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Manatū Ahu Matua

Review of International Aquatic Health Inspection and Surveillance Programmes

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1 Executive summary

Diseases and parasites pose a major biological risk to New Zealand's aquaculture industry and to other sectors that utilise and value the aquatic environment. Aquatic diseases have the potential to cause widespread mortality, large financial losses, damage to reputation, and trade impacts. With the exception of diagnostic testing for export requirements, New Zealand has no mandatory, routine surveillance programme for aquatic animal diseases and is largely reliant on passive surveillance for disease detection. Implementation of an appropriate nationwide health and disease surveillance programme would assist the New Zealand aquaculture industry with the early detection of disease, prevent the inadvertent spread of disease around the country, and minimise the consequences of diseases. However, a knowledge gap exists in terms of the feasibility and practicality of implementing a robust surveillance system for the New Zealand aquaculture industry.

This report presents the results of the following two research objectives:

1. Conduct a literature review of existing international health and disease surveillance programmes for finfish and shellfish.
2. Interview international experts regarding aspects of the implementation of existing national surveillance programmes.

This information will assist the considerations of the Ministry for Primary Industries (MPI), in conjunction with industry and other stakeholders, when determining the possibility of implementing surveillance programmes in New Zealand[1].

Health and disease surveillance programmes in six countries were reviewed: Australia (Tasmania and South Australia), United States of America (Maine, Washington and Alaska), Canada (British Columbia and New Brunswick), Scotland, Ireland and Norway. Information was obtained from scientific literature, the internet, and from interviews with 22 international disease experts.

Eight of the ten jurisdictions have an active or hazard-specific disease surveillance programme for finfish, where fish samples are regularly collected and screened for disease. South Australia and Tasmania do not have a mandatory requirement for regular disease sampling of finfish, though Tasmania has an enhanced passive surveillance programme. Seven of the jurisdictions also have routine surveillance programmes for shellfish diseases.

Drivers for the implementation of these surveillance programmes included: protection of aquaculture stocks from a serious disease outbreaks; protection of wild, native species; protecting or obtaining trade and market access; border biosecurity and preventing disease spread; legal requirements; and, public pressure. The main objective(s) of the surveillance programmes for all jurisdictions are early disease detection and/or preventing the spread of diseases. Many governments also conduct discrete, hazard-specific disease surveys to determine the presence or absence and spatial distribution of a specific disease to substantiate their freedom of disease status. This information is used to facilitate market access and/or restrict trade from jurisdictions that have the disease.

Surveillance programmes (excluding sea lice surveillance) in Norway, Maine, New Brunswick, Ireland and Scotland are entirely run by government staff or approved fish health professionals who are responsible for conducting farm inspections, collecting samples, and

[1] Any future programme may be dependent on a Government Industry Agreement should Government and the aquaculture industry enter into a Government Industry Agreement.

providing the laboratory diagnostic services. Surveillance programmes in the other jurisdictions reviewed utilise a mixture of government staff, fish health professionals and farmers to sample fish.

All of the Northern Hemisphere jurisdictions reviewed have a moderate to high degree of regulation regarding disease surveillance, with clearly stipulated mandatory requirements. By comparison, South Australia and Tasmania have relatively few disease surveillance regulations. Mandatory surveillance requirements can be grouped into six common themes:

1. *Mandatory reporting of notifiable diseases and elevated mortality*—reporting of notifiable diseases is required by all jurisdictions, and reporting of elevated mortality is required by 9/10 jurisdictions.
2. *A requirement for periodic disease sampling*—8/10 jurisdictions require periodic disease sampling, although the sampling frequency varies from monthly to once every three years. The number of diseases screened for also varies among jurisdictions.
3. *Regular farm inspections conducted by government staff or health professionals*[2]—8/10 jurisdictions require regular farm inspections, with the frequency varying from monthly to once every three years.
4. *A requirement for disease sampling prior to transfers*—7/10 jurisdictions require disease-free certification of stock prior to transfers, although some of these jurisdictions only require testing for specific diseases.
5. *A requirement for disease sampling of hatcheries*—5/10 jurisdictions require hatcheries to have regular disease sampling.
6. *Mandatory recording and/or reporting requirements*—9/10 jurisdictions require farmers to record and report information to the authorities on the incidence, history and management of disease on their farms e.g., mortalities, diagnostic results and chemotherapeutants applied.

Surveillance requirements in Scotland, Ireland, Norway, Maine, Alaska and Washington vary depending on the disease risk, disease history, and sometimes, the biosecurity practices of farms. Only Tasmania's and South Australia's surveillance programmes have a significant voluntary component.

The benefits of surveillance programmes that were identified in this review include:

1. *Early detection of disease*—farmers have been able to control or eliminate some serious diseases, such as infectious salmon anaemia (ISA) through early detection, rapid depopulation, fallowing and area management strategies.
2. *Substantiating freedom from disease status*—allowing jurisdictions to access new markets, or implement import bans or stock movement restrictions from areas where the disease(s) are present.
3. *Preventing the spread of disease*—through testing of stock prior to transfers.
4. *Financial benefits*—surveillance can help avoid widespread disease outbreaks that have major direct costs (e.g., loss of stock, control methods, stock destruction costs) and indirect costs (e.g., loss of trade, damage to reputation, loss of commercial and recreational fishing).

[2] In some jurisdictions farmers must use health professionals that are approved by the government, while in other jurisdictions farmers can employ their own health professional.

5. *Increasing knowledge and capabilities*—provides greater diagnostic expertise, a better understanding of disease management, and allows industry and government to make better informed decisions about the disease risks present in the surveyed areas.
6. *Improved reputation and social license*—confirmation that cultured fish are healthy and that industry are not spreading diseases has strengthened aquaculture's social licence in some jurisdictions.

Barriers to the implementation of surveillance programmes include:

1. *Cost*—the cost of running a surveillance programme (including site visits, sample collection, diagnostic testing, etc) can be prohibitively expensive.
2. *Lack of support by industry*—farmers may be unwilling to support a surveillance programme if they think that the cost of surveillance is too high; do not recognise the benefits and importance of surveillance; find data gathering too time consuming and difficult; find compliance requirements too onerous; fear the loss of trade or damaged reputation; have a lack of trust in the regulatory authorities; don't believe they will be affected by disease; or simply 'don't want to know'.
3. *Fear of consequences*—farmers may fear the consequences of surveillance results e.g., financial losses and control measures limiting their ability to operate.
4. *Lack of information on the target disease*.
5. *Problems with diagnostic tests*—a lack of suitable diagnostic tests, over-reliance on disease-specific diagnostic methods, or varying testing requirements among countries.
6. *Lack of suitably qualified staff and resources*—a lack of suitably qualified field and laboratory staff, and a lack of accredited laboratories can compromise sample collection and diagnostic services, particularly in terms of sample quality, laboratory capacity and turnaround times.

Potential methods of increasing industry support for a surveillance programme include:

1. *Improving relationships between industry and government.*
2. *Providing relevant information to industry on the need for, and benefits of a surveillance programme.*
3. *Focussing on endemic diseases that are causing farmers production losses.*
4. *Providing diagnostic testing, disease control advice and assistance.*
5. *Providing feedback on surveillance efforts.*
6. *Providing confidentiality.*
7. *Provision of research grants for the development of better diagnostic methods.*

An aquatic health and disease surveillance programme cannot be considered in isolation. Such a programme needs to sit within an integrated framework for aquaculture biosecurity and disease management, and must have support from industry. The objectives, costs and benefits of implementing a surveillance programme need to be considered and agreed by all parties.

Glossary & abbreviations

Active (proactive) surveillance	Investigator-initiated collection of animal health related data using a defined protocol to perform actions that are scheduled in advance. Decisions about whether information is collected, and what information should be collected from which animals is made by the investigator (Hoinville *et al.*, 2013).
ADF&G	Alaska Department of Fish and Game (United States).
AMA	Area management agreement.
APHIS	Department of Agriculture, Animal and Plant Health Inspection Service (United States).
AVG	Abalone viral ganglioneuritis.
BMA	Bay management areas.
BCARP	British Columbia's Aquaculture Regulatory Programme (Canada).
BCMAL	British Columbia Ministry of Agriculture and Land (Canada).
BCSFA	British Columbia Salmon Farmers Association (Canada).
BCSGA	British Columbia Shellfish Growers Association (Canada).
BCR	Benefit Cost Ratio.
BKD	Bacterial kidney disease.
CFIA	Canadian Food Inspection Agency.
Competent Authority	The veterinary authority or other governmental authority that has the responsibility and competence for ensuring or supervising the implementation of animal health and welfare measures, international veterinary certification and other health standards and recommendations (OIE, 2016b).
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia).
DAAF	Department of Agriculture, Aquaculture and Fisheries, New Brunswick (Canada).
DAFF	Department of Agriculture, Fisheries and Forestry. Now known as the Department of Agriculture and Water Resources (Australia).
DAWR	Department of Agriculture and Water Resources (Australia).
DFAT	Direct fluorescent antibody test.
DFO	Department of Fisheries and Oceans (Canada).
Disease freedom	A designation applied to regions or areas that can substantiate, with an accepted level of confidence, a negligible likelihood of the presence of a certain disease or pathogen.
DPIPWE	Department of Primary Industry, Parks, Water and Environment (Tasmania, Australia).
ELISA	Enzyme-linked immunosorbent assay.
Endemic disease	A disease that is constantly present in the population of interest (Hoinville *et al.*, 2013).

Enhanced passive surveillance	Observer-initiated provision of animal health related data with active investigator involvement e.g., by actively encouraging producers to report certain types of disease or by active follow up of suspect disease reports (Hoinville *et al.*, 2013).
Epizootic disease	A disease that affects a large number of animals in a region within a short period of time.
Exotic disease	A previously defined (known) disease that crosses political boundaries to occur in a country or region, in which it is not currently recorded as present (Hoinville *et al.*, 2013).
FHI	Fisheries Health Inspectorate (Scotland).
FHP	Fish health professional.
Hazard-specific surveillance	Surveillance that is focussed on one or more pre-defined hazards (disease, condition, biological, chemical or physical agent, or event). Often this form of surveillance uses diagnostic tests for the detection of particular pathogens (e.g., molecular diagnostic methods) (Hoinville *et al.*, 2013).
IFAT	Indirect fluorescent antibody test.
IHN(V)	Infectious haematopoietic necrosis (virus).
IPN(V)	Infectious pancreatic necrosis (virus).
ISA(V)	Infectious salmon anaemia (virus).
ISAV HPR0	Infectious salmon anaemia virus, non-pathogenic strain.
ISAV HPRΔ	Infectious salmon anaemia virus, pathogenic strain.
LIMS	Laboratory Information Management System.
MAF	Ministry of Agriculture and Fisheries. Now known as the Ministry for Primary Industries (New Zealand).
MPI	Ministry for Primary Industries (New Zealand).
Moderate consequences	Establishment of disease would cause significant biological consequences (significant mortality or morbidity) and may not be amenable to control or eradication. Such diseases could harm economic performance at a regional level on an ongoing basis and/or may cause significant environmental effects, which may or may not be irreversible (Diggles, 2011).
Monitoring	The systematic (continuous or repeated) measurement, collection, collation, analysis, and interpretation of animal-health and -welfare data in defined populations when these activities are not associated with a pre-defined risk-mitigation plan (although extreme changes are likely to lead to action) (Hoinville *et al.*, 2013).
MSX	Multi-nucleated sphere unknown (infection with *Haplosporidium nelsoni*).
NAAHLS	National Aquatic Animal Health Laboratory System (Canada).
NAAHP (CA)	National Aquatic Animal Health Programme (Canada).
NAAHP (US)	National Aquatic Animal Health Plan (United States).

New (emerging) disease	A previously undefined (unknown) disease or condition, which might result from the evolution or change in an existing pathogen or parasite (and therefore cause a change of strain, host range, or vector, or an increase in pathogenicity). This term would also apply to the emergence of any other previously undefined condition (Hoinville *et al.*, 2013).
NOAA	National Oceanic and Atmospheric Administration (United States).
NWIFC	Northwest Indian Fisheries Commission (United States).
OIE	World Organisation for Animal Health.
OsHV-µvar	Ostreid herpesvirus microvariants.
OsHV-µ1	Ostreid herpesvirus microvariant-1.
Passive (reactive) surveillance	Observer-initiated provision of animal health related data (e.g., voluntary notification of suspect disease) or the use of existing data for surveillance. Decisions about whether information is provided, and what information is provided from which animals is made by the data provider (Hoinville *et al.*, 2013).
PIRSA	Primary Industries and Resources South Australia (Australia).
Put-and-take fishery	The placing of hatchery-raised fish of a specific size in waters to be caught by fishermen for a payment (FishBase, no date).
q-PCR	Real-time (quantitative) polymerase chain reaction.
qRT-PCR	Real-time (quantitative) reverse transcriptase polymerase chain reaction.
Risk-based surveillance	Use of information about the probability of occurrence and the magnitude of the (biological and/or economic) consequence of health hazards to plan, design, and/or interpret the results obtained from surveillance systems (Hoinville *et al.*, 2013).
RLO	*Rickettsia*-like organisms.
RT-PCR	Reverse transcriptase polymerase chain reaction.
Sensitivity	The true positive rate, i.e., the probability of disease detection when the disease is present.
Serious (disease or pathogen)	Defined as a disease or pathogen that would have moderate or higher consequences (see ‘moderate consequences’ and Table 37).
SMDEP	State of Maine Department of Environmental Protection (United States).
SMDMR	State of Maine Department of Marine Resources (United States).
Specificity	The true negative rate, i.e., the proportion of samples correctly identified as being disease-free.
Survey	Specific activities addressed in identifying or understanding a specific problem. Surveys are discrete (time limited) (Guberti *et al.*, 2014).
Syndrome	A collection of signs and epidemiological behaviour that often occur together, and can be used to identify a disease.

Syndromic surveillance	Surveillance that uses health-related information (clinical signs or other data) that might precede (or may substitute for) formal diagnosis. This information may be used to indicate a sufficient probability of a change in the health of the population either to warrant further investigation or to enable a timely assessment of the impact of health threats which may require action. This type of surveillance is not usually focussed on a particular hazard, so can be used to detect a variety of diseases or pathogens-including new (emerging) diseases. This type of surveillance is particularly applicable for early-warning surveillance (Hoinville *et al.*, 2013).
TSHSP	Tasmanian Salmon Health Surveillance Programme (Australia).
UPEI	University of Prince Edward Island (Canada).
VHS(V)	Viral haemorrhagic septicaemia (virus).
WDF&W	Washington Department of Fish and Wildlife (United States).

2 Introduction

Diseases and parasites pose a major biological risk to the aquaculture industry and other sectors that utilise and value the aquatic environment. Disease outbreaks have the potential to cause widespread mortality, large financial losses, reputational damage, and trade impacts. Serious disease outbreaks in New Zealand aquaculture have been rare (Sim-Smith *et al.* 2016). However, recent events such as the large-scale mortalities caused by ostreid herpesvirus microvariant-1 in Pacific oysters (Castinel *et al.*, 2014) and *Bonamia ostreae* in flat oysters (Anon., 2016), and the occurrence of *Perkinsus olseni* in paua (Stone, 2014), and *Flavobacterium psychrophilum*, *Tenacibaculum maritimum* and *Rickettsia*-like organisms (RLO) in salmon (Anon., 2013; 2016), have highlighted the potential risks of disease for the industry (Georgiades *et al.*, 2016). To minimise the consequences of aquatic diseases in New Zealand, and to support the growth of the country's aquaculture industry, independent research and Ministry for Primary Industries (MPI) technical reports have recommended implementation of a national diagnostic testing and surveillance system that aligns with international best practice (Georgiades *et al.*, 2016; Sim-Smith *et al.*, 2016).

In New Zealand, aquatic health and disease surveillance largely relies on passive techniques, such as disease investigations after unusual mortalities are reported, and voluntary, company-confidential surveillance of aquaculture farms by farmers (Anderson, 1995). New Zealand does have a mandatory health surveillance programme for salmon exported to Australia[3], and MPI, in conjunction with the commercial fishing industry, have funded regular surveys for *Bonamia exitiosa* in the Foveaux Strait since 1999 (Michael *et al.*, 2015). The extent of voluntary health surveillance conducted in aquaculture farms is largely determined by the companies themselves, with around two thirds of New Zealand salmon farmers periodically testing their stock for disease (Sim-Smith *et al.*, 2016). Under the Biosecurity (Notifiable Organisms) Order 2016, farmers are legally required to report the presence of notifiable diseases to regulatory authorities (Table 2 & Table 3), but they are not legally required to routinely test their stock for diseases.

Implementation of an appropriate nationwide aquatic health and disease surveillance programme would assist the New Zealand salmon industry with early disease detection, help prevent inadvertent disease spread, and thus minimise disease consequences (Georgiades *et al.*, 2016; Sim-Smith *et al.*, 2016). However, knowledge gaps exist around the feasibility and practicality of implementing a robust diagnostic testing and surveillance system in New Zealand.

The aim of this research was to gather information to assist the considerations of the Ministry for Primary Industries (MPI), in conjunction with industry and other stakeholders, when determining the possibility of implementing surveillance programmes in New Zealand[4].

This report presents the results of the following two research objectives:

1. Conduct a literature review of existing international health and disease surveillance programmes for finfish and shellfish.
3. Interview international experts regarding aspects of the implementation of existing national surveillance programmes.

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[3] Salmon farmers wanting to export salmon to Australia under MPI certification must participate in the heath surveillance programme. MPI staff inspect fish stocks at processing facilities and test fish for all cytopathic viruses, *Vibrio* spp., *Mxyobolus cerebralis, Aeromonas salmonicida, Yersinia ruckeri* and *Renibacterium salmoninarum* (MPI, pers. comm.).

[4] Any future programme may be dependent on a Government Industry Agreement should Government and the aquaculture industry enter into a Government Industry Agreement.

3 Methodology

3.1 LITERATURE REVIEW

A literature review of existing international health and disease surveillance programmes for finfish and shellfish was conducted using information obtained from recent scientific publications, the internet (particularly government and aquaculture industry websites), and relevant legislation. The review focusses on the health and disease surveillance requirements of six countries that have established biosecurity practices: Australia, United States of America, Canada, Scotland, Ireland and Norway. In countries where disease and health regulation is governed by both federal and state or territorial governments, the review of legislation and surveillance programmes was limited to the two or three jurisdictions that have the most comprehensive surveillance programmes and also culture species that are relevant to New Zealand's aquaculture industry.

For each jurisdiction, the review includes information (where available) on:

1. Relevant legislation:
    a) regulatory authority responsible for aquaculture regulation;
    b) relevant legislation on health and disease surveillance and management;
    c) mandatory reporting requirements;
    d) consequences if disease is detected.
2. Surveillance programmes:
    a) the objective(s) of the programme;
    b) main culture species targeted by the programme;
    c) disease(s) of most concern to the jurisdiction;
    d) data collection methods (what data is collected, how is the data collected, and who collects the data);
    e) data management (how is data recorded, who manages the surveillance data, who can access it, what is the data used for);
    f) routine diagnostic tests performed as part of the programme;
    g) mandatory requirements;
    h) variable requirements;
    i) recommended voluntary measures and uptake;
    j) consequences for farmers if a disease is detected on their farm;
    k) cost[5] of implementing and running the programme to industry and to the regulatory authority;
    l) supporting material, communication, outputs of the programme, and use of the outputs;
    m) how the programme was implemented;
    n) barriers to implementation and how they were overcome;
    o) industry support for the programme or compliance problems;

[5] Economic values have been are given in the original currency at the time of publication, and in NZ dollars using current exchange rates.

p) incentives and/or drivers for compliance with the programme;
q) benefits of the programme;
r) any procedures that did not work and were abandoned;
s) recommendations for future programmes.

3. Field and laboratory capabilities of the primary laboratory in each jurisdiction[6]:
   a) laboratory details, such as, number of staff, laboratory capabilities;
   b) number of farms in the region;
   c) field and laboratory staff responsibilities;
   d) number of diagnostic tests conducted per annum.

Section 5 provides a summary of the surveillance programmes in each of the jurisdictions reviewed with more detailed information provided elsewhere (Section 13.2). An assessment of diseases of concern for the New Zealand salmon industry is provided for contextual and comparative purposes (Section 13.5).

3.2 INTERVIEWS WITH INTERNATIONAL DISEASE EXPERTS

Interviews were conducted with international disease experts from the reviewed jurisdictions that have experience in the establishment or management of surveillance programmes and/or aquatic animal health. Suitable experts were identified through recommendations from MPI staff, Coast and Catchment Ltd contacts, or other disease experts; or from the appropriate regulatory authority's website.

Interviews were conducted during the interviewee's normal working hours, and were conducted via Skype, telephone or email. Interviewees were provided with a list of interview questions (Section 13.4) and the appropriate section of the literature review (Section 5) prior to the interview. Interviews were tailored depending on the information obtained in the literature review and the expertise and experience of the interviewee.

Interviewees were asked whether they were happy to be cited or whether they'd like their comments to be anonymous. They were also asked whether they would like to receive a copy of the interview transcript to review. Twenty two disease experts participated in the interviews.

[6] Not all the laboratories that conduct diagnostic services in each jurisdiction were reviewed. The reviewed laboratory is generally the primary state-owned laboratory or an accredited laboratory that is part of the national laboratory network.

4 Aquatic animal health & disease surveillance

4.1 TYPES OF SURVEILLANCE

Surveillance is defined as:

> *"The systematic (continuous or repeated) measurement, collection, collation, analysis, interpretation, and timely dissemination of animal-health and -welfare data from defined populations. These data are essential for describing health-hazard occurrence and to contribute to the planning, implementation, and evaluation of risk-mitigation actions"* (Hoinville *et al.*, 2013).

Surveillance should be a fundamental component of any national strategy on aquatic animal health as it is important for: early disease detection; risk analysis; substantiation of freedom from disease for trade purposes; correct disease diagnosis; provision of treatment methods; monitoring of disease management methods; and, effective emergency disease preparedness (Subasinghe *et al.*, 2005; Baldock *et al.*, 2006).

A variety of terms have been used in the literature to describe different types of surveillance, including passive, active, general, targeted, syndromic and scanning surveillance. However, the use and definition of these surveillance types in the literature is inconsistent (Scudmore, 2002; Baldock *et al.*, 2006). Often, but not always, the terms passive and general are used interchangeably, as are active and targeted (e.g., Cameron, 2002; Subasinghe *et al.*, 2005). In order to facilitate the international exchange of surveillance information, Hoinville *et al.* (2013) developed a standardised list of surveillance terminology that was agreed upon by numerous surveillance experts. This report has adopted said terminology.

4.1.1 Passive (reactive) surveillance

> "*Observer-initiated provision of animal health related data (e.g. voluntary notification of suspect disease) or the use of existing data for surveillance. Decisions about whether information is provided, and what information is provided from which animals is made by the data provider*" (Hoinville *et al.*, 2013).

Passive surveillance data is often collected for some purpose other than a surveillance programme, such as, reports of disease by farmers, research, or diagnostic laboratory results (Subasinghe *et al.*, 2005; Baldock *et al.*, 2006). No special activity is undertaken by the competent authorities to generate the information (Cameron, 2002). Many jurisdictions use a form of passive surveillance called "enhanced passive surveillance", which is defined as:

> "*Observer-initiated provision of animal health related data with active investigator involvement e.g., by actively encouraging producers to report certain types of disease or by active follow up of suspect disease reports*" (Hoinville *et al.*, 2013).

For example, European Union (EU) Council Directive 2006/88/EC (Official Journal of the European Union, L 328/14) states that (enhanced) passive surveillance shall include mandatory immediate notification of the occurrence or suspicion of specified diseases, or of increased mortality.

Passive surveillance is useful for detecting emerging and exotic diseases, and for the surveillance of endemic disease outbreaks, but cannot be used for quantifying the prevalence or spatial distribution of a disease, nor for substantiating freedom from diseases that have been previously recorded in the region[7] (Scudmore, 2002; Baldock *et al.*, 2006). This is because passive surveillance: focusses on the detection of clinical disease symptoms or mortality rather than the presence of the pathogen; is reliant on inconsistent sampling effort; and, is dependent on the level of disease awareness and knowledge of farmers (Corsin *et al.*, 2009).

4.1.2 Active (proactive) surveillance

> "*Investigator-initiated collection of animal health related data using a defined protocol to perform actions that are scheduled in advance. Decisions about whether information is collected, and what information should be collected from which animals is made by the investigator*" (Hoinville *et al.*, 2013).

Active surveillance methods may include the recognition of specific clinical signs from regular farm inspections (syndromic surveillance), or from diagnostic laboratory data. Surveillance data needs to be collected on a regular, ongoing basis. EU Council Directive 2006/88/EC states that active surveillance shall include:

1. Routine inspection by the Competent Authority or by other qualified health services on behalf of the Competent Authorities.
2. Examination of the cultured animal population on the farm for clinical disease.
3. Diagnostic samples to be collected on suspicion of a listed disease or observed increased mortality during inspection.
4. Mandatory immediate notification of occurrence or suspicion of specified diseases or of any increased mortalities[8].

4.1.3 Hazard-specific surveillance

> "*Surveillance that is focussed on one or more pre-defined hazards (disease, condition, biological, chemical or physical agent, or event). Often this form of surveillance uses diagnostic tests for the detection of particular pathogens (e.g., molecular diagnostic methods)"* (Hoinville *et al.*, 2013).

Hazard-specific surveillance (previously called targeted surveillance) is used to collect information on a specific disease(s) in order to confirm its absence in a population, or quantify its prevalence and spatial distribution. Methods may include statistically designed surveys, outbreak investigations and disease eradication programmes (Cameron, 2002; Scudmore, 2002; Baldock *et al.*, 2006).

EU Council Directive 2006/88/EC states that hazard-specific (targeted) surveillance shall include:

1. Routine inspection by the Competent Authority or by other qualified health services on behalf of the Competent Authorities.
2. Prescribed samples of aquaculture animals to be taken and tested for specific pathogen(s) by specified methods.
3. Mandatory immediate notification of the occurrence or suspicion of specified diseases, or of any increased mortalities.

[7] Passive surveillance can be used to support freedom from diseases that are historically absent or have not been recorded in the region for at least 10 years (OIE, 2016b).
[8] 'Increased mortality' means unexplained mortalities significantly above the level of what is considered to be normal for the farm or mollusc farming area in question under the prevailing conditions. What is considered to be increased mortality shall be decided in cooperation between the farmer and the Competent Authority (EU Council Directive 2006/88/EC).

4.1.4 Risk-based surveillance

"*Use of information about the probability of occurrence and the magnitude of the biological and/or economic consequence of health hazards to plan, design and/or interpret the results obtained from surveillance systems*" (Hoinville *et al.*, 2013).

The aim of risk-based surveillance is to allocate available resources effectively and efficiently, and to improve the cost-benefit ratio compared with traditional disease surveillance (Oidtmann *et al.*, 2007). Risk-based surveillance uses a risk assessment approach to identify surveillance priorities and to select high-risk animals or farms based on the probability of a disease occurring and the severity of the consequences (Corsin *et al.*, 2009). However, it should be noted that there is currently a paucity of information available for most aquatic diseases, which is a major constraint for the development of risk-based surveillance (L. Hammell, University of Prince Edward Island (UPEI), pers. comm.).

Required data includes: the relative risk of farm sites becoming infected given the presence/absence of a given risk factor; transmission and introduction pathways; the prevalence of infection within a holding unit, between holding units and at the farm level; and, the sensitivity of diagnostic tests. In the absence of suitable data, the only currently feasible approach to developing risk-based surveillance is the use of expert consultation to estimate the required information (Oidtmann *et al.*, 2013).

The EU Council Directive 2006/88/EC requires member states to have a risk-based surveillance programme.

4.2 COMPONENTS OF A SURVEILLANCE PROGRAMME

The necessary components of robust surveillance programmes are discussed below. These include: clear objectives, clarifying the diseases of concern, sufficient capability and capacity of personnel and infrastructure, and good data specification, management and reporting (Subasinghe *et al.*, 2005; Baldock *et al.*, 2006; OIE, 2016b).

4.2.1 Programme objectives

The type of surveillance methods used depends on the objectives of the surveillance programme. The four most common general objectives of surveillance programmes are:

1. *Early detection of diseases*—early detection of diseases (both exotic and endemic) is important for the effective implementation of control or eradication methods, preventing the spread of the disease, and for limiting production losses. An early detection system is considered to be the minimum requirement for a national surveillance programme (Subasinghe *et al.*, 2005; Baldock *et al.*, 2006). Early-warning surveillance is typically implemented through passive or active surveillance methods and should include:
    a) general awareness and surveillance among aquaculture personnel for signs of disease;
    b) aquatic animal health professionals that are trained in recognising disease signs;
    c) systems and facilities that can provide rapid and effective disease investigation and diagnosis;
    d) a legal obligation to report notifiable diseases to authorities (OIE, 2016b).
2. *Substantiating freedom from disease status*—validation of freedom from disease is important for market access and trade purposes. It allows exporters greater market access, assists with product accreditation, and it provides the evidence necessary for

regulatory authorities to impose import and stock movement restrictions. Current international trade agreements, such as, the OIE Aquatic Animal Health Code and the World Trade Organization Agreement on Sanitary and Phytosanitary Measures[9], require a country to have scientific evidence documenting freedom from disease before it can impose import sanctions on other countries where the disease of concern exists (WTO, 1998; OIE, 2016b). Hazard-specific surveillance is usually required to substantiate freedom from disease, though this may be combined with data from passive or active surveillance methods (Subasinghe *et al.*, 2005).

3. *Quantifying the baseline level, spatial distribution and impact of diseases*—is often used for supporting the establishment of aquaculture management areas and the implementation of transport restrictions. Hazard-specific surveillance is usually required to provide accurate estimates of the prevalence and spatial distribution of a disease, though data from comprehensive passive or active surveillance programmes are also informative (Subasinghe *et al.*, 2005; Baldock *et al.*, 2006).
4. *Assessing the efficacy of control or eradication methods, or providing information to support disease control*—in areas where aquaculture is conducted, passive surveillance methods may provide sufficient data to assess the efficacy of control or eradication methods. However, it is likely that hazard-specific surveillance will also be needed to assess the disease prevalence in wild populations (Subasinghe *et al.*, 2005; Baldock *et al.*, 2006).

4.2.2 Clarifying the diseases of concern

A national surveillance programme should have a list of legally notifiable diseases. At a minimum this should include the OIE-notifiable diseases that are not already present in the country. OIE-notifiable diseases must meet the following criteria:

1. The disease has been shown to cause significant production losses at a national or multinational level; or significant mortality in wild populations; or is a public health concern.
2. A proven infectious aetiology or an infectious agent that is strongly associated with the disease.
3. The disease is likely to spread internationally.
4. Several countries or regions may be declared free of the disease.
5. There is a repeatable and robust means of diagnosing the disease (OIE, 2016b).

It is recommended that the list of legally notifiable diseases should also include:

- diseases that may have an impact on the country's trade activities;
- all serious exotic diseases that have potential hosts in the country;
- endemic diseases if they have the potential to cause serious production impacts, pose a serious risk to native organisms, are the subject of eradication programmes, or have a localised distribution that needs containment (Baldock *et al.*, 2006).

Included diseases must be infectious and able to be reliably identified using available diagnostic screening techniques (FAO/NACA, 2001).

[9] New Zealand is a member of both the World Trade Organization and the World Organisation for Animal Health.

4.2.3 Capability & capacity of personnel & infrastructure

An effective surveillance programme requires:

- recognition amongst the industry of the importance of disease reporting;
- appropriately trained and qualified farm staff and health professionals that can conduct surveillance activities and recognise a disease outbreak;
- laboratories and personnel capable of conducting a wide range of standardised diagnostic methods that are supported by quality control systems;
- specific protocols for sample collection and disease diagnosis;
- a communication system that allows information on suspected or confirmed disease events to be easily sent from farmers to health professionals and the Competent Authority (and *vice versa*);
- good emergency preparedness planning and legislation that will allow a rapid and effective response to a disease outbreak (Baldock *et al.,* 2006; Corsin *et al.,* 2009; Halliday *et al.,* 2012).

4.2.4 Data specification, management & reporting

A central data management system is needed that clarifies:

1. *What data should be collected, and by whom*—recommended data to be collected includes growth, production and mortality data, environmental data that affects the health status of fish, traceability and transfer records, disease screening data, and syndromic data (Corsin *et al.*, 2009).
2. *How the data will be collated and stored*—use of standardised data sheets and provision of appropriate training for farmers provides a more consistent and accurate recording of health data. Standardisation of observations of clinical disease signs are particularly important because signs may be reported differently by different farmers. Use of online forms for data entry increases the efficiency of data entry and the speed of information transfer from the producer to the authorities, though a quality control system is needed to check the accuracy of the information (Corsin *et al.*, 2009).
3. *Confidentiality of data and who can access it*—farmers may wish to keep certain commercially-sensitive data, such as production or farm data, confidential.
4. *How the data will be analysed and interpreted*—e.g., with geographical information systems (GIS), statistical analysis, and/or graphically. The data management system must also be capable of recording and identifying unexpected events, such as the occurrence of a new disease, temperature fluctuations and incidences of higher than normal mortalities (Corsin *et al.*, 2009).
5. *Feedback and reporting mechanisms*—feedback at a regional, national and international level is important to allow an effective response to surveillance data and potentially increase industry support for the surveillance programme. Feedback is important for the implementation of disease control methods, OIE disease reporting requirements and international trade agreements (Baldock *et al.*, 2006).

5 Review of international aquatic disease surveillance programmes

5.1 AUSTRALIA

In 2014, aquaculture production in Australia was worth around AUD$1 billion, with the majority of production value generated in Tasmania (AUD$559 million[10]) and South Australia (AUD$181 million[11]) (Savage & Hobsbawn, 2015). Over 40 aquatic species are cultured in Australia, but over 90% of the gross value of aquaculture production is generated by five main groups: salmonids (mainly Atlantic salmon *Salmo salar*, 55%), southern bluefin tuna *Thunnus maccoyii* (12%), pearl oysters *Pinctada maxima* (10%), edible oysters (mainly Pacific oysters *Crassostrea gigas*, 9%) and prawns (*Penaeus* spp., 6%) (Savage & Hobsbawn, 2015).

Australia has a nationwide strategic plan for aquatic animal health, AQUAPLAN, which was launched in 1998 and is currently up to its' third edition. The need for a national strategic plan was highlighted after the widespread outbreak of pilchard herpesvirus in 1995 (Bernoth *et al.*, 2008). This incident, which resulted in one of the largest fish kills ever recorded, was estimated to cost the country over AUD$12 million[12] (Whittington *et al.*, 2005). AQUAPLAN 1998–2003 was the first national aquatic animal health plan in the world to be collaboratively developed between a government and the aquatic animal sector. The plan also benefited from early and widespread consultation with both industry and non-commercial groups (Bernoth *et al.*, 2008).

Development of the first edition of AQUAPLAN 1998–2003 took four years. The Australian Government committed AUD$2.7 million for the development of the plan and another AUD$3 million[13] in 2000 to support specific programme areas[14] (DAFF, 2002)[15]. In contrast, AQUAPLAN 2005–2010 was implemented without any dedicated direct resources, but relied on attracting available resources from other government budgets by aligning with national strategic priorities. This lack of dedicated funding sometimes caused delays in the initiation of projects while funds were sought. In total, AQUAPLAN 2005–2010 attracted AUD$1.2 million plus considerable in-kind support from many stakeholders (Department of Agriculture, 2014a). Similarly, responsible parties for AQUAPLAN 2014–2019 are expected to attract funding and in-kind contributions for specific projects (Department of Agriculture, 2014b).

A central element to AQUAPLAN is that it encompasses all elements related to disease management (surveillance, diagnostics, response, education and training, and animal welfare), whether they are carried out by federal or territorial governments, private veterinarians or industry (Bar-Yaacov, 2008). Each edition of AQUAPLAN has different objectives, but health surveillance is a key strategy for all three editions (Table 1).

AQUAPLAN is complemented by AQUAVETPLAN, which is a series of manuals that outlines Australia's approach to disease preparedness and emergency response to disease

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[10] NZ$589 million at current exchange rates.
[11] NZ$191 million at current exchange rates.
[12] NZ$12.7 million at current exchange rates.
[13] NZ$2.84 million and NZ$3.15 million, respectively, at current exchange rates.
[14] Diagnostics, emergency management planning, emergency management training and incident simulation; and, establishment of a joint industry or government body for aquatic animal health management (DAFF, 2005).
[15] The Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) is now known as the Department of Agriculture and Water Resources (DAWR).

outbreaks. The manuals include disease strategy manuals for several specific diseases[16], operational procedures manuals for decontamination, destruction and disposal in the case of a disease outbreak, and management manuals that specify the processes that will occur during a disease outbreak (DAWR, 2016b).

Disease surveillance in Australia is the responsibility of state and territory governments, and legal requirements vary among states. Currently, aquatic disease surveillance in Australia primarily depends on passive surveillance techniques (e.g., regular health monitoring by industry, annual mortality reporting and investigation of fish kills and unusual mortality events). This passive surveillance is supported by legal requirements to report notifiable diseases or unusual mortality events, the National Animal Health Information System, and a network of government-owned animal health laboratories (Department of Agriculture, 2014b). This network of laboratories provides a surge capacity for diagnostic testing, where tests can be sent to other state laboratories during times of high demand. The Australian Animal Health Laboratory (AAHL) also has capacity to run 24 hours a day, seven days a week (Expert 1, pers. comm.).

Active surveillance in Australia is generally used for limiting the spread of endemic diseases through testing of broodstock, hatchery stock, or stock prior to transport (Expert 1, pers. comm.).

Hazard-specific surveillance surveys may be instigated as a result of pathogen detection through passive surveillance, to fulfil export requirements, substantiate disease freedom, or to inform risk-based assessments (Jones, 2016; Expert 1, pers. comm.). Generally due to costs, national surveys are finite in duration and are typically funded by federal and state governments (though there may be in-kind contributions by industry) (I. Ernst, Department of Agriculture and Water Resources (DAWR), pers. comm.). For example, following the detection of OsHV-µvar in New South Wales in 2010, oysters throughout New South Wales, South Australia and Tasmania were surveyed for OsHV-µvar. Funding for the programme was provided by the Department of Agriculture, Fisheries and Forestry (DAFF), CSIRO AAHL and New South Wales Department of Primary Industries, with local government officers coordinating sample collection with industry (Herbert, 2011). Similarly, a national survey of wild and farmed crustaceans was conducted in 2000 to determine the presence or absence of white spot syndrome in Australia. Funding for the programme was provided by DAFF and sample collection was conducted by local jurisdiction government staff (East *et al.*, 2004).

Review of Australian aquatic animal health programmes and supporting legislation in this report are limited to the two major aquaculture states—South Australia and Tasmania.

[16] Furunculosis, infectious salmon anaemia, piscirickettsiosis, viral encephalopathy and retinopathy, viral haemorrhagic septicaemia, whirling disease, abalone viral ganglioneuritis, ostreid herpesvirus-1 µ var, withering syndrome of abalone.

Table 1. Relevant health surveillance strategies, objectives and results of AQUAPLAN 1998–2003, AQUAPLAN 2005–2010 and AQUAPLAN 2014–2019.

Programme/strategy	Objectives	Results
AQUAPLAN 1998–2003 (DAFF, 1999). Surveillance, monitoring and reporting.	To consolidate information on and protect Australia's aquatic animal health status, by: • facilitating the detection and reporting of, and response to, aquatic animal disease outbreaks; • facilitating the enhancement of existing, and development of additional, national and interstate disease control programmes and zoning policies; • supporting Australia's international disease reporting obligations to OIE; • supporting regional disease reporting to the Network of Aquaculture Centres in Asia and the Pacific (NACA).	• A review of existing surveillance and monitoring programmes for aquatic diseases (DAFF, 2002). • Development of standard diagnostic techniques for priority diseases and standard operating procedures for different aspects of diagnostic procedures (DAFF, 2002). • A national list of reportable diseases of aquatic animals (Table 2 & Table 3; DAWR, 2016a). State and territorial authorities are required to report any investigations into nationally reportable diseases to the federal government on a quarterly basis (Animal Health Australia, 2016). Disease reporting is confidential. The Office of the Chief Veterinary Officer manages the database and produces non-identifiable reports that are publicly available. A restricted-access email notification system has also been established for the confidential sharing of disease information (DAFF, 2002). • An aquatic animal disease field identification guide for the aquaculture industry (1st edition) (DAFF, 2002). • Development of a surveillance and monitoring template for the establishment of surveillance programmes (Cameron, 2002). • Raising disease awareness in recreational and commercial fisheries (DAFF, 2002). • Provision of training in aquatic animal health management to tertiary students (DAFF, 2002).
AQUAPLAN 2005–2010 (DAFF, 2005). Enhanced integration and scope of aquatic animal health surveillance in Australia.	• To identify needs and gaps with respect to surveillance requirements for specific industry sectors. • To develop cost-effective surveillance systems tailored to address the identified gaps and needs. • To have a surveillance information system that addresses the deficiencies found in the first two objectives, which is organised and readily accessible at a national level. • To improve investigation and reporting of major (wild) fish kills.	• A report on the surveillance capabilities of each jurisdiction and the surveillance needs of the major aquaculture sectors (Department of Agriculture, 2014a). • Development of an internet-accessible national aquatic animal pathogen and disease database, encompassing all published records and existing datasets of aquatic diseases in Australia (Australian Biosecurity Intelligence Network) (Department of Agriculture, 2014a).

Programme/strategy	Objectives	Results
	• To create a consistent system of aquatic animal disease laboratory diagnosis and reporting across Australia.	• Development of the national investigation and reporting protocol for fish kills (DAFF, 2007). • An updated aquatic animal disease field identification guide for the aquaculture industry (4th edition, DAFF, 2012). • Provision of an aquatic animal health training scheme for health professionals and post-graduates that ran from 2010–2013 (Department of Agriculture, 2014a). • Establishment of inter-laboratory diagnostic proficiency testing (Department of Agriculture, 2014a).
AQUAPLAN 2014–2019 (Department of Agriculture, 2014b). Enhancing surveillance and diagnostic services.	• Identify possible improvements to increase the sensitivity of Australia's passive surveillance systems for aquatic animal diseases. • Make the "Aquatic animal diseases significant to Australia: identification field guide" available as an application for mobile devices. • Undertake aquatic animal health benchmarking for specific aquaculture industry sectors. • Adopt processes (new or existing) for formal recognition of validation status of diagnostic tests and identify specific test validation priorities. • Develop stable positive control material and internal controls for molecular tests for detection of important endemic and exotic pathogens. • Develop validated diagnostic tests for significant new and emerging diseases of aquatic animals in Australia. • Improve the breadth of data in Australia's national aquatic animal disease information system, particularly histopathology slide collections. • Describe existing components of Australia's aquatic animal disease diagnosis network to identify interactions, responsibilities and performance measures.	• Development and publication of an electronic version of the aquatic animal disease field identification guide for mobile devices in the form of a phone application for android, iOS and windows operating systems.

5.1.1 South Australia

The main aquatic species cultured in South Australia are southern bluefin tuna (AUD$153.5 million[17]) and Pacific oysters (AUD$35 million[18]) (PIRSA, 2014). In 2014, there were 20 bluefin tuna licences, 22 marine finfish licences, 332 oyster licences, 38 mussel licences, 30 abalone licences and 112 other land-based licences in South Australia (PIRSA, 2014).

Disease surveillance in South Australia primarily depends on passive surveillance techniques, such as, routine farm biosecurity and health checks, legislated requirements to report notifiable diseases (Table 2 & Table 3), unusual mortalities and disease outbreaks. South Australia has an aquatic animal health programme that aims to ensure on-farm biosecurity protocols are in place, approve transfer permits, investigate fish kills and disease outbreaks, conduct passive disease surveillance, and prepare emergency response plans (PIRSA, 2016). Health checks are conducted prior to importation of live animals into the state, and for intrastate translocations and release of certain species[19] (Roberts, 2012; Gago, 2014; PIRSA, 2016).

Hazard-specific surveillance programmes are implemented by Primary Industries and Regions South Australia (PIRSA) on an ‘as needed’ basis, and are typically used to inform policy or to determine disease status (Roberts, 2012). For example, when PIRSA conducted a targeted surveillance programme for abalone ganglioneuritis in 2010–11, all aquaculture facilities and the southern zone fishery were sampled for the virus. Abalone ganglioneuritis was not detected by the surveillance programme and these results were used to support state translocation policies that require imported abalone into South Australia to be certified as disease-free (Herbert, 2012; Roberts, 2012). South Australia are historically free and currently remain considered free of OsHV-µvar, and they are in the process of implementing an active surveillance programme for the disease (Table 4).

South Australia does not have a government-owned animal health laboratory, but has a contract with a commercial laboratory to provide diagnostic services. PIRSA currently has two aquatic animal health staff, however one of these staff is only on a short-term contract to assist with the OsHV-µvar surveillance programme (Expert 3, pers. comm.).

5.1.2 Tasmania

Culture of salmonids dominates aquaculture production in Tasmania and in 2013–14 accounted for 95% of the total value of aquaculture (AUD$559 million[20]) produced in the state (Savage & Hobsbawn, 2015). Pacific oysters and mussels are also grown in Tasmania.

Historically, the Tasmanian salmon industry was free of serious infectious diseases due to the lack of native salmon, and the careful import and quarantine of eggs from NSW in 1983 to ensure that they were disease free (Hortle, 1988). Amoebic gill disease was the most serious disease in the 1980s, causing mortalities of up to 90%. The disease is now generally controlled by freshwater bathing (Gjovik, 1987), but is estimated to cost the Tasmanian industry AU$40 million per year in treatment costs and production losses (CSIRO, 2016). In recent years, a number of emerging pathogens have been identified in farmed salmon e.g., Tasmanian RLO (Morrison *et al.*, 2016), Tasmanian aquabirnaviruses (Mohr *et al.*, 2015) and pilchard orthomyxo-like virus[21] (Crane & Slater, 2016). All infectious diseases currently affecting Tasmanian salmonids have originated from existing animal populations within the

[17] NZ$163 million at current exchange rates.
[18] NZ$37 million at current exchange rates.
[19] *Lates calcarifer, Macquaria colonorum, M. novemaculeata, Oxyeleotris lineolatus, Tandanus tandanus.*
[20] NZ$588 million at current exchange rates.
[21] Also known as salmon orthomyxo-like virus.

state. No diseases are known to have been transferred to Tasmanian salmonids from interstate or overseas sources. With the exception of *Streptococcus* infection, there is evidence to suggest that increased contact with wild fish populations has caused endemic pathogens to establish in farmed salmonids (DPIPWE, pers. comm.).

Tasmania has previously undertaken three health surveillance programmes: the Tasmanian Salmonid Health Surveillance Programme (TSHSP), the Tasmanian Pacific Oyster Health Surveillance Programme, and the Abalone Biosecurity Programme. The TSHSP is a voluntary programme[22] that is jointly funded by the Tasmanian salmonid industry and the Tasmanian Department of Primary Industry, Parks, Water and Environment (DPIPWE) (TSGA, 2016). The programme, which has been running since 1993, is reviewed periodically by government and industry, and is continually adapted to meet the ongoing needs of the industry. Every year, a new programme agreement is entered between DPIPWE and industry that specifies the objectives of the programme, what will be achieved (e.g., how many samples will be tested per year), what services will be provided, and the cost of the programme (DPIPWE, pers. comm.).

The TSHSP has undergone a number of changes in objectives and sampling since its implementation in 1993.

- Initially, the TSHSP was focussed on substantiating freedom from exotic OIE-notifiable diseases for trade purposes. The programme involved the testing of healthy fish for exotic diseases coupled with site visits from a programme veterinarian. While this sampling provided good baseline information on which diseases are present/absent in Tasmania, the sampling was deemed to be excessive to requirements because the majority of Tasmanian salmon is sold on the domestic market and the fish sampled were not showing signs of clinical disease.
- In 2000, the TSHSP changed to the sampling of problematic endemic diseases, with the aim of describing the distribution of these diseases. To increase the probability of detecting pathogens, sampling and testing changed to investigate moribund fish only (as per Appendix 13.2.2), and site visits were conducted by a programme veterinarian. Data gathered by the programme in the 2000s demonstrated that a different suite of diseases occurred in each of the three finfish biosecurity zones in Tasmania, and supported the maintenance of the biosecurity zones.
- In 2008, the programme veterinarian position was dis-established due to the increasing use of company veterinarians by industry. The TSHSP now only entails enhanced passive surveillance where company veterinarians submit samples of suspected diseased fish to the laboratories for testing. The routine diagnostic tests used for screening (i.e., histopathology, bacteriology, virology) are suitable for detecting most new diseases (DPIPWE, pers. comm.; Table 5).

The Tasmanian salmonid industry has also developed its own biosecurity programme that aims to gain industry and government agreement on the minimum biosecurity practices undertaken within the industry (TSGA, 2014). All salmon farming companies in Tasmania have signed up to the biosecurity programme (Knight *et al.*, 2015; S. Percival, pers. comm.), and agree to comply with its mandatory requirements, immediately report and treat signs of infectious disease in fish, and obtain health certificates before moving fish between zones (TSGA, 2014)[23]. An industry-led Area Management Agreement (AMA) has also been implemented for salmon farmers in Macquarie Harbour (Anon., 2012; Table 5).

[22] All members of the Tasmanian Salmon Growers Association agree to participate in the TSHSP.
[23] The biosecurity programme is currently under review.

The Pacific Oyster Health Surveillance Programme is a joint government-industry initiative. The programme consisted of site visits and sample collection by DPIPWE staff, passive surveillance by farmers, and efficient communication between industry and government (DPIPWE, pers. comm.; Table 6). Initially, the programme tested Pacific oysters from farms and hatcheries within Tasmania, enabling them to be transferred to other regions in Australia without the need for additional batch testing. Following the detection of Pacific oyster mortality syndrome in New South Wales, hazard-specific surveillance for OsHV-µvar was added to the programme in 2011, with annual testing conducted in Tasmania, NSW and South Australia (Herbert, 2014; NSW DPI, no date). Despite the hazard-specific surveillance programme, the first record of OsHV-µvar in Tasmania was detected via farmer's reports in January 2016 (DPIPWE, 2016c). Program testing did provide data on the time and point of entry of the virus into Tasmania. The Pacific Oyster Health Surveillance Programme has been suspended since the outbreak of OsHV-µvar in Tasmania and replaced with hazard-specific surveillance for OsHV-µvar.Surveillance data supports the establishment and maintenance of three biosecurity zones in Tasmania based on disease risk (a disease free zone, an intermediate zone, and an infected area) (DPIPWE, pers. comm.). Stock movement within the state must have a permit and is not permitted from an area of higher risk to an area of lower risk (DPIPWE, 2016c).

The Tasmanian Abalone Biosecurity Programme was developed in response to the detection of abalone herpes virus in Victoria. The program actively tested farmed Tasmanian abalone for the virus from 2006 to 2010 to enable safe translocation of stock onto farms and to enable sale of abalone to interstate markets. It was concluded that abalone herpes virus was a naturally endemic virus in wild Tasmanian abalone population. Subsequently, the surveillance programme moved to an industry-wide biosecurity programme involving the wild fishing, aquaculture and processing sectors (Baulch *et al.*, 2013). Surveillance was reduced to the daily monitoring of sentinel abalone units that were exposed to the water exiting from all production tanks and diagnostic testing for abalone herpes virus twice per year (Ellard, 2016). Since the establishment of biosecurity measures, no further cases of AVG have been detected since 2011 (DPIPWE, pers. comm.).

5.2 CANADA

Over 60 aquatic species are cultured in Canada, though the aquaculture industry is predominantly based on salmonids, mussels and oysters (FVO, 2013). The industry comprises over 4,000 aquatic farms that generated CAN$733 million[24] in 2014, with the majority produced in British Columbia (CAN$412 million[25]) and New Brunswick (CAN$124 million[26]) (FVO, 2013; DFO, 2016c).

Aquatic disease surveillance in Canada is managed by both federal and provincial governments. Diseases that:

- pose a significant threat to international and interprovincial trade status and aquatic resources are the responsibility of the federal government;
- have the potential to cause significant production losses if they are not actively controlled are the responsibility of both federal and provincial governments;
- can be managed using husbandry, therapy and circumvention are the responsibility of industry and the provincial government (McGladdery & Zurbrigg, 2006).

[24] NZ$766 million at current exchange rates.
[25] NZ$431 million at current exchange rates.
[26] NZ$130 million at current exchange rates.

At a federal level, Canada established a National Aquatic Animal Health Programme (NAAHP (CA)) in 2005, which is managed by the Canadian Food Inspection Agency (CFIA). This programme was established partially in response to the EU Commission Decision 2003/804/EC (Official Journal of the European Union, L302/22) that blocked the export of live molluscs to the EU from Canada, resulting in a loss of CAN$1.4 million[27] in sales (CFIA, 2009). Subsequent investigation in British Columbia found that the province did not meet the export requirements to the EU because:

- it relied on a small number of samples to characterise the health status of shellfish for the whole province;
- there was a lack of accredited diagnostic laboratories;
- surveillance and record keeping by industry was inadequate;
- there were legislative gaps and inadequate federal oversight (CFIA, 2009).

These findings reinforced the need for a federally-led, risk-based aquatic animal health programme in order to substantiate freedom from disease. The NAAHP (CA) has three main components: import/export, domestic disease control, and disease surveillance (DFO, 2013c; 2016g). Programme outputs include:

1. Investigations into suspected occurrences of reportable[28] and immediately notifiable[29] diseases, and publicly available reporting of reportable disease occurrences (CFIA, 2016a).
2. Nationwide disease surveys and sampling plans for specific diseases, particularly exotic diseases or diseases that are likely to affect market access. Surveys are conducted by CFIA with partner organisations. The Department of Fisheries and Oceans (DFO) provides the diagnostic and laboratory support under the NAAHP (CA) (DFO, 2013c; L. Hammell, UPEI, pers. comm.).
3. Developing and maintaining sample collection procedures.
4. Analysing data to determine the likelihood of disease freedom (CFIA, 2015b).
5. A national introductions and transfers database. Introductions and Transfers Committees maintain information on movements within each state and report annually to the National Introductions and Transfers Coordination Office (part of DFO). Data are recorded on standard forms to ensure consistent information and ease of data entry (DFO, 2013c).
6. A web-based laboratory information management system (implemented in 2012), which allows total traceability and tracking of specimens from the point of collection to reporting of results (FVO, 2013).

While the NAAHP (CA) was established in 2005, it wasn't fully functional until around 2010–11 (L. Hammell, UPEI, pers. comm.). The average expenditure for the NAAHP (CA) for all federal partners between 2005 and 2013 was CAN$10 million/year[30] (Treasury Board of Canada, 2015).

The NAAHP (CA) is supported by the National Aquatic Animal Health Laboratory System (NAAHLS), which comprises four laboratories for disease diagnostic testing (DFO, 2016l;

[27] NZ$1.47 million at current exchange rates.
[28] Reportable diseases—these diseases are of significant importance to aquatic animal health or to the Canadian economy. Anyone who owns or works with aquatic animals and knows of or suspects a reportable disease is required by law to notify the CFIA.
[29] Immediately notifiable diseases—these diseases do not exist in Canada. Only laboratories are required to contact the CFIA regarding the suspicion or diagnosis of these diseases.
[30] NZ$10.7 million at current exchange rates.

Table 8). DFO manages the NAAHLS and provides diagnostic testing, research and scientific advice to support the programme. Early reviews of the NAAHP (CA) indicated that capacity and capability of the NAAHLS was stretched due to the increased number of samples derived from the NAAHP (CA) and the requirement for the National Reference Laboratories to develop quality management systems, validate diagnostic methods, and progress with accreditation processes (FVO, 2013; DFO, 2014c). Laboratory capacity and capability was increased by approving external laboratories to conduct work under the NAAHP (CA). DFO staff provide testing protocols, training of external laboratory staff and accreditation/ proficiency assessments. External laboratories must meet the criteria stipulated in CFIA's policy on the Approval of External Laboratories for the NAAHP (CA) (CFIA, 2016c).

This review of Canada's aquatic animal health programmes and supporting legislation is limited to the two major aquaculture provinces—British Columbia on the west coast and New Brunswick on the east coast. Public perception on salmon farming is very different on Canada's two coasts. On the west coast, there is very strong anti-farming lobbying from the public, while on the east coast, salmon farming is seen to make an important economic contribution to society. As a result, aquaculture regulation, disease surveillance, biosecurity and disease management methods are more extensive on the west coast (Expert 7, pers. comm.).

5.2.1 British Columbia

Farmed salmon comprises 94% aquaculture production by value in British Columbia, with three companies producing 88% of all cultured finfish in the province, and 70% of all the salmon cultured in Canada (FVO, 2013; Standing Senate Committee on Fisheries and Oceans, 2015a). In 2015, the total value of farmed salmon produced in the British Columbia was CAN$470 million[31] (Statistics Canada, 2016a).

Health and disease surveillance practices and regulations in British Columbia have been greatly influenced by the need to control disease outbreaks. Epizootic outbreaks of infectious hematopoietic necrosis (IHN) occurred in farmed Atlantic salmon in British Columbia in 1992–1996 and 2001–2003. Investigations of both epizootic outbreaks indicated that the spread of IHN among farms was most probably facilitated by poor biosecurity practices and the mixing of year classes (St-Hilaire *et al.*, 2002; Saksida, 2006). Following the 1992–1996 outbreak, the majority of affected companies implemented several voluntary measures to try and control the disease including: simultaneous fallowing; single year class stocking; disinfection of nets; increased fish health surveillance; and, vaccination[32] of smolts (St-Hilaire *et al.*, 2002; Karreman, 2006). While these measures appeared to have reduced the incidence and duration of IHN outbreaks, not all farmers implemented the voluntary measures, and IHN was still present at some farms (St-Hilaire *et al.*, 2002; Saksida, 2006). In 2001–2003 another outbreak of IHN occurred that resulted in infection rates of between 40% and 70% on farms, and losses of approximately 12 million fish (Karreman, 2006). In response to the 2001–2003 outbreak, the provincial government implemented a Fish Health Auditing and Surveillance Programme, and introduced fish health regulations as a condition of aquaculture licences, including the requirement that all licensees develop and adhere to Fish Health Management Plans[33] (Table 9) (Karreman, 2006).

[31] NZ$504 million at current exchange rates.
[32] It was subsequently found that the autogenous vaccine used was not completely effective with 17% of vaccinated populations still developing IHN (Saksida, 2006).
[33] Fish Health Management Plans became mandatory in 2004 (Karreman, 2006).

Aquaculture in British Columbia is now highly regulated. Since 2010, aquaculture regulation and enforcement in British Columbia has been the responsibility of the federal government[34] (DFO), under British Columbia's Aquaculture Regulatory Programme (BCARP). Specific programme areas relevant to fish health include:

- the development of operational policies;
- Integrated Management of Aquaculture Plans (DFO, 2013b);
- compliance evaluations for fish health and environmental performance;
- issuing of fish farming licences;
- enforcing aquaculture regulations.

Data collected under BCARP is publicly available and includes information on compliance, escapes, introductions and transfers, fish heath management and sea lice surveillance (DFO, 2013a). Fish farming licences issued from 2010 onwards are only valid for one year and licence conditions are reviewed annually. This allows DFO to quickly strengthen regulatory requirements, if required, and streamline reporting requirements (DFO, 2014a).

Marine aquaculture in British Columbia is currently managed on a province-wide scale, though the province does have distinct shellfish and salmonid transfer zones (DFO, 2015c). Transfers within a zone are generally permitted but transfers between zones or from other provinces requires a permit (DFO, 2016j). British Columbia also has established fish health zones but these are currently only used as divisional areas for the selection of farms for fish health audits and disease incidence reporting (DFO, 2015c), rather than being true aquaculture management areas.

Each licensee must prepare a Fish Health Management Plan that provides details of their: nominated fish health professional; routine health and disease surveillance; record keeping of health status; methods for preventing, controlling or treating disease; disposal of dead fish; biosecurity protocols; sanitisation methods; staff biosecurity training; and, mortality event procedures.

British Columbia's Fish Health Programme includes a Fish Health Audit and Surveillance component where DFO staff conduct farm audits. During an audit, inspectors review the farm biosecurity procedures, feed and medication, water quality monitoring, carcass retrieval, fish health records, sea lice, fish handling and disease outbreak emergency plans. Inspectors also collect samples of recently dead fish approximately every six months, to verify the farm veterinarian's routine disease surveillance results, and to test for specific reportable diseases (DFO, 2014d).

Management of sea lice is a major component of fish health surveillance in British Columbia, though it is not typically a health problem on farms (L. Hammell, UPEI, pers. comm.). In 2003, the provincial government implemented a sea lice surveillance programme in response to research that demonstrated that lice from farmed salmon were having a negative impact on wild salmon (Morton & Williams, 2003; Saksida *et al.*, 2011). As part of the surveillance programme, farmers are required to inspect fish on a regular basis and report the results to the authorities. DFO staff also conduct random site visits to validate the accuracy of farmers' lice counts. If lice numbers exceed an average of three motile lice per fish then farmers are required to apply appropriate treatment methods and increase the frequency of inspections

[34] British Columbia's Supreme Court transferred the responsibility of the management of salmon farming in BC from the provincial government to the federal government in 2009 following Morton vs. British Columbia 2009 BCSC 136.

(Table 10). The threshold of three lice was not based on any scientific evidence, but was an arbitrary threshold agreed by government and industry as a level that would allow precautionary management while more research was being conducted. This threshold is very stringent and is based more on public pressure rather than any scientific evidence for disease spillover to wild fish (Saksida *et al.*, 2011; B. Diggles, DigsFish Services, pers. comm.) (Table 26).

Hazard-specific surveillance programmes are sometimes conducted in addition to the Fish Health Audit and Surveillance Programme. For example, in 2006–2009, CFIA conducted a survey of farmed and wild Pacific oysters and Manila clams in British Columbia for numerous commercially significant diseases. The primary objective of the survey was to establish disease-free status of specific shellfish diseases in the province (CFIA, 2009). Similarly, in 2012–2014, CFIA conducted a survey of wild salmonids in British Columbia for three significant viruses (infectious salmon anaemia virus (ISAV), infectious pancreatic necrosis virus (IPNV) and infectious haematopoietic necrosis virus (IHNV)) to substantiate disease-freedom in the province or in certain geographic areas (CFIA, 2014a; Table 11 & Table 12).

Fish farms in British Columbia are required to have a fallow period if they do not meet certain environmental criteria, and restocking of net-pens is not permitted until measured environmental parameters are below threshold criteria (Finfish Aquaculture Waste Control Regulation (BC)). Fallowing also assists with disease management by breaking the transmission cycle and reducing the number of pathogens at the farm site. At any one time, approximately 50% of licenced fish farms are active in the province (DFO, 2015a).

5.2.2 New Brunswick

Atlantic salmon farming began in New Brunswick in 1979 (Anon., 2015a) and it now comprises 95% of the aquaculture production value in the province, with the Eastern oysters (*Crassostrea virginica*) making up most of the remainder (4.6% of value) (Standing Senate Committee on Fisheries and Oceans, 2015a). Aquaculture in New Brunswick is primarily regulated by the New Brunswick Department of Agriculture, Aquaculture and Fisheries (DAAF). In 2014, the total value of farmed salmon in New Brunswick was CAN$118 million[35] (Statistics Canada, 2016b). Salmon farming occurs within a very confined space in New Brunswick with all marine farms located within 50 km of one another. Presently, there are only three salmon companies farming in New Brunswick (S. McGeachy & K. Brewer, DAAF, pers. comm.).

Infectious diseases, including ISA, bacterial kidney disease (BKD), furunculosis and vibriosis have been problematic for the New Brunswick finfish industry (DFO, 2003), and aquaculture legislation in the province has been greatly influenced by the need to manage disease outbreaks (Table 14). For example, an outbreak of ISA in the Bay of Fundy in 1997–1998 prompted the development of mandatory Bay Management Areas (BMA). Farming practices at the time, such as the high density and close proximity of farms, multi-year class culture, and the sharing of equipment and personnel between sites most likely contributed to the spread of ISA among farms (Hammell & Dohoo, 2005). The ISA outbreak decreased production by around 20% in 1998 and forced several farms to destroy all their stock and fallow their sites (Chang *et al.*, 2014). More than 5.7 million fish were destroyed between 1997 and 2001 to try and control the spread of ISA (McGeachy & Moore, 2003). It is estimated that ISA has cost both government and industry more than CAN$100 million[36] since 1999 (DAAF, 2010).

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[35] NZ$126 million at current exchange rates.
[36] NZ$105 million at current exchange rates.

As a result of the ISA outbreak, the Government of New Brunswick introduced an ISA management and control programme in 1998 that included active monthly surveillance for ISA and numerous biosecurity measures, such as, improving harvesting practices, controlling fish movements and implementing better cleaning and disinfection protocols. In 2000, to further control ISA, BMAs were implemented to support single year class farming (Standing Senate Committee on Fisheries and Oceans, 2015a; S. McGeachy & K. Brewer, DAAF, pers. comm.). Initially, 22 BMAs were formed that had a two year rotation system. Within each BMA, farmers were allowed to hold market fish and were only allowed to introduce smolt into the area every second year (DAAF, 2000). However, despite the implementation of BMAs, fish continued to be affected by ISA. Research found that the BMA policy had two major flaws from a disease prevention perspective: 1) the policy allowed for up to 20% of market size fish to be held on site when the new smolts were introduced, and 2) fallowing between year classes was not mandatory or concurrent for the whole bay (Chang *et al.*, 2014; S. McGeachy & K. Brewer, DAAF, pers. comm.). In 2006, hydrographical modelling data were used to amalgamate the 22 BMAs into three larger BMAs that had minimal overlap of mixing zones. Furthermore, a three year stock rotation with mandatory, synchronised fallowing of the whole BMA was implemented to reduce the transmission of ISA (Chang *et al.*, 2007). The mandatory fallowing period is four months per site and two months for an entire BMA, although in practice, fallowing is often around one year (DFO, 2010). Each year, one third of all sites are left to fallow, one third receive smolts, and one third hold product to be harvested that year. Within each BMA, farmers are required to coordinate health management activities (DFO, 2010). Since implementation of the new BMA scheme, ISA HPRΔ has only been detected (and rapidly eliminated) in New Brunswick on six occasions[37] (Chang & Page, 2010; CFIA, 2016d). Farmers are now very proactive about rapidly harvesting affected pens, and the disease is quickly eliminated from farms (Smith, 2016; S. McGeachy & K. Brewer, DAAF, pers. comm.).

In 2009, New Brunswick introduced a Marine Finfish Health Policy (DAAF, 2009) that stipulates the routine testing of farmed fish for certain diseases of concern, as well as a whole suite of other measures such as:

- on-farm biosecuritypractices;
- a requirement for diagnostic testing prior to movement;
- operational standards and a certification and audit programme for harvest vessels;
- operational standards for processing facilities.

As part of the programme, DAAF staff conduct site audits of biosecurity and fish health plans (Table 14).

Similarly, the need to control sea lice infestations has guided the development of sea lice regulations. The first major outbreak of sea lice in the New Brunswick salmon industry occurred in 1994. As a result, DAAF established 10 sea lice management zones with synchronised administration of in-feed anti-lice treatment within each zone. The costs of sea lice (treatment and disease related costs[38]) was estimated to increase total production costs by around 3% (Mustafa *et al.*, 2001). However, local lice populations became increasingly resistant to the anti-lice treatment, SLICE® (emamectin benzoate) over time. Consequently, DAAF, fish health experts and industry began researching alternative methods for controlling sea lice. In 2011, DAAF implemented the Integrated Pest Management Programme for Sea

[37] Two occasions in 2015 and four occasions in 2016.
[38] Reduced growth, reduced FCR, downgrading, secondary disease and mortality.

Lice Prevention that includes the use of non-chemotherapeutant control strategies such as BMAs, single year class culture, fallowing, the use of cleanerfish and sea lice traps to reduce the quantity of therapeutants required (ACFFA, 2013; Brewer-Dalton, 2013; Table 15).

Shellfish

New Brunswick have also recently developed a health policy and surveillance programme for shellfish aquaculture (DAAF, 2015; Table 16), which specifically addresses shellfish diseases of commercial significance that are not covered by the NAAHP (CA). To date, the New Brunswick shellfish industry have not experienced any major disease outbreaks, but government are trying to implement a biosecurity and surveillance programme prior to a major outbreak occurring, or as interviewees put it "*during peace time*" (S. McGeachy & K. Brewer, DAAF, pers. comm.).

Case study: Issues with the development of the management of ISA in eastern Canada (L. Hammell, UPEI, pers. comm.).

When the ISA first appeared in eastern Canada there was limited knowledge within government and industry on how to manage the disease, and the existence of ISAV-HPR0 was unknown.

Initial attempts to control the disease were hampered by:

1. Farming practices at the time (multi-year class culture, close farm proximity and lack of fallowing), and variable biosecurity practices in the industry.
2. Lack of correlation between positive diagnostic results and mortality on the farm (the existence of ISAV-HPR0 was unknown then). Consequently, there was variable consistency in industry actions. Some farmers would rapidly depopulate a cage based on one positive (unconfirmed) test result because they were convinced that early depopulation of the first cage saved other cages from being affected, while other farmers noticed that positive results were not well correlated to mortality, and chose to continue to rear fish.
3. A lack of financial compensation for culled fish. This meant that while farmers were willing to cull the infected cage, they were unwilling to cull the neighbouring four or five cages that were likely to have been exposed to the disease.
4. Some farmers initially thought that the cost of the disease was going to be less than the cost of culling fish, and thus, would not cull fish or would try and rear infected fish for a few more months in order to grow fish to reach a marketable size.
5. Poor quality control among diagnostic laboratories, with variable results produced by different laboratories.

Industry health managers were convinced of the benefits of rapid depopulation and industry would often decide to rapidly depopulate an affected cage based on the result of one positive test. While this method is effective in terms of disease control, it probably also cost the industry a significant amount of money from the culling of fish based on false positives. Researchers convinced the government that evidence-based surveillance was needed to help with disease management, and the federal government funded several research projects with ISA epidemiology as an early focus. This lead to a much better understanding on the different ISAV genotypes, the sensitivity and specificity of diagnostic tests, and disease transmission pathways, enabling more effective use of surveillance results.

In 2010, the federal government developed a national programme that addressed ISA surveillance requirements for international reporting and regulated control actions. Financial compensation was provided to farmers for culled fish, but in order to qualify for compensation, positive screening results had to be confirmed by virus culture, which resulted in delayed confirmation. The federal government also implemented more stringent biosecurity controls including: certification of processing plants and harvest vessels to ensure that they did not inadvertently spread ISA, and the requirement to cull a much larger number of fish in a confirmed case.

Industry infrastructure was frequently challenged to deal with the need to cull around 500,000 fish over a short period, resulting in insufficient approved equipment or processes to cope with the large volumes. Consequently, there were sometimes undesirable delays before affected fish were culled. The federal government wanted to implement the best biosecurity measures, but the industry surge capacity was not always available to ensure rapid removal of all infected fish in a manner that was verified as biosecure. Industry experience indicated speed of depopulation was critical to disease control but the new ISA programme compromised the speed with which farms could be depopulated.

By about 2014, federal government stepped back, and left the ISA surveillance and control programme to the Atlantic provincial governments and industry. Provincial authorities will now be challenged to ensure industry follows appropriate protocols if another outbreak occurs.

Key lessons learnt from this experience are that sufficient scientific knowledge is required for effective disease control, but implementation of the best biosecurity practices can be ineffective if they are not practical or insufficient resources are available.

5.3 UNITED STATES OF AMERICA

In 2013, aquaculture in the United States (US) was worth US$1.4 billion and comprised around 3,000 aquatic farms that primarily culture freshwater catfish (US$391 million), Atlantic salmon (US$105 million), freshwater crawfish (US$144 million), oysters (US$157 million) and clams (US$122 million)[39] (USDA, 2014; National Marine Fisheries Services, 2015). Washington is the largest aquaculture producing state in the US. In 2013, Washington generated US$233 million[40] of aquaculture products, primarily salmon, clams, mussels and oysters (USDA, 2014). Washington and Maine are the largest salmon producing states in the US, while Alaska has substantial hatchery production of salmon for the enhancement of wild stocks (Goldburg *et al.*, 2001).

On a national level, marine aquaculture in the US is guided by a national strategic plan that outlines how government organisations will "*provide science, services and policies to support the significant expansion and sustainability of U.S. marine aquaculture*" (NOAA, 2015). In relation to disease and biosecurity, the goals of the national strategic plan are to:

- support federal partners in strengthening capacity for responding to health issues by improving diagnostic tools, preventative measures and treatments;
- work with federal partners and industry to implement the National Aquatic Animal Health Plan (NAAHP US);
- support federal partners to ensure effective aquatic animal health management.

Between 2001 and 2008, federal, local, state and tribal authorities worked with stakeholders to develop a NAAHP (US) in response to the need for a coordinated government effort to ensure good aquatic animal health management practices. Twelve technical group meetings were held that focussed on specific health issues, with input from authorities, industry and researchers. Outcomes of these technical meetings were used to draft chapters of the NAAHP (US) (National Aquatic Animal Health Task Force, 2008). Development of the plan cost

[39] Currency values are NZ$1.92 billion for total aquaculture, NZ$536 million for catfish, NZ$140 million for salmon, NZ$198 million for crawfish, NZ$215 million for oysters and NZ$122 million for clams, at current exchange rates.
[40] NZ$320 million at current exchange rates.

US$375,000[41] per year (K. Amos in Bondad-Reantaso *et al.* (2005)). The NAAHP (US) recommends how aquatic animal health should be managed in the US, but it is not a mandatory regulation. The plan covers aquatic diseases of concern, surveillance, methods of disease prevention, control and management, zonation, research needs, education and training needs of the sector, and public outreach (National Aquatic Animal Health Task Force, 2008).

Implementation of outputs under the NAAHP (US) are primarily instigated by the US Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), the National Oceanic and Atmospheric Administration (NOAA) Fisheries Services, and the US Fish and Wildlife Service. The plan has facilitated the:

1. Development of a National Aquatic Animal Pathogen Testing Network (NAAPTN)—to provide oversight and training of existing animal health laboratories[42] that conduct aquatic diagnostic testing. The aim of the NAAPTN is to improve confidence in diagnostic results for the reporting of aquatic animal diseases, control of stock movements, and international trade (NOAA, no date).
2. Increased use of information technology—implementation of a nationwide database to increase efficiencies around interstate and international trade and stock movement.
3. Establishment of a Federal Advisory Committee for aquatic animal health.
4. Development of Commercial Aquaculture Health Programme Standards (CAHPS)—voluntary, non-regulatory, science-based standards for the improvement and verification of the health of aquaculture animals. These standards are still in the process of being developed by APHIS Veterinary Services and the National Aquaculture Association. The five main principles of the programme are that farmers:
    a) utilise the expertise of an aquatic animal health team;
    b) characterise and mitigate disease risk and develop a site-specific health plan;
    c) develop appropriate surveillance plans;
    d) establish investigation and reporting procedures for unusual morbidity or mortality;
    e) develop processes and infrastructure capable of responding to a disease outbreak (APHIS, 2015b; 2015a; Hartman, 2015; NOAA, no date).

There has been a lot of industry interest in CAHPS that appears to be driven by a number of reasons including: branding for marketing purposes; a better understanding of disease; and pressure from trade partners. APHIS is currently trialling CAHPS with some pilot groups that are provided with one year's free diagnostic testing and help with their biosecurity and surveillance plans (L. Gustafson, APHIS, pers. comm.).

The US also has a nationwide National Animal Health Monitoring System (NAHMS) that collects, analyses and disseminates data on animal health management to assist with disease prevention. However, few aquaculture studies have been conducted under the NAHMS over the last 10 years, and the few that have been conducted have focussed on catfish (APHIS, 2016c).

[41] NZ$513,000 at current exchange rates.
[42] USA has a National Animal Health Laboratory Network of 61 laboratories comprising two USDA National Veterinary Services Laboratories and numerous state and university laboratories. The National Veterinary Services Laboratories coordinates activities, participates in method validation, and provides training, proficiency testing and assistance for diagnostic tests. State and university laboratories conduct routine diagnostic tests and help develop new assay methods (APHIS, 2016b).

The federal government, in collaboration with state governments, sometimes conducts hazard-specific surveillance programmes for aquatic diseases in response to serious disease outbreaks or due to trade-related concerns (L. Gustafson, APHIS, pers. comm.). For example, in 2011 reports of ISA occurring in wild fish in British Columbia were made by university researchers. Although these diagnoses were never confirmed, APHIS and various Pacific Northwest state authorities initiated a survey of wild fish in Alaska and Washington, and farmed fish from Washington. Between 2012 and 2015, over 4,000 fish were tested for ISA with no positive results (Amos *et al.*, 2014; APHIS, 2016d).

Regulation and enforcement of aquaculture is generally the responsibility of state and territorial governments, and disease and health surveillance programmes vary among states.

Review of state aquatic animal health programmes and supporting legislation in this report is limited to three states: Washington and Maine—the two major salmon producing states; and Alaska—a major producer of juvenile salmonids for wild enhancement.

5.3.1 Washington

The main aquatic species grown in Washington are Atlantic salmon, Manila clams (*Ruditapes philippinarum*), Mediterranean mussels (*Mytilus galloprovincialis*), and Pacific oysters (USDA, 2014). Washington is the leading United States producer of farmed bivalves, valued at US$92 million in 2013 (Decker, 2015). There are only 14 food fish farms in Washington[43] (USDA, 2014), but the state has one of the largest salmonid hatchery programmes in the world, with around 150 hatcheries operated by the Washington Department of Fish and Wildlife (WDF&W; 83 hatcheries), treaty tribes (51 hatcheries) and the federal government (12 hatcheries) (WDF&W, no date). The vast majority of hatcheries produce fish for wild enhancement, and it is estimated that hatchery fish comprise between 75–90% of the total harvest of coho salmon, Chinook salmon and steelhead trout by commercial fishers in Washington (Nash, 2001).

The WDF&W is the lead regulatory authority for disease control in fish, shellfish and the protection of wildlife. The Treaty Tribes of the State of Washington are co-managers of the state's fisheries resource with WDF&W, and thus, have input into the state's disease control regulations (Nash, 2001). The Northwest Indian Fisheries Commission (NWIFC) also has its own fish health programme and laboratory, which provides additional support, training and disease surveillance and diagnostic services for tribal-operated hatcheries (NWIFC, 2006).

In Washington, all salmonid hatcheries and farms must comply with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (NWIFC/WDF&W, 2006 and Table 18). The disease control policy is primarily aimed at preventing the transfer of diseases around the state via the breeding and release of salmonids (Table 18). Routine testing of marine fish in the grow-out stage is not mandatory in Washington (Amos *et al.*, 2014).

There is substantial movement of shellfish stock in and out if the state of Washington. For example, a batch of stock may be bred in Washington, shipped to Hawaii as larvae for settlement, shipped to California as seed for out-growing, and then shipped back to Washington for final on-growing (Expert 6, pers. comm.). Annual diagnostic testing is required for all shellfish hatcheries in Washington, and diagnostic testing is required for aquaculture stock imported into the state[44], and for some stock moved within the state (Table 19). There is limited disease surveillance of grow-out shellfish stock in Washington (Expert 6, pers. comm.).

[43] The value of the state's salmon industry is unavailable to protect the privacy of the few companies involved (USDA, 2014).
[44] Excluding market-ready stock that is intended for immediate human consumption and will not come into contact with state waters.

5.3.2 Maine

Aquaculture in Maine was worth US$57.3 million[45] in 2013, with the vast majority of the value due to the production of Atlantic salmon[43] (USDA, 2014). Blue mussels (*Mytilus edulis*) and American oysters (*Crassostrea virginica*) are also cultivated in the state (SMDMR, no date).

Regulation of aquatic diseases in Maine is the responsibility of the State of Maine Department of Marine Resources (SMDMR) and the State of Maine Department of Environmental Protection (SMDEP). The need to control ISA in Atlantic salmon in Maine has strongly influenced legislation and surveillance. This disease was first found in Maine in 2001 and resulted in the destruction of 1.5 million infected fish in 2001–02, and farmers' losses of around US$20 million[46] (Belle, 2003). In 2002, federal and state partners began a surveillance and control programme for ISA. Between 2001 and 2007, the US government spent US$8.6 million on implementing the surveillance and control programme (including the cost of partially[47] reimbursing farmers for destroyed fish) (Miller, 2003; APHIS, 2016d). Participation in APHIS's ISA surveillance programme is voluntary at a federal level but was made mandatory in Maine shortly after the ISA outbreak (L. Gustafson, APHIS, pers. comm.).

Measures that were implemented in 2002 to control ISA included:

- the voluntary implementation of Finfish Bay Management Agreements by all private salmon farmers in the high risk areas (MAA, 2002; Belle, 2003; T. Robinson, APHIS, pers. comm.);
- single year class stocking at sites in the high risk areas (MAA, 2002; Belle, 2003; T. Robinson, APHIS, pers. comm.);
- fallowing of sites for 30–60 days by commercial salmon companies (MAA, 2002; Belle, 2003; T. Robinson, APHIS, pers. comm.);
- specific regulations on mandatory virus testing and control of ISA (13 188, Ch 24, §21G and Table 21);
- implementation of control zones;
- development of ISA Programme Standards that specify surveillance, testing procedures, and control measures for the virus (APHIS, 2010);
- deployment of a field team of four staff to run the ISA programme in Maine. The presence of a field team located near the salmon farms allowed ISA programme staff to visit the farms frequently, get to know farmers and respond quickly (L. Gustafson, APHIS, pers. comm.);
- integrated pest management of sea lice to reduce the risk of ISAV transmission (M. Nelson, SMDMR; T. Robinson, APHIS, pers. comm.).

There have been no confirmed cases of ISA in Maine since 2006, though a non-pathogenic ISAV strain (HPR0) is occasionally detected in both wild and cultured fish (APHIS, 2016c). The ISA surveillance programme was able to provide very early detection of the virus that allowed affected cages to be depopulated quickly. Early depopulation combined with

[45] NZ$80 million at current exchange rates.
[46] NZ$28 million at current exchange rates.
[47] Farmers were given 60% of the value of the fish in the first year and 40% in the second year (L. Gustafson, APHIS, pers. comm.).

fallowing and bay management strategies enabled initial elimination of ISA (L. Gustafson, APHIS, pers. comm.).

Aquatic health and disease surveillance in Maine is now highly regulated, with specific sections dedicated to fish health inspection in the Importation of Live Marine Organisms Regulations (Salmonid Fish Health Inspection Regulations (13 188, Ch. 24, §21) and Marine Fish Health Inspection Regulations (13 188, Ch. 24, §30) (Table 21).

5.3.3 Alaska

Aquatic farming in Alaska is primarily based on the hatchery production of salmonids for the enhancement of wild stocks, and the farming of Pacific oysters (*Crassostrea gigas)*, blue mussels, geoducks (*Panopea generosa*) and Pacific little neck clams (*Leukoma staminea*). The farming of finfish in Alaska has been prohibited since 1988, apart from the non-profit hatchery production of salmonids for wild enhancement. Approximately 1.5 billion smolt are released into the wild each year, which is estimated to contribute nearly 30 million fish to the commercial fishery (Alaska Sea Grant, 2016). Pink salmon (*Oncorhynchus gorbuscha)* (57%) and chum salmon (*O. keta*) (35%) are the main species produced, with much smaller quantities of sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*) and Chinook salmon (*O. tshawytscha*) produced (McGee, 2004). Nearly all Alaska salmonid hatcheries are operated by private non-profit corporations that are self-funded through the sale of a portion of the captured returning fish (T. Meyers, Alaska Department of Fish and Game (ADF&G), pers. comm.).

Alaska has a general policy for fish and shellfish health and disease control that is primarily focussed on limiting the transfer of diseases around the state by testing stock prior to transfers or release into the wild (Meyers, 2014; Table 23). Importation of all fish stocks for aquaculture purposes is prohibited in Alaska, with the exception of Pacific oyster seed[48] from certified disease-free hatcheries in the Pacific Northwest (5 AAC 41.070). This restriction has been extremely significant in lowering the risk of introducing exotic finfish or shellfish pathogens into the state (T. Meyers, ADF&G, pers. comm.).

5.4 NORWAY

Aquaculture in Norway is almost entirely based on Atlantic salmon and rainbow trout (*Oncorhynchus mykiss*), with these two species accounting for 94.5% and 5.2% of the total volume produced in 2015, respectively. Nearly 1.4 million tonnes of aquaculture produce was sold in 2015, generating NOK$46.7 billion[49] (Directorate of Fisheries, 2016a).

Aquaculture practices and regulation in Norway have been greatly influenced by the need to control disease outbreaks. In the 1980s, the Norwegian aquaculture industry experienced epizootic outbreaks of bacterial infections such as vibriosis, cold water vibriosis and furunculosis, which resulted in high mortalities and a major increase in the use of antibiotics (Grave *et al.*, 1988). Several methods have been implemented to control bacterial infections while reducing the industry's requirement for antibiotics. These include:

- development of effective vaccines by the pharmaceutical industry and widespread use of these by the industry;
- single year class production with mandatory fallowing between production cycles;
- zoning and spatial rearrangement of the farms by the government to minimise the horizontal transmission of disease (minimum of 3 km distance between farms);

[48] Aquaculture of Pacific oysters in Alaska is totally dependent on hatchery spat because Pacific oysters do not spawn in the cold Alaskan waters (RaLonde, 1992).
[49] NZ$7.7 billion at current exchange rates.

- selective breeding for increased disease resistance;
- increased sanitary measures implemented through regulations e.g., daily collection of dead fish, prohibition of movement of fish among sites, disinfection of well-boats between shipments and disinfection of seawater intake in smolt farms (Lyngøy, 2003);
- increased disease surveillance.

These measures have been very successful in controlling bacterial disease outbreaks, and antibiotic usage has decreased from 48 tonnes in 1987 to around 1 tonne per annum since the late 1990s (Lyngøy, 2003; Håstein & Gudding, 2005; Midtlyng *et al.*, 2011).

Viral disease outbreaks have also been a problem for the Norwegian aquaculture industry. In the 1980s and 1990s, outbreaks of IPN and ISA resulted in high mortalities of farmed salmon (Jarp *et al.*, 1995; Jarp & Karlsen, 1997). ISA was first found in Norway in 1984 with peak mortalities recorded in 1990 (Alvial *et al.*, 2012). Losses due to ISA were estimated to cost NOK$100 million[50] per year (Hastings *et al.*, 1999), and overall (direct and indirect) losses to disease is estimated to cost the aquaculture industry €246[51] million in 2004 (Aunsmo *et al.*, 2006). Regulatory action to control disease outbreaks include:

- creating temporary management zones and prohibiting movement of stock between zones;
- restricting contact between farms;
- mandatory diagnostic testing and surveillance;
- a requirement for fish health certificates prior to stock transfers;
- destruction of stock;
- disinfection of equipment;
- mandatory fallowing for six months;
- disinfection of ballast and transport water from well-boats used for the transport of stock to be destroyed;
- disinfection of all processing plant effluent water and waste;
- sharing information on the infected site among industry (Rolland, 2006; Alvial *et al.*, 2012; Hjeltnes *et al.*, 2016) (Table 25).

Sea lice has been an issue in Norway almost since salmon farming began in the 1960s. Sea lice are currently the biggest threat to Norwegian salmon farming (Lillehaug *et al.*, 2016), costing the industry around €131 million[52] in 2006 (Costello, 2009). Farmers initially managed sea lice infestations with chemotherapeutants, but it became increasing obvious that *ad-hoc* application of chemotherapeutants was not effective in controlling lice populations. Overuse of anti-lice chemotherapeutants facilitated the development of drug resistance in lice, increased fish mortality, and reduced fish growth (Midtlyng *et al.*, 2011; Liu & Bjelland, 2014). In 1997, Norwegian authorities developed a National Action Plan against sea lice to try and manage these parasites more effectively. The legislation around the mandatory surveillance and treatment of sea lice has been refined over the years (Ritchie & Boxaspen, 2011) (Table 26).

[50] NZ$16.6 million at current exchange rates.
[51] NZ$376 million at current exchange rates.
[52] NZ$200 million at current exchange rates.

Norwegian aquatic disease experts believe that voluntary Codes of Practice are ineffective at controlling infectious diseases (Håstein & Gudding, 2005; Midtlyng *et al.*, 2011). The first fish disease legislation in Norway was established in 1968, and today, aquaculture in Norway is very highly regulated with numerous acts and regulations covering various issues relevant to fish health and disease surveillance (Håstein & Gudding, 2005; Directorate of Fisheries, 2016b) (Table 25).

The Norwegian Veterinary Institute[53] and the Food Safety Authority have conducted several hazard-specific surveillance programmes for aquatic diseases, primarily to substantiate freedom from disease in Norwegian farms and regions. These hazard-specific surveillance programmes include surveys for: BKD between 2005–2011 (Nilsen *et al.*, 2012); pancreas disease (Gjevre *et al.*, 2016c); and for *Gyrodactylus salaris* infections (Hytterød *et al.*, 2015a) (Table 27 & Table 28). The coordination of the surveillance programmes, sampling, diagnostics and reporting is conducted by the regulatory authorities or institutes that are contracted by the authorities. Other surveillance programmes (viral haemorrhagic septicaemia (VHS), IHN, piscine orthoreovirus) are risk-based. Routine collections are not made, but suspicious samples are tested for the targeted diseases (Gjevre *et al.*, 2016a; Gjevre *et al.*, 2016b).

5.5 SCOTLAND

Aquaculture in Scotland is dominated by the production of Atlantic salmon with over 171,000 tonnes produced in 2015. Smaller quantities of rainbow trout (8,588 tonnes), mussels (*M. edulis, M. trossulus, M. galloprovincialis* and their hybrids) (7,270 tonnes) and Pacific oysters (2,693 tonnes) are also produced (Munro & Wallace, 2016a; 2016b).

The EU Council Directive 2006/88/EC is the overarching legislation on aquatic health in the United Kingdom, including Scotland. Council Directive 2006/88/EC is implemented in Scotland by the Aquatic Animal Health (Scotland) Regulations 2009. Regulation of fish health in Scotland is administered and carried out by Marine Scotland. The Fisheries Health Inspectorate (FHI), which is a division of Marine Scotland, conducts farm inspections, provides diagnostic services, and is responsible for disease response strategies (Fofana & Baulcomb, 2012; The Scottish Government, 2015c). Scotland also has an industry-government working group, the Aquaculture Health Joint Working Group, that makes recommendations to government and industry on improvements to aquatic animal health, welfare and management (Spreiji, 2005).

Aquatic disease and health surveillance in Scotland is risk-based, where high risk farms are inspected more frequently than low risk farms. Risk assessments are conducted by FHI inspectors with farm risk categorised by the:

- frequency of stock movements on and off the farm, and the number of suppliers;
- water source and whether the farm is an open or closed system;
- susceptibility of the cultured species;
- proximity of the farm to processing plants, or whether the farm has on-site processing;
- disposal practices of fish;
- use of unpasteurised feeds;
- whether the farm shares staff and equipment with other sites;

[53] The Norwegian Veterinary Institute is a government agency.

- biosecurity practices of the site, including compliance with the Code of Good Practice (Scottish Salmon Producers Organisation, 2015);
- the disease history of the site (The Scottish Government, 2016b).

Typically, high risk farms are inspected annually, moderate risk farms are inspected biennially, and low risk farms are inspected every three years for finfish and every four years for shellfish (The Scottish Government, 2014; 2016b; N. Purvis, Marine Scotland, pers. comm.). Samples may be taken for diagnostic testing where there is evidence of increased and/or unexplained mortality, the presence of clinical signs of disease, or a suspicion of the presence of a listed disease. In situations where there are no clinical expression of disease[54], statutory sampling would be undertaken in accordance with the diagnostic manual (Commission Implementing Decision (EU) 2015/1554)[55]. However, there are no situations in Scotland where this is currently being undertaken (N. Purvis, Marine Scotland, pers. comm.).

The rationale behind this approach is that routine, mandatory diagnostic testing is not considered justifiable where disease freedom has been established and biosecurity measures exist to reduce the risk of disease introduction. The surveillance programme, which mainly comprises inspections (and diagnostic testing as needed), is supported by intelligence-led and passive surveillance initiatives (N. Purvis, Marine Scotland, pers. comm.).

In the event of an outbreak of a listed disease, FHI designates control and surveillance zones, inspection frequency is increased, and hazard-specific diagnostic sampling and improved biosecurity measures are implemented. Epidemiological investigations are conducted to establish the extent of disease spread. Actions are taken to ensure appropriate control measures are in place, and where possible, eradication of the pathogen to regain disease freedom (Murray *et al.*, 2010; N. Purvis, Marine Scotland, pers. comm.) (Table 30).

ISA is a disease of concern for Scotland, though the country is currently declared free of the disease (The Scottish Government, 2015a). ISA was first confirmed in Scotland in 1998 with a major outbreak of the disease occurring throughout the country and lasting 14 months. Transport of live fish around the country via well-boats is thought to have facilitated the rapid spread of the disease (Murray *et al.*, 2002). The disease was eventually eradicated from Scotland but it required the slaughter of 4,400 tonnes of fish and was estimated to cause losses of around £38 million[56] (The Royal Society, 2002).

Following the ISA outbreak, Scotland implemented a number of methods to prevent disease introduction and spread, including: the formation of disease management areas; a voluntary Code of Good Practice for ISA (Fisheries Research Services, 2000), and a well-boat disinfection guide (Fraser *et al.*, 2006). The efficacy of these methods was demonstrated by the rapid detection, containment and eradication of a second ISA outbreak that occurred in the Shetland Islands in 2008–09 (Scott, 2010). The 2008–09 outbreak was diagnosed within a week of the initial inspection, which was prompted by a report of unusual mortality. The disease was contained to one disease management area, which was completely depopulated within seven weeks of disease confirmation, and then fallowed for at least six months (Murray *et al.*, 2010). The disease was successfully eradicated from the Shetlands, and following two years of surveillance and testing, Scotland was re-declared as ISA-free (Murray *et al.*, 2010; The Scottish Government, 2015a).

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[54] For example, farmed rainbow trout in seawater (in the absence of Atlantic salmon) are susceptible to ISAV but do not express clinical signs of disease (N. Purvis, Marine Scotland, pers. comm.).
[55] The level is prescribed at a 30 animal test conducted twice per year at high risk sites, yearly at medium risk sites and once every two years at low risk sites.
[56] NZ$64.5 million at current exchange rates.

5.6 IRELAND

Aquaculture in Ireland generated €149 million[57] in sales in 2015 and is dominated by the production of salmon and sea-reared rainbow trout (13,000 t in 2015), mussels (*M. edulis, M. galloprovincialis* and their hybrids) (16,000 t) and Pacific oysters (9,000 t in 2015) (BIM, 2016).

An assessment of the impact of fish diseases on Irish aquaculture found that infection with sea lice, pancreas disease and gill disorders were the three most economically significant diseases between 2004–2008. The average direct cost[58] of disease was estimated to be €1,179/tonne[59] (€519/tonne for sea lice, €339/tonne for pancreas disease, and €214/tonne for gill disorders). Overall, the cost of these three diseases represented 24% of the sale price (Ruane *et al.*, 2015).

The most significant infectious salmon disease in Ireland is pancreas disease, which first appeared in the mid-1980s. The disease began causing serious problems for the industry in the early 1990s, with mortalities of up to 50% occurring (Menzies *et al.*, 1996). Between 2002 and 2007, pancreas disease was found at 60–90% of sites, resulting in average mortalities of 10–23% (Rodger *et al.*, 2008).

Fish health legislation in Ireland is governed by EU Council Directive 2006/88/EC, which is translated into Irish law by several regulations (Table 32). The Marine Institute is the Competent Authority of EU Council Directive 2006/88/EC in Ireland. It is responsible for: issuing fish health authorisations, import/export permits and transport permits; providing aquatic disease diagnostic services, and co-ordination of the national fish health surveillance programme (Marine Institute, 2016e).

Ireland's fish health surveillance programme is risk-based, with a higher inspection frequency required for high risk farms. Risk assessments are carried out by the Marine Institute. The risk categories of farms are defined below:

1. High risk farms are sites that:
    a) import live fish and eggs;
    b) contain broodstock that produce fish for themselves as well as others;
    c) produce stock that are on-grown elsewhere;
    d) are marine sites (except those with protected water);
    e) have on-site processing that also process fish from other sites; or,
    f) are quarantine facilities.
2. Medium risk farms are sites that:
    a) contain broodstock that they only produce for themselves;
    b) are freshwater sites producing fish for human consumption (including sites that only process their own fish); or,
    c) produce fish for ranching.
3. Low risk farms are sites that:
    a) are put-and-take fisheries;

[57] NZ$221.6 million at current exchange rates.
[58] Cost of disease included the: value of mortalities, increased feed costs due to poorer feed conversion rates, loss due to lower quality fish, cost of treatments, and cost of mortality collection and disposal (Ruane *et al.*, 2015).
[59] NZ$1,755/tonne at current exchange rates.

b) ornamental commercial aquaria;

c) rear species that are not susceptible to the listed diseases; or,

d) recirculation systems (IFA Aquaculture, 2011).

High risk finfish farms are inspected annually by both private health professionals and Marine Institute staff; medium risk finfish farms are visited annually with visits alternating between private health professionals and Marine Institute staff; and, low risk finfish farms are visited biennially by Marine Institute staff. Similarly, high risk shellfish farms are inspected annually and medium risk shellfish farms are inspected biennially by Marine Institute staff (Marine Institute, 2016j).

Ireland also has a mandatory sea lice surveillance programme that is enforced through aquaculture licencing requirements. The programme has five principal components:

1. Single year class production.
2. Compulsory annual fallowing of sites, and, if possible, synchronous fallowing in bays with multiple sites.
3. Early harvest of fish that have been reared in the sea for two winters to reduce the potential reservoir of lice.
4. Synchronous, targeted treatments to increase the efficacy of treatments (particularly autumn/winter treatments to reduce the lice burden on fish that are over-wintered).
5. Agreed fish health husbandry practices within bays (Single Bay Management) (IFA Aquaculture, 2011 & Table 33).

The Marine Institute has also conducted three hazard-specific surveillance programmes for koi herpes virus (Marine Institute, 2016b), OsHV-µ1 (Marine Institute, 2016h), and *Bonamia ostreae* (Marine Institute, 2016d), in order to obtain disease-free status for these three diseases. The whole of Ireland is declared free of koi herpes virus, while certain areas of Ireland are declared free of OsHV-µvar and *B. ostreae*. In the EU, on-going, routine surveillance is required to maintain a disease-free status, and movement of stock into areas that have been declared disease-free is only permitted from other disease-free areas (Marine Institute, 2016h).

In 2007, Ireland launched the AquaPlan project, which is a collaboration between industry and government to develop and implement a national strategy for fish health (Ruane *et al.*, 2015). Outputs of AquaPlan include:

- the farmed salmonid health handbook—a comprehensive manual on fish health that provides practical advice on how to protect animal health and promote fish welfare (IFA Aquaculture, 2011);
- information leaflets for industry on diseases of concern to Ireland, cleaning and disinfection, and biosecurity (Marine Institute, 2016i);
- contingency planning in the case of a disease outbreak (not available at present);
- training courses and manuals on biosecurity, disease screening, sampling and diagnosis for farm workers, fishery officers, biologists, and fish health professionals (Marine Institute, 2016a);
- an assessment of the financial losses to industry due to infectious fish diseases (Ruane *et al.*, 2015);

- hydrographic modelling of the potential risk of disease spread via water currents around Ireland (IFA Aquaculture, 2014).

6 Drivers of surveillance programmes

6.1 MAJOR DISEASE OUTBREAKS & PROTECTION OF AQUACULTURE STOCKS

Half of the jurisdictions reviewed (British Columbia, New Brunswick, Maine, Norway and Scotland) implemented routine surveillance programmes in direct response to a major disease outbreak that caused catastrophic losses within their aquaculture industries. Similarly, numerous hazard-specific disease surveys have been implemented in the reviewed jurisdictions because of notifiable disease outbreaks (Expert 1; I. Ernst (DAWR), pers. comm.). Implementation of surveillance programmes or surveys combined with a range of biosecurity measures have allowed these jurisdictions to effectively control or eradicate some diseases of concern. For example, ISA has not been detected in Maine since 2006, or Scotland since 2009, and there have been no major outbreaks of ISA in New Brunswick since 2006, though it was detected and rapidly eliminated in 2015 and 2016 (Chang & Page, 2010; The Scottish Government, 2015a; APHIS, 2016d; CFIA, 2016d).

Implementation of surveillance programmes to protect cultured animals is sometimes driven by industry requesting assistance from the government to help manage disease. For example, APHIS's ISA control programme was industry-initiated (L. Gustafson, APHIS, pers. comm.). Industry are particularly supportive of surveillance and disease control programmes where the main objective is to protect cultured stock from disease. This is particularly the case after industry have experienced or witnessed a major disease outbreak. For example, after experiencing ISA, New Brunswick salmon farmers are now very proactive in rapidly depopulating cages at the first sign of ISA (K. Brewer-Dalton & S. McGeachy, DAAF, pers. comm.), and farmers have requested surveillance methods that would allow them to detect the disease earlier (L. Hammell, UPEI, pers. comm.). Similarly, South Australian oyster farmers are currently very nervous about the possibility of OsHV-µvar entering the state, and farmers will currently notify the government if they find "*a handful of dead oysters*" (Expert 4, pers. comm.). Industry are less supportive of surveillance programmes when they have little experience with disease (Kathy Brewer-Dalton & Sandi McGeachy, DAAF, pers. comm.).

The species cultured is also a determining factor regarding government implementation of surveillance programmes. Governments are less likely to forcibly implement a surveillance program on industry when the cultured species is an introduced species, the disease is unlikely to affect native species, and, industry are not supportive of the programme (Expert 4; B. Brady, WDF&G, pers. comm.).

6.2 PROTECTION OF WILD, NATIVE SPECIES

The need to protect wild, native species from disease is the major driver for the implementation of surveillance programmes in some jurisdictions, such as Alaska, Washington and British Columbia (K. Cain, University of Idaho (Uni. of Idaho); T. Meyers, ADF&G, pers. comm.). Governments have an obligation to manage the risks associated with diseases that pose a threat to wild animals or the environment (I. Ernst, DAWR; Expert 6; Expert 4, pers. comm.). For example, British Columbia's sea lice surveillance programme was implemented by the provincial government in response to research that demonstrated that lice from farmed salmon were having a negative impact on wild salmon (Morton & Williams, 2003; Saksida *et al.*, 2011). Similarly, the need for a national aquatic animal health strategic plan in Australia was triggered by an outbreak of the pilchard herpes virus in wild fish

(Bernoth *et al.*, 2008). Surveillance gives the public assurance that producers are not spreading disease or endangering wild populations (Expert 4, pers. comm.).

6.3 TRADE, BORDER BIOSECURITY & PREVENTION OF SPREAD

Trade is a driver of hazard-specific surveillance programmes in all the reviewed jurisdictions, whether it is for enabling export or preventing the import of high risk products. Surveillance is also implemented to support movement control measures when a disease is only present in certain parts of the country (T. Meyers, ADF&G; I. Ernst, DAWR; Expert 6, pers. comm.).

6.4 LEGAL REQUIREMENTS

A major driver of the design and implementation of surveillance programmes in some jurisdictions e.g., EU countries and US states, is the need to meet legal requirements that are set at a federal or international level (Expert 2; K. Cain, Uni. of Idaho, pers. comm.).

6.5 PUBLIC PRESSURE OR SOCIAL LICENSE

Public pressure on the aquaculture industry can be a major driver for surveillance programmes. For example, on the west coast of Canada there is very strong anti-aquaculture lobbying from the public, while on the east coast, more significance is given to the economic contribution of salmon farming. Consequently, aquaculture regulation, disease surveillance, biosecurity and disease management methods are more extensive on the west coast—"*The different level of regulatory oversight in the two coasts is a reflection of stakeholder perception*" (Expert 7, pers. comm.). Salmon farmers on the west coast of Canada feel that they need to comply with surveillance and health management reporting to improve their social license.

7 Programme objectives

Many of the international experts interviewed stated that the key first priority for a surveillance programme is to clearly define the objectives of the programme and what it aims to achieve (DPIPWE; Experts 1 & 7, pers. comm.). It is important to understand the different priorities of all the stakeholders involved, and programme objectives need to be defined and agreed in consultation with all stakeholders (Expert 7, pers. comm.).

Clearly articulated programme objectives will determine the design of the surveillance programme, e.g., what diseases should be tested for, when should testing occur, etc. (DPIPWE, pers. comm.). For example, programmes that are purely designed for trade purposes typically utilise targeted diagnostic tests for the specific diseases of interest, while programmes that aim to detect all new disease outbreaks are likely to require the use of more general diagnostic methods, such as histopathology.

The main objectives of the reviewed surveillance programmes are predominantly associated with early detection and/or preventing the spread of diseases. The vast majority of programmes were hazard-specific, though the European countries also had an active surveillance component to their programme, and South Australia and Tasmania generally relied on enhanced passive surveillance for finfish diseases. The European countries also use routine surveillance to substantiate freedom from certain diseases to support trade (Table 35).

8 Requirements of the reviewed surveillance programmes

Surveillance programmes (excluding sea lice surveillance) in Norway, Maine, New Brunswick, Ireland and Scotland are entirely run by government staff or approved fish health professionals, who are responsible for conducting farm inspections, collecting samples and providing the laboratory diagnostic services. Surveillance programmes in the other jurisdictions reviewed utilise a mixture of government staff, fish health professionals and farmers to sample fish (Table 35).

Sea lice surveillance programmes in farmed salmon have often been driven (in part) by concerns about farmed fish acting as a source and reservoir of lice for wild salmonid populations (Jackson, 2011; Ritchie & Boxaspen, 2011; Saksida *et al.*, 2011). Sea lice surveillance and treatment are generally conducted by industry with government oversight, except in Ireland, where surveillance is conducted by government staff. Farmers are required to report lice counts and treatments to the authorities on a regular basis. Farm audits for lice counts are conducted by government staff in British Columbia, New Brunswick, Norway and Scotland (Table 35).

8.1 MANDATORY REQUIREMENTS

All the Northern Hemisphere jurisdictions reviewed had a moderate to high degree of regulation around disease surveillance with clearly stipulated mandatory requirements. By comparison, South Australia and Tasmania have relatively few disease surveillance regulations (Table 36). Mandatory surveillance requirements of the reviewed jurisdictions can be grouped into six common themes:

- reporting of notifiable diseases and elevated mortality;
- periodic testing for pathogens;
- regular farm inspections;
- pathogen testing prior to transfers;
- pathogen testing at hatcheries;
- recording/reporting requirements.

8.1.1 Reporting of notifiable diseases & elevated mortality

The mandatory reporting of notifiable diseases and elevated mortality is an essential component of passive surveillance, and greatly assists with the early detection of new disease outbreaks (EU Council Directive 2006/88/EC; Stagg, 2003). All jurisdictions reviewed have a mandatory requirement for people to immediately report the presence of certain diseases to the authorities. Most jurisdictions have a specified list of legally notifiable diseases, apart from New Brunswick, where all diseases of commercial significance are legally reportable (Table 2 & Table 3).

The list of notifiable aquatic diseases for a jurisdiction should include:

- exotic diseases with potential hosts in the jurisdiction that:
  - are OIE-notifiable; or,
  - have caused serious production impacts or mortality in other jurisdictions;
- emerging diseases with potential hosts in the jurisdiction that:
  - have caused serious production impacts or mortality in other jurisdictions;

- endemic diseases:
  - with potential to cause serious production impacts;
  - with potential to cause serious impacts on native organisms;
  - that are the subject of eradication programmes; or,
  - that have a localised distribution that needs containment.

All diseases included in a notifiable list must also:

- have a proven aetiology or an infectious agent that is strongly associated with the disease;
- have a repeatable and robust means of diagnosis.

Relying only on a notifiable disease list for early disease detection can leave the jurisdiction vulnerable to outbreaks of new, emerging or unlisted diseases (Carnegie *et al.*, 2016). Some jurisdictions, e.g., Tasmania, Washington and Scotland, increase the chances of detecting unlisted diseases by also making it mandatory to report disease outbreaks, mortalities for which the cause is unknown, and the presence of commercially damaging species. In addition, all jurisdictions reviewed, except for Maine, also have a requirement to report any incidence of significant or elevated mortality to the authorities (Table 36). In practice, assessments of elevated mortality can be difficult for some industries. For example, oyster farmers in South Australia are required to report when daily mortality is 10% higher than the average daily mortality of the preceding three months. However, oyster farmers don't look at their stock very often and historically have not kept very good records of the number of animals on their farm, thus, it is very difficult for farmers to assess whether mortality is higher than average (Expert 4, pers. comm.; Sim-Smith *et al.*, 2016).

Furthermore, there are several inconsistencies between the OIE-notifiable list and notifiable disease lists in each jurisdiction (Table 2 & Table 3), which can complicate trade agreements and increase the likelihood of a disease spreading around a region (Carnegie *et al.*, 2016). For example, the molluscan disease *Perkinsus olseni* is listed in the OIE-notifiable list but is not included in Norway's or the EU's notifiable lists, despite its presence in certain EU countries (Portugal, Spain, France and Italy) and absence in other EU countries (Carnegie *et al.*, 2016; OIE, 2016a).

8.1.2 Periodic testing for pathogens

All jurisdictions reviewed, except for South Australia and Tasmania, require compulsory, periodic diagnostic testing of finfish, though the number of diseases tested for, and sampling frequency, varies greatly between jurisdictions. Sampling frequency is partially influenced by the disease experience and current disease risk in each jurisdiction. Jurisdictions that have experienced significant production and financial losses due to disease outbreaks generally have more frequent sampling requirements. At the high end of the scale, Norway, Maine, and New Brunswick require finfish samples to be screened for disease 4–12 times per year. British Columbia, Washington and Alaska require finfish to be sampled for disease at least annually, while Scotland and Ireland require finfish to be sampled every 1–3 years, depending on the risk classification of the farm (Table 35). Alaska, New Brunswick, Scotland and Ireland also require periodic diagnostic testing of shellfish every 1–3 years.

Given the complexity of issues regarding surveillance programmes, it is not surprising that information on the optimal frequency of disease sampling for surveillance programmes is lacking. Oidtmann *et al.* (2013) recommended that the frequency of inspections/testing should take into account the probability of a farm being exposed to a disease, as well as the probability of a farm spreading the disease to other farms.

The number of diseases screened for varied among jurisdictions. Diseases that were screened for were typically determined by trade requirements and commercial demand (Expert 8, pers. comm.), legal requirements (Expert 2, pers. comm.), the likely risk the disease posed to the jurisdiction or industry (Expert 6; Expert 2, pers. comm.), or whether the disease had a limited distribution that authorities were trying to contain (Expert 1; DPIPWE, pers. comm.).

8.1.3 Farm health inspections

Most of the reviewed jurisdictions have a requirement for farm health inspections, which typically involves a visual assessment of the health of fish, inspection of the farm health records, and sampling of moribund fish. New Brunswick and Maine also conduct separate farm biosecurity audits. Farm health inspections in Alaska differ, in that, their main objective is to assess the disease control measures of the facility and to provide advice on how to improve these measures (Meyers, 2014).

Farm health inspections are conducted by government staff and/or fish health professionals. New Brunswick requires monthly farm inspections; Norway requires 4–12 farm inspections per year, depending on the size of the farm and the species cultivated; British Columbia requires approximately two inspections per year; and, Maine, Alaska, Scotland and Ireland require farm inspections every 1–3 years, depending on the disease-risk status of the farm. Washington does not have farm inspections during the grow-out phase, but requires annual biosecurity inspections of hatcheries. South Australia and Tasmania do not have a mandatory requirement for farm inspections.

8.1.4 Pathogen testing prior to transfers

Movement of live animals poses a key risk for the introduction and spread of diseases among geographic regions. Pathogen screening of animals prior to transport coupled with potential movement bans provides a means of limiting the spread of diseases. The majority of jurisdictions reviewed require stock to be certified as disease-free prior to transfers. Maine does not have a specific requirement for diagnostic testing prior to transfers, but instead generally prohibits any marine to marine transfers, and requires all fish to be sourced from certified disease-free hatcheries. South Australia and Tasmania require farmers to apply for transfer permits, but only stock that is imported into the state is legally required to be certified as disease-free.

8.1.5 Pathogen testing at hatcheries

Hatcheries may pose a high risk of spreading disease because they can send stock to numerous locations (see Georgiades *et al.*, 2016). Finfish farmers in Maine and Ireland, and shellfish farmers in Ireland, Washington and Alaska are required to purchase stock from approved hatcheries that are regularly inspected and tested for disease, usually on an annual basis. Norway is more stringent, requiring every batch of fish that leaves a hatchery to be inspected by a veterinarian and tested for a number of likely diseases.

8.1.6 Mandatory recording & reporting

All the jurisdictions reviewed, except for Tasmania, require farmers to keep records of factors that may provide information on the disease risk and history of their farm, such as mortality, diagnostic results, stock transfers, chemotherapeutants applied, fallowing periods, and stocking biomass. These records can be used by health professionals to improve disease management, to trace the source and spread of a disease outbreak, to develop a picture of the overall epidemiology of the disease, and to better understand the factors leading to the cause of the outbreak.

8.2 RISK-BASED REQUIREMENTS

A number of jurisdictions have risk-based surveillance programmes with varying requirements depending on the probable disease risk. The required frequency of farm inspections and diagnostic testing in Scotland and Ireland depends on the probable disease risk, which is based on the disease history and biosecurity measures of the farm. In Norway, the required surveillance frequency depends on the disease risk of the farm, while in Maine and Alaska, surveillance frequency depends on the disease history of the farm. Maine also allows farmers to reduce the sample size of fish tested if there have been no pathogens present in samples from the previous three years. In Washington and Alaska, where wild enhancement is the primary objective, the number of diseases to be tested for depends on the disease transfer risk (e.g., pathogen status of broodstock, rearing water supply, pathogen history of watershed, disease presence in destination, and susceptibility of culture species).

Improvement of the cost-benefit ratio is a major objective of risk-based surveillance programmes (Oidtmann *et al.*, 2007). Risk-based surveillance programmes may incentivise farmers to reduce their probable disease risk by implementing good biosecurity practices.

8.3 VOLUNTARY MEASURES

Tasmania and South Australia were the only jurisdictions reviewed that have a significant voluntary component to their surveillance programmes. Many jurisdictions also have their own voluntary biosecurity standards or Codes of Good Practice, which include several recommended best-practice surveillance measures that are additional to mandatory requirements. However, it is not known what percentage of farmers participate in these voluntary programmes. Voluntary disease control measures can be undermined by farmers with diseased stock, that do not choose to participate (Peeler & Otte, 2016), and many disease experts believe that voluntary measures are ineffective at controlling the exacerbation and spread of aquatic diseases (e.g., Håstein & Gudding, 2005; Midtlyng *et al.*, 2011; B. Jones, MPI, pers. comm.).

9 Benefits of surveillance programmes

9.1 EARLY DETECTION

Early detection of disease allows for control measures to be rapidly implemented, increasing the probability that a disease is contained or eradicated, which is particularly critical for exotic diseases.

Early detection of endemic diseases can also assist with disease management, but these benefits can be difficult to quantify. This is largely because a number of other biosecurity measures such as zonation, fallowing and disinfection are generally implemented at a similar time to surveillance programmes, thus any observed decrease in infection rates or mortality cannot be attributed to a single practice. Nevertheless, surveillance is thought to play an important role in disease control (Johansen *et al.*, 2009; Murray *et al.*, 2010; Stärk & Häsler, 2015). For example, early detection and early removal of affected cages, combined with fallowing and bay management strategies, facilitated the elimination of the pathogenic strain of ISA from Maine (L. Gustafson, APHIS, pers. comm.).

It should be noted that while a review and discussion on disease control methods and biosecurity methods is outside the scope of this project, the benefits of a surveillance programme are limited without suitable on-farm, area-based or industry wide preventive practices, disease control management strategies, and regulations in place to contain and manage a disease outbreak (Stärk & Häsler, 2015; Georgiades *et al.*, 2016; DPIPWE; B. Jones, MPI, pers. comm.). Furthermore, the level of surveillance required is strongly tied to the level of biosecurity practices implemented—"*biosecurity and surveillance go hand in hand, the less biosecurity you have, the more surveillance you need, and vice versa*" (DPIPWE, pers. comm.).

While routine, hazard-specific surveillance can confirm the absence of a pathogen, it can be less effective than passive surveillance for detecting new outbreaks (Stagg, 2003; L. Gustafson, APHIS; N. Purvis, Marine Scotland, pers. comm.). For example, new outbreaks of VHS and ISA in Scotland (Munro, 1996; Rodger *et al.*, 1998; Murray *et al.*, 2010), OsHV-µvar in Tasmania (DPIPWE, 2016c) and white spot disease in Queensland (Diggles, 2017) were first detected through passive surveillance on aquaculture farms. However, diagnostic and communication systems that are established as part of a routine surveillance programme can greatly assist with the speed of diagnosis and the implementation of disease control methods (Stagg, 2003).

For some diseases that manifest with clinical signs, regular syndromic surveillance by industry can have a higher probability of detecting the pathogen than hazard-specific surveillance (CFIA, 2014a). For example, syndromic surveillance resulted in the detection of IHN in British Columbia farms in 2012 prior to the detection of any significant elevations in mortality. This early detection of IHN allowed the disease to be controlled before it spread to other farms in the region (CFIA, 2014a).

9.2 SUBSTANTIATION OF FREEDOM FROM DISEASE TO SUPPORT TRADE

A comprehensive, statistically-designed surveillance programme is essential for countries, or certain zones within a country, that wish to substantiate freedom from certain diseases or pathogens to support trade (e.g., allow trade to other disease-free jurisdictions, to re-establish trade after a successful eradication following a disease outbreak, or to prevent imports from countries that pose a disease risk) (OIE, 2016b). Hazard-specific surveillance is not required to substantiate freedom from disease if:

- there are no susceptible host species present in the country or zone;
- the disease has never been recorded in the country or zone, or has not been recorded in the country or zone in the last 10 years (historical freedom), provided that:
  - the country meets basic biosecurity conditions i.e., "*the disease, including suspicion of the disease, is compulsorily notifiable to the Competent Authority; an early detection system is in place within the zone or country; and, import requirements to prevent the introduction of disease into the country or zone, as outlined in the Aquatic Code, are in place*" (OIE, 2016b);
  - the pathogens produce identifiable clinical signs;
  - no vaccination against the disease has been carried out (unless otherwise allowed for in the OIE aquatic code);
  - the disease is not known to be established in wild aquatic animals in the country or zone (OIE, 2016b).

The World Trade Organization (WTO) Agreement on Sanitary and Phytosanitary Measures requires a country to have scientific evidence documenting freedom from disease before it can impose import sanctions on other countries where the disease of concern exists (WTO, 1998;

OIE, 2016b). Furthermore, a country's surveillance requirements must be consistent for all animals. This requirement was demonstrated in a case where Australia tried to ban the import of fresh or chilled Atlantic salmon from Canada. The WTO ruled that this action was in breach of the WTO agreement because Australia's ban on Canadian salmon was 1) not based on a risk assessment; and 2) stricter than their import policy on other species of finfish that also were a potential disease risk to Australia (WTO, 2015).

9.3 PREVENTION OF SPREAD

Good hygiene and biosecurity practices are used to prevent diseases being spread within a regions. Disease surveillance can be used to support the value of ongoing biosecurity, particularly when diseases have different geographical distributions. Hazard-specific, statistically-designed surveillance programmes can be used to describe the spatial extent of a disease in a country or jurisdiction. This knowledge can be used to assist with management or eradication of the disease, or to demonstrate regional disease freedom to facilitate interstate market access or implementation of movement control measures (Expert 1; Expert 4; I. Ernst, DAWR, pers. comm.). For example, surveillance of endemic diseases in Tasmania supported the maintenance of the three biosecurity zones, because each zone was found to have a different suite of endemic diseases (DPIPWE, pers. comm.).

9.4 FINANCIAL BENEFITS

A disease outbreak can cause serious financial losses, both for industry and the government. For example, the total cost of the ISA outbreaks in Scotland, New Brunswick and Maine was around £38 million, CAN$100 million, and US$29 million, respectively (The Royal Society, 2002; Belle, 2003; DAAF, 2010; APHIS, 2016d).

The costs of a surveillance programme needs to be assessed against the benefits derived, for both the private and public sectors, to ensure that the limited financial resources available are used effectively. Despite this need, there are few examples in the literature of cost-benefit analyses for aquatic disease surveillance. In one such study, Moran and Fofana (2007) conducted an economic analysis of the costs of the surveillance and control programmes in the United Kingdom for ISA, VHS, and IHN. The authors estimated that every £1 spent on the programme by the government would return between £3.20–4.30 in economic benefits by avoiding or containing an ISA outbreak. Both direct costs (e.g., loss of stock, disease control methods) and indirect costs (e.g., loss of trade, loss of recreational fishing) were taken into account. Likewise, every £1 spent on the VHS surveillance programme was predicted to return between £5.70–6.80 in benefits. By contrast, surveillance for IHN was only predicted to return between £0.80–1.00 for every £1 spent, making the cost of surveillance for IHN harder to justify (Moran & Fofana, 2007). In a similar economic study, Hall *et al.* (2014) estimated that the cost of surveillance for bacterial kidney disease in the UK, combined with movement restrictions and eradication was cost-effective.

Surveillance combined with a range of disease control measures has been shown to be effective in preventing financial losses from disease outbreaks. For example, ISA has not been detected in Maine since 2006, or Scotland since 2009, and there have been no major outbreaks of ISA in New Brunswick since 2006, though it was detected and rapidly eliminated in 2015 and 2016 (Chang & Page, 2010; The Scottish Government, 2015a; APHIS, 2016d; CFIA, 2016d). "*Surveillance programmes have been essential for the survival of the industry*" (L. Hammell, UPEI, pers. comm.).

Surveillance in Tasmania provided identification of endemic pathogens that affected the salmon industry. This knowledge was used to develop vaccines for the most problematic pathogens. It is estimated that the development and deployment of vaccines saves the

Tasmanian salmon industry AUD$10 million[60] per year per vaccine from the prevention of stock losses (DPIPWE, pers. comm.).

9.5 INCREASED KNOWLEDGE & CAPABILITIES

Surveillance data can provide researchers and the authorities with information on diseases, such as their rate of spread, spatial extent, epidemiology, and prevalence. This knowledge can be used to assist with disease management, or to assess whether disease control measures were effective (Stärk & Häsler, 2015). Implementation of surveillance programmes can also facilitate the development of research and diagnostic expertise. A key output of the Tasmanian Salmon Health Surveillance Programme has been the development of diagnostic expertise of their animal health laboratory. The laboratory is now recognised as a Competent Authority and is respected by industry, who value the expertise and knowledge of laboratory staff (DPIPWE, pers. comm.).

Surveillance can also provide a better understanding of what diseases are present in a region. While industry are often wary about looking for unknown diseases because of the fear of finding a disease that may impact on their ability to trade, international disease experts believe that it is important to know what diseases are present so that they can be managed appropriately (Experts 1 & 7, pers. comm.):

- to not test for diseases because of the risk of finding an unknown one "*is putting your head in the sand*" (Expert 1, pers. comm.).
- without knowledge of what diseases are present, it is difficult to know if a disease is endemic to a region (and therefore not necessarily reportable), or exotic (K. Cain, Uni. of Idaho, pers. comm.).

Examples of how surveillance information can be beneficial include:

- informing aquaculture companies of the disease risks present in an area prior to their investment into the development of new farms (Expert 1, pers. comm.);
- providing mortality estimates of wild fish that can be used in stock assessment models to provide more accurate stock estimates (Expert 4, pers. comm.);
- providing information on conditions that increase the probability of the onset of the disease, if data on environmental conditions and other risk factors are collected at the same time as disease prevalence (L. Gustafson, APHIS, pers. comm.).

9.6 IMPROVED REPUTATION & SOCIAL LICENCE

Publicly reported disease surveillance also has indirect benefits for both the jurisdiction and the aquaculture industry including: peace of mind, reputational benefits and increased consumer confidence (Stärk & Häsler, 2015). Implementation of disease surveillance in British Columbia has been partially driven by the need to demonstrate that farmed salmon were not posing a disease risk to wild fish (Expert 7, pers. comm.). Likewise, surveillance has resulted in large gains in social licence for aquaculture in South Australia and eastern Canada (Expert 4; L. Hammell, UPEI, pers. comm.).

Confirmation that fish are healthy through surveillance programmes can be used to:

- demonstrate that wild populations are sustainable (regarding disease threats) (Expert 4, pers. comm.); or,

[60] NZ$10.9 million at current exchange rates.

- support applications for insurance of aquaculture stock by providing a level of certainty of the health of farmed animals (Expert 4, pers. comm.).

10 Barriers to implementation & mitigation methods

10.1 COST

Available finances can have a large impact on the design of surveillance programmes—"*it is difficult to optimise good health management with economic feasibility*" (L. Hammell, UPEI, pers. comm.). The cost of diagnostic testing is relatively high and costs can rapidly accumulate if multiple samples need to be tested, or multiple diseases need to be screened for. Careful consideration needs to be given to the diseases that are tested for (unless the aim of the programme is a baseline study), even if it means missing the opportunity to collect a lot of potentially valuable disease information:

- "*we need to stop testing for what is not there, or for diseases that are not economically or socially important. Often there are large and unnecessary costs in surveillance programmes*" (Expert 7, pers. comm.);
- "*testing for more diseases would have turned surveillance from being very expensive to prohibitively expensive*" (Expert 4, pers. comm.);
- "*the ideal frequency of testing may incur prohibitive cost. Practicality and sustainability of any effort should be paramount*" (Expert 5, pers. comm.).

Diagnostic costs are heavily influenced by the methods used, the disease prevalence in a population, and the sensitivity and specificity of a test. The cost of testing for disease in a healthy population with no clinical signs, and thus, a low assumed disease prevalence can be prohibitive. For example, the cost of testing whether ISAV is present in a cage of apparently healthy fish, assuming a 10% prevalence rate is CAN$1,502[61] per cage, because 48 fish are required to be tested to achieve 95% group-level sensitivity and 95% group-level specificity. In contrast, if only moribund fish are tested that have an assumed prevalence rate of 70%, then, the cost of testing decreases to CAN$132[62] per cage ($n$ = 3 fish) to achieve the same level of sensitivity and specificity (Nérette *et al.*, 2008).

Given these issues, many of the jurisdictions reviewed: 1) only conduct diagnostic testing on moribund fish or those that are showing clinical signs of disease (e.g., Tasmania, Norway, Ireland, Scotland, British Columbia and New Brunswick); and, 2) only routinely test for certain diseases (e.g., Washington, Alaska, New Brunswick, Maine and Norway). While the cost of diagnostic testing can be varied, to some extent, by altering the sampling methodology, there are also large fixed costs in a surveillance programme, such as, laboratories, staffing and data management systems.

Industry may be reluctant to send fish for diagnostic testing if the costs of diagnostics are thought to be too high, or if individual animals are very valuable[63] (Expert 4, pers. comm.). Industry see surveillance as an additional cost and typically only want to investigate when there is a problem:

- "*it is hard to get industry to pay for surveillance as the benefits are often nebulous*" (Expert 7, pers. comm.);

[61] NZ$1,606 at current exchange rates. Cost are based on CAN$25 per fish for IFAT screening and CAN$44/fish for RT-PCR with no cytopathic effect, and $88/fish for RT-PCR with a cytopathic effect.
[62] NZ$141 at current exchange rates.
[63] Testing methods usually require the destruction of the animal.

- "*industry will always balance biosecurity regulation with economic risk*" (L. Hammell, UPEI, pers. comm.);
- "*industry think that not looking* (for disease) *when things are going well is an excellent option*" (Expert 4, pers. comm.).

Provision of free diagnostic testing by government will increase the probability of industry submitting samples for testing. For example, Biosecurity Australia commissioned a programme that paid for the diagnostic testing of imported ornamental fish, which generated a lot of useful data (Stephens *et al.*, 2009). By contrast, New Zealand ornamental fish importers are required to pay for diagnostic services, and importers generally chose to destroy their fish rather than send them for testing (B. Jones, MPI, pers. comm.). Destruction of fish may be the easier and cheaper option, but it does not provide any disease information that can be used to inform future decision making.

Industry and government need to come to some agreement on who pays for the surveillance programme. Diagnostic testing and farm inspections that are part of surveillance programmes in Scotland, Ireland and British Columbia are entirely paid for by the government, while in other reviewed jurisdictions, industry are generally required to pay for diagnostic testing. Some governments will pay for the diagnostic testing of certain diseases. For example:

- the Norwegian government pay for diagnostic testing of reported suspected notifiable diseases;
- the governments of the USA and New Brunswick pay for ISA testing;
- the federal government of Australia pay for the cost of diagnostic testing for nationally significant or exotic diseases;
- the state government of Tasmania subsidises the cost of diagnostic testing as part of established surveillance programmes (B. Jones, MPI; Expert 1; DPIPWE, pers. comm.).

The issue of both cost-benefit and cost-sharing is complicated by the fact that aquaculture industries often comprises both small businesses with limited incomes and large, international companies (Bar-Yaacov, 2008; Expert 1, pers. comm.). The cost of diagnostic testing may make it uneconomic for small businesses to continue operating (L. Gustafson, APHIS, pers. comm.).

Many countries are now looking at agreements with the industry whereby economic liability or reward is dependent on the producers' biosecurity practices and risk handling (Bar-Yaacov, 2008). For example, financial compensation for losses caused by ISA in USA is conditional on the farmer complying with APHIS' ISA Programme Standards (APHIS, 2010). Similarly, Norwegian farmers are allowed to increase their maximum stocking biomass if sea lice levels are maintained below a certain threshold.

A lack of financial compensation for the loss of stock due to disease or mandatory culling could be a barrier for farmers reporting disease events promptly (Expert 1; I. Ernst, DAWR, pers. comm.). Lupo *et al.* (2014) reported that oyster farmers that were provided financial compensation for the loss of stock were more likely to report mortalities than farmers that received no compensation. However, if financial compensation was perceived as inadequate by farmers, it did not result in increased reporting (Lupo *et al.*, 2014). Financial compensation was one of the reasons the Maine salmon industry requested assistance from APHIS during the 2001 ISA outbreak (L. Gustafson, APHIS, pers. comm.).

Financial compensation also reduces inequity between affected and unaffected farms (Peeler & Otte, 2016). Australian governments and aquaculture industries are currently in discussion about sharing the responsibilities and costs for responding to disease outbreaks, including for the costs of providing financial compensation for culled animals (I. Ernst, DAWR, pers. comm.). In some jurisdictions, e.g., New Brunswick, both industry and government gradually contribute to an emergency fund, which is used to support affected farms during and after a disease outbreak (Belle, 2003; Bar-Yaacov, 2008; Peeler & Otte, 2016).

10.2 LACK OF SUPPORT BY INDUSTRY

Farmers may be unwilling to support a surveillance programme because they:

- perceive that the cost of surveillance is too high;
- do not recognise the benefits and importance of surveillance, biosecurity and disease reporting;
- find data gathering time-consuming and difficult;
- find surveillance activities required for compliance with regulations onerous;
- fear loss of trade, movement bans or damaged reputation in the event a disease is detected;
- have a lack of trust in the regulatory authorities;
- don't believe they will have a disease outbreak; or,
- simply "*don't want to know*" (Halliday *et al.*, 2012; Stärk & Häsler, 2015; Brugere *et al.*, 2017;Experts 4 & 7, pers. comm.).

Keeping international market access open requires evidence to support declarations of disease freedom, but industry are often very nervous that surveillance will also find new diseases that will generate negative publicity or stop market access to certain countries (L. Hammell, UPEI; Expert 4; Expert 8, per. comm.). Disease experts agree that surveillance does pose some risks to industry:

- *"surveillance of aquatic animals will always find new diseases because there are so many emerging diseases"* (I. Ernst, DAWR, pers. comm.);
- *"industry need scientists to stand up for the truth, but must be willing to also accept some uncomfortable results"* (L. Hammell, UPEI, pers. comm.);
- *"in some cases we have detected serious diseases that have put aquaculture companies out of business"* (Expert 8, pers. comm.).

This is a serious issue for industry, and the disease experts interviewed agree that the situation is difficult to resolve. Experts suggest that:

- the risk of introducing a new disease is minimised if: risk management pathways are identified and mitigated, good biosecurity practices are in place and stock movement is controlled and minimised (Expert 7, pers. comm.);
- a potential surveillance programme is conducted as a trial to demonstrate the potential benefits for the industry (L. Hammell, UPEI, pers. comm.).

An understanding of the factors that motivate farmers to participate in surveillance programmes is essential to the implementation of an effective and sustainable surveillance programme. Potential methods of increasing industry support for a surveillance programme include:

1. *Improving relationships between industry and government*—a good relationship between government surveillance staff and industry is essential to an effective surveillance programme. Regular site visits by government staff and the development of good personal relationships greatly increase the likelihood that farmers will inform government of disease events in a timely fashion. Farmers appreciate having a familiar 'face' for government and a direct phone number to call (DPIPWE, pers. comm.).
2. *Providing relevant information to industry on the need for, and benefits of a surveillance programme*—farmers that don't understand the reasons behind a surveillance programme, or do not see the benefits of surveillance are less likely to participate in it (Lupo *et al.*, 2014; Expert 7; S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.). For example, a surveillance programme for VHS in the USA lacked industry support because the disease was mainly found in wild fish but the federal government imposed a requirement for diagnostic testing in both wild and cultured fish prior to stock transfers. Industry disapproved of the need to pay for diagnostic testing for a disease that they believed posed little risk to their industry (L. Gustafson, APHIS, pers. comm.).
3. *Focussing on endemic diseases that are causing farmers production losses*—this will help to engage and empower farmers because the results are immediate and tangible. It is also likely to increase the trust and communication between industry and the authorities (Halliday *et al.*, 2012). For example, with industry agreement, the focus of the TSHSP in 2000 shifted from the surveillance of exotic diseases to the surveillance of problematic endemic diseases (DPIPWE, pers. comm.). This surveillance information enabled the development of vaccines, which are estimated to save the industry AUD$10 million/year/vaccine (DPIPWE, pers. comm.).
4. *Providing diagnostic testing, disease control advice and assistance*—providing assistance to farmers to help them prevent and control disease outbreaks on their farms is likely to increase participation in surveillance programmes and disease reporting (Corsin *et al.*, 2009; B. Jones, MPI, pers. comm.). Norway and Australia encourage farmers to report suspected notifiable diseases by providing free diagnostic testing for reported notifiable diseases or national significant diseases. Many other jurisdictions subsidise the cost of diagnostic testing that is conducted as part of surveillance programmes. USA are currently trialling a voluntary certification programme where they incentivise farmers by collaborating with industry in the application of uniform standards for health verification and improvement (L. Gustafson, APHIS, pers. comm.).
5. *Providing feedback on surveillance efforts*—feedback to farmers, such as, acknowledgement of reports, diagnostic test results and advice on disease management may provide incentives for increased participation in surveillance programmes (Subasinghe *et al.*, 2005; Halliday *et al.*, 2012; Lupo *et al.*, 2014). Analysis of surveillance and environmental monitoring data may provide farmers with information that allows them to improve their management methods. For example, surveillance information may provide a better understanding of the drivers of mortality (e.g., whether mortality is likely to be due to disease or environmental factors, or whether environmental factors drive the disease), and may provide indicator thresholds where management actions are triggered to facilitate rapid response (L. Gustafson, APHIS, pers. comm.). Industry are sometimes reluctant to disclose this sort of information to government or researchers, and pilot-scale trials

may be necessary to demonstrate the benefits of data sharing to industry (Expert 7, pers. comm.).

Providing confidentiality—farmers that are assured of confidentiality of their farm's disease status are more likely to report disease outbreaks to the authorities. New Brunswick and Maine provide farmers confidentiality of disease outbreaks on their farms. Conversely, disease confidentiality doesn't allow diseases to be effectively managed by region. In Norway and British Columbia, full disclosure of disease outbreaks to neighbouring farms or the public is required to limit the risk of spread of disease around the region.

10.3 LACK OF INFORMATION ON THE TARGET DISEASE

A lack of information on the target disease can prevent a surveillance programme from being implemented (K. Cain, Uni. of Idaho; Expert 4, pers. comm.). A lack of knowledge can also make it difficult to establish properly validated tests, but research funding and good data for disease epidemiology can be difficult to obtain (L. Hammell, UPEI; MPI, pers. comm.). Industry generally don't want to fund research that is ultimately owned by all companies e.g., research on diagnostic specificity or sensitivity, but many governments consider this applied research, and thus, should be largely funded by industry (L. Hammell, UPEI, pers. comm.). British Columbia's Salmon Farmers Association has recently created an industry research fund for industry-wide applicable research (BCSFA, no date).

10.4 PROBLEMS WITH DIAGNOSTIC TESTS

10.4.1 Lack of suitable diagnostic tests

Properly validated and accredited laboratory diagnostic tests are not available for all aquatic diseases. Diagnostic tests may be unavailable or limited by:

- low sensitivity or specificity;
- cost;
- a requirement to sample a large number of healthy animals;
- a short period of time when the pathogen can be detected; or,
- detection of the presence of a pathogen for several years after infection (Brugere *et al.*, 2017).

These limitations need to be taken into consideration when designing a surveillance programme. New research methods for aquatic disease diagnosis are constantly being developed to overcome these problems. Provision of research grants for the development of better diagnostic methods may increase the speed of the development, validation, and accreditation of suitable diagnostic tests.

10.4.2 An over-reliance on disease-specific diagnostic methods

The development and increasingly widespread application of disease-specific diagnostic methods, such as PCR assays, for disease screening, means that there is an increasing risk of failing to detect the presence of non-targeted pathogens. If the objective of a surveillance program is the detection of unknown or unspecified pathogens, then more general methods, such as histopathology, will allow for the detection of a much broader suite of pathogens. However, these methods are becoming less and less frequently due to the time required and the lack of suitably qualified staff (see Section 10.5.2) (Carnegie *et al.*, 2016; Expert 8, pers. comm.).

10.4.3 Different testing requirements

The varying testing requirements among countries means that it difficult for laboratories to conduct diagnostic tests in a cost-efficient manner that also fulfils the requirements of all countries that a producer may export to. Even standardised OIE protocols have a fair degree of leeway in their protocols, and countries may choose to add additional requirements on top of OIE protocols. Furthermore, legislated testing requirements can also be out-dated with current best practice diagnostic methods (Expert 8, pers. comm.).

10.5 LACK OF SUITABLY QUALIFIED STAFF & RESOURCES

10.5.1 Lack of qualified field staff

The reliance on farm staff to gather surveillance data can be problematic if farm staff are unable to identify health problems in their stock. Furthermore, it is difficult to ensure a random and representative sample is collected when using farm staff to collect samples:

- "*it is hard to convince an oyster farmer that he has to walk diagonal across his entire farm to collect samples in the rain when he can just get them all from the nearest basket*" (Expert 4, pers. comm.);
- "*don't rely on farmers to do all the sampling. Intersperse this with government collections for quality control and independent credibility"* (L. Hammell, UPEI, pers. comm.);
- "*we have moved away from using farmers to collect samples. Now most sample collection is conducted by government staff, fish health specialists or veterinarians to improve the reliability of samples"* (Expert 8, pers. comm.).

Some jurisdictions address this problem by:

- using trained government staff to conduct all farm inspections and collect samples (e.g., Norway and Scotland);
- using accredited fish health specialists or veterinarians to conduct farm inspections and collect samples (e.g., Washington and British Columbia);
- providing disease surveillance training for the industry (e.g., Tasmania and New Brunswick for sea lice surveillance).

10.5.2 Lack of qualified laboratory staff

A lack of trained aquatic animal health professionals and lack of staff capacity in government-owned laboratories is a problem in many jurisdictions, with many governments reducing staffing numbers in aquatic animal surveillance despite industry expansion (Expert 1; B. Jones, MPI; T. Meyers, ADF&G, pers. comm.). There is also a lack of available staff trained in the recognition of pathogens using general screening techniques, such as, histopathology and gross pathology. Nowadays, there is an increasing focus on training in molecular techniques, with relatively few students trained in techniques relevant to general screening. This can lead to an over-reliance on disease-specific molecular diagnostic techniques, which are not suitable for diagnosing unknown diseases or those not tested for (Carnegie *et al.*, 2016; Expert 8, pers. comm.).

10.5.3 Lack of suitably accredited laboratories

A lack of suitably accredited laboratories and infrastructure may hinder the timely implementation of a disease surveillance programme. In addition, poor quality control in some laboratories can be a problem, resulting in inconsistent results amongst laboratories (Expert 8; L. Hammell, UPEI, pers. comm.).

A lack of demand for certain diagnostic tests may result in difficulties in getting these tests conducted, particularly by commercial laboratories that may be reluctant to offer tests if there is little demand for them (Expert 8, pers. comm.).

Implementation of a surveillance programme will require investment in appropriate education and training, recruitment of staff, quality control, and the establishment of suitably accredited facilities, as required (Corsin *et al.*, 2009; Stärk & Häsler, 2015).

10.6 LOGISTICAL PROBLEMS

A variety of logistical problems can be barriers to the effective implementation of a surveillance programme. These include:

- conflicts, different objectives and miscommunication between different regulatory bodies involved:
  - "*it is difficult working with multiple regulatory authorities, there is lots of miscommunication. A simple vertical communication system would be very helpful. When we have a serious detection we send an email out to multiple people simultaneously to avoid communication gaps*" (Expert 8, pers. comm.).
  - there have been disagreements between the federal government and the provincial government around funding of surveillance programmes and disease control measures (L. Hammell, UPEI, pers. comm.);
- difficulties getting consensus when there are a large number of aquaculture companies involved, or managing the programme when it encompasses a wide geographic area. For example:
  - the extensive relaying of shellfish stock that occurs in North America means that there is a huge network to monitor in terms of assessing disease risk. Competent Authorities need to rely on the surveillance and biosecurity measures in other jurisdictions to do their job. The sheer size of a surveillance programme required, in terms of the number of sites and samples required, is "*daunting and almost undoable*" (Expert 6, pers. comm.);
  - "*when ISA first hit there were lots of small companies (around 50). It was difficult to get everyone on board. Now there are only three* (companies), *it is much easier*" (K. Brewer-Dalton and S. McGeachy, DAAF, pers. comm.);
- difficulties getting samples to the laboratory quickly when farms are located in remote regions. In Alaska, where most hatcheries are remote and have no road access, samples are sent by air to the laboratory (T. Meyers, ADF&G, pers. comm.).

11 Conclusions

An aquatic health and disease surveillance programme cannot be considered in isolation. Such a programme needs to sit within an integrated framework for aquaculture biosecurity and disease management, and must have support from industry. The objectives, costs and benefits of implementing a surveillance programme need to be considered and agreed by all parties.

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13 Appendices

13.1 NOTIFIABLE DISEASES IN THE REVIEWED JURISDICTIONS

Table 2. Finfish diseases that are legally reportable for OIE members, and in each of the jurisdictions reviewed. Ex = exotic; P = present; NL = not specifically legislated, but reportable under the OIE agreement; L = only laboratories are required to report this disease.

Sources

OIE–(OIE, 2017); NZ–Biosecurity (Notifiable Organisms) Order 2016; Australia (AUS)–(DAWR, 2016a); Tasmania (TAS)–(DPIPWE, 2016a); South Australia (SA)–(Bignell, 2015); United States (US)–(APHIS, 2016a); Maine (ME)–13 188, Ch. 24; Alaska (AK)–5 AAC 41.080; Canada (CAN)–(CFIA, 2016e); British Columbia (BC)–(Government of British Columbia, no date-b); Norway (NOR)–2008-06-17 No. 819; Scotland (SCO)–(The Scottish Government, 2016c; 2006/88/EC); Ireland (IRE)–(2006/88/EC).

Disease	OIE	NZ	AUS	TAS	SA	US[64]	ME	AK[64]	CAN	BC[64]	NOR	SCO	IRE
Finfish viral diseases													
Aquabirnavirus								✓					
Channel catfish virus disease			✓Ex	✓Ex	✓Ex								
Epizootic haematopoietic necrosis	✓	✓Ex	✓P	✓Ex	✓P	✓		NL[65]	✓	✓	✓Ex	✓Ex	✓Ex
Erythrocytic inclusion body syndrome virus								✓					
European catfish virus/European sheatfish virus			✓Ex	✓Ex	✓Ex								
Grouper iridoviral disease			✓Ex	✓Ex	✓Ex								
Heart and skeletal muscle inflammation (probably *Piscine reovirus*)											✓P		
Herpesvirus disease *(Herpesvirus salmonis)*								✓					
Infectious haematopoietic necrosis (IHN virus)	✓	✓Ex	✓P	✓Ex	✓Ex	✓	✓Ex	✓	✓	✓	✓P	✓	✓
Infectious pancreatic necrosis (IPN virus)		✓Ex[66]	✓Ex	✓Ex	✓Ex	✓	✓	✓	✓	✓			
Infectious spleen and kidney necrosis (ISKN virus-like (ISKNV-like) viruses)			✓Ex	✓Ex	✓Ex								
Infectious salmon anaemia (HPR-deleted or HPR0)	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓	✓Ex	✓	✓	✓	✓P	✓	✓

[64] Not categorised as exotic or present.
[65] On the national notifiable list.
[66] Some pathogenic agents of this disease are present in the jurisdiction. Only exotic strains are notifiable.

Disease	OIE	NZ	AUS	TAS	SA	US[64]	ME	AK[64]	CAN	BC[64]	NOR	SCO	IRE
Koi herpesvirus disease	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓		NL[65]	✓	✓	✓P	✓	✓
Lymphocystis *(Lymphocystivirus)*								✓					
Oncorhynchus masou virus disease		✓Ex		✓Ex	✓Ex	✓	✓Ex	✓	✓Ex, L				
Paramyxovirus								✓					
Red sea bream iridoviral disease	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓		NL[65]	✓Ex, L	NL[65]	NL, Ex	NL, Ex	NL, Ex
Reovirus								✓					
Salmonid alphavirus/Pancreas disease	✓	NL, Ex	✓Ex	✓Ex	✓Ex	✓	✓Ex	NL[65]	NL, Ex	NL, Ex	✓P	NL, P	NL, P
Salmon orthomyxo-like virus/Pilchard orthomyxo-like virus)				✓P									
Spring viraemia of carp	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓		NL[65]	✓	✓	✓P	✓	✓
Tasmanian aquatic birnavirus				✓P									
Viral encephalopathy and retinopathy/Viral nervous necrosis			✓P	✓Ex	✓P	✓P	✓				✓P		
Viral erythrocytic necrosis								✓					
Viral haemorrhagic septicaemia	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓P	✓Ex	✓[67]	✓P	NL, P[65]	✓P	✓	✓
White sturgeon irdoviral disease					✓Ex	✓			✓	✓			
Finfish bacterial diseases													
Aeromonas salmonicida (atypical strains)		P	✓P	✓P	✓P								
Bacterial kidney disease (*Renibacterium salmoninarum*)		✓Ex	✓Ex	✓Ex	✓Ex	✓	✓	✓	✓P, L		✓P	✓	✓
Cold water disease (*Flavobacterium psychrophilum*)								✓					
Coldwater marine Hitra (*Vibrio salmonicida)*								✓					
Columnaris (*Flavobacterium columnare*)								✓					
Enteric redmouth disease (*Yersinia ruckeri*–Hagerman strain)		✓Ex[66]	✓Ex	✓Ex	✓Ex		✓	✓	✓P, L				
Enteric septicaemia of catfish (*Edwardsiella ictaluri*)			✓P	✓P	✓Ex								
Francisellosis (*Francisella* sp.)							✓Ex				✓P		
Furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*)		✓Ex	✓Ex	✓Ex	✓Ex		✓	✓	✓P, L		✓P		
Ichthyophthiriasis *(Ichthyophthirius multifiliis)*								✓					

[67] Some pathogenic agents of this disease are present in the jurisdiction. All strains are notifiable.

Disease	OIE	NZ	AUS	TAS	SA	US[64]	ME	AK[64]	CAN	BC[64]	NOR	SCO	IRE
Motile bacterial septicemias (*Aeromonas hydrophila; Pseudomonas* sp.)								✓					
Piscirickettsiosis (*Piscirickettsia salmonis*)			✓Ex	✓Ex	✓Ex	✓		✓					
Rickettsia-like organism (RLO) of salmonids				✓P									
Streptococcosis (*Lactococcus gravieae*)				✓P									
Streptococcosis (*Streptococcus iniae*)									✓P, L				
Vibriosis (*Vibrio anguillarum, V. ordalii, V. alginolyticus*)							✓Ex[68]	✓					
Finfish parasitic diseases													
Infection with *Ceratomyxa shasta* (myxosporidian)							✓Ex	✓	✓	✓			
Gyrodactylosis (*Gyrodactylus salaris)* (Platyhelminthes)	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓		NL[65]	✓Ex, L	NL[65]	✓P	✓	✓
Helminth diseases								✓					
Hexamitiasis *(Hexamita)* (diplomonads)								✓					
Ichthyobodiasis (*Ichthyobodo* = *Costia*) (protozoan)								✓					
Infection with *Lepeophtheirus salmonis* (sea lice)				✓Ex							✓P		
Infection with *Loma* sp. (microsporidian)							✓	✓					
Proliferative kidney disease (*Tetracapsula bryosalmonae*) (myxozoan)							✓Ex	✓					
Trichodiniasis (*Trichodina* sp.) (protozoans)								✓					
Whirling disease (*Myxobolus cerebralis*) (myxosporean)		✓P	✓Ex	✓Ex	✓Ex	✓	✓Ex	✓	✓	✓			
Finfish fungal diseases													
Epizootic ulcerative syndrome (*Aphanomyces invadans*)	✓	✓Ex	✓P	✓Ex	✓P	✓		✓	✓Ex, L	✓	✓Ex	✓	✓
Fungal diseases (*Saprolegnia* sp.; *Phoma herbarum*)								✓					

[68] *Listonella (Vibrio) anguillarum* serotype 02 ß

Table 3. Molluscan diseases that are legally reportable for OIE members and in each jurisdiction reviewed. Ex = exotic; P = present; NL = not specifically legislated, but reportable under the OIE agreement; L = only laboratories are required to report this disease.

Sources

OIE–(OIE, 2017); NZ–Biosecurity (Notifiable Organisms) Order 2016; Australia (AUS)–(DAWR, 2016a); Tasmania (TAS)–(DPIPWE, 2016a); South Australia (SA)–(Bignell, 2015); United States (US)–(APHIS, 2016a); Alaska (AK)–5 AAC 41.080; Canada (CAN)–(CFIA, 2016e); British Columbia (BC)–(Government of British Columbia, no date-b); Norway (NOR)–2008-06-17 No. 819; Scotland (SCO)–(The Scottish Government, 2016c; 2006/88/EC); Ireland (IRE)–(2006/88/EC).

Disease	OIE	NZ	AUS	TAS	SA	US[69]	AK[69]	CAN	BC[69]	NOR	SCO	IRE
Molluscan viral diseases												
Abalone viral ganglioneuritis /abalone herpes-like virus/abalone viral mortality	✓	✓Ex	✓P	✓P	✓Ex	✓	NL[70]	✓Ex	NL[70]	NL	NL	NL
European hemocyte and gill iridoviruses							✓					
Iridoviroses			✓Ex	✓Ex	✓Ex							
Herpesvirus in clams and scallops							✓					
Pacific oyster mortality syndrome (Ostreid herpesvirus-1 μ variant)		P	✓P	✓P	✓Ex	P					✓	✓
Ostreid herpesviruses							✓					
Velar disease virus (OVVD Iridovirus)					✓Ex		✓					
Ovacystis virus (gametogenic papilloma/polyoma-like virus)							✓					
Molluscan bacterial diseases												
Bacillary necrosis (*Vibrio, Pseudomonas, Aeromonas,* others)							✓					
Brown ring disease (*Vibrio tapetis*)								✓Ex, L				
Pacific oyster nocardiosis (*Nocardia crassostreae*)				✓Ex			✓					
Prokaryote inclusions (chlamydia; mycoplasma, rickettsia)							✓					
Mycelial disease (Actinomycete-like)							✓					
Withering syndrome of abalone (*Xenohaliotis californiensis)*	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓	NL[70]	✓Ex, L	NL[70]	NL	NL	NL

[69] Not categorised as exotic or present.
[70] On the national notifiable list.

Disease	OIE	NZ	AUS	TAS	SA	US[69]	AK[69]	CAN	BC[69]	NOR	SCO	IRE
Molluscan parasitic diseases												
Infection with *Boccardia knoxi*					✓Ex							
Infection with *Bonamia exitiosa* (protist)	✓	NL, P	✓P	✓Ex	✓Ex	✓	✓	✓Ex, L	NL[70]	✓Ex	✓Ex	✓Ex
Infection with *Bonamia ostreae* (protist)	✓	✓P	✓Ex	✓Ex	✓Ex	✓	✓	✓	✓	✓P	✓	✓
Infection with *Bonamia roughleyi*[71] (protist)		✓Ex		✓Ex	✓Ex	✓	✓	✓Ex, L				
Infection with *Bonamia* species (protist)			✓P	✓P	✓P		✓					
Infection with ciliates (*Sphenophrya*, thigmotrichs, trichodinids, *Ancistrocoma*)							✓					
Infection with Gregarines (protist)							✓					
Infection with *Haplosporidium nelsoni* (protist)				✓Ex	✓Ex	✓	✓	✓	✓			
Infection with *Haplosporidium costale* (protist)					✓Ex	✓	✓	✓P, L				
Infection with Helminth parasites							✓					
Infection with *Hexamita* sp. (protist)							✓					
Infection with histozoic coccidian							✓					
Infection with *Mikrocytos mackini* (protist)		✓Ex	✓Ex	✓Ex	✓Ex		✓	✓	✓	✓Ex	✓Ex	✓Ex
Infection with *Marteilia refringens* (protist)	✓	✓Ex	✓Ex	✓Ex	✓Ex	✓	✓	✓	✓	✓P	✓	✓
Infection with *Marteilia maurini* (protist)		✓Ex					✓					
Infection with *Marteilia sydneyi* (protist)		✓Ex	✓P	✓Ex	✓Ex	✓	✓	✓Ex, L				
Infection with *Marteilioides chungmuensis* (protist)			✓Ex	✓Ex	✓Ex	✓	✓	✓	✓			
Infection with *Mytilicola intestinalis* or *M. orientalis* (copepod)							✓					
Infection with *Nematopsis* sp. (sporozoan)							✓					
Infection with *Perkinsus marinus* (protist)	✓Ex	✓Ex	✓Ex	✓Ex	✓Ex	✓	✓	✓	✓	✓Ex	✓Ex	✓Ex
Infection with *Perkinsus olseni* (protist)	✓	✓P	✓P	✓Ex	✓P	✓	✓	✓	✓	NL	NL	NL
Infection with *Perkinsus* spp.				✓Ex	✓Ex[72]		✓					
Infection with *Pseudomyicola* sp. (parasitic copepod)							✓					
Infection with *Pseudoklossia coccidia*							✓					
QPX disease (Quahog parasite)						✓		✓P, L				

[71] Synonymous with *Mikrocytos roughleyi*.
[72] Some pathogenic agents of this disease are present in the jurisdiction. Only exotic strains are notifiable.

Disease	OIE	NZ	AUS	TAS	SA	US[69]	AK[69]	CAN	BC[69]	NOR	SCO	IRE
Molluscan fungal diseases												
Infection with *Sirolpidium zoophthorum*							✓					
Shell disease (*Ostracoblabe implexa*)							✓					
Infection with Microsporidea							✓					
Molluscan diseases of unknown aetiology												
Neoplasia (germinomas)							✓					
Malpeque Bay disease							✓					

13.2 SURVEILLANCE PROGRAMMES OF THE REVIEWED JURISDICTIONS

13.2.1 South Australia

Table 4. South Australia's Aquatic Animal Health Programme, hazard-specific surveillance programme for OsHV-µvar, and relevant aquatic health and disease surveillance regulations.

SOUTH AUSTRALIA	Cultured host species	Southern bluefin tuna, yellowtail kingfish, Pacific oysters, mussels (*Mytilus galloprovincialis*), greenlip abalone (*Haliotis laevigata*), salmonids.
	Start date	April 2017 for OsHV-µvar surveillance programme.
	Regulatory authority	Government of South Australia, Primary Industries and Regions, SA (PIRSA).
	Relevant legislation	• Aquaculture Act 2001 (South Australia): – Aquaculture Regulations 2016 (AR). • Livestock Act 1997 (LA) (South Australia).
	Objectives	• To protect marine resources from the impact of aquatic diseases. • To maintain their 'clean, green' image (PIRSA, 2016). • Improved early detection of OsHV-µvar in South Australian oyster growing areas through active surveillance (Expert 3, pers. comm.).
	Diseases of most concern	• Pacific oyster mortality syndrome (OsHV-µvar; exotic to SA). • Abalone viral ganglioneuritis (AVG; exotic to SA).
	Sampling and data collection	Aquatic Animal Health Programme: • PIRSA staff review submitted laboratory results and veterinarian reports. • PIRSA staff investigate wild fish kills and disease threats/outbreaks. • Fish samples are submitted by farmer to an approved laboratory for diagnostic testing prior to importation into SA (PIRSA, 2016). OsHV-µvar surveillance programme (Expert 3, pers. comm.): • Farmers collect spat samples and submit to their bay representative, who will submit all bay samples to the laboratory. • Spat should be < 15 mm, preferably not from hatchery-bred OsHV-µvar resistant stock, on lease site for > 4 weeks but not over the previous summer, representative of the lease site and the growing area as far as practicable (spat are more susceptible to the virus). • 33 samples of 10 spat are collected per growing area. • Samples are collected in autumn following two < 18°C water temperature readings that are weeks apart, and spring following two water temperature readings > 16°C that are two weeks apart. Timing is based on virus behaviour at different water temperatures—the aim is to detect the virus before clinical disease to give the industry the earliest warning possible. • Number of farms sampled will depend on available spat and the number of growers per growing area. It is expected that around 200 farms would be involved. • Some sampling of wild adults will also occur.
	Routine diagnostic tests	• OsHV-µvar: PCR, one test per sample pool of 5 spat (with 5 spat reserved). Over 700 tests are expected to be conducted per annum (Expert 3, pers. comm.).
	Mandatory requirements	• Any unusually high, unexplained mortality over a 24 h period must be reported to the Minister immediately and all reasonable steps must be taken to isolate affected fish. Unusually high mortality is a daily mortality rate that is 10% higher than the average daily mortality over the previous 3 months (AR, §13; Expert 4, pers. comm.). • Farmers must comply with approved sector-based aquaculture strategies, if available. If no sector-based strategy is available then farmers must have their own strategy approved. The strategy is to cover methods of minimising, avoiding and dealing with disease, stock disposal methods and surveillance plans (AR, §18–19). Oysters: • Import permits are required for importation of live oysters from other states into SA. Imported stock must be from an approved supplier and certified as disease-free (Gago, 2014). No importation of live oysters or oyster growing equipment from Tasmania into SA (temporary ban until 31 Mar 2018, to prevent the introduction of OsHV-µvar) (Bignell, 2017).

		Abalone: • Importation of live abalone into SA requires a permit and must be sourced from an accredited farm that has a surveillance system for AVG and has been free of AVG for > 12 months (PIRSA, 2015c). • Abalone moved within the state must be certified as disease-free (PIRSA, 2015c). Finfish: • Within state transfers of hatchery reared, prescribed finfish must be certified disease-free before release into open systems (Gago, 2014). • Importation of finfish from outside of SA requires disease-free certification (Gago, 2014).
	Variable requirements	• None.
	Voluntary measures	• Participation in the OsHV-µvar surveillance programme is voluntary (Expert 3, pers. comm.). Biosecurity standards for abalone aquaculture (PIRSA, 2015a): • Regular inspection of stock for the presence of disease, morbidity or unusual behaviour. • New stock must be quarantined for > 2 weeks. • Transfer of stock between states requires active disease surveillance.
SOUTH AUSTRALIA	Reporting requirements	• Notifiable diseases must be reported immediately to the authorities (PIRSA, 2015b). • Any unusually high, unexplained mortality over a 24 h period must be reported to the Minister immediately (AR, §13). • Farmers must provide annual reports of their standing stock, stock acquisition, stock movement, mortality and therapeutic or prophylactic treatments used to the authorities (AR, §22).
	Data management	• Data for the OsHV-µvar surveillance programme will be stored in either Excel or Sharepoint. Data is owned and will be managed by PIRSA (Expert 3, pers. comm.).
	Outputs	• Annual reporting of results to farmers, individual farmers will not be identified. (Expert 3, pers. comm.).
	Use of outputs	• n/a. OsHV-µvar programme hasn't started yet.
	Consequences if disease is detected	• Prohibition of stock importation or transfers.
	Cost to industry	• Costs incurred with collecting samples and diagnostic testing of grow-out animals. Industry is expected to fund the OsHV-µvar programme after 2017 if it continues (Experts 3 & 4, pers. comm.). • Industry is required to meet the cost of all services provided by PIRSA. Diagnostic testing and translocation certification is on a fee-for-service basis (PIRSA, 2015d). • Part of the licence fee that is paid by industry goes towards disease control services performed by government (Expert 4, pers. comm.).
	Cost to regulatory body	• Government will fund the OsHV-µvar programme in 2017 (diagnostic testing in spat). PCR testing is estimated to cost AUD$25,000 per year (Expert 3, pers. comm.).
	Supporting material	• Policy guidelines for biosecurity standards for abalone aquaculture (PIRSA, 2015a). • Emergency disease response simulation exercises (Roberts *et al.*, 2013).
	Implementation	• OsHV-µvar programme took around two months to develop and around 1 month to implement. Industry were involved in the programme design (Expert 3, pers. comm.).
	Industry support	• Industry have been very supportive of the OsHV-µvar programme so far. The programme is designed to protect industry (Expert 3 & 4, pers. comm.).
	Uptake of voluntary requirements (%)	• It is expected that around 200 farms will be involved in the OsHV-µvar programme (Expert 3, pers. comm.).
	Compliance problems	• n/a, programme hasn't started.
	Incentives for compliance	• None, but the surveillance was designed to help the industry with early detection so participation is in their best interests (Expert 3, pers. comm.).
	Benefits	• n/a, programme hasn't started.
	Barriers to implementation	• None identified. Spat shortage may impact the number of samples collected in autumn (Expert 3, pers. comm.).
	Solutions	• n/a, programme hasn't started.

Abandoned processes	• Prior to OsHV-µvar appearing in Australia, oyster surveillance used to involve less frequent sampling of larger number of hatchery stock using histopathology. Now PCR for OsHV-µvar is conducted on all batches of hatchery stock and histopathology is infrequently used (Expert 4, pers. comm.).

13.2.2 Tasmania

Table 5. Tasmania's Salmonid Health Surveillance Programme and relevant aquatic health and disease surveillance regulations.

TASMANIA	Cultured host species	Salmonids, primarily Atlantic salmon.
	Start date	1993.
	Regulatory authority	• DPIPWE. • Inland Fisheries Service.
	Relevant legislation	• Animal Health Act 1995 (AHA) (Tasmania). • Living Marine Resources Act 1995 (LMRA) (Tasmania). • Inland Fisheries Act 1995 (IFA) (Tasmania).
	Objectives	• Passive surveillance to exclude exotic diseases from Tasmania and Australia. • Monitoring the prevalence of endemic diseases to support biosecurity management. • Early detection of new or re-emerging pathogens. • Investigation of unusual morbidity or mortality to identify cause. • Collection of disease prevalence data to support policy and trade (DPIPWE, pers. comm.).
	Diseases of most concern	• Notifiable diseases.
	Sampling and data collection	• TSHSP is currently based on passive surveillance. Routine visual surveillance of fish heath by farmers. Company fish health professionals or farmers collect samples for testing if disease is suspected (Anon., 2012). • DPIPWE recommends that at least five clinically affected fish are sampled per affected cage (DPIPWE, 2016b). • DPIPWE co-ordinate the TSHSP programme and conduct the diagnostic testing (DPIPWE, pers. comm.). • DPIPWE staff review submitted laboratory results and veterinarian reports. For some submissions, Biosecurity Tasmania veterinary officers will sample fish as directed by the CVO in relation to investigations of an emerging or exotic disease (DPIPWE, pers. comm.).
	Routine diagnostic tests	• Histopathology, bacteriology, virology (cell culture), PCR (DPIPWE, pers. comm.).
	Mandatory requirements	• All leaseholders must participate in any fish health or fish biosecurity programmes as directed by the Chief Veterinary Office or Director of Marine Resources (AHA, §50).
	Variable requirements	• Macquarie Harbour has a separate fish health management plan that is managed by industry (Anon., 2012).
	Voluntary measures (all signatories agree to comply with these rules)	Tasmanian Salmon Health Surveillance Programme: • Participation in the TSHSP is not mandatory but all members of the TSGA agree to participate in the programme (and contribute to the costs) (DPIPWE, pers. comm.). • Sample submission for diagnostic testing is voluntary (DPIPWE, pers. comm.). Tasmanian Salmonid Growers Association Biosecurity Programme[73] (TSGA, 2014): • Regular inspections of stock health and condition. • Vaccination of all salmon for *Yersinia ruckeri*; vaccination of all rainbow trout for *Vibrio anguillarum* at least 6 weeks prior to transfer to seawater; vaccination for all Atlantic salmon destined for Macquarie Harbour for *Aeromonas salmonicida* and *V. anguillarum* at least 4 weeks prior to transport. • Environmental monitoring of water parameters that may affect stock stress, e.g., temperature, pH, dissolved oxygen, ammonia, nitrites, nitrates and net fouling.

[73] The TSGA biosecurity programme is currently under review and is likely to change significantly (S. Percival, pers. comm.).

TASMANIA		• Veterinarians to certify that fish are disease-free prior to transfer between biosecurity zones. Macquarie Harbour Fish Health Management Plan (Anon., 2012): • Each company must have access to a fish veterinarian. • Each farm must have a biosecurity and fish health management plan that has been reviewed by a veterinarian. • Stock must be regularly inspected and mortalities removed. • Fish health must be assessed by a veterinarian < 4 weeks before transfer from the hatchery and a disease-free certificate issued by the veterinarian. • All fish transferred to Macquarie Harbour must be vaccinated against any disease known to exist in the harbour for which there is an effective vaccine. • Farmers may choose to submit moribund fish to DPIPWE for diagnostic testing on a monthly basis.
	Reporting requirements	• Farmers must legally report presence of notifiable diseases, suspected new diseases and unknown diseases that are causing mortality to the authorities as soon as possible (DPIPWE, 2016a and AHA, §27–30). • Farmers must report significant mortality or morbidity to the authorities as soon as possible (AHA, §30). Significant mortality is defined as: – weekly mortality > 0.2% for 2 consecutive weeks in finfish due to be harvested within the next 3 months; or, – mortality > 0.25% for 3 consecutive days. Macquarie Harbour Fish Health Management Plan (Anon., 2012): • Veterinarians must notify other company veterinarians of any suspected new or exotic diseases, outbreaks of endemic diseases, or therapeutants applied to fish. TSHSP (DPIPWE, pers. comm.): • Each month, DPIPWE inform companies what proportion of their testing quota they have used. • Companies are also advised how many submissions were made for each lease. Results and company information is kept confidential.
	Data management	• Companies participating in the Macquarie Harbour AMA submit fish surveillance data to the AMA management officer for collation and reporting (Anon., 2012). • Diagnostic results are managed through a Laboratory Information Management System (LIMS) database that is only available to certain government staff (DPIPWE, pers. comm.). • Data is owned and managed by DPIPWE (DPIPWE, pers. comm.).
	Outputs	• Monthly data collected under the FHMP will the collated into a report by the AMA management officer and circulated to all participating companies, company veterinarians and the authorities. Reports do not identify individual company data. The specific data collected will be agreed by the company veterinarians (Anon., 2012). • Quarterly and annual reports on the results of diagnostic testing are produced for the TSHSP and issued to participating companies. Reports do not identify individual company data (DPIPWE, pers. comm.).
	Use of outputs	• Description of the distribution of endemic diseases and support for the maintenance of three biosecurity zones (DPIPWE, pers. comm.). • Enabled market access through substantiation of freedom from disease (DPIPWE, pers. comm.).
	Consequences if disease is detected	Macquarie Harbour Fish Health Management Plan (Anon., 2012): • Transfer of fish from a hatchery to the harbour is prohibited when there is unexplained mortality in the hatchery.
	Cost to industry	• Cost of the TSHSP programme is agreed annually by industry and government for a set quota of samples. DPIPWE and industry share the cost of the programme. Cost of diagnostic testing provided under the programme is discounted substantially. In addition, the government provides a further discount on a core number of samples to ensure a minimum level of monitoring is undertaken to support claims of an adequate level of surveillance (DPIPWE, pers. comm.).

TASMANIA		• Industry must pay for diagnostic testing that is for commercial benefit and falls outside of the TSHSP. All Tasmanian primary producers receive a 20% discount on diagnostic testing (DPIPWE, pers. comm.).
	Cost to regulatory body	• DPIPWE and industry share the cost of the programme (DPIPWE, pers. comm.).
	Supporting material	• Tasmania's biosecurity strategy 2013–2017 (Tasmanian Biosecurity Committee, 2012). • Field sampling guide for fish disease surveillance (DPIPWE, 2016c). • Tasmanian Salmonid Growers Association Biosecurity Programme (TSGA, 2014). • Macquarie Harbour Fish Health Management Plan (Anon., 2012). • DPIPWE provides each farm with a bacteriology sampling kit each month to facilitate timely and routine bacteriological sampling and conducts training days for farm staff on how to correctly sample fish (Anon., 2012; DPIPWE, pers. comm.).
	Implementation	• Initiation of the project was government-led. Industry were asked to contribute from the start. Every year the programme is reviewed and the objectives, costs and outputs are agreed for the following year (DPIPWE, pers. comm.). • 0.2 of an FTE is required for programme development and management (DPIPWE, pers. comm.).
	Industry support	• Industry support for the TSHSP is strong (DPIPWE, per. comm.). • The viability of the programme is dependent on the willingness of companies to engage in the programme (DPIPWE, pers. comm.).
	Uptake of voluntary requirements (%)	• 100% participation in the Tasmanian salmonid growers biosecurity programme (Knight *et al.*, 2015).
	Compliance problems	• Commercially in-confident information is not always available (DPIPWE, pers. comm.).
	Incentives for compliance	• Individual company data on disease is kept confidential (Anon., 2012). • DPIPWE staff have always stressed that disease information provided will be kept confidential and that the government will work with farmers to help control disease. DPIPWE staff liaising with farmers need to very clear about what information they are legally obliged to report (DPIPWE, pers. comm.). • Discounts on diagnostic testing are offered to farmers (DPIPWE, pers. comm.).
	Benefits	• Identification of endemic pathogens that enabled the development of vaccines. Each vaccine that has been deployed is estimated to save the industry AUD$10 million per year (DPIPWE, pers. comm.). • Increased laboratory competency and implementation of better diagnostic tests and procedures. • Facilitated the development of AMAs and provides support for the maintenance of three biosecurity zones because different diseases are present in the different zones (DPIPWE, pers. comm.). • Enabled market access through substantiation of freedom from disease (DPIPWE, pers. comm.). • Surveillance data supports Tasmania's status as free of a number of major salmon disease (DPIPWE, pers. comm.).
	Barriers to implementation	• Costs: some small hatcheries were reluctant to participate in the TSHSP because they felt that the costs were too high (DPIPWE, pers. comm.). • Company sensitivity about surveillance data can limit its use for further analysis (DPIPWE, pers. comm.). • Correct sample collection and submission can be a problem because farmers collect the samples (DPIPWE, pers. comm.).
	Solutions	• Larger companies paid for the smaller hatcheries to participate in the TSHSP because the larger companies were buying fish from the hatcheries (DPIPWE, pers. comm.). • DPIPWE provide training to farm staff in sample collection (DPIPWE, pers. comm.) and have produced sampling guides (DPIPWE, 2016c).
	Abandoned processes	• Hazard-specific sampling for exotic diseases ceased in 2012. Sufficient data had been gathered through the programme to support claims of disease freedom from OIE listed viral diseases (DPIPWE, pers. comm.). • Active sampling for regional presence of endemic diseases (DPIPWE, pers. comm.). • Sampling of healthy fish (only moribund fish sampled now) (DPIPWE, pers. comm.). • Regular site visits by a TSHSP veterinarian because companies all employ their own veterinarians now (DPIPWE, pers. comm.).

Table 6. Tasmanian Pacific Oyster Health Surveillance Programme[74] and relevant aquatic health and disease surveillance regulations.

TASMANIA	Cultured host species	Pacific oysters.
	Start date	• 1990, sample collection and diagnostic testing introduced in 2010–11 (Ellard, no date). • The programme has been suspended and the focus has shifted to OsHV-µvar surveillance since the 2016 outbreak (DPIPWE, pers. comm.).
	Regulatory authority	• DPIPWE.
	Relevant legislation	• Animal Health Act 1995 (AHA) (Tasmania). • Living Marine Resources Act 1995 (LMRA) (Tasmania).
	Objectives	• Maintenance of disease free zones in Tasmania (DPIPWE, pers. comm.).
	Diseases of most concern	• Infection with OsHV-µvar.
	Sampling and data collection	• Farmers submitted samples to DPIPWE when unusual mortality is detected (DPIPWE, pers. comm.). • DPIPWE visited farms and collects samples during summer (Dec–Mar) when disease is most likely to occur, sample collection is focussed on poorly performing or clinically affected stock. Annual sample collection was designed based on region and the results of passive surveillance. DPIPWE aimed to test 600–700 oysters per year (Ellard, 2013; DPIPWE, pers. comm.). • 60 oysters for each farm that supplies broodstock to hatcheries must be tested (Ellard, no date). • DPIPWE also sampled wild oysters around ports (DPIPWE, pers. comm.).
	Routine diagnostic tests	• PCR, histopathology and bacteriology for general screening (DPIPWE, pers. comm.).
	Mandatory requirements	• None.
	Variable requirements	• None.
	Voluntary measures	Best Practice Guide for Tasmanian Oyster Producers (Duthie, 2014): • Oysters should be inspected[75] and be free from disease prior to transfer. • Regular inspections of stock health should be conducted.
	Reporting requirements	• Farmers must legally report presence of notifiable diseases, suspected new diseases and unknown diseases that are causing mortality to the authorities (DPIPWE, 2016a and AHA, §27–30). • Farmers must report mortality or morbidity above the prescribed rate to the authorities (AHA, §30). Significant shellfish mortality is defined as > 15% between two observations 15 days apart (Duthie, 2014).
	Data management	• Diagnostic results are managed through a Laboratory Information Management System (LIMS) database that is only available to certain government staff (DPIPWE, pers. comm.).
	Outputs	–
	Use of outputs	–
	Consequences if disease is detected	• Transfers of diseased animals will not be permitted (AHA, §17). • Quarantine areas may be established by the Chief Veterinary Officer where stock movement is restricted (AHA, §11–16). • Possible destruction of stock and disinfection of equipment and facilities (AHA, §65–66).
	Cost to industry	• Industry previously paid for 50% of the programme costs (Ellard & Knowles, 2014). • Diagnostic testing was on a fee for service basis, fees are subsidised for Tasmanian clients.
	Cost to regulatory body	• Government previously paid for 50% of the programme costs (Ellard & Knowles, 2014).

[74] This programme has now been suspended while there is an active programme to mitigate the spread of OsHV-µvar. The information on the programme is no longer current.
[75] The reference doesn't specify whether the inspection is only visual or whether it involves sampling of oysters for disease.

TASMANIA	Supporting material	• Tasmania's biosecurity strategy 2013–2017 (Tasmanian Biosecurity Committee, 2012). • Field sampling guide for fish disease surveillance (DPIPWE, 2016c). • Best Practice Guide for Tasmanian Oyster Producers (Duthie, 2014).
	Implementation	• The programme was discussed with an Oysters Tasmania working group each year and a costed agreement was provided to industry prior to sampling (DPIPWE, pers. comm.).
	Industry support	• Industry were involved in the programme design as they part own the programme. Oysters Tasmania has a vocal technical group (DPIPWE, pers. comm.).
	Uptake of voluntary requirements (%)	• 100% participation rate (DPIPWE, pers. comm.).
	Compliance problems	• Voluntary programme but failure to co-operate has never been an issue (DPIPWE, pers. comm.).
	Incentives for compliance	• Previously, hatcheries that participated in the programme could sell spat to other Australian states and overseas (DPIPWE, pers. comm.).
	Benefits	• Previously allowed the sale of hatchery spat to NSW, SA and overseas (prior to the occurrence of OsHV-µvar in Tasmania) (DPIPWE, pers. comm.).
	Barriers to implementation	• DPIPWE tried to improve passive surveillance but oyster farmers don't look at their stock very often and typically only empty shells left (DPIPWE, pers. comm.). • Differing opinions on how the surveillance programme should be run (DPIPWE, pers. comm.).
	Solutions	• In 2006 the programme implemented a government-industry liaison role. DPIPWE staff now conduct site visits, talk to farmers and collect samples (DPIPWE, pers. comm.).
	Abandoned processes	• Laboratory staff used to ring farmers to request samples. In 2006 the programme moved to an industry liaison approach where DPIPWE staff visit farms and collect samples. This way, higher risk stock can be targeted for sample collection (DPIPWE, pers. comm.).

Table 7. Aquatic health and disease surveillance field and laboratory capabilities in Tasmania.

No. of farms in region	In 2015 there were 64 salmon farms (48 marine and 16 freshwater) (The Senate, 2015).
Laboratory capabilities	
Organisation name	Animal Health Laboratories, DPIPWE.
No. of laboratories	1, but supported by CSIRO's Aquatic Animal Health Laboratory in Victoria.
Laboratory capabilities	• Necropsy, microbiology, histology, molecular diagnostics. • Testing for all endemic diseases of farmed Tasmanian salmon (DPIPWE, pers. comm.)[76]. • Virology for endemic pathogens, PCR for OsHV-µvar (Ellard, 2013). • ISO/IEC 17025 accredited.
No. staff & qualifications	• 8 scientists and pathologists. • 20 technicians (DPIPWE, pers. comm.).
Staff responsibilities	• Conducts most of the testing for the Tasmanian salmon industry (Anon., 2012). • Maintenance of diagnostic capability in accordance with state, national and OIE recommendations (DPIPWE, pers. comm.). • Prepare reports on diagnostic results for industry and government (DPIPWE, pers. comm.). • Annual review of the TSHSP in collaboration with industry (DPIPWE, pers. comm.). • Training of farm staff in sample collection (DPIPWE, pers. comm.).
No. of tests per annum	• In 2015–16 around 11,000 tests were conducted (DPIPWE, pers. comm.).
Field capabilities	
Organisation name	DPIPWE
No. staff & qualifications	• 1 Pacific oyster biosecurity officer.
Staff responsibilities	• Design oyster sampling programme, visit oyster farms, collect samples.
No. of farm visits per year	• Sampling is conducted by epidemiological region rather than farm. In 2014–15 farmed oysters from 11 bays were sampled and wild oysters from 10 other sites were sampled (DPIPWE, pers. comm.).

[76] Exotic disease testing is conducted by the Fish Diseases Laboratory, Australian Animal Health Laboratory in Victoria (DPIPWE, pers. comm.).

13.2.3 Canada

Table 8. Aquatic health and disease surveillance field and laboratory capabilities in Canada.

No. of farms in region	~4,000 (FVO, 2013).
Laboratory capabilities	
Organisation name	National Aquatic Animal Health Laboratory System, DFO
No. of laboratories	4
Laboratory capabilities	• National Reference Laboratories develop standard operating procedures for diagnostic tests than comply with OIE standards. • Tissue culture, parasitology, bacteriology, virology, histology, molecular biology, genetics-based testing, serology and biotechnology. • The Gulf Biocontainment Unit is a level 3 containment laboratory that is capable of performing research on exotic pathogens.
No. staff & qualifications	• Staff conducting tests for regulated pathogens must be trained and undergo proficiency testing annually to demonstrate that they are competent for each diagnostic test (DFO, 2016f).
Staff responsibilities	• Diagnostic testing for aquatic animal diseases. • Disease research. • Providing scientific advice to industry (DFO, 2014c).
No. of tests per annum	In 2012–13, 16,277 tests were conducted as part of the NAAHLS (DFO, 2014c).
Field capabilities	
Organisation name	DFO
No. staff & qualifications	• 33 FTEs under the NAAHP (includes field and laboratory staff) (DFO, 2014c).
Staff responsibilities	• Administration of the National Code on Introductions and Transfers of Aquatic Organisms, which issues permits for transferring or releasing live animals around the country (DFO, 2013c).
No. of farm visits per year	• In 2012–13, 69 facilities required fish health certificates (DFO, 2014c).

13.2.4 British Columbia

Table 9. British Columbia's Aquaculture Regulatory Programme and relevant aquatic health and disease surveillance regulations.

BRITISH COLUMBIA	Cultured host species	Salmonids.
	Start date	2011[77].
	Regulatory authority	• Fisheries and Oceans Canada (DFO).
	Relevant legislation	• Fisheries Act 1985 (Canada): – Pacific Aquaculture Regulations 2010 (Canada); – Fishery General Regulations 1993 (FGR) (Canada). • Health of Animals Act 1990 (Canada): – Health of Animals Regulations 2015 (HAR) (Canada); – Reportable Diseases Regulations 2014 (Canada). • Fish Health Protection Regulations 2011 (FHPR) (Canada).
	Objectives	• "*To* monitor *and minimize the potential risks of disease and disease transmission both to and from farmed fish*" (DFO, 2014d).
	Diseases of most concern	• Reportable diseases and OIE-notifiable diseases (Table 2 & Table 3). • Infectious hematopoietic necrosis. • Infectious pancreatic necrosis (exotic to BC). • Infectious salmon anaemia (pathogenic and non-pathogenic strains, exotic to BC). • Viral haemorrhagic septicaemia (North American strain). • Infection with *Piscirickettsia salmonis*.
	Sampling and data collection	Government audits: • DFO staff conduct unannounced farm audits to ensure that farmers are meeting the conditions of their licence. Farm audits are prioritised by risk. • DFO staff conduct fish health audits of marine farms[78]. Each quarter, approximately 50% of the active farms in the province are audited. Farm audits are scheduled to coincide with the farm's regular carcass collection to allow inspectors access the freshest dead fish (DFO, 2015a). Farms are selected randomly with the number of farms audited in each fish health zone representative of the proportion of farms in that zone. During the audit, inspectors inspect the farm and documentation, interview the farmers on recent unexplained mortality events, measure environmental conditions (temperature, dissolved O2), oversee the collection, enumeration and classification of mortality from each pen, and then takes tissue samples from 10 fresh carcasses per farm. Samples are shipped to the BC Animal Health Centre for diagnostic testing (CAHS, no date). • If a reportable or notifiable disease is reported, CFIA staff will visit the site and oversee the collection of samples to ensure that test results are valid (CFIA, 2016b). Industry surveillance: • Farmers are required to routinely check the condition of their stock and investigate abnormal or significant mortalities on their farms as part of their fish health management plan. Industry also routinely send samples for testing if there is elevated mortality or prior to transfers of stock. Samples are collected by farmers or fish health professionals and are submitted to diagnostic laboratories for testing (CFIA, 2014a).
	Routine diagnostic tests	• Standard histopathology, bacteriology, virology and molecular diagnostic tests are conducted (CAHS, no date). • Polymerase chain reaction (PCR) is routinely conducted for: – Infectious hematopoietic necrosis; – Infectious pancreatic necrosis; – Infectious salmon anaemia; – Viral haemorrhagic septicaemia (North American strain); – Infection with *Piscirickettsia salmonis*; – Salmonid alphavirus.

[77] A similar government audit and surveillance programme was previously conducted by the BC Ministry of Agriculture and Lands from 2002–2010 (CFIA, 2014a).
[78] Freshwater hatcheries and broodstock facilities are not audited (CFIA, 2014a).

BRITISH COLUMBIA		• Tissues from up to five fish are pooled for PCR analyses for IHN, IPN, ISA, VHS and infection with *P. salmonis* (CFIA, 2014a). • If there is a positive PCR result, samples are cultured on appropriate cell lines or another gold-standard diagnostic test is used to confirm the results (CFIA, 2014a).
	Mandatory requirements	• Movement of all life stages of salmonids between provinces requires a permit. Fish must come from facilities that have a fish health certificate stating that fish are free of certain diseases (FHPR, §3–5). To obtain a fish health certificate, facilities must pass 4 inspections over a period of > 18 months (DFO, 1984). • Release of live fish into the environment or transfer of fish to a rearing facility requires a permit and fish must be disease-free (FGR, §55–56). Marine Finfish Aquaculture Licence under Fisheries Act 1985 (DFO, 2016a): • Transfer of salmonids within same transfer zone must have a certificate from a veterinarian confirming that mortality is < 1% per day, stock to be moved show no signs of disease, and no stock at the facility have diseases of regional or national concern[79]. • Farmers must prepare and comply with a Fish Health Management Plan, which is to cover routine health and disease surveillance, record keeping of health status, methods for preventing, controlling or treating disease, disposal of dead fish, biosecurity protocols, sanitisation methods, staff biosecurity training and mortality event procedures. • Farmers must keep records of disease history and management, sampling and diagnosis, actions taken to prevent or control disease and fish movement within the facility.
	Variable requirements	• The Fish Health Management Plans vary among companies (Expert 7, UPEI, pers. comm.).
	Voluntary measures	• Disease screening of broodstock prior to spawning. • Vaccination for IHN, vibriosis and furunculosis, BKD and enteric red mouth (Thompson, 2013; BCSFA, 2016). • Single year class production and fallowing after each production cycle. • All salmon farmers in BC have at least one third party certification or recommendation e.g., Global Aquaculture Alliance Best Aquaculture Practices (BCSFA, 2016).
	Reporting requirements	• Farmers are legally required to report diseases listed in the Reportable Disease Regulation (see Table 2 & Table 3) to the authorities within 24 h. • Farmers must provide scheduled, regular (usually quarterly) reports for: – peak biomass (DFO, 2016a); – standard operation procedures for health management (DFO, 2016a); – stock transfers (DFO, 2016j); – therapeutants and chemicals used (DFO, 2016a); – % mortality and probable cause (DFO, 2016b); – use of lights (DFO, 2017a). • Farmers must provide incidental reports for significant mortality events to the authorities within 24 h, followed by a report (within 10 days) outlining the total mortality rate and cause of mortality (DFO, 2016a; 2017a). A significant mortality event means: – mortalities equivalent to 4000 kg or more, or losses reaching 2% of the current facility inventory, within a 24 h period; or – mortalities equivalent to 10,000 kg or more, or losses reaching 5%, within a five day period (DFO, 2017a).
	Data management	• DFO manages surveillance data and publishes results on the internet that are publicly available and identifiable to the company (DFO, 2013a). • National introductions and transfers database: each Introductions and Transfers committee maintain information on movements within their state and report annually to the National Introductions and Transfers Coordination Office (part of DFO). Data are recorded on standard forms to ensure consistent information and easy of data entry (DFO, 2013c). • Web-based laboratory information management system implemented in 2012 that allows total traceability and tracking of specimens from the point of collection to reporting of results (FVO, 2013).

[79] Infectious hematopoietic necrosis, infectious pancreatic necrosis, viral haemorrhagic septicaemia, infectious salmon anaemia, *O. masou* virus disease, whirling disease, cold water vibriosis (Hitra disease).

BRITISH COLUMBIA	Outputs	• Infringements of licence conditions for audited sites (DFO, 2016e). • Monthly percentage mortality rate and probable causes (DFO, 2016b). • All outside/across zone stock transfers (DFO, 2016j). • The results of fish health audits and use of therapeutants to treat fish (DFO, 2014b). • All outputs are identifiable by licensee. • National introductions and transfers database. Only aggregated statistics are publicly available on the internet (DFO, 2016h). • Periodic reports on surveillance activities that provide the basis for market access through health certification (CFIA, 2015b). • Monthly updates on confirmed cases of reportable diseases (CFIA, 2016a).
	Use of outputs	• Introductions and transfers data used to support Canada's domestic and international reporting to the Ministers (DFO, 2013c).
	Consequences if disease is detected	• Confirmed cases of reportable or immediately notifiable disease requires immediate destruction and disposal of infected stock and disinfection of facilities and equipment. The farm will be placed under quarantine, potentially for several months (CFIA, 2016b). • Loss of fish health certificate. • The transfer or release of fish is prohibited.
	Cost to industry	• None, apart for the fish that are sacrificed for surveillance and the labour costs of compliance. Industry pay for the diagnostic costs of investigations outside of BCARP (Expert 7, UPEI, pers. comm.).
	Cost to regulatory body	• Government pays for all inspection and diagnostic costs that are part of BCARP. The programme is funded by the taxpayer (Expert 7, UPEI, pers. comm.). • 1339 hours to audit licence conditions of 37 marine finfish farms (DFO, 2014a).
	Supporting material	• National code on introductions and transfers of aquatic organisms (DFO, 2013c). • Fish health protection regulations: manual of compliance (DFO, 1984).
	Implementation	–
	Industry support	• BC farmers have invested CAN$1.5 million to fund disease research between 2015–2020 (BCSFA, 2016).
	Uptake of voluntary measures	• Most BC farms rear single year classes of finfish and fallow after every production cycle (Saksida, 2006; DFO, 2016a). • In 2012, BC farmers agreed to 100% vaccination for IHN (Stewart, 2012).
	Compliance problems	• None (Expert 7, UPEI, pers. comm.).
	Incentives for compliance	• BC farmers feel they need to comply in order to prevent negative publicity (Expert 7, UPEI, pers. comm.).
	Benefits	• Trade (Expert 7, UPEI, pers. comm.).
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 10. British Columbia's sea lice surveillance programme.

BRITISH COLUMBIA	Cultured host species	Salmonids.
	Start date	2003.
	Regulatory authority	Fisheries and Oceans Canada (DFO).
	Relevant legislation	• Fisheries Act 1985 (Canada): – Pacific Aquaculture Regulations 2010 (Canada); – Fishery General Regulations 1993 (FGR) (Canada). • Health of Animals Act 1990 (Canada): – Health of Animals Regulations 2015 (HAR) (Canada); – Reportable Diseases Regulations 2014 (Canada). • Fish Health Protection Regulations 2011 (FHPR) (Canada).
	Objectives	• To minimise the potential exposure of wild and farmed fish to sea lice.
	Diseases of most concern	• Infection with *Lepeophtheirus salmonis.*
	Sampling and data collection	• Farmers with 3 or more stocked pens to conduct fortnightly sampling for sea lice on Atlantic salmon and trout between 1 March and 30 June when wild fish migrate out to sea, and at monthly intervals for the rest of the year. Sampling to comprise 20 fish from each of 3 pens (1 regular pen and 2 random pens). All stages of *L. salmonis* and *Caligus clemensi* are counted but *C. clemensi* are not considered harmful to salmon and no further action is required from the farmer (DFO, 2016a). • Farmers to conduct quarterly sampling for sea lice on Pacific salmon (DFO, 2016a). • DFO staff conduct random audits to validate the farmers' reported lice counts on 50% of active Atlantic salmon farms during spring. Spot checks (25% of active farms/quarter) are conducted for the remainder of the year. During audits DFO staff count the lice on 10 fish and farm staff count the lice on 10 fish (per pen) to compare counts between auditors and farm staff (Saksida *et al.*, 2011).
	Routine diagnostic tests	• Visual examination.
	Mandatory requirements	• Farmers must participate in the sea lice surveillance programme (DFO, 2016a).
	Variable requirements	• Sampling may be skipped during stressful environmental conditions e.g., low dissolved oxygen or harmful algae blooms (DFO, 2014a).
	Voluntary measures	• Farmers with 2 or less stocked pens may choose whether or not to monitor for sea lice (DFO, 2016i). • Farmers have assisted with the establishment sea lice monitoring programmes on wild salmon (BCSFA, 2016).
	Reporting requirements	• Farmers must notify the authorities if more than an average of 3 motile sea lice/fish are found (DFO, 2016a). • Farmers are required to provide monthly reports of sea lice counts to DFO (DFO, 2016i). • Farmers are required to report on the use of any anti-lice therapeutants (DFO, 2016d).
	Data management	• DFO manages a lice database and publishes surveillance results on the internet. Data is updated quarterly (DFO, 2016i).
	Outputs	• Monthly industry reports of sea lice counts are publicly available on the internet, identifiable to company (DFO, 2016i). • Quarterly DFO audits of sea lice counts for each farm are publicly available on the internet, identifiable to company (DFO, 2016i). • Annual use of in-feed anti-lice therapeutants, aggregated totals (DFO, 2016d). • Graphs of sea lice abundance per month per fish health zone (DFO, 2016i).
	Use of outputs	• Improvement of management of sea lice, assessment of the efficacy of treatments. • Determine if farmed salmon are contributing to lice numbers on wild fish (BCSFA, 2016).
	Consequences if disease is detected	• If more than an average of 3 motile sea lice/fish found the farmer must notify the authorities and implement a plan to reduce lice numbers within 15 days. This may entail an in-feed treatment or the harvest of stock (DFO, 2016a).
	Cost to industry	–

BRITISH COLUMBIA	Cost to regulatory body	–
	Supporting material	–
	Implementation	–
	Industry support	–
	Uptake of voluntary measures	–
	Compliance problems	• None (I. Gardener, UPEI, pers. comm.).
	Incentives for compliance	• BC farmers feel they need to comply in order to prevent negative publicity (I. Gardener, UPEI, pers. comm.). • In 2015, there was a 93% agreement between industry and DFO sea lice counts (DFO, 2017a).
	Benefits	–
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 11. Salmon disease surveys in British Columbia (multiple discrete, hazard-specific surveys).

BRITISH COLUMBIA	Cultured host species	Salmonids (*Oncorhynchus kisutch, O. keta, O. tshawytscha, O. nerka, O. gorbuscha* and *O. mykiss*).
	Start date	2012.
	Regulatory authority	Canadian Food Inspection Agency (CFIA) and Fisheries and Oceans Canada (DFO).
	Relevant legislation	• n/a.
	Objectives[80]	• Substantiate disease freedom from infectious salmon anaemia virus (ISAV) and infectious pancreatic necrosis virus (IPNV) in BC in cultured and wild anadromous salmonids (2012–2014) (CFIA, 2011). • Substantiate disease freedom from infectious haematopoietic necrosis virus (IHNV) in certain areas and species (2012–2014) (CFIA, 2011). • Demonstrate that infection rates of wild fish by VHSV and IHNV are sufficiently low to prevent introduction to other countries to support international trade requirements (2014–2015) (CFIA, 2015a).
	Diseases of most concern	• ISA and IPN (exotic to BC). • IHN and VHS (endemic to BC).
	Sampling and data collection	Wild fish: • CFIA coordinated collection of broodstock and fry from federal enhancement hatcheries. • CFIA coordinated collected of mature, saltwater fish from processing plants. • DFO collected wild fish. • 8006 fish sampled between 2012–14 (no. of fish sampled allows the detection of 1% disease prevalence) (CFIA, 2014c). • 9800 tests conducted between 2012–14 (3850 for ISAV, 3850 for IHNV, 2100 for IPNV). • In 2014–15, 208 wild salmon were tested for VHSV and IHNV. The survey was designed to detect a 2% infection rate (CFIA, 2015a). Cultured fish: • CFIA veterinary inspectors visited 10% of marine farms in BC. Farm selection was risk-based. The inspector reviewed the biosecurity plan, inspected premises and collected samples (CFIA, 2011).

[80] Objectives and survey design vary between surveys.

BRITISH COLUMBIA		• In 2014–15, farmed salmon were collected from processing plants by CFIA. 3312 farmed salmon were tested for ISAV HPR0 (non-pathogenic strain) (CFIA, 2015a).
	Routine diagnostic tests	• Screening by RT-PCR or qRT-PCR, with subsequent confirmation of positive findings by an independent test (preferably virus isolation) (CFIA, 2014c).
	Mandatory requirements	• Farmers must allow DFO staff to inspect their farms and sample fish.
	Variable requirements	• n/a.
	Voluntary measures	• n/a.
	Reporting requirements	• Reports on the results of the surveillance programme (CFIA, 2014a; 2014b; 2015a).
	Data management	• CFIA owns and manages the data.
	Outputs	• Reports on the results of the surveillance programme (CFIA, 2014a; 2014b; 2015a).
	Use of outputs	• Provided support for domestic disease control policy (CFIA, 2014b). • Supported international trade negotiations (demonstrated freedom from disease) (CFIA, 2014b). • Supported a risk-based compartmentalisation programme (estimates of the risk for disease introduction) (CFIA, 2014b).
	Consequences if disease is detected	• Trade impacts.
	Cost to industry	• Sampled fish.
	Cost to regulatory body	• Estimated time and costs to sample 3,850 fish (target number per year) was 278 hours and CAN$18,181[81] (comprises labour $6,181, shipping $1,500, travel and accommodation $7,500, equipment and supplies $3,000) (CFIA, 2011). • Laboratory testing fees.
	Supporting material	–
	Implementation	–
	Industry support	• BC Salmon Farmers Association (BCSFA) collaborated with CFIA for this programme (CFIA, 2014a).
	Uptake of voluntary measures	• n/a.
	Compliance problems	• n/a.
	Incentives for compliance	• Confidentiality agreements were made between BCSFA and CFIA (CFIA, 2014a).
	Benefits	• Facilitated trade agreements and disease control policies.
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

[81] NZ$19,010 at current exchange rates.

Table 12. Shellfish disease surveys in British Columbia (multiple discrete, hazard-specific surveys).

BRITISH COLUMBIA	Cultured host species	Pacific oysters and Manila clam (*Venerupis phillippinarum*).
	Start date	2006.
	Regulatory authority	Canadian Food Inspection Agency (CFIA) and Fisheries and Oceans Canada (DFO).
	Relevant legislation	• n/a.
	Objectives[80]	• To determine the health status of Pacific oysters and Manila clams in British Columbia for diseases of trade significance (2006–2009) (CFIA, 2009). • To determine the status of specific shellfish diseases in Manila clams and oysters in British Columbia (2014–2015) (CFIA, 2015a).
	Diseases of most concern	• Infection with *Marteilia refringens*. • Infection with *Perkinsus marinus*. • Infection with *Perkinsus olseni.* • Infection with *Bonamia ostreae.* • Infection with *Bonamia exitiosa*. • Infection with *Bonamia (= Mikrocytos) roughleyi*. • Infection with *Marteilia sydneyi*. • Infection with *Marteilioides chungmuensis.* • Infection with *Vibrio tapetis.* • Infection with *Haplosporidium nelsoni* (MSX). • Infection with *Haplosporidium costale* (SSO). • Infection with *Mikrocytos mackini.*
	Sampling and data collection	• Cultured shellfish were collected from processing plants. Wild shellfish were collected from the beach. Collection occurred at times when the pathogens of concern were most likely to be detected (CFIA, 2009). • In 2006, CFIA staff collected all samples. In 2007, industry collected samples and shipped them to the diagnostic laboratory, with sampling co-ordinated by a contractor on behalf of CFIA. CFIA staff performed audits on the sample collection, tracking and traceability in order to demonstrate to a trade partner that sampling was satisfactory (CFIA, 2009). • Between the fall of 2006 and the spring of 2009, 2035 Pacific oysters and 2354 Manila clams were screened using histopathology. The number of animals sampled was based on an assumed infection rate of 2% and a confidence level of 95% (CFIA, 2012). • In 2014–2015, 1170 Pacific oysters were tested for OsHV-µvar (751 tests) and 350 wild blue mussels were tested for M. refringens. The number of shellfish sampled was designed to detect a 1–2% infection rate (CFIA, 2015a).
	Routine diagnostic tests	• Shellfish were screened using histopathology. Molecular diagnostic methods (e.g., PCR and *in situ* hybridisation) were used to confirm the presence of a pathogen. Positive results for exotic diseases were sent to the OIE reference laboratory for external validation (CFIA, 2009). • *Perkinsus marinus*: molecular diagnostic testing (CFIA, 2015a). • OsHV-µvar: molecular diagnostic testing. 10 spat were pooled for testing (CFIA, 2015a).
	Mandatory requirements	• Farmers must allow DFO staff to inspect their farms and sample shellfish.
	Variable requirements	• n/a.
	Voluntary measures	• n/a.
	Reporting requirements	• Reports on the results of the surveillance programme (CFIA, 2009; 2015a).
	Data management	–
	Outputs	• Laboratory results were sent to CFIA, the British Columbia Shellfish Growers Association (BCSGA) and the participating shellfish processors (CFIA, 2009; 2014b). • Reports on the results of the surveillance programme (CFIA, 2009; 2015a).

BRITISH COLUMBIA	Use of outputs	• To support trade.
	Consequences if disease is detected	• Trade implications.
	Cost to industry	• Cost of sampled shellfish.
	Cost to regulatory body	• The survey was funded by CFIA.
	Supporting material	–
	Implementation	• In April 2004, the BCSGA formed a working group with key government stakeholders and aquatic veterinarians to develop a shellfish health programme. • In May 2004, the BC Ministry of Agriculture and Land (BCMAL) contracted a study to investigate why BC did not meet the EU export requirements for live shellfish. • In March 2005, BCMAL and DFO provided funds to assist with surveillance of industry health practices and development of a health programme. • In November 2005, a two year surveillance programme was funded by the CFIA. The design if the surveillance programme was developed in close collaboration with the British Columbia Shellfish Growers Association, DFO and BCMAL. Sampling methodology was consistent with OIE standards. • The surveillance programme began in June 2006. Methodology was changed twice in 2007 (see abandoned processes below) (CFIA, 2009).
	Industry support	–
	Uptake of voluntary measures	• n/a.
	Compliance problems	• n/a.
	Incentives for compliance	• n/a.
	Benefits	–
	Barriers to implementation	• Targeted sample numbers of wild shellfish were not achieved because of: – lack of human resources to carry out sampling; – reduced wild harvest of shellfish available; – unknown timing of harvest events (CFIA, 2009). • Lack of contact between CFIA staff and processors that undermines the importance of compliance and industry participation rate (CFIA, 2009). • Remote locations are less likely to be sampled by CFIA staff (CFIA, 2009).
	Solutions	• Methodology changes (see below).
	Abandoned processes	• In April 2007, methodology was changed to refocus sampling effort from processing plants to regions to optimise representativeness of samples and to allow for making inferences of disease freedom at the provincial level (CFIA, 2009). • In June 2007, methodology was changed again to overcome challenges associated with processing large numbers of small lots. Shellfish collection changed from being collected by government staff to being collected by industry and co-ordinated by a contractor on behalf of CFIA. This change was due to logistic problems with CFIA staff conducting the inspections, and a desire to promote an “industry-driven” surveillance programme. Shellfish collection by industry was audited by CFIA staff (CFIA, 2009).

Table 13. Aquatic health and disease surveillance field and laboratory capabilities in British Columbia.

No. of farms in region	109 licenced salmonid farms in 2016, with around 54 active farms at any one time (DFO, 2015a; BCSFA, 2016).
Laboratory capabilities	
Organisation name	Animal Health Centre.
No. of laboratories	1
Laboratory capabilities	• Bacteriology, histopathology, molecular diagnostics, pathology (necropsy), serology, and virology. • Accredited by the Standard Council of Canada and the American Association of Veterinary Laboratory Diagnosticians (Government of British Columbia, no date-a).
No. staff & qualifications	• 3 veterinarians. • 1 microbiologist (Government of British Columbia, no date-a).
Staff responsibilities	• Diagnostic testing.
No. of tests per annum	• 5000 (Townsend, 2014).
Field capabilities	
Organisation name	Fisheries and Oceans Canada (DFO).
No. staff & qualifications	
Staff responsibilities	• Conduct farm audits and sample fish. • Conduct sea lice audits.
No. of farm visits per year	• In 2014, DFO conducted 227 conditions of licence audits (DFO, 2015b). • In 2015, 120 fish health audits were conducted (~50% of active farms per quarter), 820 carcasses were sampled, and 31 farms were audited for sea lice counts (CFIA, 2014a; DFO, 2016k; 2017a; CAHS, no date). • DFO aim to visit each facility at least once per production cycle (DFO, 2017a).

13.2.5 New Brunswick

Table 14. New Brunswick's Marine Aquaculture Finfish Health Policy, Infectious Salmon Anaemia management and control programme, and relevant aquatic health and disease surveillance regulations.

NEW BRUNSWICK	Cultured host species	Atlantic salmon
	Start date	• 1998 for ISAV management and control programme (last update 2008). • 2009 for marine aquaculture finfish health policy.
	Regulatory authority	New Brunswick Department of Agriculture, Aquaculture and Fisheries.
	Relevant legislation	• Aquaculture Act 1988 (AA) (revised 2011) (New Brunswick): – General Regulation 91-158 (GR).
	Objectives	Finfish health policy: • To minimise the risk of disease transfer between aquaculture facilities (DAAF, 2009). ISA control programme: • To provide a comprehensive and standardised approach to the management and control of ISA in New Brunswick. • To minimize the overall economic impact of ISA on the New Brunswick aquaculture industry.
	Diseases of most concern	• Infection with *Aeromonas* sp. • Enteric redmouth disease. • Bacterial kidney disease. • Infection with *Vibrio* sp. • Other diseases that have a significant commercial impact (DAAF, 2009).
	Sampling and data collection	• DAAF staff conduct farm health inspections (called site visits) every two months (usually every 6 weeks), assess overall fish health and collect samples from 5 moribund fish for diagnostic testing. Fish are tested for ISAV, *Aeromonas* spp., enteric redmouth disease, *Vibrio* spp., and bacterial kidney disease. Private veterinarians also visit sites on alternating months from DAAF or more often as required (GR, §20(2); S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.). • Approved fish health diagnostic services sample broodstock for bacterial kidney disease within 1 month of fertilisation (GR, §21). • DAAF staff conduct annual site biosecurity audits of farms (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.). ISA management and control programme (DAAF, 2008): • 10 broodstock per site are sampled for ISAV and BKD between Sep and Oct for pre-screening (DAAF, 2008). • 30 broodstock from each water source are sampled for ISAV just prior to spawning (DAAF, 2008). • Any fish that become weak or die during the spawning season, or 60 days after spawning season must be sampled for ISAV (DAAF, 2008). • 60 pre-smolts per lot are lethally sampled for ISAV annually (Nérette et al., 2008). • Monthly site visits of marine farms are conducted by DAAF staff and company veterinarians (alternating visits). 5–20 moribund fish per site are sampled for ISAV each month (DAAF, 2008). • Sites suspected to contain ISAV must be sampled within a week of positive results and then fortnightly thereafter (DAAF, 2008). • Samples are submitted to a DAAF contracted laboratory for diagnostic testing (DAAF, 2008).
	Routine diagnostic tests	• Bacterial kidney disease: bacterial culture and one of the following: double antibody sandwich enzyme-linked immunosorbent assay (ELISA), indirect fluorescent antibody test (IFAT) or direct fluorescent antibody test (DFAT), PCR (DAAF, 2008). • ISAV: IFAT and RT-PCR (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Mandatory requirements	• Farmers must keep records of all transfers, mortalities, stocking biomass, the presence of disease and feed used (GR, §14(1)). • Transfer of stock from inland areas to a marine site requires stock to be certified free from furunculosis, bacterial kidney disease and antimicrobial residues (GR, §15(1)).

NEW BRUNSWICK		• Transfer of stock between a marine site to another culture site requires stock to be certified free from *Aeromonas* sp., enteric redmouth disease, *Vibrio* sp., and bacterial kidney disease. Fish in the receiving site must have the same disease profile as the fish to be transferred (GR, §16(1)). • Transfer of stock between inland sites requires stock to be certified free from *Aeromonas* sp., enteric redmouth disease, bacterial kidney disease, external parasites and any other uncommon disease (GR, §18). • Participation in the ISA control programme. Each site must have a private veterinarian to carry out the responsibilities of the ISA control program (DAAF, 2008). • Broodstock sites must be certified under DFO's Fish Health Protection Regulations (fish health certificate) (DAAF, 2008).
	Variable requirements	• None.
	Voluntary measures	• Codes of practice and 3rd party certification e.g., Best Aquaculture Practices certification from Global Aquaculture Alliance (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Reporting requirements	• Fish health diagnostic services report diagnostic testing results to the authorities immediately after testing (GR, §21). • Farmers shall immediately report the presence of a commercially significant disease or disease agents to regulatory authorities (AA, §25). Diseases that have no commercial significance are considered non-reportable (DAAF, 2009). • Farmers are required to submit annual sea lice management plans that detail the name of therapeutants to be used, method of treatment and estimated timing of treatment (GR, §12.1). • Farmers are required to provide sea lice reports to the authorities within 48 h of conducting the counts (GR, §12.1). • Farmers must inform the authorities of any diagnostic work or any therapeutants administered to stock (GR, §14(4)). • Farmers and the company veterinarian must submit a monthly fish health report to DAAF that includes details on: site inspections, samples submitted, any unexplained mortality and diagnostic results (DAAF, 2008).
	Data management	• Fish Health Unit manages fish health data (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Outputs	• Some reporting of disease incidences to public. Farmers details are confidential. Data is also shared with CFIA (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Use of outputs	–
	Consequences if disease is detected	• Authorities may order farmers to quarantine, destroy or dispose of stock (AA, §19.1). List 1 diseases (exotic, highly infectious or no acceptable control methods) typically require immediate quarantine and destruction of stock. List 2 diseases (contagious but can generally be managed) typically require increased surveillance. Destruction of stock may be necessary in some cases (DAAF, 2009). • Infected areas may be deemed Controlled Aquaculture Areas (DFO, 2010).
	Cost to industry	• Industry pays for company veterinarian who conducts site visits at a minimum of once every two months as part of the surveillance programme (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Cost to regulatory body	• Programme and diagnostic testing paid for by government. Total cost of fish and shellfish health programme is CAN$500,000–700,000 per annum (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.). • The government provided compensation of over CAN$14 million for the destruction of ISA infected fish between 1996 and 2001 (Woodman, 2006).
	Supporting material	• New Brunswick Marine Aquaculture Finfish Health Policy 2009 (DAAF, 2009). • Bay of Fundy Marine Aquaculture Site Allocation Policy (DAAF, 2000). • Government conducted risk management pathway studies and have worked on eliminating the risk pathways (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Implementation	• Government worked with industry and private veterinarians to develop the ISA programme. Hosted a workshop with Norwegian experts to learn from their experience in 1997 (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Industry support	• Industry were generally very supportive and the industry association was 100% supportive (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).

	Uptake of voluntary measures	• n/a.
	Compliance problems	• There were some minor compliance issues at the beginning (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Incentives for compliance	• All fish health records and diagnostic results are confidential (AA, §38). • Compensation was initially paid to farmers for culled fish, from a fund provided by provincial and federal governments (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Benefits	• Early detection of ISAV. Farmers are now very proactive about rapidly depopulating or harvesting affected cages, which allows the disease or disease agent to be controlled. The last major outbreak of ISA was in 2007 (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Barriers to implementation	• At the time of the 1997 ISA outbreak there were about 50 salmon farming companies in New Brunswick, many of which were small family businesses. It was difficult to get everyone to agree. Now there are only three salmon farming companies (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Solutions	• Education of farmers on the benefits and need for surveillance helped. The government ran fish health workshops (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.). • Regular site visits by newly hired company veterinarians also helped farmers with disease management and awareness (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Abandoned processes	• Histopathology and virus culture for ISAV have been replaced by PCR and IFAT because these techniques are much quicker and more reliable. Can get a test result in the same day if urgent, otherwise it usually takes 24 hours (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.; McGeachy & Moore, 2003). • Marine broodstock are no longer allowed (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).

Table 15. New Brunswick's sea lice monitoring program and Integrated Pest Management Programme (IPMP) for sea lice.

NEW BRUNSWICK	Cultured host species	Atlantic salmon.
	Start date	• 2011 for the IPMP.
	Regulatory authority	• New Brunswick Department of Agriculture, Aquaculture and Fisheries.
	Relevant legislation	• Aquaculture Act 1988 (AA) (revised 2011): – General Regulation 91-158 (GR).
	Objectives	• Monitoring programme: to maintain sea lice numbers below an agreed upon threshold that is intended to prevent the spread to other farms and reduces the potential impact to wild stocks (DAAF, 2012). • IPMP: to provide a science-based management framework for the prevention, research, surveillance and control strategies required to manage sea lice (Brewer-Dalton, 2013).
	Diseases of most concern	• Infection with *Lepeophtheirus salmonis.*
	Sampling and data collection	• Farmers conduct sea lice counts (6 cages, 5 fish per cage) on a weekly or monthly basis (dependent on water temperature), or before administering any anti-lice treatment. Farmers submit data to a database that is maintained by the Atlantic Veterinary College (ACFFA, 2013). • Lice numbers must be reported as: *L. salmonis* chalimus; *L. salmonis* pre-adults and males; *L. salmonis* adult females; and *Caligus* spp. adults (DAAF, 2012). • Government staff conduct 10–15 audits per year for lice counts, which corresponds to 60% of active sites at least twice per year (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.; DAAF, 2012).
	Routine diagnostic tests	• Visual counts for sea lice.

NEW BRUNSWICK

Mandatory requirements	• Farmers must develop an annual seal lice management plan in collaboration with fish health professionals and government that establishes a treatment plan that follows the principles of the IPMP, and complies with the monitoring programme, any BMAs, and regulations (DAAF, 2012). • Farmers must conduct sea lice counts (6 cages, 5 fish per cage): – within 7 days before any anti-lice treatment is used; – following lice treatment within the period specified by the manufacturer; – weekly when water temperatures are ≥ 5°C; – monthly when water temperatures are < 5°C (GR, §12.1). • Two cages with probable high sea lice numbers are to be sampled and four other random cages. If treatment is to be applied, cages scheduled for treatment should be sampled both before and after treatment (DAAF, 2012).
Variable requirements	• Frequency of monitoring is dependent on the water temperature ((GR, §12.1)).
Voluntary measures	• None, but farmers often go beyond the mandatory requirements and have invested a lot of money on alternative control methods such as cleaner fish and well boats. Also industry uses codes of practices and private company veterinarians to provide additional fish health measures and biosecurity (ACFFA, 2013; S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Reporting requirements	• Farmers are required to submit annual sea lice management plans that detail the name of therapeutants to be used, method of treatment and estimated timing of treatment (GR, §12.1). • Farmers are required to provide sea lice reports to an independent 3rd party managed database within 24 h of conducting the counts (GR, §12.1; DAAF, 2012). • Farmers must provide a monthly fish health assessment to DAAF that confirms that weekly sea lice counts have been conducted and submitted. The report is also to include details on any anti-lice treatments applied (DAAF, 2012). • Farmers must submit a sea lice count report to DAAF within 7 days of receiving any information relating to diagnostic work conducted on their site. The report must include diagnostic results (DAAF, 2012).
Data management	• Sea lice database (Decision Support System) is maintained by the Atlantic Veterinary College (ACFFA, 2013). This includes data on lice counts, bioassay data and treatment data (Anon., 2015a).
Outputs	• The Atlantic Canada Fish Farmers Association produces an annual report on sea lice numbers and management (e.g., ACFFA, 2013).
Use of outputs	• Provides information on lice trends and 'hot spots' that are prone to high numbers. This information is used to assist lice management, analyse lice trends and regional differences, evaluate the efficacy of treatment and identify signs of resistance to therapeutants (Brewer-Dalton, 2013; S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Consequences if disease is detected	• Administration of in-feed anti-lice treatment is synchronised within each management zone (Chang *et al.*, 2014).
Cost to industry	• Reporting database for sea lice counts. • Labour required for sea lice counts.
Cost to regulatory body	• Cost of field staff to conduct lice count audits.
Supporting material	• All lice counters are trained and certified by the Atlantic Veterinary College. Each counter has a unique identification number so their counts can be individually tracked. This allows the government to identify any counters that may require extra training (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Implementation	• DAAF, fish health experts and industry researched non-chemical methods for controlling sea lice in the development of the integrated pest management plan. Development of the plan was a collaborative process and the plan is continually refined (ACFFA, 2013; Brewer-Dalton, 2013).
Industry support	• Good. Farmers were already monitoring sea lice numbers and using veterinary support before the programme became mandatory (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Uptake of voluntary measures	• n/a.

NEW BRUNSWICK	Compliance problems	• Compliance is generally very good. Farmer counts are 90–95% accurate with audits. Farmers have more difficulty counting the smaller lice stages (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Incentives for compliance	• None provided.
	Benefits	• Lice burden is similar to before the programme started but the programme provides information on trends in lice numbers and 'hot spot' areas that is used to inform management decisions (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 16. New Brunswick's health policy for shellfish aquaculture, shellfish health surveillance programme, and relevant aquatic health and disease surveillance regulations.

NEW BRUNSWICK	Cultured host species	Eastern oysters (*Crassostrea virginica*).
	Start date	• 2015.
	Regulatory authority	New Brunswick Department of Agriculture, Aquaculture and Fisheries.
	Relevant legislation	• Aquaculture Act 1988 (AA) (revised 2011) (New Brunswick): – General Regulation 91-158 (GR).
	Objectives	• To provide comprehensive and timely information on MSX and *Bonamia* in order to allow for a rapid response for controlling or managing these diseases if required. • To assess the status of other diseases and pests of concern to the shellfish aquaculture industry. • To provide adequate sampling of targeted organisms (oysters and other bivalves) and timely results on samples collected (DAAF, 2015).
	Diseases of most concern	• Infection with *Haplosporidium nelsoni* (MSX disease) (federally notifiable). • Infection with *Bonamia* spp. (federally notifiable). • Infection with *Perkinsus marinus* (Dermo disease). • Other diseases that have a significant commercial impact (DAAF, 2015).
	Sampling and data collection	• DAAF shellfish biologists coordinate the programme, conduct farm health inspections, assess overall shellfish health and collect samples for diagnostic testing (DAAF, 2015). • 30 farmed oysters are randomly collected from 9 specified sites twice a year for disease screening (DAAF, 2015). • 5 wild oysters from each of 3 spat collecting areas will also be randomly collected each month during summer for disease screening (DAAF, 2015). • Samples are sent to a DAAF contract laboratory for testing for MSX and *Bonamia* spp. (DAAF, 2015; S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.). • The DAAF veterinarian oversees all shellfish health issues and concerns (DAAF, 2015).
	Routine diagnostic tests	• PCR for MSX and *Bonamia* spp. (DAAF, 2015). • Positive samples are sent to the NAAHLS laboratory for confirmatory testing (DAAF, 2015). • Histopathology may also be conducted (DAAF, 2015).
	Mandatory requirements	• Farmers must keep records of all transfers, mortalities, stocking biomass, the presence of disease, diagnostic results and other relevant health information. (GR, §14(1)). These records must be provided to an inspector upon request (DAAF, 2015). • Transfers of live shellfish require a permit from DFO (DAAF, 2015).
	Variable requirements	• None.
	Voluntary measures	• None.
	Reporting requirements	• Fish health diagnostic services report diagnostic test results to the authorities immediately after testing (GR, §21).

NEW BRUNSWICK		• Farmers shall immediately report the presence of a commercially significant disease or disease agents to regulatory authorities (AA, §25). This includes aquatic pest species (DAAF, 2015). • Farmers must inform the authorities of any diagnostic work or any therapeutants administered to stock (GR, §14(4)).
	Data management	• Fish Health Unit manages data (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Outputs	• A generic report of the surveillance results will be produced for each surveillance period (DAAF, 2015). • Some reporting of disease incidences to public. Farmers details are confidential. Data is also shared with CFIA (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Use of outputs	• CFIA use data in epidemiological studies (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Consequences if disease is detected	• Authorities may order farmers to quarantine, destroy or dispose of stock (AA, §19.1). List 1 diseases (exotic, highly infectious or no acceptable control methods) typically require immediate quarantine and destruction of stock. List 2 diseases (contagious but can generally be managed) typically require increased surveillance. Destruction of stock may be necessary in some cases (DAAF, 2009). • Infected areas may be deemed a Controlled Aquaculture Areas (DFO, 2010).
	Cost to industry	–
	Cost to regulatory body	• Programme and diagnostic testing paid for by government. Total cost of shellfish and fish health programme is CAN$500,000–700,000 per annum (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Supporting material	• New Brunswick Health Policy for Shellfish Aquaculture 2015 (DAAF, 2015).
	Implementation	• The programme is quite young. DAAF are slowly trying to implement a biosecurity and surveillance programme prior to a significant outbreak (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Industry support	• Industry support has been less than for finfish surveillance. This is probably because there have been no major disease outbreaks in the shellfish industry in New Brunswick (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
	Uptake of voluntary measures	• n/a.
	Compliance problems	–
	Incentives for compliance	• All fish health records and diagnostic results are confidential (AA, §38).
	Benefits	–
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 17. Aquatic health and disease surveillance field and laboratory capabilities in New Brunswick.

No. of farms in region	~90 salmon farms (Government of New Brunswick, no date).
Laboratory capabilities	
Organisation name	New Brunswick's Provincial Fish Health Laboratory[82].
No. of laboratories	1
Laboratory capabilities	• Certified level 2 containment facility. • Necropsy, bacteriology, parasitology, immunofluorescent antibody staining and polymerase chain reaction. • HPLC analyser that can be used to detect chemical and drug residues in fish tissue. • Private laboratories are used for confirmation testing and diagnostic tests not performed at the Provincial Laboratory (DAAF, no date).
No. staff & qualifications	• 1 manager. • 2 technicians (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Staff responsibilities	• Provide diagnostic services.
No. of tests per annum	• 10,000–15,000 tests per annum, of which, approximately 8,000 are for ISA and the remaining tests are for MSX, BKD and other bacterial pathogens (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Field capabilities	
Organisation name	Fish Health Unit
No. staff & qualifications	• 3–4 biologists. • 1–2 veterinarian (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
Staff responsibilities	• Conduct annual biosecurity harvest vessel audits. • Conduct site visits once every two months (usually every 6 weeks) and sample fish for testing. Frequency of site visits is higher following a suspected or positive test result (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).
No. of farm visits per year	• 150–300 marine farm visits and 10–15 hatchery visits (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).

[82] New Brunswick's Provincial Fish Health Laboratory has recently been disestablished and replaced with a non-government laboratory (S. McGeachy & K. Brewer-Dalton, DAAF, pers. comm.).

13.2.6 Washington

Table 18. Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (NWIFC/WDF&W, 2006) and relevant aquatic health and disease surveillance regulations.

WASHINGTON	Cultured host species	Salmonids.
	Start date	1991.
	Regulatory authority	• Department of Ecology, State of Washington. • Washington Department of Fish and Wildlife. • US Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services. • US Fish and Wildlife Service. • National Marine Fisheries Service (NOAA Fisheries).
	Relevant legislation	• National Aquaculture Act (16 U.S.C 48, 2801–2810) (USA). • Animal Health Protection Act (AHPA, 7 U.S.C. 109, 8301–8322) (USA). • Federal Food Drug & Cosmetic Act (21 U.S.C. 9, 301–399) (USA). • National Environmental Policy Act (42 U.S.C. 55, 4321–4370) (USA). • Washington Administrative Code (WAC Title 220) (Washington).
	Objectives	• To prevent introduction of exotic pathogens into the state. • To prevent introduction of regulated endemic pathogens to new watersheds within the state. • To minimise the amplification of pathogens that can have adverse effects on fish. • To facilitate communication between co-managers[83] and co-operators[84] on fish health issues.
	Diseases of most concern	Regulated diseases: • Infection with *Oncorhynchus masou* virus; • Viral haemorrhagic septicaemia; • Infectious haematopoetic necrosis; • Infectious pancreatic necrosis; • Infection with *Myxobolus cerebralis.*
	Sampling and data collection	• Sampling of fish is conducted by a Fish Health Inspector[85]. • Adult fish and broodstock are sampled annually for viruses. The number of fish tested must be sufficient to detect a assumed pathogen prevalence level of 2 or 5%, respectively (NWIFC/WDF&W, 2006). • Juvenile fish reared in surface water are tested for viruses before transfer (NWIFC/WDF&W, 2006). • Fish are tested for whirling disease once every 3 spawning cycles (NWIFC/WDF&W, 2006). • Surveillance of fish health is overseen by WDF&W staff (Amos *et al.*, 2014).
	Routine diagnostic tests	• Most diagnostic tests follow protocols outlined in the American Fisheries Society 'blue book' (AFS-FHS, 2014) or OIE protocols (Expert 8, pers. comm.). • Virus testing involves cell culture using Chinook salmon embryo (CHSE-214) and *Epithelioma papulosum cyprini* (EPC) cell lines (AFS-FHS, 2014; Amos *et al.*, 2014). • Diagnostic tests at the Washington Animal Disease Diagnostic Laboratory (WADDL) are conducted with accredited sample turnaround times, which is 48 hours for autopsies, 7–10 days for histopathology, 7 days for bacterial culture, and 4 weeks for viral culture for disease-free certification (Expert 8, pers. comm.).
	Mandatory requirements	• Farmers must permit authorities to inspect the farm and take samples (WAC220-77-081). • Farmers must keep records of laboratory test results and shipping records of live fish for 2 years (WAC 220-77-082). • Fish to be regularly monitored (~monthly) by a fish health specialist. For tribal hatcheries, NWIFC staff conduct the monthly fish health inspections of all hatcheries between the time adults return to spawn and the release of juveniles (NWIFC, 2006).

[83] Federally recognised Treaty Indian Tribes within Washington State and the State of Washington Department of Fish and Wildlife.
[84] All entities, apart from co-managers, that are involved in rearing salmonids in Washington State.
[85] An individual who holds or meets the requirements of the following certifications: American Fisheries Society Fish Health Inspector of Fish Pathologist; Canadian Fish Health Officer; or United States Title 50 Inspector (NWIFC/WDF&W, 2006).

WASHINGTON		• Any significant mortality or suspected disease is to be promptly investigated by a fish health inspector (NWIFC/WDF&W, 2006). • Broodstock must be tested annually for viruses (NWIFC/WDF&W, 2006). • Juvenile fish reared on surface water must be tested for viruses before (within 8 weeks) transfer to another watershed (NWIFC/WDF&W, 2006). • All water supplies containing fish to be transferred to another watershed are to be tested for *M. cerebralis* once every 3 spawning cycles. The most susceptible species or a sentinel species that has been exposed to the water for at least 6 months or 1800 degree-days is to be tested (NWIFC/WDF&W, 2006). • Fish transfers require a permit and completion of a health information form (NWIFC/WDF&W, 2006). • All facilities must have a management plan that describes the actions that will be taken in the event that a regulated pathogen or previously undescribed pathogen causes significant mortality (NWIFC/WDF&W, 2006).
	Variable requirements	• Level of diagnostic testing (low, moderate or high) prior to transfers depends on the level of disease risk (e.g., pathogen status of broodstock, water supply, pathogen history of watershed and susceptibility of species) (NWIFC/WDF&W, 2006).
	Voluntary measures	• Vaccination of fish against enteric redmouth disease and vibriosis (NWIFC, 2006). • Many producers obtain disease-free certification for their fish in order to export fish (Expert 8, pers. comm.).
	Reporting requirements	• Disease outbreaks must be reported to the authorities immediately (WAC 220-76-030). • Presence of regulated pathogens must be reported to authorities by the day following diagnosis (WAC 220-77-030). • Epidemics due to unknown causes must be reported within 10 working days (NWIFC/WDF&W, 2006).
	Data management	• Diagnostic results by WADDL are stored using the LIMS database. This has a web-based login that allows farmers to access their own results (Expert 8, pers. comm.).
	Outputs	• Co-managers are to produce an annual report to the signatories of the disease control policy that lists the number of fish tested for pathogens, the number of positive tests, the location of positive fish, the suspected sources of infection and whether positive species were transferred as eggs or fish (NWIFC/WDF&W, 2006).
	Use of outputs	–
	Consequences if disease is detected	• Transfer of eggs or fish from the facility is prohibited if any regulated organism is detected in samples from the last five years (Nash, 2001). • Possible mandatory quarantine, destruction of stock and sterilisation of facilities (WAC 220-76-030). • Loss of disease-free certification (WAC 220-77-040).
	Cost to industry	• Farmers pay for sample collection and diagnostic testing. Funds collected are used for the administration of the disease inspection and control programme (WAC 220-77-080). • Farmers pay for the cost of diagnostic testing required for export or movement certification (Expert 8, pers. comm.).
	Cost to regulatory body	–
	Supporting material	• The salmonid disease control policy of the fisheries co-managers of Washington State (NWIFC/WDF&W, 2006). • National Aquatic Animal Health Plan (National Aquatic Animal Health Task Force, 2008). • Tribal Fish Health Manual (NWIFC, 2006). • Fish Health Section Blue Book: Suggested procedures for the detection and identification of certain finfish and shellfish pathogens (AFS-FHS, 2014). • Workshops to train industry staff in fish health (NWIFC, 2006; WAC 220-76-150).
	Implementation	–
	Industry support	–
	Uptake of voluntary measures	–
	Compliance problems	–
	Incentives for compliance	–

Benefits	–
Barriers to implementation	–
Solutions	–
Abandoned processes	–

Table 19. Washington's shellfish disease surveillance programme and relevant aquatic health and disease surveillance regulations.

WASHINGTON	Cultured host species	Pacific oysters, Manila clams, Mediterranean mussels.
	Start date	Around the 1970s (Expert 6, pers. comm.).
	Regulatory authority	• Department of Ecology, State of Washington. • Washington Department of Fish and Wildlife. • US Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services. • US Fish and Wildlife Service. • National Marine Fisheries Service (NOAA Fisheries).
	Relevant legislation	• National Aquaculture Act (16 U.S.C 48, 2801–2810) (USA). • Animal Health Protection Act (AHPA, 7 U.S.C. 109, 8301–8322) (USA). • Federal Food Drug & Cosmetic Act (21 U.S.C. 9, 301–399) (USA). • National Environmental Policy Act (42 U.S.C. 55, 4321–4370) (USA). • Washington Administrative Code (WAC Title 220) (Washington).
	Objectives	• To prevent introduction of exotic pathogens into the state. • To prevent introduction of regulated endemic pathogens to new watersheds within the state.
	Diseases of most concern	• OsHV-µvar; • Infection with *Bonamia exitiosa* or *B. ostreae*.; • Infection with *Haplosporidium nelsoni*; • Infection with *Marteilia refringens* or *M. sydneyi*; • Infection with *Marteilioides chugmuensis*; • Infection with *Mikrocytos mackini;* • Infection with *Perkinsus marinus* or *P. olseni*; • Infection with *Vibrio tapetis* (APHIS, 2013; Expert 6, pers. comm.).
	Sampling and data collection	• Health certification for interstate transfers requires annual testing of 60 animals of each life stage by histopathology, and sometimes PCR. Samples are collected by the competent authority, or in some cases, the producer. Diseases to be tested for are assessed on a case-by-case basis depending on the source and destination and consultation with regional shellfish health experts (APHIS, 2013; Expert 6, pers. comm.). • Health certification for export requires sampling of 150 animals per lot. Samples are collected by an accredited veterinarian. The facility is also required to be inspected by a veterinarian 3–4 times per year (APHIS, 2013). • Annual diagnostic testing of hatcheries and nurseries (Expert 6, pers. comm.). • All samples are sent to a private pathologist who performs the diagnostic services for all of Washington shellfish growers (Expert 6, pers. comm.). • WDF&W staff conduct biosecurity inspections of hatcheries, quarantine facilities and wet-holding facilities (Expert 6, pers. comm.).
	Routine diagnostic tests	• Most diagnostic tests follow protocols outlined in the American Fisheries Society 'blue book' (AFS-FHS, 2014) or OIE protocols (Expert 8, pers. comm.).
	Mandatory requirements	• The government shall develop a program of disease inspection and control for aquatic farmers (RCW 77.115.010). • Farmers must permit authorities to inspect the farm and take samples (WAC220-77-081). • Farmers must keep records of laboratory test results and shipping records of live fish for 2 years (WAC 220-77-082). • Imported stock must have a permit and disease-free certification provided by an approved fish health professional (WAC 220-370-200). Some species are also required to be quarantined (WAC 220-77-040).

WASHINGTON		• WDF&W staff may inspect quarantine facilities at reasonable times without prior notification (WAC 220-77-040).
	Variable requirements	–
	Voluntary measures	• Shellfish High Health Program (Elston, 2004): • Participation in the Shellfish High Health Program is a requirement for West Coast shellfish producers seeking eligibility for APHIS endorsement of export health certificates (APHIS, 2013). • Participants must maintain a record of heath examinations. • Shellfish will be regularly examined for reportable diseases. Frequency of testing and diseases to be tested for depends on the jurisdiction and export requirements. • Broodstock will be regularly tested for disease.
	Reporting requirements	• Disease outbreaks must be reported to the authorities immediately (WAC 220-76-030). • Presence of regulated pathogens must be reported to authorities by the day following diagnosis (WAC 220-77-030). • Significant mortality potentially caused by a serious shellfish pathogen must be reported to the authorities within 24 h (WAC 220-77-040). • Elevated mortality (5% above the normal mortality rate) in hatcheries must be reported to the authorities (Expert 6, pers. comm.). • Producers may be required to report the presence of shellfish diseases to the authorities annually (WAC 220-77-040).
	Data management	• Database is in development. Have around 3 decades of pathology reports, some are still paper-based (Expert 6, pers. comm.).
	Outputs	–
	Use of outputs	–
	Consequences if disease is detected	• Possible mandatory quarantine, destruction of stock and sterilisation of facilities (WAC 220-76-030). • Loss of disease-free certification (WAC 220-77-040). • Import bans or stock movement restrictions (Expert 6, WDF&W, pers. comm.).
	Cost to industry	• Farmers pay for sample collection and diagnostic testing. • Farmers pay for the cost of diagnostic testing required for export or movement certification (Expert 6, pers. comm.).
	Cost to regulatory body	• Authorities pay for the costs of running the shellfish programme. Annual budget is $US100,000 (includes more responsibilities than just disease control and surveillance) (Expert 6, pers. comm.).
	Supporting material	• Fish Health Section Blue Book: Suggested procedures for the detection and identification of certain finfish and shellfish pathogens (AFS-FHS, 2014).
	Implementation	• Historically the surveillance requirements and regulations have been heavily influenced by industry wants (Expert 6, pers. comm.).
	Industry support	• Industry are generally supportive, to varying degrees. They want to be protected but still need to make money. Some growers are reluctant to support surveillance because they haven't any experience with serious disease (Expert 6, pers. comm.).
	Uptake of voluntary measures	• Some hatcheries participate in the Shellfish High Health Program (Expert 6, pers. comm.).
	Compliance problems	• Estimated that only around 50% of wet-holding facilities have permits (Expert 6, pers. comm.).
	Incentives for compliance	–
	Benefits	• Protection of state from the risk of disease introduction and the spread of disease around the state.
	Barriers to implementation	• The geographic size of the relaying network involved in shellfish production in the Pacific Northwest (Expert 6, pers. comm.).
	Solutions	• Education of industry, lots of personal interaction with industry (Expert 6, pers. comm.).
	Abandoned processes	• Hazard-specific surveillance for Denham Island disease was implemented to try and gain access to EU markets. However, this was stopped when the disease was found throughout the state (Expert 6, pers. comm.).

Table 20. Aquatic health and disease surveillance field and laboratory capabilities in Washington.

No. of farms in region	• 370 shellfish farms (APHIS, 2013). • 3 large-scale shellfish hatcheries (APHIS, 2013). • 146 salmonid hatcheries (WDF&W, no date). • 14 food fish farms (USDA, 2014).
Laboratory capabilities	
Organisation name	Washington Animal Disease Diagnostic Laboratory, Washington State University (A National Animal Health Laboratory)
No. of laboratories	1
Laboratory capabilities	• Virology, bacteriology, pathology, parasitology, molecular diagnostics, serology, immunohistochemistry, antigen detection, toxicology (WADDL, 2014). • Approved laboratory for VHSV and ISAV surveillance testing (Loiacono, 2015). • Provides diagnostic services and disease-free certification for movement and export (Expert 8, pers. comm.). • Diagnostic testing services offered are producer driven (Expert 8, pers. comm.).
No. staff & qualifications	• Histopathology: 3 board certified members (1 pathologist), 8 veterinarians in residency training. • Microbiology: 2 microbiologists. • Fish health certification: 6 staff. • Around 6 technicians (who also work on terrestrial animals) (Expert 8, pers. comm.).
Staff responsibilities	• Ensure that correct protocols are followed. • Check that samples are suitable for the diseases tested for. • Ensure that the accredited turnaround time is met (Diagnostics: autopsy 48 hours, histopathology 7–10 days, bacterial culture 7 days. Certification: 4 weeks. • Liaise with company fish health staff to provide biosecurity or sampling advice [86] (Expert 8, pers. comm.).
No. of tests per annum	In 2013–14 the following aquatic disease surveillance tests were conducted: • 27,180 aquaculture tests in total; • 9,268 viral culture screenings; • 7,671 bacterial screenings; • 3,969 bacterial kidney disease screenings; • 2,106 *Piscirickettsia salmonis* screenings; • 2,389 *Myxobolus cerebralis* digests; • 1,953 standard and real time PCR (WADDL, 2014).
Field capabilities	
Organisation name	Washington Department of Fish and Wildlife
No. staff & qualifications	• 1 shellfish biologist[87] (Expert 6, pers. comm.).
Staff responsibilities	• Implement the shellfish disease control programme. • Conduct site inspections of hatcheries, quarantine facilities and wet-storage facilities (Expert 6, pers. comm.).
No. of farm visits per year	• ~20 (Expert 6, pers. comm.).

[86] AFS blue book states viral cultures must be for a minimum of 4 weeks (AFS-FHS, 2014).
[87] There may also be field staff responsible for finfish facilities.

13.2.7 Maine

Table 21. USDA's Infectious Salmon Anaemia Programme Standards[88] (APHIS, 2010) and relevant aquatic health and disease surveillance regulations for finfish and shellfish.

<table>
<tr><td rowspan="8">MAINE</td><td>Cultured host species</td><td>Salmonids, other finfish, blue mussels, American oysters.</td></tr>
<tr><td>Start date</td><td>• 1999 for fish health inspection regulations.
• 2002 for ISA control programme (revised in 2010).</td></tr>
<tr><td>Regulatory authority</td><td>• US Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services.
• US Fish and Wildlife Service.
• National Marine Fisheries Service (NOAA Fisheries).
• State of Maine Department of Marine Resources (SMDMR).
• State of Maine Department of Environmental Protection (SMDEP).</td></tr>
<tr><td>Relevant legislation</td><td>• National Aquaculture Act (16 U.S.C 48, 2801–2810) (USA).
• Animal Health Protection Act (7 U.S.C. 109, 8301–8322) (USA).
• Federal Food Drug & Cosmetic Act (21 U.S.C. 9, 301–399) (USA).
• National Environmental Policy Act (42 U.S.C. 55, 4321–4370) (USA).
• USDA APHIS (9CFR 53.10e).
• Maine Revised Statutes (Title 12, Pt 9, Ch. 605) (Maine).
• General permit—Atlantic salmon aquaculture (Maine) (SMDEP, 2008).
• Department of Marine Resources Regulations (Maine):
– Aquaculture lease regulations (13 188, Ch. 2).
– Importation of live marine organisms (13 188, Ch. 24).</td></tr>
<tr><td>Objectives</td><td>• Early detection, diagnosis, and prevention of spread of diseases of concern.
• Elimination of ISA from aquaculture operations (APHIS, 2010).</td></tr>
<tr><td>Diseases of most concern</td><td>Hazard-specific surveillance is required for:
• VHSV, IHNV, ISAV, whirling disease (exotic).
• IPNV, BKD, furunculosis, enteric redmouth disease (endemic, limited distribution).

Passive surveillance is required for:
• Infection with Oncorhynchus masou virus, ceratomyxosis, whirling disease, proliferative kidney disease, salmonid Infection with pancreatic disease virus, and other exotic diseases.
• Furunculosis, enteric redmouth disease, BKD and other endemic diseases (13 188, Ch. 24, §21).</td></tr>
<tr><td>Sampling and data collection</td><td>• Farm health inspections and sampling of fish are conducted by an independent certified health inspector/veterinarian (not an employee or owner) at least annually, at a time when disease detection is most likely (13 188, Ch. 24, §21).
• Sufficient fish shall be sampled to have a 95% confidence interval (CI) of detecting 5% prevalence of virus and 10% prevalence of bacteria (13 188, Ch. 24, §21).
• Broodstock sampling is to be conducted 30 days either side of spawning. Sampling can be conducted by a trained employee under the direction of an inspector. Reproductive fluids of all fish must be sampled, or lethal sampling conducted on a maximum of 30 fish assuming a 10% prevalence rate and reproductive fluids at a 2% prevalence rate (13 188, Ch. 24, §21).
• Sampling for ISA will be conducted by veterinarians or inspectors designated by SMDMR and will be in accordance with the ISA programme standards (APHIS, 2010). Site inspections and samples of 10–30 recently dead or moribund fish are collected each month (13 188, Ch. 24, §21).
• Biosecurity audits are conducted annually on all sites by the ISA programme fish biologists (M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.).
• 60 fish shall be sampled annually per water supply for whirling disease. The most susceptible species and life stage present will be sampled (13 188, Ch. 24, §21).
• USDA fish biologist conducts annual to semi-annual biosecurity audits of all vessels and marine sites involved in aquaculture (13 188, Ch. 24, §21; M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.).</td></tr>
</table>

[88] The ISA Technical Board is currently reviewing and revising the Program Standards. The reviewed standard is expected to be available in mid-2017 (M. Nelson, SMDMR, pers. comm.).

MAINE	Routine diagnostic tests	• ISA—q-PCR used for screening. In the case of detection, RT-PCR, IFAT plus segment 6 sequencing to determine the HPR genotype is conducted. Virology is kept for any follow-ups (M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.). • ISA testing must be conducted by a USDA approved laboratory and all tissue samples archived for at least 1 year (APHIS, 2010). Positive results for ISA from a site with no history of ISA will be confirmed by the National Veterinary Services Laboratory (APHIS, 2010). • Approximately 1200 tests for ISAV are conducted per annum by a commercial laboratory under the surveillance programme, but this number can vary greatly depending on how many sites are in production and whether any suspect findings were investigated (M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.).
	Mandatory requirements	Finfish: • Farmers must retain records of mortalities and treatments for 5 or more years (13 188, Ch. 24, §16). • Importation of live finfish into the state requires a permit and a disease-free certification. The source facility must be shown to be disease-free for 3 or more years (13 188, Ch. 24, §21 & §30). • Fish to be released in the wild must submit a fish health inspection report stating that the fish have been inspected for all pathogens of regulatory concern (13 188, Ch. 24 & §30). • Live fish collected from the wild must be isolated for > 90 days and inspected for diseases (13 188, Ch. 24, §21 & §30). • Sellers of live fish or gametes must provide a current fish health certification to purchasers (13 188, Ch. 24, §21 & §30). • Stock received from uncertified sources will invalidate the farms annual inspection status (13 188, Ch. 24, §21). • Atlantic salmon farmers must participate in the USDA ISA surveillance programme unless the Commissioner approves another surveillance programme (13 188, Ch. 24, §21). • All companies must have a veterinarian who is responsible for implementing the ISA programme standards and have an ISA action plan (APHIS, 2010). • Hatchery fish must be tested annually for reportable diseases (13 188, Ch. 24, §21). • Spawning broodstock must be tested for reportable diseases within 30 days before or after spawning (13 188, Ch. 24, §21). • Fish in marine sites must be tested monthly for ISA (13 188, Ch. 24, §21). Shellfish: • All hatchery stock must be from an approved hatchery. Approved laboratory staff conducts annual inspections of hatcheries on behalf of SMDMR where: stock are tested for diseases; the disease history of the hatchery is assessed; and, biosecurity practices are audited (13 188, Ch. 2) (M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.). • Wild stock collected for culture must originate from the same Health Area as the farm. A permit is required to use wild stock from a different Health Area and stock must be shown to be disease-free (13 188, Ch. 2). • DMR shall provide a shellfish pathology diagnostic service related to the exportation and importation of shellfish (12, 9, 605, §6075). • Hatchery shellfish must be free of infectious diseases or parasites (13 188, Ch. 2). • Importation of all live shellfish requires a permit. Shellfish are prohibited to be imported from restricted areas unless they are proven to be disease-free (13 188, Ch. 24, §6). • Farmers must keep > 2 years of records of all transport, transfers, harvest, surveillance and health status of shellfish (13 188, Ch. 2).
	Variable requirements	• If bacterial tests are negative for 3 consecutive years, the sampling numbers may decrease to 20% prevalence (13 188, Ch. 24, §21). • Frequency of ISA sampling varies from weekly to monthly, or as needed, depending on the infection history of the site (APHIS, 2010). • Monthly ISA surveillance may be skipped (with permission) if all fish are to be harvested within the next month (APHIS, 2010).
	Voluntary measures	• Implementation of Finfish Bay Management Agreements by all private salmon farmers in Maine, single year class culture, and fallowing by commercial salmon

MAINE		companies (MAA, 2002; Belle, 2003). SMDMR is also able to make these management actions mandatory through Chapter 24, stocking permits and USDA ISA Program (M. Nelson, SMDMR, pers. comm.).
	Reporting requirements	• Farmers are required to report annual harvest totals to SMDMR (SMDMR, no date). • Finfish disease outbreaks must be reported to the authorities within 24 h for exotic pathogens and 14 days for other reportable pathogens (13 188, Ch. 24, §16; M. Nelson, SMDMR, pers. comm.). • Farmers are required to report any therapeutants used to treat or control diseases (SMDEP, 2008). • The fish health inspector will produce a report for the facility outlining the test results. The SMDMR will review the report (13 188, Ch. 24, §21). • ISA surveillance results must be reported to the SMDMR within 24 h of completion (13 188, Ch. 24, §21). • Information on stock biomass, age, origin, transfer details, vaccination and therapeutants history must be provided to the ISA programme veterinarian upon enrolment in the programme (APHIS, 2010). SMDMR also requires monthly reporting of these particulars (M. Nelson, SMDMR, pers. comm.). • Records on mortalities must be kept and produced upon request (APHIS, 2010).
	Data management	• All ISA sampling data are sent to the ISA programme veterinarian and fish biologist (APHIS, 2010). Data is stored in a Microsoft Access database and is only accessible by the ISA programme staff. The database is owned by USDA APHIS (T. Robinson, APHIS, pers. comm.).
	Outputs	• Monthly summary data is provided on the USDA APHIS webpage (USDA, 2017). Data is not identifiable by company or site (T. Robinson, APHIS, pers. comm.). • Positive ISAV detections are reported to OIE (M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.).
	Use of outputs	• Surveillance data is used to: – assess area management; – assess the programme success; – improve diagnostic methods; – predict the spread of the disease from an infected farm (data was combined with hydrological models); – identify high risk farms and inform farmers so that they could implement better disease management strategies (L. Gustafson, APHIS, M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.).
	Consequences if disease is detected	• Possibly quarantine, prohibition of movement, destruction of stock, requirement to disinfect facilities, fines (AHPA, § 8303, 8306). • All fish on site are not allowed to be transferred if a regulated pathogen is detected. Fish may be ordered to be destroyed, treated for the pathogen or quarantined (13 188, Ch. 24, §16).
	Cost to industry	• Industry incurs costs required to participate in the programme and comply with regulations except for the cost of diagnostic testing (T. Robinson, APHIS, pers. comm.).
	Cost to regulatory body	• Initially, the ISA surveillance programme was fully funded by the federal government. There were 4 full-time positions for the first four years of the programme (APHIS, 2010; L. Gustafson & T. Robinson, APHIS, pers. comm.). • Currently, APHIS pays for the monthly diagnostic testing, a part-time fish biologist and varied hours for the programme veterinarian (T. Robinson, APHIS, pers. comm.).
	Supporting material	• Infectious Salmon Anaemia Programme Standards (APHIS, 2010).
	Implementation	• The programme was implemented by the federal government, working with the state government and industry (T. Robinson, APHIS, pers. comm.). Initially, 4 field staff were located in Maine to run the ISA surveillance programme. This has now been reduced to one part-time fish biologist and varied hours for the programme veterinarian (L. Gustafson & T. Robinson, APHIS, pers. comm.). • An ISA Technical board was assembled to serve in an advisory capacity to the programme veterinarian and the state (T. Robinson, APHIS, pers. comm.).
	Industry support	• Industry initially asked APHIS for assistance and are very supportive of the programme (L. Gustafson & T. Robinson, APHIS, pers. comm.).
	Uptake of voluntary measures	• 100% participation in the Bay Management Agreements (MAA, 2002; Belle, 2003).

MAINE	Compliance problems	• None.
	Incentives for compliance	• Compensation payments were available to farmers that complied with the Infectious Salmon Anaemia Programme Standards during the first two years (60% in the first year and 40% in the second year for any diseases and depopulated animals) (L. Gustafson & T. Robinson, APHIS, pers. comm.; APHIS, 2010).
	Benefits	• Elimination of ISA from Maine is largely attributed to surveillance that provided very early detection of the disease. This allowed early depopulation of the affected pens, reducing the disease burden to the area (L. Gustafson, APHIS, pers. comm.).
	Barriers to implementation	• None.
	Solutions	• Involvement of the industry veterinarians and the Maine Aquaculture Association helped overcome any resistance to the program by industry. Also, partial compensation payments for diseased and depopulated animals during the first two years was very helpful (T. Robinson, APHIS, pers. comm.).
	Abandoned processes	• Compensation payments ceased after the first two years because of lack of funding (T. Robinson, APHIS, pers. comm.). • Diagnostic tests for ISA have changed over the years. Initially conventional RT-PCR and IFAT were used for screening and virology used for confirmation. Later, only RT-PCR was used for screening, IFAT for corroboration, and cDNA sequencing added. Virology was still used for confirmation. Now, q-PCR used for screening and IFAT and sequencing used to corroborate, and virology for confirmation (M. Nelson, SMDMR & T. Robinson, APHIS, pers. comm.).

Table 22. Aquatic health and disease surveillance field and laboratory capabilities in Maine.

No. of farms in region	• 25 Atlantic salmon marine farms; • 82 marine shellfish farms; • 261 limited-purpose aquaculture licences[89] that culture at least one species of shellfish (M. Nelson, SMDMR, pers. comm.).
Laboratory capabilities	
Organisation name	Fish Health Laboratory[90] (DIFW, no date).
No. of laboratories	1
Laboratory capabilities	• Level 1 laboratory. • Primarily tests freshwater pathogens of salmonids.
No. staff & qualifications	• 1 fish pathologist. • 1 microbiologist (also a certified fish health inspector).
Staff responsibilities	• Health management of the state's freshwater fish culture facilities. • Disease screening of fish prior to transfers and breeding. • Health certification for hatcheries. • Provides advice on disease management and prevention. • Conducts research for improved fish health. • Education of hatchery staff, biologist and the public on fish health.
No. of tests per annum	–
Field capabilities	
Organisation name	APHIS, USDA.
No. staff & qualifications	• 1 part-time fish biologist. • 1 programme veterinarian that spends variable hours on the ISA programme.
Staff responsibilities	• Conduct biosecurity audits of farms and vessels. • Provide guidance for good management. • Collect and maintain surveillance data and periodically report to appropriate authorities. • Liaise with industry, SMDMR and New Brunswick DAAF. • Collect samples when needed (T. Robinson, USDA, pers. comm.).
No. of farm visits per year	• 10–14 biosecurity audits per year (T. Robinson, APHIS, pers. comm.).

[89] Experimental leases for commercial or scientific aquaculture research and development.
[90] Maine does not have any laboratories that are part of the National Animal Health Laboratory Network. There are also private laboratories in the state that are involved in the surveillance and certification of salmonid hatcheries and farms (M. Nelson, SMDMR, pers. comm.).

13.2.8 Alaska

Table 23. Policies and guidelines for Alaska fish and shellfish health and disease control (Meyers, 2014) and relevant aquatic health and disease surveillance regulations.

ALASKA	Cultured host species	Salmonids, oysters, mussels, geoduck, clams.
	Start date	1987.
	Regulatory authority	• Alaska Department of Fish and Game (ADF&G). • Division of Commercial Fisheries US Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services. • US Fish and Wildlife Service. • National Marine Fisheries Service (NOAA Fisheries).
	Relevant legislation	• National Aquaculture Act (16 U.S.C 48, 2801–2810) (USA). • Animal Health Protection Act (7 U.S.C. 109, 8301–8322) (USA). • Federal Food Drug & Cosmetic Act (21 U.S.C. 9, 301–399) (USA). • National Environmental Policy Act (42 U.S.C. 55, 4321–4370) (USA). • Aquatic Farming Statutes (AS 16.40.100–199) (Alaska). • Title 5 Fish and Game Code, Part 1, Chapter 41 (5 AAC 41) (Alaska).
	Objectives	• Prevention of spread and amplification of diseases present in region. • Protect the health of wild and cultured finfish and shellfish through regulatory oversight of pathogens, development of disease policies and application of technical expertise to prevent, detect and treat fish diseases in cultured or wild finfish and shellfish in Alaska. • Provide pathology/diagnostic services to fisheries managers, state and private salmon hatcheries, aquatic farmers and sport fishers (T. Meyers, ADF&G, pers. comm.).
	Diseases of most concern	• Bacterial kidney disease. • Furunculosis. • Enteric redmouth disease. • Infectious hematopoietic necrosis. • Infection with *Ichthyophthirius multifiliis.*
	Sampling and data collection	• Finfish samples (live, moribund and dead fish) and sometimes, struck agar plates, are submitted by hatchery staff to an approved laboratory via air transport: – when there is unexplained mortality (5–10 fish); – prior to transport of eggs or fish between areas (permission for the transfer of adults to areas that have significant stocks also requires sampling in the year prior to transport); – prior to release of juveniles into the wild (at hatchery site) if disease symptoms or significant mortality occurs; – prior to release of juveniles into the wild at other sites; – annually from returning broodstock (kidney tissues and ovarian fluids) (T. Meyers, ADF&G, pers. comm.). • 60 broodstock per farm are tested annually for BKD (Meyers, 2009). • All sockeye broodstock are tested annually for IHNV. • Live shellfish samples are submitted by farmer to an approved laboratory: – prior to transport (≤ 60 days); – when there is unusual mortality (5–10 shellfish); – annually, if disease-free certification is required (30 adults for disease history; 60 adults, 200 spat and 1000 larvae for certification to import seed from out-of-state) (Meyers, 2009). • Testing for all diseases listed above is done every four years for all hatcheries on a staggered basis (60 fish per farm) (T. Meyers, ADF&G, pers. comm.; Meyers, 2009). • Certified fish pathologists conduct farm health inspections at least once every two years, or more frequently depending on the disease history of the facility (5 AAC 41.080). The purpose of the visit is to assess and provide advice on the facility's disease control measures. Standardised hatchery inspection reports are completed by pathologists for each visit (T. Meyers, ADF&G, pers. comm.).
	Routine diagnostic tests	• Gram-negative bacteria: fluorescent antibody test (FAT). • BKD: ELISA. • Cell culture (viruses; T. Meyers, ADF&G, pers. comm.).

ALASKA	Mandatory requirements	• Operators must allow regulatory authorities to inspect their farms with 48 h notice (5 AAC 41.260). • Diagnostic testing of finfish required prior to transport of all life stages. Permission to transport is dependent on test results and disease occurrence in receiving waters (5 AAC 41.295). • No importation of live shellfish into the state for rearing or release except from: ≥ third generation, certified disease-free oyster spat (≤ 20 mm)[91] that are commercially cultured on the Pacific coast of North America; and, certified disease-free scallops from SE Alaska and Yakutat for release into the same areas (5 AAC 41.070).
	Variable requirements	• Frequency of farm inspections by regulatory authority is dependent on the farm's disease history (5 AAC 41.080). • If transport is within the state then the farmer may supply a disease history for the donor site rather than live samples (Meyers, 2014). • Requirement to test for the diseases listed above depends on the culture species and the disease status of the stocks in the receiving water (Meyers, 2014).
	Voluntary measures	• Establishment of a disease history of stock by sampling in the year prior to transfer. • Recognition of a fish health problem and correct submission of samples (T. Meyers, ADF&G, pers. comm.). • Reporting of mortality above 0.5% per day to the authorities (Meyers, 2009).
	Reporting requirements	• Immediate reporting to authorities of the presence of listed pathogens and diseases (5 AAC 41.080). • Farmers must report any mortalities due to disease that are over 5% per day to regulatory authorities within 48 h (5 AAC 41.310). • Annual hatchery management plan that specifies estimated broodstock collection numbers, species, collection location, transport and production numbers (5 AAC 41.276). • Annual report containing production, stock acquisition, transport, mortality and inventory (5 AAC 41.270).
	Data management	• Diagnostic results from both laboratories are stored in a Microsoft Access databases. Both laboratories can access the database to generate reports requested by any user group and to produce annual reports. Laboratory results and hatchery inspection reports are public information (T. Meyers, ADF&G, pers. comm.).
	Outputs	• Annual aquatic farm status reports (Alaska Department of Fish and Game, no date).
	Use of outputs	–
	Consequences if disease is detected	• Shellfish hatcheries: loss of disease-free certification if category A disease is detected (Meyers, 2014). • Finfish hatcheries: permission to transport or release denied until disease is treated. Destruction of fish for certain diseases (5 AAC 41.080; Meyers, 2014). Possible quarantine, prohibition of movement, destruction of stock, requirement to disinfect facilities, fines (AHPA, § 8303, 8306).
	Cost to industry	• Labour costs to collect samples and shipping costs. • Stock disposal and disinfection costs for endemic diseases (T. Meyers, ADF&G, pers. comm.).
	Cost to regulatory body	• Diagnostic testing and site inspections are funded by the Alaskan Government. • Programme cost is US$589,677 per annum (includes funding of 4 staff). The programme is funded through a general fund allocated by the state legislation and a Reciprocal Service Agreement from the sport fish division of ADF&G using their federal funds (T. Meyers, ADF&G, pers. comm.).
	Supporting material	• Alaska sockeye salmon culture manual (McDaniel *et al.*, 1994). • Booklets on common diseases of wild and cultured finfishes and shellfish in Alaska (Meyers *et al.*, 2008; Meyers & Burton, 2009). • Workshops on fish health for hatchery staff to assist with the recognition of fish health problems and adequate sample collection and shipping are conducted every 3–4 years (T. Meyers, ADF&G, pers. comm.).
	Implementation	• Industry participated in the development of the state-wide fish disease policy (1987) for implementation of the day-to-day decision making processes regarding the outcome of fish disease evaluations (T. Meyers, ADF&G, pers. comm.).
	Industry support	• Industry participated in the formation of the disease policy and agreed to comply with it. Hatchery operators have been very supportive of this program. Government staff

[91] Spat must be less than 20 mm shell height to reduce the chances on infection by the parasitic copepod, *Mytilicola* sp.

ALASKA		have gained the trust of the industry through consistent and fair permit evaluations and the willingness to compromise and work with the hatcheries and shellfish growers when state resources and interests are not put at significant risk (T. Meyers, ADF&G, pers. comm.).
	Uptake of voluntary measures	–
	Compliance problems	• Non-compliance has never been an issue (T. Meyers, ADF&G, pers. comm.).
	Incentives for compliance	• None offered.
	Benefits	• Alaska has healthy and sustainable wild and cultured stocks of finfish and shellfish with no significant diseases affecting these stocks. No exotic pathogens have been detected in Alaska (T. Meyers, ADF&G, pers. comm.).
	Barriers to implementation	• The lack of road access to most hatcheries in Alaska (T. Meyers, ADF&G, pers. comm.).
	Solutions	• All sample submission and site inspections utilise air transport (T. Meyers, ADF&G, pers. comm.).
	Abandoned processes	• None.

Table 24. Aquatic health and disease surveillance field and laboratory capabilities in Alaska.

No. of farms in region	• 28 finfish hatcheries (24 private non-profit, 2 state, 1 federal research and 1 tribal). • 76 shellfish farms. • 2 shellfish hatcheries (T. Meyers, Alaska Fish and Game, pers. comm.).
Laboratory capabilities	
Organisation name	Fish pathology section, Alaska Department of Fish and Game.
No. of laboratories	• 2.
Laboratory capabilities	• Bacteriology, virology, serology, histopathology, DNA probe, PCR, immunocytochemical staining, standard microscopy, transmission electron microscopy.
No. staff & qualifications	• 2 microbiologists. • 2 pathologists/inspectors (note that the laboratory is currently understaffed to handle the caseload from the programme (T. Meyers, ADF&G, pers. comm.)).
Staff responsibilities	• Provide pathology/diagnostic services to fisheries managers, state and private salmon hatcheries, aquatic farmers and sport fishers. • Issue transport permits (200 per annum). • Issue disease certification for mollusc imports (Meyers, 2014; T. Meyers, ADF&G, pers. comm.). • Maintain results database. • Report writing. • Research.
No. of tests per annum	• 23,193 tests on 9,474 finfish and shellfish in 2016 (T. Meyers, ADF&G, pers. comm.).
Field capabilities	
Organisation name	Fish pathology section, Alaska Department of Fish and Game.
No. staff & qualifications	• 2 microbiologists. • 2 pathologists.
Staff responsibilities	• Conduct farm and hatchery inspections and reporting of results. • Staff to maintain fish health specialist certification. • Disease control methods including destruction of diseased stock. • Train farm staff in the collection of samples and prevention of disease (Meyers, 2014; T. Meyers, ADF&G, pers. comm.).
No. of farm visits per year	• Around 50 shellfish and finfish farms (Meyers, 2014; T. Meyers, ADF&G, pers. comm.).

13.2.9 Norway

Table 25. Norway's aquatic health and disease surveillance regulations.

NORWAY	Cultured host species	Atlantic salmon.
	Start date	
	Regulatory authority	• Department for Fisheries and Aquaculture, Ministry of Trade, Industry and Fisheries. • Norwegian Food Safety Authority.
	Relevant legislation	• Aquaculture Act 2005 (reviewed 2013) (NAA). • Food Safety Act 2003 (FSA). • Animal Welfare Act 2009 (AWA). • Fish Diseases Act 1997 (FDA). Regulations[92]: – Aquaculture Operations Regulations 2008 (2008-06-17 No. 822). – Regulations relative to authorizations for the breeding of salmon, trout and rainbow trout 2004 (2004-12-22 No. 1798). – Regulations on sales of aquaculture animals and products of aquaculture animals, the prevention and combating of infectious diseases in aquatic animals 2008 (2008-06-17 No. 819). – Regulation relative to the establishment and expansion of aquaculture installations, zoo boutiques and similar 2008 (2008-06-17 No. 823). – The Regulation relative to disinfection and cleaning aquaculture facilities 1997 (1997-02-20 No. 194). – Regulation relative to the control of residues in animal foodstuffs, production animals and fish 2000 (2000-01-27-65).
	Objectives	• Early detection and prevention of spread of diseases. • Substantiation of freedom-from disease.
	Disease of most concern	• Notifiable diseases.
	Sampling and data collection	• Fish Health Services staff conduct routine farm health inspections on: – broodstock, 6 or 12 times per year; – food fish, 4–6 times per year; – anadromous fish for wild enhancement, ≥ 12 times per year; – freshwater fish for wild enhancement, ≥ 4 times per year (2008-06-17 No. 822, §50 & 62). • For each health inspection, at least 30 moribund fish are sampled, autopsied by a veterinarian and tested for any relevant diseases (Gjevre *et al.*, 2016a; 2008-06-17 No. 822, §62). • At least 30 dead or moribund anadromous fish are tested for disease before release into the wild (2008-06-17 No. 822, §62). • At least 30 dead or moribund hatchery fish must be tested for disease ≤ 3 weeks prior to leaving the hatchery (2008-06-17 No. 822, §62). • Wild-caught anadromous broodstock are to be tested for bacterial kidney disease, furunculosis and infectious pancreatic necrosis (2008-06-17 No. 822, §50).
	Routine diagnostic tests	–
	Mandatory requirements[93]	• Farmers must have suitable aquaculture training and fish welfare expertise (2008-06-17 No. 822, §6). • Farmers must keep an up-to-date disease emergency plan that details methods to deal with a disease outbreak and mass mortality (2008-06-17 No. 822, §7). • Farmers must keep records of stocking biomass, escapes, disease events, mortalities, feed consumption, diagnostic test results, health inspections, environmental monitoring results, water quality parameters, fish welfare, therapeutants used, slaughtering, and lineage of boodstock for at least 4 years (2008-06-17 No. 822, §10 & 40). • Daily inspections of the condition of finfish, and weekly inspections of the condition of shellfish must be conducted (weather permitting) (2008-06-17 No. 822, §12).

[92] Many of these regulations are authorised under multiple acts.
[93] Mandatory requirements for sea lice management and *Gyrodactylus salaris* are given in the section below.

NORWAY		• Farmers must arrange for a health inspection by a veterinary surgeon if mortality is above average or if an infectious disease is suspected (2008-06-17 No. 822, §13 & 14). Further, fortnightly health inspections are to be conducted if mortalities remain high (2008-06-17 No. 819, §27). • Broodstock must have a routine health inspection 6 or 12 times per year, depending on the number of broodstock (2008-06-17 No. 822, §50). • Food fish must have between 4–6 routine health inspections a year, depending on the farm biomass (2008-06-17 No. 822, §50). • Anadromous fish for wild enhancement must have at least 12 routine health inspections per year; freshwater fish for wild enhancement must have at least 4 routine health checks per year (2008-06-17 No. 822, §62). • Anadromous fish (≥ 30 dead or moribund fish) must be tested for disease prior to permission to release a batch into the wild (2008-06-17 No. 822, §62). • Hatchery fish must be tested ≤ 3 weeks prior to leaving the hatchery (2008-06-17 No. 822, §62). • Farmed fish must have a health inspection before leaving the facility (2008-06-17 No. 822, §13). • Wild caught broodstock are to be tested for bacterial kidney disease, furunculosis and infectious pancreatic necrosis (2008-06-17 No. 822, §50). • All Atlantic salmon must be vaccinated against furunculosis, vibriosis and cold water vibriosis (2008-06-17 No. 822, §63).
	Variable requirements	• Frequency of health inspections depends on the number of fish cultured (2008-06-17 No. 822, §50).
	Voluntary measures	• None.
	Reporting requirements	• Farmers must notify the regulatory authorities immediately of any infectious disease occurrences or if there is reason to believe that animals are in danger of infectious diseases (FDA, §5). • Farmers must submit a biennial operations plan to the authorities that details farm location, stocking density, fallow periods and stock transfers (2008-06-17 No. 822, §40). • Farmers must submit monthly reports to the authorities detailing stocking details, biomass, mortalities, slaughtering, transfers, escapes and feed consumption (2008-06-17 No. 822, §44 & 58). • Farmers must immediately inform the authorities when the mortality rate increases substantially or if any notifiable diseases (list I–III) are present (2008-06-17 No. 822, §13).
	Consequences if disease is detected	• The Ministry may order the destruction of stock, decontamination of facilities, vehicles and equipment and fallowing of the farm when an infectious disease is found or suspected at the cost to the farmer (FDA, §23 & 25). • The Ministry may establish no-transfer zones during a disease outbreak (FDA, §26). • Loss of VHS or IHN disease-free status (Gjevre *et al.*, 2016a). • Breeding of animals from areas where notifiable diseases are present or suspected is prohibited, unless the licensee has a permit (2008-06-17 No. 819, §29). • Farms that have had a notifiable disease must be fallowed for a period prior to restocking (2008-06-17 No. 819, §34).
	Cost to industry	• Industry to pay for diagnostic testing. Testing for suspected notifiable diseases is free if the Food Safety Authority is notified (Norwegian Veterinary Institute, 2015).
	Cost to regulatory body	–
	Data management	• All the information from the submitted fish samples is stored in the Veterinary Institute's Laboratory Information system (Bang Jensen, 2016).
	Supporting material	–
	Outputs	• Annual fish health reports (Norwegian Veterinary Institute, no date-c).
	Use of outputs	–
	Implementation	–
	Industry support	–
	Uptake of voluntary measures	• n/a

	Compliance problems	–
	Incentives for compliance	• Diagnostic testing for suspected notifiable diseases is free if the Food Safety Authority is notified (Norwegian Veterinary Institute, 2015).
	Benefits	–
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 26. Norway's surveillance and control programme for sea lice and relevant aquatic health and disease surveillance regulations.

NORWAY	Cultured host species	Salmonids.
	Start date	1997.
	Regulatory authority	• Department for Fisheries and Aquaculture, Ministry of Trade, Industry and Fisheries. • Norwegian Food Safety Authority.
	Relevant legislation	• Regulations on combating lice in aquaculture facilities 2009 (2009-08-18 No. 1095).
	Objectives	• To reduce the detrimental effects of lice on farmed and wild fish. • To document the levels of lice on wild and farmed fish (Ritchie & Boxaspen, 2011).
	Diseases of most concern	• Infection with *Lepeophtheirus salmonis.*
	Sampling and data collection	• Farmers to examine fish for lice (*L. salmonis*) every fortnight when temperatures are ≥ 4°C (2009-08-18 No. 1095, §4). • Government staff conduct farm audits to check lice counts (Standing Senate Committee on Fisheries and Oceans, 2015b). • Surveillance information is submitted to the local district Veterinary Officer (2009-08-18 No. 1095, §4).
	Routine diagnostic tests	• Visual examination by trained staff.
	Mandatory requirements	• Sites in selected areas must synchronise their anti-lice treatments and stocking and fallowing (2009-08-18 No. 1095, §7).
	Variable requirements	• Treatment may be suspended if the exceedance is small and there is sufficient cleaner fish activity that it is likely that they can control the lice (2009-08-18 No. 1095, §5).
	Voluntary measures	• Use of cleaner fish. • Synchronisation of anti-lice treatment with neighbouring companies. In some areas, synchronisation is mandatory (Ritchie & Boxaspen, 2011).
	Reporting requirements	• Monthly report to be delivered to the local district Veterinary Officer (2009-08-18 No. 1095, §4). • