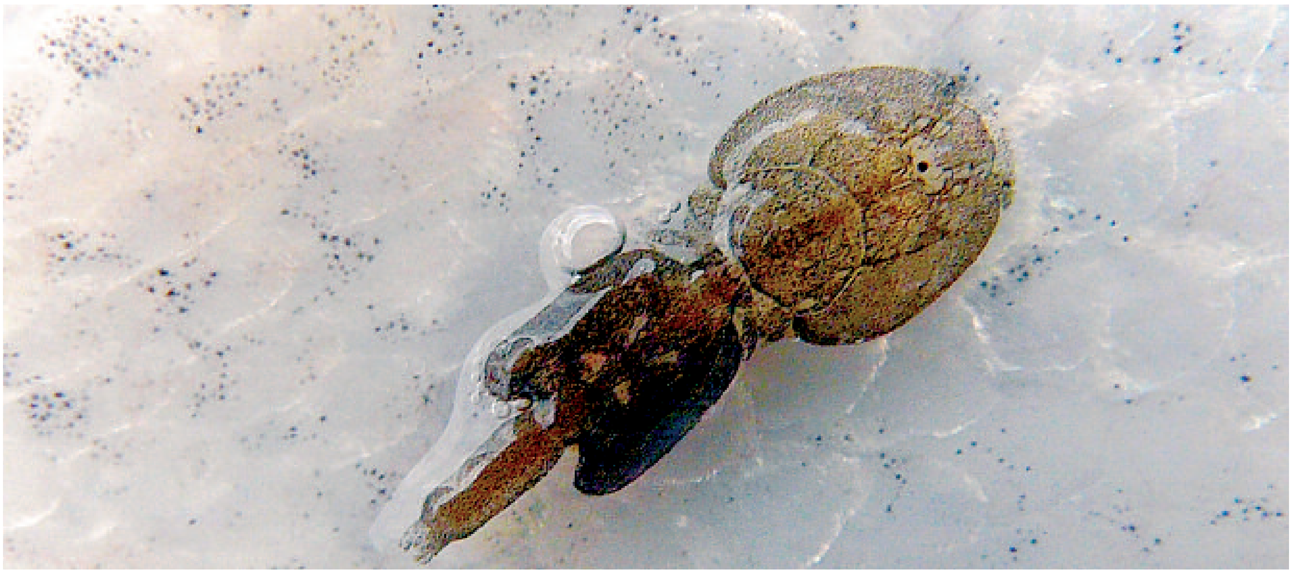
The summer of 2018 was the warmest and driest for several decades. For wild salmon, this meant a situation dominated by low water levels and high water temperatures in many rivers. During this type of season returning salmon wait in the sea for longer than normal before proceeding upriver. Fish densities during low water in late summer are greater than normal. To avoid stressing the fish, measures including stopping of angling are important. The organisation 'Norske lakseelver' (Norwegian salmon rivers), reported reduced catches in Norwegian rivers in 2018.

Fish are more prone to certain diseases during periods of high water temperature. As expected, outbreaks of proliferative kidney disease (PKD) and furunculosis were registered during the year. Acute mortalities during the summer extending into the autumn were reported from rivers in the south of the country. Several reasons have been speculated upon, but in many cases the underlying causes have not been identified. Water chemistry, environmental and climatic conditions undoubtedly considerably influence fish health and rapid changes in such conditions can have serious consequences.

In aquaculture, fish are confined within a limited area (tank or cage) and signs of disease are relatively easily observed. The health of farmed fish is continually monitored and while the situation is not perfect, we have a relatively good oversight of the fish health situation in farmed fish. This is not the case for wild fish.

The Norwegian Veterinary Institute is the responsible body for identification of infectious diseases in wild fish. Our surveillance is, however, restricted to material submitted for investigation. The Norwegian Veterinary Institute does not have a field apparatus for collection of material and is therefore dependent on contribution of information and samples from members of the public, councils, government institutions etc. On identification of notifiable diseases, responsibility for disease management transfers to the Norwegian Food Safety Authority. In cases involving non-notifiable diseases there is a requirement for local coordination and collation of information such that the cause of the disease is identified and remedial measures initiated.

The ocean and environment in general are under pressure from human activity. In 2018, the negative effects of plastic pollution in the oceans were highlighted.
The Norwegian Veterinary Institute is the public organ responsible for diagnosis of disease and unexplained mortality in wild fish. Below is a summary of cases submitted to the Norwegian Veterinary Institute in 2018.



Salmon louse. Photo Trygve Poppe

9.2 News from the diagnostic service

Papillomatosis in salmon in the river Etne

A fish trap has been established in the river Etne as part of a research project (Institute of Marine Research) to allow removal of escaped farmed fish. This allows a good opportunity to individually monitor all fish moving up the river. During August 2018, fish displaying skin ulcers and growths were identified. The growths were subsequently identified as epidermal papilloma, which is a benign tumour type. Papillomatosis can be identified in both wild and farmed salmon in both fresh and saltwater. Papillomatosis in salmonids is most probably caused by a herpes-like virus specific for salmonids and may transmit between salmonids. The prevalence of papillomatosis is seasonal, with skin changes appearing in summer and disappearing in the autumn and winter. Papillomatosis has not been linked to clinical disease or mortality, but affected fish lose value as a food fish.

Furunculosis in the river Namsen

Furunculosis is a notifiable disease of fish caused by the bacterium *Aeromonas salmonicida* subsp. *salmonicida*. The Norwegian Veterinary Institute identifies furunculosis in wild salmonids submitted from the Namsen watershed in Trøndelag region regularly (almost annually). Mortality levels vary. Furunculosis outbreaks generally occur during periods of warm weather and low water levels, which stress the fish.

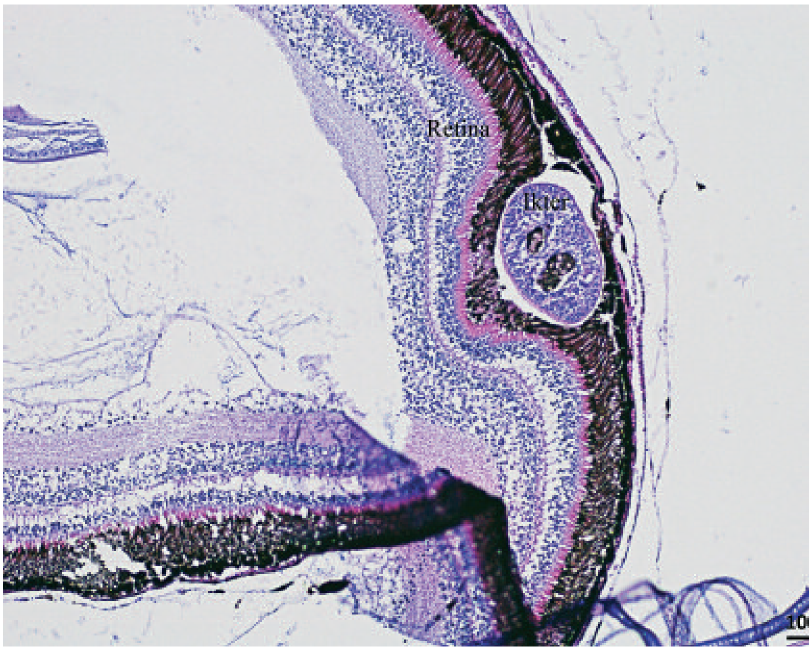
Furunculosis was diagnosed in fish submitted from three rivers in the Namsen watershed in 2018. During the outbreak in the river Sandøla in July, water temperatures of 25oC were registered and 356 dead salmon (total 1756kg) were recovered from the river. A smaller outbreak was registered in the river Ferga from which 50 dead fish were recovered. Later in the year 32 broodstock in the river Bogna were euthanised following diagnosis of furunculosis.

Fish submitted to the Norwegian Veterinary Institute for diagnostic investigation (seatrout and salmon) displayed furuncles and ulcers and A. salmonicida subsp. salmonicida was cultured.

Figure 9.2.2: Following the outbreak of furunculosis in the river Sandøla in 2018, 356 dead salmon were registered. Photo: Anton Rikstad, County Governor in

Figure 9.2.1: Papillomatosis (Warts) in salmon is caused by a viral infection. Photo: Håvard Kambo

Figure 9.2.3 . Three-spined stickleback with tapeworm Photo: Kristine Gismervik, Norwegian Veterinary Institute.



Figur 9.2.4. Histologically visible fluke in the eye. Photo Jinni Gu, Norwegian Veterinary Institute.

Diverse parasites in stickleback

A number of sick and dead three-spined sticklebacks were observed in September 2018 in a small lake (Blomstertjønna) in Trondheim. The fish displayed distended abdomens and the tapeworm *Schistocephalus solidus* was visible from the anal opening. Sticklebacks submitted to the Norwegian Veterinary Institute for diagnostic investigation were found to be infected with several parasites including the aforementioned tapeworm, and several other species found within the eyes, brain and intestine. Such parasites cannot infect humans. Parasites are common in three-spined sticklebacks.

Mortality associated with toxic pollution

An unusually high mortality event was registered in several rivers in the south of the country in October 2018. In the river Barbuelva in Arendal a number of dead seatrout were observed. Various theories were proposed as to the underlying cause including toxic pollution and electrocution (!). The Norwegian Veterinary Institute received seven fish for diagnostic investigation. The main finding was identification of precipitated aluminium and iron in the gills, which is normally associated with acidification of the water in the rivers.

Mortality in the river Homla in Trøndelag

Reports were received in October 2018 of dead salmon found in the river Homla in Malvik. Two weeks previously to these reports four small lakes in proximity of the river had been treated with rotenone to remove pike. Three of these lakes drain into a tributary of the Homla and rotenone poisoning was therefore suspected in this case. Samples investigated by the Norwegian Veterinary Institute did not provide clear indications of the cause of mortality but small amounts or iron-containing material was found in the gills. Iron precipitation in the gills is toxic and may cause acute mortality but the effect of the small amounts identified is uncertain. A low concentration of rotenone was identified in the gills of one fish, but not in the remaining fish. It remains unclear what caused the mortality episode in the Homla, but rotenone poisoning cannot be discounted.

Proliferative Kidney Disease

The disease PKD is a result of an immunological reaction to spores of the parasite *Tetracapsuloides bryosalmonae*, which is spread by bryozoans. Macroscopically visible pathological changes are largely confined to an enlarged kidney and spleen. Diseased fish display pale gills and a very enlarged kidney and (later in the infection course) distended abdomen. The parasite is found in a number of Norwegian rivers.

Disease normally occurs following a period of warm water (>15oC). This is a disease we expect to see more commonly in the future due to climate change. The Norwegian Veterinary Institute has surveyed 45 salmon and trout juveniles for PKD in a river in Trøndelag. Tetracapsuloides bryosalmonae and pathological changes consistent with PKD were confirmed in 28. Pharmaq Analytiq report identification of PKD in farmed brown trout from a farm in southern Norway (Norsk veterinærtidsskrift nr 9/2018).

Fungal infections in spawning fish (Saprolegniosis)

In the course of the summer, significant mortality amongst salmon in Swedish rivers was reported. Although the main clinical finding was fungal infection, the possible involvement of a vitamin B1 deficiency was discussed. Vitamin B1 deficiency in wildfish, game, birds and domestic animals is a current research focus in Sweden.

In Norway, dead fish with obvious fungal infection were reported from the river Figgj0 in Rogaland and from a hatchery in the same region. Unusually virulent and prevalent saprolegnia infections were also identified in spawning fish in the river Sandvikselva, with corresponding high mortality. The presumptive causes included high fish densities, low water level and high temperature. Although mortality was high, local reports indicate upward migration of many apparently healthy fish when the rain finally came. (pers comm. Trygve Poppe).

Figur 9.2.5: Saprolegniosis in wild salmon in the river Sandvikselva. Photo: Trygve Poppe.

9.3 Health surveillance in wild salmonids

In 2016, salmon gill pox virus (SGPV) was demonstrated to be widely prevalent in Norwegian wild salmon and SGPV-associated pathological changes were also identified in the gills of wild salmon. Investigation of farmed fish show that gill disease may be related to infection with a single infectious agent or be dependent on a combination of different agents and environmental conditions. Amplification of infectious agents in farmed stocks may have implications for wild stocks. In 2018 the Norwegian Veterinary Institute mapped the prevalence and range of a number of gill pathogenic agents in wild caught salmon, brown trout, arctic char and whitefish; Ca. *Branchiomonas cysticola* and Ca. *Piscichlamydia salmonis, Desmozoon lepeophtherii*, Salmonid gill poxvirus, Atlantic salmon paramyxovirus and *Paramoeba perurans* which causes amoebic gill disease (AGD).

The programme was performed as a PCR based screening of gill tissues. The aim was to identify the prevalence and range of pathogens individually and in combination. Pathogen prevalence in the sea was compared to andromous and non-anadromous freshwater bodies. The PCR analyses were performed by Patogen AS. A simple presentation of the results is provided here. A more complete report will be published later this year.

	Salmon	Landlocked salmon	Seatrout	Brown trout	Arctic char	whitefish
Atlantic salmon paramyxovirus	0	0	5	0	0	0
Ca. *Branchiomonas cysticola*	116	0	54	26	17	5
Ca. *Piscichlamydia salmonis*	43	0	14	9	0	0
Desmozoon lepeophtherii/ Paranucleospora theridion	44	0	7	0	0	0
Salmonid gill poxvirus (SGPV)	35	0**	0	0	0	0
Paramoeba perurans	0*	-	0*	-	0*	-
Total investigated	132	71	69	60	44	21

*Investigated 33 net-caught salmon and two seatrout, and 13 seatrout and four sea-run arctic char from anadrome freshwater bodies.

** Investigated in 2016.

The prevalence of SGPV in wild salmon varied considerably amongst the different groups of salmon. The virus was not detected in landlocked salmon investigated during 2016. In 2018, the virus was not detected in 33 net-caught salmon from the sea. A prevalence of 13% was identified amongst river-caught fish, while 90% of investigated wild-caught broodfish for restocking hatchery purposes were infected. This is consistent with the previous 2016 investigation. The high prevalence in broodfish is presumably due to fish to fish transmission while held in the pre-spawning holding tank.

