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Working Group on Pathology and Diseases of Marine Organisms (WGPDMO)

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Contents

i Executive summary

The Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) investigates diseases and pathology in wild and farmed finfish, shellfish and crustaceans. This report describes new disease trends in wild and farmed fish and shellfish in the ICES area, based on national reports from fourteen member countries. Notable reports for wild fish included a widening geographic scope of the enigmatic “red skin disease” in wild Atlantic salmon, with reports now from Norway, Scotland and Ireland as well as the Baltic Sea countries where it was originally observed; increased prevalences of *Ichthyophonus* sp. infection in herring from Iceland and mackerel from Norway, suggesting potentially increased affects of this pathogen on wild fish in the north; and the first detection of eel rhabdovirus (EVEX) in England and Wales since the 1980s. Detection of piscine orthoreovirus (PRV) in exotic pink salmon straying from cultivation in Russian rivers to Norway raised questions about potential disease interactions between pink salmon and farmed Atlantic salmon that deserve further attention. Reports of diseases in farmed fish included the first detections of infectious pancreatic necrosis virus (IPNV, pathogenic genogroup 5) and *Parvicapsula pseudobranchicola* in Atlantic salmon from Iceland, increased detection of *Pasteurella skyensis* in Atlantic salmon in Scotland, and increased detection of furunculosis caused by *Aeromonas salmonicida* in Atlantic salmon from Ireland. Sea lice parasitism and complex gill disease (CGD) remain highly significant concerns for Atlantic salmon aquaculture, with reports for 2019 noting increasing prevalences and impacts of both.

Notable reports of diseases for shellfish included an outbreak of *Haplosporidium costale* in cultured Pacific oysters in France; mortality caused by *Vibrio aestuarianus* in cultured Pacific oysters in Scotland and Ireland, with additional and unusual detection of bacteria belonging to the *Vibrio splendidus* clade in association with Pacific oyster mortality in Ireland; mortality caused by a coccidian parasite in wild bay scallops in the USA; and documented expansions of the distributions of *Bonamia ostreae* in flat oysters in Scotland and *Marteilia refringens* in blue mussels in Norway.

The group also summarized work on the role of *Vibrio* pathogens in contributing to mortalities in shellfish aquaculture as well as seafood-associated disease risks in humans, on the contemporary status of oyster pathogen *Bonamia ostreae*, on complex gill disease in salmon, on emerging health issues affecting wild salmonids of the Baltic region, and on disease considerations related to cleaner-fish use in salmon culture. The group additionally discussed the status and future directions of the ICES Identification Leaflets for Diseases and Parasites of Fish and Shellfish, and priorities for their work from 2021, potentially including health threats to endangered pen shells in the Mediterranean; eel diseases; and a consideration of which host-pathogen systems might be most promising for management through selective breeding. Group members published two new ICES Identification Leaflets for Diseases and Parasites in Fish and Shellfish in 2019 and five new leaflets are planned for completion in 2020.

ii Expert group information

Expert group name	Working Group on Pathology and Diseases of Marine Organisms (WGPDMO)
Expert group cycle	Multiannual fixed term
Year cycle started	2019
Reporting year in cycle	2/3
Chair(s)	Ryan Carnegie, USA
Meeting venue(s) and dates	4-7 February 2020, Reykjavik, Iceland

1 Terms of Reference a) – j)

ToR a) Summarize new and emerging disease trends in wild and cultured fish, molluscs and crustaceans based on national reports.

ToR b) Deliver leaflets on pathology and diseases of marine organisms.

ToR c) Synthesize information on the spread and impact of *Bonamia ostreae* in flat oysters in the ICES area.

ToR d) Summarize the role of *Vibrio* pathogens contributing to mortalities in shellfish aquaculture and to seafood-associated disease risks in humans.

ToR e) Synthesize perspective on complex gill disease (CGD) in salmon and identify strategies for mitigation.

ToR f) Integrate perspective on emerging health issues affecting wild salmon populations of Baltic member countries.

ToR g) Identify strategies to prevent further spread of ostreid herpesvirus OsHV-1 within the ICES region and mitigate impacts where it occurs.

ToR h) Complete assessment and refine application of the Fish Disease Index (FDI).

ToR i) Provide expert knowledge and management advice on fish and shellfish diseases, if requested, and related data to the ICES Data Centre.

ToR j) Synthesis of the current and future biosecurity and ecological implications of cleaner fish use for sea lice control in salmon aquaculture.

2 Summary of work plan

ToR a) New disease conditions and trends in diseases of wild and cultured marine organisms will be reviewed. This is an annual, ongoing ToR for WGPDMO and will provide information for ToRs b-i.

ToR b) A number of ICES publications currently in preparation will be reviewed by WGPDMO. This is an ongoing, annual ToR.

ToR c) *Bonamia ostreae* is a major pathogen of European flat oysters that has expanded its range in recent years. The present distribution, recent trends in parasite prevalence and infection intensity, and the effectiveness of contemporary management strategies will be summarized. Relevant observations on the related species *Bonamia exitiosa*, recently documented in oysters from some ICES Member Countries, will also be provided.

ToR d) *Vibrio* bacteria have long been associated with larval production problems in shellfish hatcheries, and the potential impacts of vibriosis in sub-market and market-sized Pacific oysters in European production areas have become an important emerging concern. Likewise, concern about *Vibrio* risks to human consumers has also grown. This ToR will synthesize the current knowledge of *Vibrio* and highlight critical gaps in our understanding of these species.

ToR e) Complex gill disease (CGD) is an emergent, economically important health issue that limits productivity in salmon aquaculture. CGD is believed to result from a complex interaction of environmental, host and infectious factors. The performance and survival of affected fish is influenced by the severity of the gill lesions. Environmental factors associated with CGD include exposure to harmful algae, jellyfish, low dissolved oxygen and elevated water temperatures. Relevant infectious agents include Atlantic salmon paramyxovirus, salmonid gill poxvirus, *Candidatus Piscichlamydia salmonis* and the microsporidian *Desmozoon lepeophtherii*. This ToR will describe the causes and consequences of CGD in salmon aquaculture in ICES Member Countries and identify mitigation strategies in the context of climate change.

ToR f) National reporting in recent years has revealed an array of disease concerns in Baltic salmon populations, with elevated mortality being widely reported. Determining similarities and differences in patterns of disease and mortality and gaining insight into potential aetiological factors is urgently needed for effective management of salmon health in the region. This ToR will involve coordination among representatives of member countries around the Baltic to consolidate information concerning Baltic salmon health problems and identify strategies for better understanding and mitigating them.

ToR g) The emergence of 'microvar' variants of the ostreid herpesvirus OsHV-1, which have caused significant Pacific oyster mortality in Europe, New Zealand and Australia, is the most significant mollusc disease development in decades. Preventing further spread of these pathogens and mitigating damage in affected areas are twin challenges of OsHV-1 management today. This ToR will aim to identify strategies to prevent OsHV-1 microvariant dispersal to North American member countries, currently free of the microvars, and to maintain commercial production should an epizootic emerge. It will also more broadly consider the OsHV-1 microvar emergence as a case study in response to emerging viral and bacterial pathogens, to identify general strategies for future responses and potential pitfalls with regard to their application.

ToR h) Results of assessment of the FDI will be reviewed, and data harmonization and quality assurance will be addressed as refined guidelines are produced for FDI application.

ToR i) This is an annual ToR in compliance with requests from the ICES Data Centre.

ToR j) It is widely acknowledged that mitigation of sea lice infections on farmed salmon is challenged by the widespread emergence of resistance to most classes of chemotherapeutants. Cleaner fish, including wrasses (*Ctenolabrus rupestris*, *Symphodus melops*, *Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*), are used in several ICES Member Countries as part of integrated pest management strategies for sea lice control. The WGPDMO recognizes a growing body of scientific knowledge related to the use of cleaner fish. The purpose of this document is to summarize the available knowledge concerning the infectious agents and diseases reported from cleaner fish, to identify the ecological and biosecurity implications of cleaner fish use in salmon aquaculture. Knowledge gaps will be identified and recommendations made concerning mitigation of biosecurity concerns related to use of cleaner fish.

3 List of outcomes and achievements of the WG in this delivery period

- Published an annual summary of new and emerging disease trends in wild and cultured fish and shellfish in the ICES area, the most comprehensive synopsis of marine disease trends for any region
- Published two new leaflets on pathology and diseases of marine organisms, on Piscirickettsiosis and *Tenacibaculum maritimum*
- Published a report on the Workshop on Emerging Mollusc Pathogens (WKEMOP), identifying priorities for an improved preparedness for emerging diseases affecting shellfish aquaculture and fisheries

4 Progress report on ToRs and workplan

4.1 Summarize new and emerging disease trends in wild and cultured fish, molluscs and crustaceans based on national reports (ToR a)

The update in the following sections is based on national reports for 2019 submitted by Denmark, England & Wales, Finland, France, Iceland, Ireland, Latvia, the Netherlands, Norway, Poland, Portugal, Scotland, Sweden and the USA. It documents significant observations and highlights the major trends in newly emerging diseases and in those identified as being important in previous years.

4.1.1 Farmed Fish

Viruses

Infectious Pancreatic Necrosis Virus (IPNV) – In Iceland, detected for the first time in October 2019, in Atlantic salmon from sea cages in the east fjords. The virus was detected in 8/8 fish screened during routine health surveillance. None of the fish showed any signs of disease and no abnormal mortality was observed. The virus was determined to be pathogenic genogroup 5.

Viral Hemorrhagic Septicaemia Virus (VHSV) – In Iceland, lumpfish have continued for a fourth year to be free of detection of the virus. VHSV was first identified from lumpfish in Iceland in 2015, when Genotype 4 of the virus was first identified in wild-caught broodfish and subsequently in farmed juveniles.

Bacteria

Renibacterium salmoninarum – In Iceland, the effects of bacterial kidney disease (BKD) caused by *R. salmoninarum* in Atlantic salmon improved in 2019 relative to 2014-2018, when many farms were affected. BKD has been a problematic disease in Icelandic aquaculture since the 1980s.

Aeromonas salmonicida* subspecies *salmonicida – In Ireland, furunculosis in Atlantic salmon caused by *A. salmonicida* was diagnosed in fish from four sites in 2019. Prior to 2019, isolation of the bacterium had only been sporadic so this represents a marked change. A different strain of Atlantic salmon was used on some sites, so it is unclear whether the increase reflects a change in pathogen activity or use of fish more susceptible to clinical furunculosis.

***Pasteurella skyensis* -** In Scotland, detected in Atlantic salmon at 7 sites in 2019, an increase from 2 sites in 2018. There is concern that this is an emerging issue for the Atlantic salmon aquaculture industry in Scotland.

Parasites

Sea lice - Lice remain the most significant disease concern for aquacultured Atlantic salmon in the ICES region. In Norway, lice infection increased moderately in 2019 relative to 2018. In Iceland, salmon lice have emerged as significant salmon pathogens over the last 2-3 years, with treatments applied in 2017 for the first time since the 1980s.

Parvicapsula pseudobranchicola – In Iceland in Atlantic salmon, detected for the first time in this country in early 2019. Prevalence of infection at sites in the west fjords where the parasite was detected was high. The extent of related mortality is unclear because of the co-occurrence of other infectious agents. Work to better understand the prevalence and potential impacts of this parasite on farmed and wild Atlantic salmon and Arctic char is ongoing.

Coccidian infection in lumpfish – In Iceland, detected at high intensity infecting the intestinal epithelium of lumpfish from sea cages in the context of a mortality event.

Other Diseases

Complex gill disease (CGD) - In ICES Member Countries where Atlantic salmon are farmed, CGD in the marine environment continues to be a highly significant issue. In Scotland, 22 CGD diagnostic cases were reported in 2019 compared to 14 in 2018. In Ireland, many farm sites were affected, with high mortality in some cases.

Algal bloom affecting Atlantic salmon – In Norway, an algal bloom of the flagellate *Chryso-chromulina leadbeaterii* was associated with the deaths of approximately 8 million Atlantic salmon summer of 2019. Affected regions were Nordland and Troms in the northern part of the country.

Cardiomyopathy syndrome (CMS) – In Scotland, 4 cases were detected in 2019, an increase from 2 cases in 2018. The disease continues to cause mortality in Atlantic salmon farmed in seawater in Scotland.

Failed smolt syndrome – In Ireland, failed smolt syndrome affected Atlantic salmon in a significant number of sites with S1 inputs. Most of the affected fish died within 4 months of being put to sea. The aetiology of the syndrome was not clear and no significant diseases were detected in the fish.

Conclusions

- Sea lice remain the most significant disease concern for aquacultured Atlantic salmon in the ICES region, with a notable increase in impacts most recently in Iceland.
- Complex gill disease in Atlantic salmon continues to be a significant issue, with increasing cases in 2019 reported from Scotland, and high mortality in some cases in Ireland.
- Observation of coccidian infection of lumpfish in Iceland adds to the list of known disease concerns in this important cleaner fish species.

4.1.2 Wild Fish

Viruses

Infectious Pancreatic Necrosis Virus (IPNV) – In Norway, 3 of 252 post-smolt Atlantic salmon captured in fjords in 2017-2019 were positive for the virus by qPCR, an unusual observation of the virus in wild salmon. In Sweden, an IPN-like virus was identified in lumpfish caught on the Swedish west coast, with analyses ongoing.

Gill pox virus – In Scotland, detected in Atlantic salmon from two rivers by histopathology and quantitative PCR. This is the first report of this virus from Scotland.

Eel Rhabdovirus (EVEX) – In England, substantial mortalities of European eels (270 in a 7-day period) were observed in the river Waveney, East Anglia, in August 2018, with fish showing haemorrhaging of fins and abdomen. Seven of 8 fish collected for diagnostic analyses were positive for EVEX by PCR. This represents the first time EVEX has been detected in eels in England and Wales since the 1980s and the first in wild-caught eels.

Piscine Orthoreovirus (PRV) – In Norway, detected in 1/60 pink salmon in a small screening study. Increasing numbers of pink salmon have been caught in Norwegian rivers. This Pacific salmon has been cultivated in Russian rivers in the Barents Sea region, and this is probably the source of stray fish. The question of whether this Pacific salmon can spread pathogens, in particular IHNV and VHSV, and other viruses, is one that warrants attention. VHSV, IHNV, SAV, ISAV were not found in these sampled fish.

Bacteria

Renibacterium salmoninarum – In Iceland, prevalence in Atlantic salmon has continued to decrease, to 2-6%, from a maximum of 28% in 2008-2009.

Parasites

***Ichthyophonus* sp.** – In Iceland in Atlantic herring, new infections in younger cohorts are being detected after having not been observed for several years. Prevalence has increased in all age groups, reaching 38%, suggesting an increased impact on herring populations in Iceland. In Norway, over 50% prevalence was detected in mackerel from the northern North Sea by macroscopic and microscopic screening of heart, kidney and spleen for cysts. The comparatively high prevalence in mackerel highlights the need for continued monitoring due to the parasite's potential to cause mortalities in wild marine fish stocks including herring from the North Atlantic. SSU rDNA gene sequencing revealed DNA sequence divergent from that of the *Ichthyophonus* sp. detected in herring, suggesting the parasite could be a marker for understanding mackerel migration.

Gyrodactylus salaris – In Sweden, analyses have provided improved resolution to the distribution of *Gyrodactylus* clades in Atlantic salmon, with clades A and C present in all river systems except Göta älv (including lake Vänern), the northernmost infected river. In Göta älv, only Clade E has been detected.

Anguillicoloides crassus – In Latvia, detected in European eels at 3/3 sampled locations, at prevalences of 47-77% and with intensities ranging from 1-27, suggesting that the nematode is likely compromising eel health in the area.

***Anisakis simplex* sensu lato** – In the Polish EEZ parasite effects in Baltic herring for the period 2013–2019, estimated in the GLM model of prevalence of infection, strongly decreased compared with effects of 2011 and 2012. The highest prevalence of infection (> 26%) was reported in herring caught in 1st and 2nd quarter of the year in coastal waters of Subdivision 24. In Norway the prevalence of *A. simplex* in Arctic cod is very high, approaching 100% in fish flesh and viscera, resulting in losses of market product.

***Contracaecum osculatum* sensu lato** – In Polish samples from the Baltic Sea, the prevalence of infection in Baltic cod was high in ICES Subdivisions 24, 25, 26 and 28. Infection extended through the entire area of the southern Baltic, reaching 90% prevalence in Subdivision 26 for length classes of cod 35 cm and greater, and showing an increasing trend for the period of 1987–2019. Data from Latvia data revealed a prevalence of 80% in cod sampled from Subdivision 26 (length classes 26 cm and greater) and 53% in Subdivision 28 (length classes 18 cm and greater).

Kudoa thyrsites – In Norway in Atlantic mackerel, prevalence of clinical signs of infection increased from 0.8 to 2%, translating to a loss of approximately 15 000 mt from the fisheries industry, as affected filets cannot be marketed. The potential for impacts of *Kudoa* on Atlantic salmon aquaculture has emerged as a question warranting attention.

Other Diseases

Red skin disease in Atlantic salmon - In Norway, disease and mortalities in Atlantic salmon were registered during summer 2019 in the river Enningsdalselva, Østfold county. A total of between 50 and 60 sick or dead salmon were found, all fish returning to the river to spawn. Typical findings were hemorrhages in the ventral skin. A few cases were found in other rivers, and similar conditions have been reported from Scotland, Ireland, Sweden, Denmark, Finland and Russia. The cause of the disease is not known. In Scotland, moribund salmon displaying similar disease signs were reported from 18 locations around the Scotland coast. In Sweden, reports of moribund and dead salmon increased to 421 in 2019 from 199 in 2018, with red skin disease and fungal infections detected in many observed fish. The Swedish west coast as well as the Baltic coast was affected.

Poor condition in common dab – In Scotland, analyses using the Fish Disease Index (FDI) identified poor condition in dab in three of ten years at a location in northern North Seawaters of Scotland. Fish condition was not correlated with the distribution of chemical contaminants in the area.

Conclusions

- Increased prevalences of *Ichthyophonus* sp. infection registered from herring in Iceland and mackerel in Norway suggest potentially increased impacts of this pathogen on wild northern fish populations.
- Enigmatic red skin disease in wild Atlantic salmon is more widespread than earlier appreciated, with observations now from Norway, Scotland, and Ireland as well as the Baltic states.
- Potential disease interactions of non-native pink salmon straying from Barents Sea rivers and key resource species like cultured Atlantic salmon in Norway warrants further study.

4.1.3 Wild and farmed molluscs and crustaceans

Viruses

Oyster Herpes Virus (OsHV-1) – In England, detected in the context of mortality in wild Pacific oysters in the Solent in Hampshire in September 2019. DNA sequencing revealed the presence of reference strain OsHV-1 and the absence of OsHV-1 microvariants. In Ireland, OsHV-1 uVar continues to be widespread in farmed oyster populations but mortality associated with the virus has continued to decline since 2014.

In the USA, in the months since detection of an OsHV-1 microvariant in Pacific oyster seed in September and December 2018 in San Diego Bay, California, 15 separate sample clusters from seed Pacific oyster deployments, feral Pacific and native Olympia oysters in the same and nearby embayments, plus all other West Coast sampling by qPCR for this disease agent, have been negative for the pathogen. Depopulation of the affected farm following initial detection may have been eradicated the pathogen from the system. At the very least, it is notable that appearance of this particular pathogen was not accompanied by a major epizootic expanding through Pacific oyster populations in western North America.

Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) – In Scotland and England in 2019, infections in whiteleg shrimp were detected by PCR and confirmed by DNA sequencing in shrimp exhibiting slow growth in land-based culture facilities. The infections were traced back to the Texas hatchery that was the source of the shrimp. This is the first official report of an IHHNV infection in Europe.

Bacteria

Vibrio aestuarianus – In Scotland, detected by quantitative PCR in diploid Pacific oysters displaying high mortality (50-70%) in summer 2019. Histological lesions characteristic of *V. aestuarianus* infection were observed. In Ireland, mortality caused by *Vibrio aestuarianus* continues to be a significant problem, with the bacterium causing mortality in a new area, in Donegal, in 2019. Mortality exceeding 50% was observed in 9 of 14 affected bays, and it exceeded 80% in 2 of these bays. At two sites in Ireland, 15-20% mortality in spat Pacific oysters associated with *V. aestuarianus* was observed, with OsHV-1 not detected in these cases.

Vibrio splendidus – In Ireland, bacteria belonging to the *Vibrio splendidus* clade were detected in Pacific oysters during mortality events in 5 bays. While *splendidus* clade bacteria have been detected sporadically since routine bacteriological analysis was implemented in 2013 this is the first year that growth of the bacterium has been consistently recorded at high levels. Concurrent detections with OsHV-1 or *Vibrio aestuarianus* were observed in all cases.

***Arcobacter* sp.** – In Ireland, detected in Pacific oysters in conjunction with OsHv-1 μVar and a Pseudoalteromonad during a mortality event in spat in a site on the west coast. *Arcobacter* was detected on numerous occasions in 2015 and 2016 but its potential role in the mortality was never explored. Typically, it was detected in sites where mortality associated associated with *V. aestuarianus* was occurring.

Parasites

Haplosporidium costale– In France, detected in juvenile Pacific oysters in March 2019 that were displaying mortality of about 15% in the Vendee, on the Atlantic coast. Identity of the parasite was confirmed by SSU rDNA sequencing. Efforts to resolve the distribution of this parasite in France are ongoing.

Perkinsus marinus – In the USA, dermo disease in eastern oysters caused by *P. marinus* continued to decline in the Chesapeake Bay of the eastern USA, as a result of depressed salinities in this system. In the upper, Maryland part of Chesapeake Bay, mean annual fall prevalence of infection over 40 sampled locations decreased to 27% in 2019, from 40% in 2018, 69% in 2017 and 63% in 2016. The prevalence of 27% represented a new historical low. In the lower, Virginia part of the Bay, at the 28 locations from which samples could be collected in 2019, mean autumn prevalence increased slightly to 54% in 2019, from 51% in 2018, as salinities in this typically higher-salinity part of the bay began increasing to more normal levels. Quantitative PCR-based analyses for *P. marinus* in Maine, USA, continue to point to a wide distribution of the pathogen (and congeneric *Perkinsus chesapeaki*) that is not generally associated with patent infections in oyster hosts, highlighting a gap that exists in our understanding of the ecology of this pathogen in cooler northern waters.

Coccidian in bay scallops – In the USA, mortality of wild bay scallops in the Peconic Bays of Long Island, New York was observed to exceed 90% mortality. Heavy infection of scallop kidneys by an undescribed coccidian parasite was observed by histology to be associated with this mortality.

Bonamia ostreae – In Scotland, detected in flat oysters by histopathology and quantitative PCR at Dornoch Firth and a second site on the west coast of Scotland, both new locations.

Marteilia refringens **–** In Norway, detected infecting blue mussels in Espevik, representing an extension of the known range of this species. Flat oysters from the same site were not infected.

Mytilicola orientalis – In England, detected in Pacific oysters at 17% prevalence in each of two samples of oysters from the south of England. Mean intensity was 8 and 15 copepods/host in the two samples, and reached 29 in one individual. This is the first record of *M. orientalis* in the UK.

Hematodinium perezi – In the USA, research investigating prevalence in megalopae and early benthic juvenile blue crabs from multiple locations along the Atlantic coast of Virginia found no detection of the pathogen in megalopae from several locations within the oceanic coastal bay complex in which *H. perezi* is endemic. Prevalence was 50-100%, on the other hand, in early benthic juveniles from 2 oceanic coastal embayments. Prevalence was also high in winter (56-63%) indicating that juveniles can overwinter the parasite. These results suggest that rapid *H. perezi* transmission to newly settled crabs is an important element of the epidemiology of this pathogen in endemic systems (Small et al., 2019, Parasitic dinoflagellate *Hematodinium perezi* prevalence in larval and juvenile blue crabs *Callinectes sapidus* from coastal bays of Virginia. Diseases of Aquatic Organisms 134: 215-222).

Other Diseases

Summer mortality of oysters – In the USA, reports of summer Pacific oyster mortality of unknown etiology increased in summer 2018 and 2019, with assays for OsHV-1 and other pathogens negative in sampling from these events. Reports of late spring to early summer mortality in farmed eastern oysters also continued to increase from growers on the Atlantic and Gulf of Mexico coasts. While the etiology of this mortality remains unclear, the emerging model for eastern suggests a convergence of environmental stressors, the metabolic demands associated with reproduction at a time of high water temperatures and reduced food quantity and quality, and physiological or genetic factors inherent in the domesticated oysters.

Conclusions

- OsHV-1 microvariants remain a key disease threat to Pacific oyster culture, but it is not certain that this lineage has become established in western North America where an OsHV-1 microvariant was observed in 2018, following negative screening results for the pathogen in 2019 at this and other locations.
- *Haplosporidium costale* has emerged as a pathogen of concern with regard to Pacific oysters in Europe, with an outbreak in 2019 in France.
- Summer mortality in cultured Pacific and eastern oysters is an increasing concern as aquaculture of these species expands.

4.2 Deliver leaflets on pathology and diseases of marine organisms (ToR b)

The WGPDMO has produced ICES identification leaflets since 1984 with 70 leaflets produced to date. In recent years, the WG has placed a particular focus on providing new leaflets and updating older historical leaflets with new information. It is envisaged that this will increase the visibility and relevance of the leaflets.

All leaflets now get a doi number and are available to download from the ICES website at the following link: http://www.ices.dk/publications/our-publications/Pages/ID-Leaflets.aspx

New Leaflets

Due to a changeover in the editor position for the leaflets, there were no new publications in 2018. Two leaflets were published in 2019.

No. 69: Piscirickettsiosis (S. Jones) http://doi.org/10.17895/ices.pub.4675
No. 70: *Tenacibaculum maritimum*, causal agent of tenacibaculosis in marine fish (S. Jones & L. Madsen) http://doi.org/10.17895/ices.pub.4681 (an update on No. 55)

The following draft leaflet has been removed from the list:

- Gonadal neoplasia in bivalves (Renault)

Draft Leaflets for 2020

The list below contains disease conditions that are currently being prepared and it is expected that they will be published in 2020.

- *Mikrocytos* spp. infections (R. Carnegie)
- QPX in hard clams (R. Carnegie & B. Allam)
- Pancreas disease (N. Ruane)
- Infectious salmon anaemia in Atlantic salmon (E. Munro)
- Sea lice infesting Atlantic salmon (B.O. Kvamme, M. Powell)

The following list contains leaflets which have previously been proposed but require a commitment from the proposed authors.

- Ostreid herpesvirus (D. Cheslett)
- Vibriosis in oysters (T. Renault)
- Vibriosis in farmed salmonids (A. Lillehaug) **Update of leaflet Nos. 27, 29, 50
- *Sphaerothecum* in common dab (S. Feist & R. Paley)
- Mycobacteriosis in wild fish (L. Madsen)
- Bonamiosis in the flat oysters (R. Carnegie & L. Madsen) **Update of leaflet No. 18
- *Marteilia cochillia* (R. Carnegie, N. Carrasco)

Tasks/discussion items for 2020 meeting

- Confirmation of authors from draft list above.
- Proposed new/updated leaflets:
  - Disease should be present in more than one country.
  - Authors should commit to providing a draft within 12 months.

4.3 Synthesize information on the spread and impact of *Bonamia ostreae* in flat oysters in the ICES area (ToR c)

Bonamiosis caused by *Bonamia ostreae* is a disease that has had a significant impact on European flat oyster production since its appearance in 1979, wherefore it is classified as a notifiable disease, both to the OIE and the EU (under Directive 2006/88/EC). In the 1980s and 1990s the disease spread across Europe and its detection in new areas was invariably associated with high mortality. In recent years, however, the disease has spread to new areas but in many cases without accompanying high mortality. Questions have been raised as to whether this might reflect an adaptation of the host species to the parasite or whether other factors are influencing the lack of mortality that was originally seen as a significant sign for infection with the parasite.

Work toward this ToR will produce a review involving several authors (both WGPDMO members as well as shellfish experts outside the group), which will be a synthesis covering the following three areas:

1) *Current status of Bonamia ostreae in the ICES area and beyond*. Information regarding the spread and impact of *B. ostreae* in flat oysters will be synthesized from published papers and grey literature as well as surveillance programs in different countries. Data regarding spread of disease, mortality rates, human activities in an area, climate change, density of oyster populations as well other features exist in many countries where bonamiosis has had an impact, often in non-published forms.

2) *Inferences that may be made into the evolution of the oyster-pathogen interaction or relationship*. Has there been a change when it comes to the outcome of the encounter between host and pathogen as from the devastating disease outbreaks seen in the early years of the disease occurrence to now a more modest reaction where the pathogen does not have the same impact on the host, and thereby both being able to survive? Is the latter site dependant and are there other factors influencing this outcome? Has there been a genetic selection when it comes to the flat oysters, favouring oysters that are able to "live" with *Bonamia*? The answers to these questions will be based on the available information from countries/areas where *Bonamia* is having or has had an impact (or not an impact) on the flat oyster production.

3) *Implications for aquaculture and restoration of flat oysters*. Interest is increasing in Europe and North America in aquaculture of flat oysters to provide some diversification of industries highly reliant on cupped oysters. Interest is also greatly increasing in restoring this native species for the potentially important ecological benefits this will provide. *Bonamia ostreae* is a key disease influence on flat oysters, and may impact these activities to varying degrees across the European and North American geography. The synthesis will provide pathology perspective on the prospects for flat oyster culture and restoration, and offer a way forward with regard to flat oyster activities against the backdrop of bonamiosis, pointing as well to the most urgent areas for future research.

4.4 Summarize the role of *Vibrio* pathogens contributing to mortalities in shellfish aquaculture and to seafood-associated disease risks in humans (ToR d)

Vibrio bacteria pathogenic to Pacific oysters and other bivalve molluscs have been increasingly documented in WGPDMO national reports over the last number years both in open sea environments as well as in hatchery and nursery areas. While it is becoming increasingly apparent that certain species such as *V. aestuarianus* and *V. splendidus* are involved in the mortalities observed in cultured bivalves in natural waters, a lack of clarity in relation to the pathogenic role of many other *Vibrio* spp. still exists despite the increasing reporting trend. In addition, the ability of diagnostic laboratories to both identify *Vibrio* spp. and to assess their role in mortality events remains problematic particularly where multiple species or other pathogens such as the OsHV-1 microvariants are detected in a single event. In hatchery and nursery systems there is also a lack of knowledge of what species to expect and hence to assess the impact of detected *Vibrio* spp. on mortalities which occur in these systems.

At the same time human pathogens such as *V. parahaemolyticus* and *V. vulnificus* are increasingly a concern as oceans warm and as more shellfish are eaten raw in summer as mollusc aquaculture expands, but the influences on the epidemiology of these vibrios are also not completely understood.

The WGPDMO will provide a synthesis on the current state of knowledge relating to these pathogens through a review of the existing literature and data from events which have occurred in recent years, with a view toward elucidating the established roles of different *Vibrio* species in mortalities in both wild and aquaculture populations as well as to identify key knowledge gaps to be addressed through future research.

A number of research initiatives are already in place such as the EU project "Vivaldi" (*Preventing and mitigating farmed bivalve diseases*) which among its aims will attempt to investigate the roles of the pathogens OsHV-1 and *Vibrio* species and their interactions. Vivaldi partners involved in this work will be included as collaborators in this review. The product of this ToR will be a journal article completed in early 2021.

4.5 Synthesize perspective on complex gill disease (CGD) in salmon and identify strategies for mitigation (ToR e)

Complex gill disease (CGD) is an emergent, economically important health issue that limits productivity in salmon aquaculture. CGD is believed to result from a complex interaction of environmental, host and infectious factors. The performance and survival of affected fish is influenced by the severity of the gill lesions. Environmental factors associated with CGD include exposure to harmful algae, jellyfish, low dissolved oxygen and elevated water temperatures. Relevant infectious agents include Atlantic salmon paramyxovirus, salmonid gill poxvirus, *Candidatus Piscichlamydia salmonis* and the microsporidian *Desmozoon lepeophtherii*. This ToR will describe the causes and consequences of CGD in salmon aquaculture in ICES Member Countries and identify mitigation strategies in the context of climate change. A peer-reviewed journal article is scheduled for completion in 2021.

4.6 Integrate perspective on emerging health issues affecting wild salmon populations of Baltic member countries (ToR f)

Update for 2019

SVA reporting site

In 2019 there was an increase in reported sick, dying and dead salmon in Swedish rivers. The total number of reports on salmonids to the SVA reporting site was 421 in 2019. This is more than twice the number of salmonids, 203, that were reported in 2018. Of the 421 reports, 352 related to salmon, 23 to brown trout, 16 to sea trout and 18 to salmon or sea trout (based on reported fish size) not identified to species, 8 to whitefish and 4 to arctic char. Due to the timing of the 18 "unknown species" reports (6 in June, 21 in July, 4 in August) most of the fish were likely salmon. Figure 1 presents a monthly species distribution of reports on salmon and trout in 2016 – 2019.

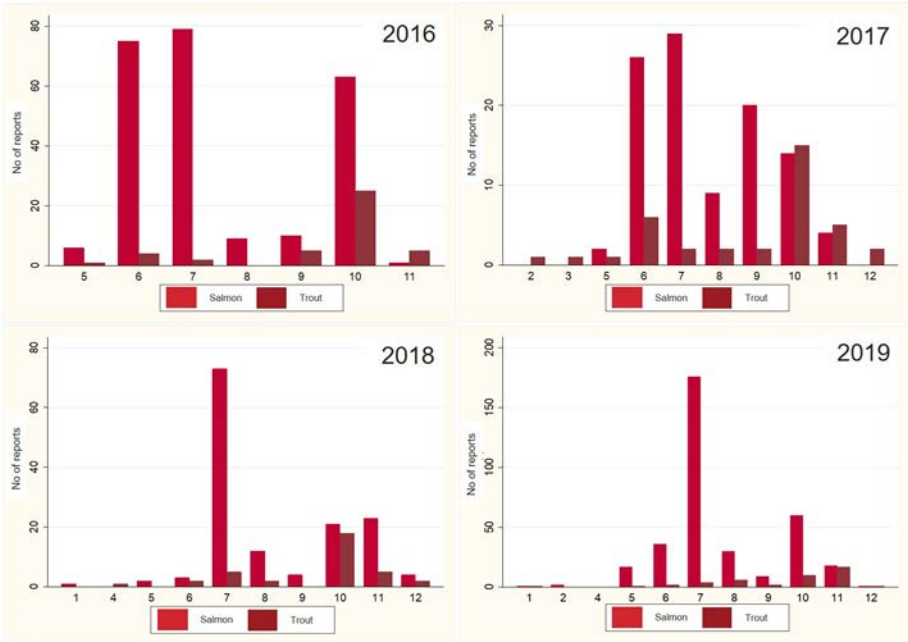

Figure 1. Reports on salmon and trout in Swedish and Finnish rivers to the SVA reporting site from 2016 to 2019. Note the temporal pattern with a dominance of salmon in June-July, whereas trout (both sea trout and brown trout) is mainly reported in autumn. Fish that are either salmon or sea trout but with species unspecified have not been included.

Reports came from more rivers than in 2018, but there was also an increase in reports from the Tornio river and Umeälven. The number of returners in Umeälven were approximately the same as in 2018. The number of returners to the Tornio river increased from 47 000 to 65 000, but there was still a 200% relative increase in reports of diseased fish in the Tornio river, from 0.07% of returners in 2018 to 0.2% of returners in 2019. Another factor contributing to increased number of reports was that the same symptoms that have been observed in Swedish east coast rivers since 2014 started to occur more frequently in Swedish west coast rivers. West coast reports in previous years have mainly been on red vent syndrome (anisakiasis) or fungal infections in late autumn, but in 2019 summer disease and mortalities similar to that in Baltic salmon were reported.

New health issue – "fry mortality syndrome"

In summer 2019, all restocking farms on the Swedish east coast (i.e. those stocking Baltic salmon) experienced fry mortalities. The mortalities occurred when fry was approximately 1 to 1.5 g in size and mainly affected salmon, however some disease also occurred in sea trout fry. Affected fry swam erratically, became lethargic and then died. SVA investigated for presence of bacteria and viruses but no specific pathogen was detected. Whole body longitudinal sectioning and histology did not show any significant findings that can be related to infection or, for example, thiamine deficiency. The condition could be treated with alternate bathing in formaldehyde and salt solutions. Repetitive intense treatment produced better results than lower doses and fewer repetitions, the latter leading to a longer period before all symptoms were resolved. There is no reason to believe that there has been transmission among farms; rather, we believe this could be something transmitted from the mothers to their offspring and thus a new addition to the ongoing health issues of the adult Baltic salmon. The etiology could be a vertically transmissible virus or bacterium that cannot be cultivated, deficiency of an essential nutrient or vitamin or antioxidant (similar to the M74 syndrome/thiamine deficiency, although this do not seem to be the problem due to lack of lesions and the fact that thiamine treatment is not necessary to solve the problem), or transmission of a toxic agent or pollutant that interferes with fry homeostasis. The fact that one of the restocking farms also receives fertilized eggs of west coast salmon and rears these to smolt, with this population being unaffected throughout the problems with the local salmon stock, also indicates that this is something related to the health status of the local parents.

Sampling and monitoring of salmon health

To explore potential correlations between mother and offspring health in the event fry mortality syndrome occurs in summer 2020, samplings have been performed of broodstock females from four restocking farms. Samplings were performed after stripping of roe, in conjunction with mandatory sampling for viral investigations. Both salmon and sea trout females were sampled, 15-20 females per farm in total depending on availability. Three farms were east coast farms and the fourth was the west coast farm that rears their fry in an east coast farm mentioned above. The identity of each female was noted in our sampling protocol, and the farms also noted which females were sampled in order to keep these groups together and not mix this fry with fry from unsampled females. If fry mortality syndrome occurs in 2020 in fry from sampled females, samples cab be analysed from both generations to look for potential transmission of pathogens, deficiencies or toxicities.

No samplings with regard to summer health issues in returning salmon were performed in Sweden during 2019. Analyses of samples collected in 2018 are ongoing. For instance, the Swedish University of Agricultural Sciences (SLU) has begun to look at stable isotopes to see if this would provide clues to where the different stocks are feeding in the Baltic Sea, and whether this could be a factor involved in the disease pattern. In depth analysis of metabolomic data from 2018 are underway by Gothenburg University.

The Agency for Marine and Water Management (HaV) has given SVA a mandate to set up a general health monitoring program for wild fish, shellfish and molluscs, and anadromous fish (salmonids and lampreys) have a specific program within this. For anadromous fish, the focus is on salmon because of the ongoing disease problems. The SVA is limited in its ability to design an efficient sampling monitoring program at the moment because of the uncertainties about the etiology of the disease problems. Samplings will be performed in five river systems during 2020, including the Baltic (Tornio river, Umeälven), land locked salmon (Lake Vänern), and the west coast (rivers Ätran and Örekilsälven or Enningdalselva). Samplings will focus on securing samples to allow further investigations of potential factors causing the disease, to identify useful monitoring tools. Funding for analyses still must be resolved.

Other Baltic countries

Reports from Tornio river are relevant to Finland, as this river forms the border between Sweden and Finland. The Finnish Food Authority (Ruokavirasto) performed some samplings and analyses during 2019 and concluded that there was no difference between healthy and wounded fish in thiamine levels (per a report on the Ruokavirasto website in Swedish and Finnish). There is no information on the number of investigated salmon, but it is stated that many wounds on Tornio river salmon are of mechanical origin. Ruokavirasto and the Finnish Natural Resources Institute (Luke) will work together with SVA on the sampling of Tornio river salmon during 2020.

There were no reports from Estonia or Lithuania to the ICES WGPDMO, and Latvia and Poland do not report any problems with salmon health in 2019. A Polish publication from 2018 was identified in 2019 ("Pattern of secondary infection with *Saprolegnia* spp. in wild spawners of UDN-affected sea trout *Salmo trutta* m. *trutta* (L.), the Słupia River, N Poland", Ciepliński et al., Oceanological and Hydrobiological Studies 47(3):230-238 -- DOI: 10.1515/ohs-2018-0022). In this publication it is stated that UDN diagnosis was performed from photos. For a certain UDN diagnosis, histological investigations of affected skin areas must be made, and prior to secondary fungal infection. Thus, the "UDN problem" in Poland may not at all or only partly be related to UDN.

Apparent spread of the problem outside the Baltic Sea

Norway and Denmark were included in last year's report as a reference because they are geographically proximate to the Baltic Sea yet their salmon stocks are distinct, and had seemingly not been affected by the same problems as Baltic populations. Russia has also been included in the ToR because of recent issues with UDN in returning salmon on the Kola peninsula.

In summer 2019, SVA was contacted by the Norwegian Veterinary Institute (NVI) and the Norwegian Institute for Nature Research (NINA) because reports on diseased returning salmon were coming from the river Enningdalselva, on the border with Sweden. NVI and NINA performed necropsies and sampling on a few fish. Marine Scotland also made contact after investigating returning salmon. Diseased returners also occurred in Ireland, England and Denmark. In November 2019, a meeting was arranged in Oslo, Norway, gathering the involved institutes in these countries, Sweden, Finland and Russia. The conclusions were that there are both similarities and differences in disease signs in the Atlantic and Baltic occurrences. Skin hemorrhages are common, mainly on the abdomen, but to not exclude any other symptoms that may be related, the group decided on naming the syndrome "red skin disease". None of the investigating institutes have isolated a virus or bacterium that could explain the problem, but an infectious aetiology has not been excluded. It is not known whether the similarities in disease expression mirror a common or partly common aetiology, or if there are different aetiologies manifesting with the same disease signs. For instance, the pathogen spectrum that salmon are exposed to probably differs between the Baltic Sea and the Atlantic.

Through the Oslo meeting, a platform for future international cooperation on the salmon health issue has been formed. Sampling procedures should be somewhat synchronized in the future, and the participating countries will benefit from information sharing on analyses and diagnostics and so on.

Reviews on Baltic salmon health

In early 2019, the Swedish Agency for Marine and Water Management (HaV) tasked Gothenburg University with producing a written review on salmon health in the Baltic Sea. The review included information on the Baltic Sea from a ecological point of view (brackish water, inflow of saline water, oxygen levels, eutrophication, etc.), the salmon life cycle and feeding behaviour in the Baltic Sea, M74, the disease problems in returners and environmental pollution in the Baltic Sea. The conclusions were:

- A clear mandate for the overall responsibility on salmon health is needed, with a leadership charge to one of the large Authorities (like HaV or the Swedish Environment Protection Agency);

- A monitoring program for salmon health is needed (starts 2020, by the SVA);

- A joint investment in environmental monitoring would be beneficial; and

- A joint research program between Swedish researchers and researchers from other Baltic countries should be established. This has been done previously on Reproductive Disturbances in Baltic Fish (FiRE, 1994-1998).

Finally, the Linnaeus University in Kalmar, Sweden, have been given a mandate to review thiamine ecology in the Baltic Sea, which may have great relevance to salmon ecology. The review is to be submitted to the HaV early in summer 2020.

4.7 Identify strategies to prevent further spread of ostreid herpesvirus OsHV-1 within the ICES region and mitigate impacts where it occurs (ToR g)

Emerging pathogens represent one of the most significant threats to the growth and sustainability of aquaculture industries worldwide. In the realm of mollusc aquaculture, there is a long history of emerging diseases devastating shellfish populations, with effects often altering ecosystems, sometimes permanently. In eastern oysters, for example, the emergence of *Haplosporidium nelsoni* in the 1950s and intensification of perkinsosis caused by *Perkinsus marinus* along the Atlantic coast of North America in the 1980s effectively abolished a century-old extensive aquaculture industry that had existed in the Chesapeake Bay, and contributed to a permanent shift in that system from benthic- to pelagic-dominated in production. In Europe, emergence of an iridovirus disease in the Portuguese oyster in the 1960s drove that species to commercial extinction, and was closely followed by catastrophic disease outbreaks caused by *Marteilia refringens* and *Bonamia ostreae* that crippled flat oyster industries. These events provided the impetus for the massive introduction to Europe of Pacific oyster *Crassostrea gigas* from Asia, with far reaching effects for the European shellfish aquaculture industry and coastal ecosystems more generally.

More recently, a "microvar" variant of the ostreid herpesvirus OsHV-1 emerged in France in 2008 to cause sharply elevated disease and mortality in cultured Pacific oysters. This emergence was subsequently followed by damaging outbreaks caused by other OsHV-1 microvariants in cultured Pacific oysters in New Zealand and Australia beginning in 2010. In Europe, the virus was quickly recognized as distinct from existing European strains, and as a "necessary cause" of the mortality, yet it was not adequately controlled and rapidly spread through most European Pacific oyster growing areas. Part of reason for this was conflation of vibriosis caused by *Vibrio splendidus*, *Vibrio aestuarianus*, or other species as inherent to this "syndrome", which challenged construction of a clear case definition for the disease; coming to terms with the diversity of *Vibrio* pathogens affecting shellfish and their contributions to disease, in Europe as well as in North America, Australia and elsewhere, in fact remains a challenge and the focus of intensive study.

Our collective experience as a community of aquatic animal health scientists and professionals with the OsHV-1 microvariant emergence in particular raises questions about our preparedness to manage emerging disease threats. The challenges we have faced with viral as well as bacterial detection and characterization, and in understanding the contributions of these pathogens to disease and their broader ecology, highlight the challenges we face in dealing with viral and bacterial pathogens in particular, as a mollusc health community that to a significant extent has historically concerned itself with protozoan parasites. There is an urgency to our becoming better prepared and meeting these challenges. Aquaculture is growing rapidly in the ICES region and elsewhere, and marine aquaculture will contribute increasingly and essentially to food and nutritional security of growing human populations in the coming years. Bivalve mollusc aquaculture is a particularly important element of this given its low carbon footprint and sustainability. More immediately, we must recognize that *today* there are important Pacific oyster production areas as yet unchallenged by the emergent OsHV-1 microvariants, notably in the Americas, and that for these populations and production areas these emerging viruses represent a grave contemporary threat.

With this context in mind, we convened an ICES Workshop on Emerging Mollusc Pathogens on 6-7 June 2019, in Copenhagen and with sixteen participants from Denmark, France, Germany, Iceland, Ireland, Norway, Spain, the USA, New Zealand, Australia, and the World Organisation for Animal Health (OIE), to address fundamental questions in two broad areas. First, with regard to capabilities, *do we have the expertise we need, in the right places with regard to our national and international aquatic animal health management infrastructures, to effectively detect and manage emerging mollusc pathogens (EMOPs)?* What is this expertise, especially with regard to viral and bacterial pathogens? What are essential tools, platforms, and capabilities do we need to have at our disposal? Do we need other tools, platforms, and capabilities to *understand* these pathogens? What questions do we need to be prepared to ask in terms of advancing essential science to inform management? And second, with regard to communication, *is communication adequate within the pathology community? Is it adequate among the pathology community, regulators and policy-makers, and the private sector? Is it adequate between academic and research institutions and national veterinary labs?* Where, and how, do we fall short? How might this be improved? What would a framework for improved future response to EMOPs look like?

Our goal was to identify areas warranting investment and support, development and improvement as we consider managing emerging diseases against the backdrop of growing shellfish aquaculture industries; and to articulate compelling justification for ICES Member Countries and others to direct resources to these areas as appropriate, for more effective management of shellfish health moving forward. A proximate motivation behind this workshop was the US concern about emerging mollusc pathogens, specifically the OsHV-1 microvariants, that could adversely affect US shellfish aquaculture production; this is reflected in the financial support for the workshop, which was provided by the US Department of State and National Oceanographic and Atmospheric Administration (NOAA). Uncovering what we might learn from the decade of experience with OsHV-1 microvariants in Europe, New Zealand, and Australia with regard to preventing introduction to new areas, and effectively mitigating effects where the virus does occur—what has worked, what has not—is a keen North American interest. It is also an important objective of broader ICES Working Group of Pathology and Diseases of Marine Organisms (WGPDMO) activities under which the WKEMOP resides. More broadly, however, we recognize a need to prepare to detect and manage emerging mollusc pathogens from whichever taxon they emerge, as history has shown they inevitably will.

Results of the WKEMOP are fully described in a workshop report, soon to be released. Some key elements are presented here. Thirty-six priority considerations were identified that spanned four broad areas: improving communication and frameworks, essential infrastructure and expertise, key research priorities, and the central role of husbandry in shellfish aquaculture health management. Improving communication within and across all levels was recognized as the greatest need: within and between industry, the pathology and scientific community, and regulators and competent authorities, across regions and nations. Better coordinating efforts, improving data sharing, and working to increase trust on the part of industry to create buy-in and improve reporting were among identified priorities. It was emphasized with regard to emerging pathogens such as OsHV-1 microvariants in particular that regulatory frameworks should be flexible, given the at times urgent need to act with often incomplete information.

With regard to essential infrastructure and expertise the workshop emphasized the continued relevance and importance of conventional platforms and applications, including histopathology, electron microscopy, bacteriology and virology, which remain foundational to disease diagnostics and aquaculture health management of molluscs and other species. There should be a committed focus to broaden expertise in these areas, which has eroded with the retirement of senior scientists in these fields. Molecular diagnostics and the application of next-generation DNA sequencing technologies, along with proteomic, metabolomic and other approaches, represent powerful tools that will find increasing application in aquatic animal health. However, they all have their limitations, and should be applied with a clear view of the purposes and environmental contexts to which they are best suited, with robust validation to substantiate this perspective. Maintain laboratory capacity is also important, with regard not just to technologies available but also to distribution: while it is important to have well resourced national and, in the case of the European Union, pan-national laboratories, there is value in maintaining a constellation of regional governmental and academic laboratories, which can be closer and more intimately engaged with aquaculture production in local areas, and familiar with local ecological and oceanographic systems.

Other areas of infrastructure and expertise viewed as important included disease challenge models and facilities, which are essential to testing hypotheses concerning the pathobiology and ecology of disease systems, including those emerging from genetic analyses and surveillance; and expertise in epidemiology, which is limited with regard to marine diseases in particular.

Discussion of key research priorities highlighted the great value of long-term studies for understanding what is normal or "typical" with regard to infection patterns; for appreciating the trajectories of host-pathogen systems, including evolutionary dynamics such as resistance and tolerance evolution and virulence evolution that that would be relevant to management approaches; and for understanding the gradual effects of changing marine and aquatic systems. The importance of improving ecological and evolutionary perspective in general was emphasized, as was the need to develop strategies for continuously monitoring and characterizing the diversity of potential pathogens, including the new variants of known pathogens. Establishment of molluscan cell lines for viral work in particular would be a particularly valuable tool for diagnostics and research.

Aquatic animal husbandry in the broadest sense, from breeding to maintenance of cultured animal populations and the entire production cycle, offers myriad opportunities to effect control of pathogens to maintain a high level of biosecurity. Understanding the intersections of disease with aquaculture production for different host-pathogen systems is requires a research investment in this area as well, but focused investment would also be required to advance some of the strategies for aquaculture health management that would likely emerge, which could include selective breeding and ploidy manipulation as widely practiced in oyster industries.

Finally, funding was recognized as presenting a continuing challenge. That funding for surveillance and research in aquatic animal health is limited is obvious to everyone. It is also the case that there is not always a good fit match between donors and funding agencies and priorities from the perspective of industry and health management. Competitions for research grants, for example, will typically be decided based on intellectual merit and scientific innovation. Proposing basic surveillance, despite its immense value in providing perspective on known and potentially emerging pathogens, would not necessarily be competitive in this light. There is a substantial amount of practical aquaculture health-related science, in fact, that would be outside the realm of what reasonably might be supported through competitive grant funding in North America, Europe and elsewhere. Identifying other mechanisms besides competitive grants to support activities like targeted surveillance is essential if we are to close the gaps that exist in our understanding of pathogen distributions (not to mention biology, ecology and other areas) and to maintain adequate vigilance with regard to emerging pathogens. A second and related point is that timelines for funding are often inappropriate. Sustained, long-term funding would have many advantages over short term, 1-3 year grants that are far too common. This would perhaps most obviously be the case with regard to selective breeding for disease resistance, which necessarily would span multiple animal generations, but it applies to surveillance and ecological and evolutionary research on marine diseases as well.

While focused initially on the pathology community, the WKEMOP dialogue will be expanded in coming months to incorporate perspective from industry and the regulatory community.

4.8 Complete assessment and refine application of the Fish Disease Index (ToR h)

Results of assessment of the FDI will be reviewed, and data harmonization and quality assurance will be addressed as refined guidelines are produced for FDI application.

4.9 Provide expert knowledge and management advice on fish and shellfish diseases, if requested, and related data to the ICES Data Centre (ToR i)

There have been no such requests in the present cycle.

4.10 Synthesis of the current and future biosecurity and ecological implications of cleaner fish use for sea lice control in salmon aquaculture (ToR j)

It is widely acknowledged that mitigation of sea lice infections on farmed salmon is challenged by the widespread emergence of resistance to most classes of chemotherapeutants. Cleaner fish, including wrasses (*Ctenolabrus rupestris*, *Symphodus melops*, *Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*), are used in several ICES Member Countries as part of integrated pest management strategies for sea lice control. The WGPDMO recognizes a growing body of scientific knowledge related to the use of cleaner fish. The purpose of this document is to summarize the available knowledge concerning the infectious agents and diseases reported from cleaner fish, to identify the ecological and biosecurity implications of cleaner fish use in salmon aquaculture. Knowledge gaps will be identified and recommendations made concerning mitigation of biosecurity concerns related to use of cleaner fish. Work on this ToR j will result in a peer-reviewed journal publication anticipated in 2021.

5 Next meetings

2021, Tenerife, Spain, dates to be determined

Annex 1: List of participants

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Annex 2: Common and scientific names of host species in the report

char, Arctic	*Salvelinus alpinus*
clam, hard	*Mercenaria mercenaria*
cod, Baltic	*Gadus morhua*
crab, blue	*Callinectes sapidus*
dab, common	*Limanda limanda*
eel, European	*Anguilla anguilla*
herring, Atlantic	*Clupea harengus*
herring, Baltic	*Clupea harengus membras*
lamprey, European river	*Lampetra fluviatilis*
lumpfish (lumpsucker)	*Cyclopterus lumpus*
mackerel	*Scomber scombrus*
mussel, blue	*Mytilus edulis*
oyster, eastern	*Crassostrea virginica*
oyster, European flat	*Ostrea edulis*
oyster, Pacific	*Crassostrea gigas*
oyster, Portuguese	*Crassostrea angulata*
salmon, Atlantic	*Salmo salar*
salmon, pink	*Oncorhynchus gorbuscha*
scallop, bay	*Argopecten irradians*
shrimp, whiteleg	*Litopenaeus vannamei*
trout, brown	*Salmo trutta*
trout, sea	*Oncorhynchus mykiss*
whitefish	*Coregonus* sp.
wrasse, ballan	*Labrus bergylta*
wrasse, corkwing	*Symphodus melops*
wrasse, goldsinny	*Ctenolabrus rupestris*