A similar pattern was observed for the microsporidean *Desmozoon lepeophtherii (Paranucleospora theridion)*. This marine parasite was not identified in landlocked salmon but was detected in gill tissues from wild salmon in the sea (9%) and in rivers (19%). Again, wild caught broodstock displayed a high prevalence (97%). These are valuable findings, not least for the health of wild caught broodstock utilised for restocking or gene bank purposes.

Trollveggen rises behind the Steinhølen pool in the river Rauma. This river was last rotenone treated in 2014. Before the river can be declared free of infection, the river must be monitored for the parasite for a period of five years. Photo: Trond Haukebø. County Governor in Møre og Romsdal.

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 current legislation and has until 2018 included post-mortem and testing for infectious pancreatic necrosis virus (IPNV), *Renibacterium salmoninarum* (causative agent of bacterial kidney disease) and *Aeromonas salmonicida* subsp. *salmonicida* (furunculosis bacterium). Both IPNV and *R. salmoninarum* may be transmitted vertically, while *A. salmonicida* is satisfactorily killed during compulsory egg disinfection. The Norwegian Food Safety Authority can therefore award dispensation from testing for *A. salmonicida* (dispensation must be applied for).

There are indications that Piscine myocarditis virus (PMCV) which causes cardiomyopathy syndrome (CMS) in salmon may be vertically transmitted.
All salmon have therefore been tested for this virus since 2016. In 2018, 259 salmon and 46 seatrout were investigated. IPNV and R. salmoninarum were not detected. PMCV was identified in one salmon from Nordland and eggs from this fish were destroyed.

Table 9.4.1 Results after PCR-analysis for *Renibacterium salmoninarum* (BKD), infectious pancreatic necrosis virus (IPNV) and piscine myocarditis virus (PMCV) performed on wild-caught broodstock destined for the gene bank for wild salmon and three localities in Trøndelag unconnected with the gene bank.

Region	Salmon	Seatrout	Comment
Nordland	23		1 salmon positive for PMCV
Trøndelag	73		not genbank, not tested for PMCV
Møre og Romsdal	57		
Hordaland	98	46	
Buskerud	31		
Totalt	259	46	

Aquaculture legislation- changes in requirement for investigation of wild-caught broodstock

Recent years have seen a dramatic increase in knowledge relating to various fish diseases. Diseases which have been recognised in farming for decades, but of unknown or uncertain aetiology, have now been related to concrete agents through use of new diagnostic and bioinformatic tools. Examples include piscine orthoreovirus-1 (PRV-1) which causes heart and skeletal muscle inflammation (HSMI), salmon gill pox virus (SGPV) related to particular gill pathologies and PMCV which causes cardiomyopathy syndrome (CMS). The origins, infection routes and natural reservoirs of these viruses remain largely unknown. The lengthy period between recognition of these diseases and identification of the responsible agents has however, allowed them to become established and thus difficult to eradicate/control.

In such a situation, any specifically formulated fish health legislation will not manage to keep abreast of developing knowledge.

In April 2018, the following legislation related to investigation of wild-caught broodstock for the gene bank entered into force:

'On stripping or other form of reproduction of wild-caught fish, relevant investigations shall be performed dependent on the area from which the wild fish were caught'.

'Wild-caught anadromous fish for stripping shall as a minimum be tested for bacterial kidney disease'

This legislation is demanding as neither the gene bank, re-stocking hatcheries, Fish Health Services or the Norwegian Food Safety Authority have any real knowledge of the health status (of wild and farmed fish) in the area where the fish have been caught. This is a result of the fact that many important diseases e.g. IPN, CMS and HSMI are non-notifiable and that knowledge of the health status of wild populations are generally unknown. Infection with IPN is only sporadically identified in wild-caught broodstock and is not related to any particular geographic area. To meet these challenges, the gene bank for wild salmon has performed its own studies on vertical transmission of 'novel' infectious agents

Studies of vertical transmission in the Gene bank for wild salmon

As part of health surveillance of wild salmonids, the Norwegian Veterinary Institute has performed screening for infectious agents in wild-caught broodstock for the Gene bank for wild salmon. Positive findings have been followed up by investigation of the offspring within the gene bank to illuminate possible vertical transmission routes. The investigation has been somewhat limited, but is an important biosecurity related procedure and a supplement to other research within the aquaculture industry. Research does not always provide black and white results and results are often associated with a certain degree of uncertainty. A risk evaluation must therefore be performed in each case, which is based on the probability that the event may occur and the consequences of the event should it occur. This is simple as long as there are few virus detections. Since 2014, studies of vertical transmission in PRV-1, SGPV and PMCV have been performed in salmon and PRV-3 in seatrout.

The results relating to vertical transmission of PMCV are given here. The remaining results will be published in a separate report.

Vertical transmission of PMCV?

Histological changes consistent with CMS were identified in wild salmon in 2001/2002, but mapping of the prevalence in wild-caught broodstock in 2007-2009 indicated a low prevalence of the virus in this type of fish (< 0.2%). During broodstock testing for PMCV in the Hardanger region in 2016 and 2017 a very different situation was identified (7 of 93 positive in 2016, 1 of 48 in 2017). Whether these differences are due to regional differences or a general change in the prevalence in wild salmon is unknown. Identification of PMCV in broodstock captured for gene bank purposes in 2016 stimulated the previously mentioned study on vertical transmission.

To investigate whether PMCV is transmitted from parent to offspring in the gene bank for wild salmon, three rounds of offspring testing (offspring of PMCV positive parents) have been performed at different life stages.

- 60 yolksac larvae from 7 families (tested by the Norwegian Veterinary Institute)- No PMCV detected
- 60 fry from 7 families (tested by Patogen AS) – No PMCV detected
- 50 parr from one family, heart, head kidney and spleen analysed separately from each individual (tested by Patogen AS) – No PMCV detected

Patogen AS use a cut-off value of Ct37 for their analyses. We have therefore collated results above that threshold. In our material, there are few PMCV positive broodstock, and positive fish had a low viral load (high Ct value). Our results are not conclusive for cases in which the number of infected broodstock is high and where individual fish have a higher viral load.

Gill inflammation in wild caught broodstock

Gill inflammation in wild caught broodstock for restocking and gene bank purposes is not a new phenomenon. Gill-associated parasites, metal deposition and fungal infections have been associated with mortality episodes. Wild caught salmon are captured in the river and held in a cage in the river until ready for stripping.

Table 9.4.2. PCR results performed on gill tissues from two regions during diagnostic investigation of wild caught broodstock for the gene bank for wild salmon

Agent	Region	
	Buskerud	Møre og Romsdal
Atlantic salmon paramyxovirus (ASPV)	0	0
Ca *Candidatus Branchiomonas cysticola*	5	6
Desmozoon lepeophtherii/ Paranucleospora theridion (Microsporidia)	5	2
Ca *Candidatus Piscichlamydia salmonis*	3	3
Salmon gill poxvirus (SGPV)	5	6
Flavobacterium psychrophilum	5	6
Total number analysed	5	6

The period of captivity may vary from days to months (in tanks). In 2018, acute high level mortality episodes were experienced in captive broodstock in Møre og Romsdal and Buskerud. In Møre og Romsdal, capture of broodstock had started earlier in the year than is normal and as autumn progressed fungal infection was identified in the fish, as was gill inflammation dominated by parasites (*Ichthyobodo* sp.) and several other infectious agents. Treatment was performed and mortality in the facility reduced. In Buskerud, the broodstock had been collected approximately 4 weeks in advance of stripping and fish were held in tanks supplied with river water. An acute and high mortality was experienced amongst male fish one week before stripping and within the week nearly all the fish had died. Diagnostic investigations identified gill inflammation dominated by bacteria. PCR analyses identified the presence of several agents within the gill tissues.

The results illustrate the value of extensive investigation of fish health. In the gene bank for wild salmon, prophylactic treatments aimed at improving the gill health of captive fish will be initiated.

9.5 *Gyrodactylus salaris*

Control of Gyrodactylus salaris

Gyrodactylus salaris was introduced to Norway in the 1970's and the parasite has since been found in 50 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 was, as part of this eradication plan, awarded National Expert Laboratory status and given responsibility for practical execution of all anti-gyrodactylus activities in Norwegian rivers. For the most part, treatments are rotenone based, but one successful treatment has also utilised acidified aluminium. All control measures are performed under contract from the Norwegian Environment Agency.

Many successful treatments were performed during the period 2000-2016, with several rivers subsequently declared free of infection. By the end of 2018, only seven Norwegian rivers remain infected. These rivers are distributed between the regions Driva and Drammen. Development of new control measures is considered important in the mission to remove *G. salaris* from all Norwegian rivers. The Norwegian Environment Agency has therefore financed a project in which the Norwegian Veterinary Institute, the Norwegian Institute for Nature Research and the Norwegian Institute for Water Research will explore the use of chlorine compounds as an anti-*G. salaris* treatment in large river systems, without killing fish present during the treatment. Activity is planned in the Driva region during 2019.

In addition to *G. salaris* eradication work, the Norwegian Veterinary Institute carries out extensive mapping programmes in relation to restocking of treated rivers with salmon, trout and arctic char. A programme of restocking is performed over several years following successful *G. salaris* treatment. The Norwegian Veterinary Institute also leads the national surveillance programme for *G. salaris*.

For more information on the fight against *G. salaris*, see: http://www.vetinst.no/dyr/villfisk/tiltak-mot-gyrodactylus-salaris-og-andre-fremmede-arter

Surveillance for *G. salaris* in Norway in 2018

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). An additional survey of the *G. salaris* situation in the upper migratory region of the Drammen river system was performed in 2018.

During the Ok-programme for *G. salaris* in 2018, 3301 salmon and rainbow trout from 97 hatcheries and 2615 salmon from 78 rivers were examined. During the FM-programme, 1363 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 river or farm during 2018.

At the start of 2019, seven Norwegian rivers are recognised to be *G. salaris* infected, while eleven rivers are under post-treatment surveillance.

9.6 Status update - risk of salmon louse induced mortality in wild salmon smolts

Transmission of salmon louse infection from the aquaculture industry to the wild salmon population is considered second only to genetic pollution as the most significant threat posed to wild salmon by salmon farming. It has also a severe effect on wild seatrout. Expansion of the aquaculture industry must be sustainable and is regulated via the so-called 'traffic light system' in which levels of salmon lice infestation are used as a sustainability indicator.

A group of experts from central Norwegian research institutions was established to consider the effects of transmission of salmon lice from the farmed population to the wild salmon population. The country is divided into 13 production areas (PO). The table summarises the expert group's conclusions for the period 2016-2018. From 2019, areas of high risk will be subjected to compulsory reduction in volume salmon produced.

Table 9.6.1. Traffic light: Green light (low risk), equivalent to <10% louse-induced mortality in wild salmon smolts, Yellow (moderate risk) and red (high risk) >30% louse-induced mortality in wild salmon smolts.

Production area	2016	2017	2018
1. Swedish border - Jæren	Low risk	Low risk	Low risk
2. Ryfylke	Moderate risk	Low risk	Moderate risk
3. Area Karmøy-Sotra	High risk	High risk	High risk
4. Nord- Hordaland - Stadt	Moderate risk	High risk	Moderate risk
5. Stadt - Hustavika	Moderate risk	Moderate risk	Moderate risk
6. Nordmøre - Sør-Trøndelag	Moderate risk	Low risk	Low risk
7. Nord-Trøndelag including Bindal	Moderate risk	Low risk	Moderate risk
8. Helgeland - Bodø	Low risk	Low risk	Low risk
9. Vestfjorden and Vesterålen	Low risk	Low risk	Low risk
10. Andøya - Senja	Low risk	Low risk	Low risk
11. Kvaløya - Loppa	Low risk	Low risk	Low risk
12. Vest-Finnmark	Low risk	Low risk	Low risk
13. Øst-Finnmark	Low risk	Low risk	Low risk

9.7 Recent developments

Pink salmon

Pink salmon *Oncorhynchus gorbuscha*, are not native to Norway and are black-listed by the Norwegian Biodiversity Information Centre. This species is the smallest and most numerous of the pacific salmon species and was released in Russian rivers running into the White- and Barent –seas several times in the period 1956-2000. 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. It is mainly release of 'odd-year' fish that has led to self-maintaining populations in Russian rivers.

Pink salmon have been registered in rivers in Finnmark for many years, but were in 2017 registered in 272 rivers along the entire Norwegian coast line. The Norwegian Institute for Nature Research (NINA) reported capture of more than 6500 pink salmon, and more than 5500 were observed by snorkelling in rivers in Finnmark. Successfully hatched fry were observed in several Norwegian rivers between early autumn 2017 and early 2018. Juvenile pink salmon grow quickly, smoltify and migrate to sea at 3-4cm in length.

Offspring spawned in 2017 can be expected to return to Norwegian rivers in 2019. If they do return, observations may be expected from early June onwards, but the peak of migration will coincide with the main Atlantic salmon upstream migration period. NINA urges anyone observing pink salmon to report their observation. From 2019, capture of pink salmon will also be reported in the annual salmonid capture statistics compiled by the Norwegian Environment Agency.

Currently we have little knowledge of how the presence of pink salmon will affect the wild Atlantic salmon populations of Norwegian rivers. Pink salmon migrate over long distances and do not necessarily return to the river in which they were spawned. They may migrate past both Russian and Norwegian salmon farms and become infected from fish held in these farms. A limited survey of

Table 9.7.1.

Examined	References (in Norwegian)
Pink salmon from the rivers Tana (38) and Neiden (36) for IHN-virus, IPN-virus and ISA-virus. No positive findings were made.	Skjåkvik H. (2008) Undersøkelse av pukkellaks for forekomst av virus. Oslo 2008. Fordypningsoppgave-Norges Veterinærhøgskole
34 pink salmon from the river Glomma were examined for the presence of the tapeworm *Eubothrium crassum*, the nematodes *Hysterothylacium aduncum* in the intestine and *Anisakis simplex* in inner organs. No positive findings were made.	Mo T.A. og Poppe, T. Pukkellaks invaderte norske elver i 2017. Norsk Veterinærtidsskrift 4. 2018 130 s 243-5
Forty fish from the river Etne were examined for PMCV, SAV, ISAV and IPN-virus. Five individuals were positive for ISAV (of unknown HPR).	Grefsrud E.S. med flere (2018) Risikorapport norsk fiskeoppdrett 2018. Fisken og havet, særnr. 1-2018.

Plastic pollution

There has been a much greater focus than previously on plastic pollution in 2018.There are great concerns over the amount of plastic found in the ocean and its effect on animal life. Plastic pollution consists of large and small objects. Particles <5mm in size resulting from degredation of larger plastic objects are known as microplastic. These small particles can bind to environmental toxins, virus and bacteria which may enter fish on uptake of microplastic particles. Studies have been initiated to investigate the prevalence and eventual importance of plastic pollution for fish in Norwegian waters.

Gas supersaturation

NORCE (Norwegian Research Center) has through field-, laboratory- and literature studies investigated the phenomenon of gas supersaturation in 'flow-regulated' Norwegian rivers. Gas supersaturation can result in various degrees of 'gas bubble disease' in fish and benthic animals and thereby reduce the biodiversity and cause fish mortality in affected areas.

Gas supersaturation can occur in power stations and different construction types pose a greater danger than others. In some cases, supersaturation will be visible as an opaqueness in the water downstream of the power station, caused by formation of very small bubbles in the water. The extent and biological significance of gas supersaturation has only been slightly investigated in Norway. NORCE has provided recommendations as to how this phenomenon may be reduced. Observations of gas supersaturation in rivers should be reported to Ulrich Pulg (ulpu@norceresearch.no) in NORCE.

Photo: Morguefile.com

10 The health situation in cleaner-fish

By Cecilie Walde, Snorre Gulla, Haakon Hansen, Even Bysveen Mjølnerød and Geir Bornø

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 2018, a total of 41.6 million cleaner-fish (40 million lumpsucker and 1.6 million ballan wrasse) were farmed for this purpose (Kontali Analyse). Commercial production of lumpsucker in particular is under rapid expansion. .

One reason why lumpsucker are attractive is that they actively remove lice at temperatures lower than wrasse species. Lumpsucker also have a considerably shorter life cycle than wrasse and are more easily raised in captivity.

All lumpsucker used for louse removal in Norway are farmed. Ballan wrasse are also farmed but the majority utilised are wild-caught. Wrasse are caught in fyke nets and pots during the summer and transported on deck in tanks to land, then transported further either on lorries or in well-boats to their final destination where they are used as cleaner-fish. The longest transport distances include transport of fish from the Swedish west coast and the Baltic Sea to Nordland in Norway. There is a risk of transmission of infectious disease associated with these transports.

Mortality and problems directly or indirectly associated with handling (particularly in association with transfer to sea and non-medicinal lice treatments), fin-rot, skin disease and several bacterial diseases are the most significant health and welfare related challenges in cleaner-fish use in Norway today.

Common diseases/agents in cleaner-fish

Bacteria

The most commonly identified bacteria associated with disease in cleaner-fish and considered as pathogenic in all cleaner-fish species are atypical *Aeromonas salmonicida* and *Vibrio anguillarum*. *Pasteurella* sp., *Pseudomonas anguilliseptica* and *Vibrio ordalii* are considered pathogenic only in lumpsucker. 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. Cleaner-fish infections are almost exclusively related to infection with two genetic variants of the bacterium (A-layer types V and VI). Typical *A. salmonicida* (subsp. *salmonicida*) has not been identified in wrasse species in Norway in recent years, but has been diagnosed in lumpsucker used as cleaner-fish in Trøndelag in 2015 and 2016. These infections most probably represent spread from wild salmon infected with a local strain of the bacterium.

Vibrio anguillarum may cause disease (vibriosis) in all cleaner-fish species and is considered one of the most pathogenic bacterial species in marine fish in general. Vibriosis is associated most commonly with high water temperatures. Serotypes O1 and O2 (including sub-types of O2) are most common in Norway.

Pasteurella sp. is a pathogen of lumpsucker. Macroscopic signs of *Pasteurella* infection include caudal fin erosion, skin lesions (white spots), gill haemorrhage, haemorrhage at fin bases and ascites. These findings are, however, non-specific and may also be associated with other bacterial diseases.

Histopathologically, pasteurellosis is usually associated with the identification of bacterial micro-colonies in the spleen, kidney and heart. Tissue reactions in near-lying areas may vary from absent to obvious tissue necrosis, haemorrhage and infiltration of inflammatory cells. Infections with *Pasteurella* sp. are diagnosed in both hatchery and sea-transferred lumpsucker.

Pseudomonas anguilliseptica was identified for the first time in Norway in 2011 in lumpsucker. This bacterium is an opportunist fish pathogen that can cause disease in a range of fish species in freshwater, seawater and brackish water. Temperature is considered the most important factor for outbreak of disease.

Vibrio ordalii has been cultured from sick cod and lumpsucker in both the far north and far south of the country . The bacterium can cause significant mortality and recurring outbreaks. The number of outbreaks in lumpsucker has been relatively low in recent years.

Other bacteria including many Vibrio species are normal members of the marine microbiota. The most commonly isolated species from cleaner-fish include *Vibrio splendidus, V. logei, V. wodanis* and *V. tapetis*, but the significance of these bacteria in relation to disease is unclear. Some strains of *V. tapetis* and *V. splendidus* have been described as pathogenic to wrasse, but later infection trials have failed to confirm this in a convincing manner. 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.

Moritella viscosa is isolated regularly from cleaner-fish, often in association with skin lesions.

Piscirickettsia salmonis was identified in lumpsucker in Ireland in 2017, but has never been identified in Norwegian cleaner-fish.

Virus

A virus belonging to the family Flaviviridae, called cyclopterus lumpus virus (CLuV) or lumpfish flavivirus, was identified in lumpsucker in 2015. Macroscopic signs of infection included a pale, hard liver and histological examination identified massive degeneration of hepatocytes. Mortality rates of over 50% are reported from disease episodes associated with flavivirus infection. Culture of the virus in cell-cultures has not yet been accomplished. The virus has only been detected in sick fish.

Previous investigations of Norwegian wild caught cleaner-fish have not identified infectious pancreatic necrosis virus (IPNV), although experimental infections have shown that both ballan wrasse and lumpsucker may harbour the virus. Viral haemorrhagic necrosis virus (VHS) has not been identified in Norwegian cleaner-fish, but has been detected in wild-caught wrasse and lumpsucker in Scotland and Iceland, respectively.
A recent publication described finding nodavirus in wrasse (all three most commonly used species) caught along the Swedish and Norwegian coasts in 2014. Salmonid alphavirus (SAV) was reported from a farm in which wrasse were held in close contact with salmon during an outbreak of pancreas disease (PD). A similar situation has been described involving infectious salmon anaemia virus (ISAV).
Clinical disease was not identified in the wrasse, and sample contamination cannot be excluded.

Piscine myocarditis virus (PMCV) was detected in wrasse held in a cage with salmon suffering cardiomyopathy syndrome (CMS) in Ireland in 2016.

Parasites

A broad spectrum of parasites has been identified in both farmed and wild cleaner-fish. A focus on the possibility of cross species transmission from cleaner-fish to salmon and vice versa is important for all pathogens and parasites are no exception.

Several parasites are considered particularly serious in cleaner-fish and may result in mortality, including *Paramoeba perurans, Nucleospora cyclopteri, Trichodina* sp., *Ichtyobodo* sp., *Kudoa islandica, Gyrodactylus* sp., *Caligus elongatus* and *piscine coccidia* (Eimeria sp.). *Paramoeba perurans, C. elongatus* and *Anisakis simplex* can also potentially transmit between salmon and cleaner-fish.

Paramoeba perurans (which causes amoebic gill disease, AGD) has been identified in lumpsucker, corkwing wrasse, ballan wrasse and other wrasse species held in cages with salmon. Tank-held lumpsucker have also been affected. The pathogenic changes to the gills are similar to those experienced in salmon.

Infections with the intracellular microsporidea *Nucleospora cyclopteri* and *Tetramicra brevifilum* are relatively normal in teleosts. *Nucleospora cyclopteri* infection in lumpsucker has been identified as highly prevalent in Norwegian and Icelandic waters. Lumpsucker is the only recognised host species for this parasite. The parasite is found intracellularly within lymphocytes and macroscopic signs of infection include an extremely enlarged and pale kidney.

Tetramicra brevifilum was identified for the first time in lumpsucker on a broodstock farm in Ireland in 2015, where it was associated with low level chronic mortalities. Clinical findings included exophthalmos (protruding eyes), distended abdomen and small white spots in the skin, fins and head. A number of affected fish were sluggish with a poor appetite while others displayed normal behaviour. The parasite has not been reported in Norway.

Gyrodactylus sp. may be found on the skin and gills of lumpsucker. The prevalence of *Gyrodactylus* sp. and gill damage possibly caused by these parasites has not been studied. Such infections may cause problems in the future.

Caligus elongatus infestation is considered a problem in lumpsucker farmed in some regions of Finnmark and Troms. A study from 2007 revealed that the lumpsucker is the main host for this parasite. Caligus can cause skin lesions, which may lead to secondary infection. The parasite can also infect salmon.

Intestinal coccidia are found in both farmed and wild lumpsucker in Norway and Iceland. This type of parasite does not normally present a serious threat of disease, but cases of associated pathology in both farmed and wild lumpsucker have been reported.

The health status of cleaner-fish in 2018 is presented below. Welfare issues relating to cleaner-fish have been presented in chapter 3 Fish Welfare. Sensitivity of cleaner-fish pathogenic bacteria to antibiotics was presented in chapter 5.7 Sensitivity to antibiotic treatment. Reduced antibiotic susceptibility was not identified in cleaner-fish pathogenic bacteria by the Norwegian Veterinary Institute in 2018.

The health situation in 2018

Data from the Norwegian Veterinary Institute

In 2018, the Norwegian Veterinary Institute received diagnostic submissions related to cleaner-fish from 135 farming localities. The main findings from last year and previous years are summarised in Table 10.1. The data

Table 10.1: Frequency (number of farms diagnosed) of selected diseases/agents of cleaner-fish diagnosed by the Norwegian Veterinary Institute between 2012-2018.

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

represents both wild-caught and farmed 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’.

Bacteria

Significant problems continued to be experienced with atypical *Aeromonas salmonicida* in both lumpsucker and wrasse spp. in 2018, although the number of positive diagnoses made by the Norwegian Veterinary Institute fell again last year. *Aeromonas salmonicida* subsp. salmonicida was not identified in cleaner-fish in 2018.

Pasteurella sp. has also been a problem in lumpsucker, although the number of positive localities fell slightly from 28 in 2016 to 15 in 2018. The outbreaks were spread throughout the year and all were identified post sea-transfer.

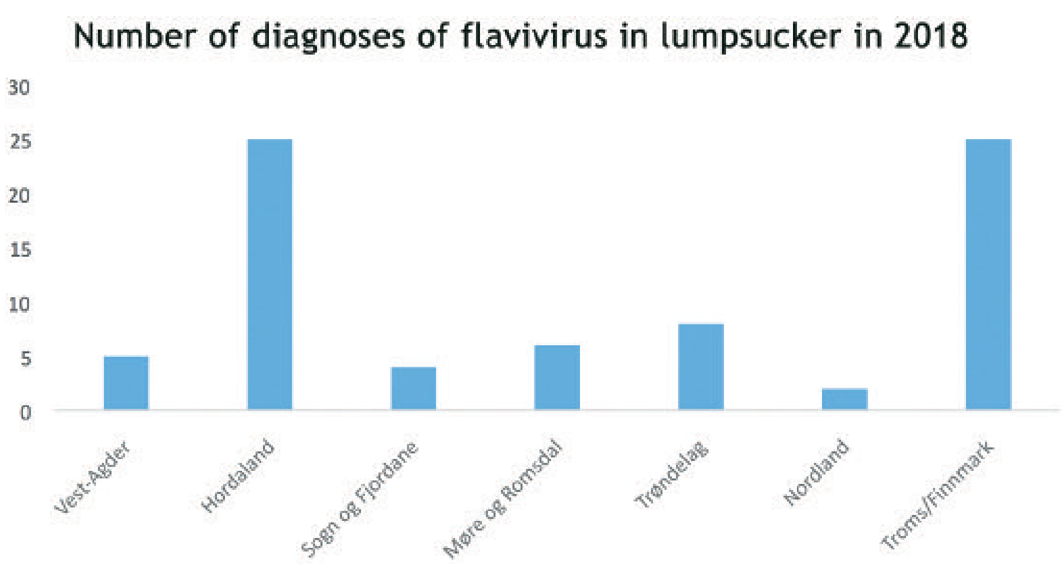
The number of lumpsucker localities affected by *Pseudomonas anguilliseptica* increased again between 2017 and 2018. There has been a relatively dramatic increase over the last three years. Outbreaks were spread throughout the year. P. *anguilliseptica* was not identified in wrasse in 2018.

V. anguillarum was identified in sick lumpsucker (primarily serotype O2, but also O1) in seven farms. The bacterium was also identified in wild-caught goldsinny wrasse on two farms and on a single farm holding wild-caught ballan wrasse (serotype O2 and several isolates which could not be serotyped). The detections were primarily made between September and January.

V. ordalii was identified on very few farms during 2018. The bacterium did however cause significant mortality and recurring outbreaks in the affected farms.

A broad array of Vibrio species (*V. splendidus*, *V. logei*, *V. tapetis*, *V. wodanis*, *Vibrio* sp.), were frequently isolated from cleaner-fish in 2018, often in mixed culture and the role of individual isolates in each situation is not easily identified.

Table 10.2 Number of diagnoses of flavivirus infection in lumpsucker in 2018



Virus

TNo viral disease or viral agent was identified in the diagnostic material submitted from cleaner-fish to the Norwegian Veterinary Institute in 2018. The Norwegian Veterinary Institute does not presently have diagnostic tools capable of detection of Lumpsucker flavivirus.

Statistics from private laboratories reveal a total of 75 identifications of virus in 2018, with the majority (67%) reported from Hordaland, Troms and Finnmark. The statistics relate to the number of positive detections and not the number of affected localities. The statistics may include several detections from the same farming locality.

Parasites

AGD was identified in four populations of lumpsucker in 2018. AGD was not identified in wrasse in 2018.

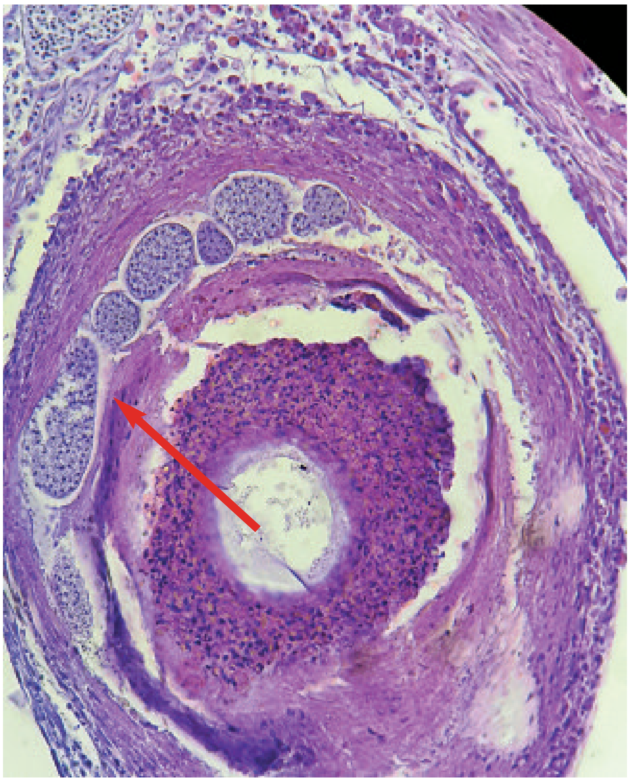


Figure 10.1 *Ichthyophonus* sp.in the heart musculature of ballan wrasse (arrow) (histology) Photo Hanne Nilsen, Norwegian Veterinary Institute.

Ichthyophonus sp. was identified in ballan wrasse from one farm in 2018 in association with increased mortality, but no external signs of disease other than white nodules on the liver and heart of a single fish were observed. Histopathological investigation revealed structures consistent with *Ichthyophonus* sp. infection. This protist causes a systemic granulomatous disease primarily in marine fish species and has a broad host spectrum. Reports of mass Ichthyophonus related mortality have been reported in Herring, also in Norway.

Kudoa sp. were identified in the skeletal musculature of lumpsucker from two farms in 2018. This is a myxosporidean, which has also been identified in lumpsucker in Iceland. The parasite is found within the somatic musculature. The spores can be so numerous that they nearly replace the musculature.

Various numbers of coccidia were reported in the intestine of lumpsucker in four different farms in 2018.

Sporadic identification of ectoparasites including *Trichodina* sp. and other gill-related ciliates could not be related to significant health problems. Nematodes (probably Hy*sterothylacium aduncum*) within the peritoneum and internal organs are regularly identified in wild caught goldsinny wrasse.

Fungal agents

Systemic mycosis was identified in two populations of lumpsucker in 2018, one of which led to increased mortality.

Other diseases

oth private laboratories and the Norwegian Veterinary Institute have received several submissions from lumpsucker displaying white, hard, recessed skin structures commonly referred to as 'crater disease'. Most cases have been identified during the winter in northern Norway. *Tenacibaculum* sp. has been identified in all cases, but it is uncertain whether this bacterium is associated with the clinical changes observed.

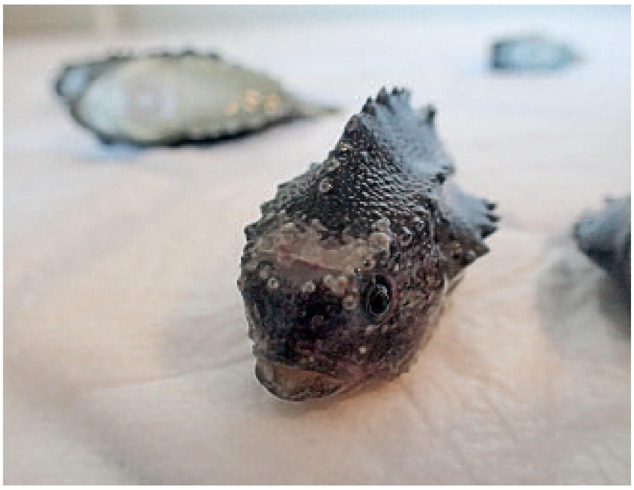


Figure 10.2 Lumpsucker with 'crater disease'.
Photo Mattias Bendiksen Lind, HaVet AS.

Figure 10.3 Caudal fin-rot in lumpsucker.
Photo Mattias Bendiksen Lind, HaVet AS.

Response to the survey

For cleaner-fish generally, it appears that they continue to have considerable health and welfare challenges. For lumpsucker post sea-transfer, just under half (45%) of respondents are of the opinion that mortality remains similar to previous years. Just over a quarter (28%) are not sure if there has been a change in the situation, 21% consider mortality levels to be lower and 6% consider mortality to be higher than in previous years.

The situation for lumpsucker appears on the whole to be relatively stable. For wrasse, 47% are uncertain whether there has been a change in the health and welfare situation, 28% consider the situation unchanged, 12% think the mortality was higher in 2018 and 12% think mortality was lower than in previous years.

Mortality related to non-medicinal delousing and handling, poor welfare, lack of knowledge, skin lesions, fin-rot and particular bacterial diseases are considered important health related risk factors for both lumpsucker and wrasse. Comments received in the survey appear divided regarding cleaner-fish health and welfare. Some are of the opinion that welfare remains extremely poor and that there is much disease. Others appear to consider the health situation as improving and that there is an increasing focus on the health and welfare of these fish species.

Fin-rot (not associated with any specific agent), was reported as the major countrywide challenge during production of juvenile lumpsucker alongside vibriosis and flavivirus infection. Infections with atypical *Aeromonas salmonicida* and *Pasteurella* sp. were considered less important than previously although they remained a problem in certain areas.

In post sea-transfer lumpsucker, fin-rot is again considered important over the whole country. Bacterial diseases are considered more important during this phase than in the hatchery. The single most important problem appears though to be post louse-treatment mortality, particularly following non-medicinal lice treatments and associated handling. Caligus infections are reported as important. They are considered a significant problem in the mid and northern areas of the country.

Wrasse seem to suffer from many of the same problems as lumpsucker and the overall situation appears similar to the previous year. Skin lesions, mortality resulting from non-medicinal lice treatments and handling score high for wrasse held in marine salmon sites. Bacterial infections are considered more important in wrasse than in lumpsucker, both during the hatchery phase and at sea. This is especially so for atypical furunculosis and vibriosis. Hatchery stage fish appear particularly prone to vibriosis. Wrasse held in marine salmon sites are considered prone to both vibriosis and atypical furunculosis. Furunculosis scored highest in north-western and mid-Norway.

Evaluation of the cleaner-fish situation

Significant health and welfare challenges exist, particularly in relation to non-medicinal lice treatments and associated handling. Poor welfare and lack of

Figure 10.4 Measurement of lumpsucker body length.
Photo: Toni Erkinharju, Norwegian Veterinary Institute

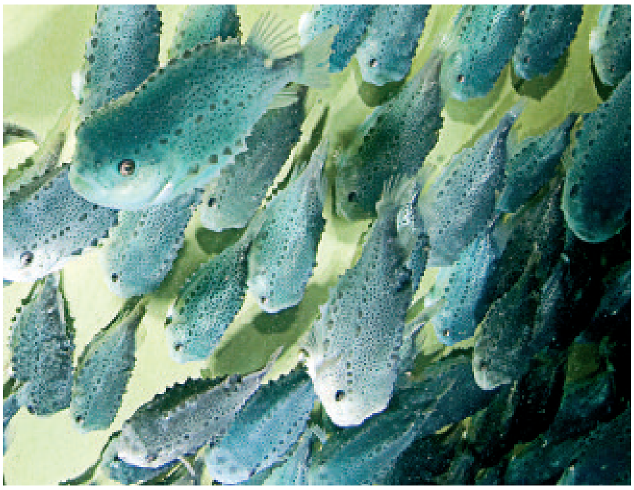


Figure 10.5 Farmed lumpsucker.
Photo: Rudolf Svensen, UW Photo

knowledge are considered major problems. Feedback from the survey may however, indicate that there is an increasing focus on welfare and mortality in cleaner-fish.

Frequent physical handling, fin-rot, skin lesions and generally weak individuals undoubtedly make fish more susceptible to infectious agents. Bacterial diseases like atypical furunculosis and vibriosis cause many deaths. From the survey and reported statistics from private laboratories, it would seem that flavivirus has caused serious problems for lumpsucker in 2018, as have parasites like Nucleospora cyclopteri and Caligus elongatus. Agents we should be on our guard against include nodavirus, VHSV and PMCV. As nodavirus has been detected in wild cleaner-fish populations in other European countries, it represents a clear risk to Norwegian stocks.

Irrespective of infectious agent, good cleaner-fish health and welfare (via e.g. good feeding regimes, adequate cover and minimal handling) will contribute to reduction of the threat from infectious disease. Vaccination of farmed cleaner-fish against some bacterial diseases has started, but there remains work to do in relation to development of satisfactory vaccine regimes. Vaccination against atypical *A. salmonicida* and *Vibrio anguillarum* appears to be widespread.

There are many unsolved problems related to cleaner-fish, both during juvenile production and following sea-transfer. There is therefore a continued need for increased knowledge of the health and welfare requirements of these new species to farming.

Figure 10. 6 Lumpsucker juvenile, 5mm long and 10 weeks old (coloured scanning electron micrograph, enlarged 60x). Photo: Jannicke Wiik-Nielsen, Norwegian Veterinary Institute

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 production cycle for halibut in the sea is lengthy. Land-based farms for halibut are now active and there is an increased focus on selective breeding.

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 wolf-fish 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. Production is largely based on wild caught broodstock.

Only a few cod producers remain. Cod farming met significant challenges related to juvenile production and early maturation.

The situation in 2018

Data from the Norwegian Veterinary Institute

Halibut and turbot

In 2018, 29 submissions involving halibut (26) and turbot (3) were submitted, 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*.

In a few cases, as in previous years, high mortality has been associated with identification of *Vibrio (Aliivibrio) logei*. Eye infections and skin lesions have been associated with *Tenacibaculum-like* bacteria.

Myxosporidia infection in the excretory tubules of the kidney has been identified in large halibut. Problems related to gill infections involving *Ichthyobodo* sp. "costia", and *Trichodina* sp. are identified irregularly. Nephrocalcinosis (calcium deposition in the kidney) was identified in both fish species.

Nodavirus infection was not identified or suspected in 2018.

Cod

Two submissions were received in 2018 from cod. The material represented wild-caught cod and commercial production. As previously, parasites and related tissue reactions are regularly observed.

Francisellosis, caused by *Francisella noatunensis* subsp. noatunensis, was not identified in 2018.

Nodavirus infection was not identified or suspected in cod in 2018.

Spotted wolffish

Four submissions involving farmed spotted wolffish were submitted in 2018. The material originated from wild caught and aquarium held fish.

In wild-caught fish (Atlantic wolffish) a microsporidian, probably a *Pleistophora* sp. was identified. This parasite develops spores in the muscle fibres and may be killed by heat treatment. Other findings include systemic bacterial infections and nephrocalcinosis.

Survey 2018

For cod and halibut the survey indicates that vibriosis is the disease that has been most problematical in 2018.

Noda virus infections, atypical furunculosis, tenacibaculosis, francisellosis are described as equally important in the north of the country. Atypical furunculosis appears to be less serious than previously and *Tenacibaculum*, nodavirus and IPN are considered equally serious in halibut in 2018. Increased knowledge and better vaccines are required.

Figure 11.1
Atlantic wolffish with skeletal muscle changes associated with a microsporidean parasite, most probably a *Pleistophora* spp.
Photo Geir Bornø, Norwegian Veterinary Institute.

Figure 11.2 Farmed cod.
Photo: Rudolf Svensen, UW Photo

Photo: Colourbox.

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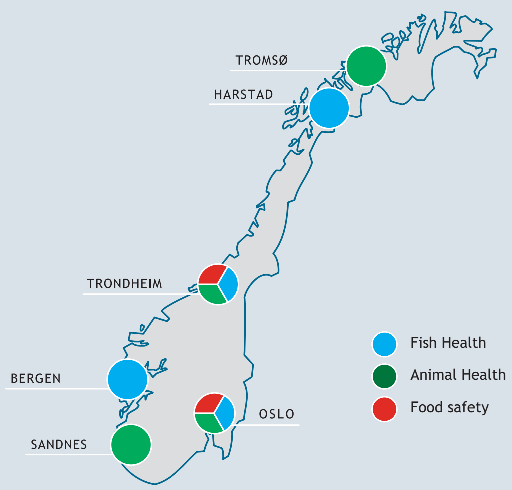
Scientifically ambitious, forward looking and working together- for one-health!

The Norwegian Veterinary Institute is a national research institute within the fields of animal health, fish health, food safety and feed hygiene and provides independent support to the public authorities as its primary task.

Preparedness, diagnostics, surveillance, reference functions, advisory and risk evaluations are important areas of work. Our products and services include reports related to research, analyses, diagnostics, investigations and advice.

The Norwegian Veterinary Institute has its main laboratory in Oslo and regional laboratories in Sandnes, Bergen, Trondheim, Harstad and Tromsø. The Norwegian Veterinary Institute cooperates with a number of other institutions both in Norway and abroad.



Fiskehelse	Dyrehelse	Mattrygghet

Oslo
postmottak@vetinst.no

Trondheim
vit@vetinst.no

Sandnes
vis@vetinst.no

Bergen
post.vib@vetinst.no

Harstad
vih@vetinst.no

Tromsø
vitr@vetinst.no

www.vetinst.no

Veterinærinstituttet
Norwegian Veterinary Institute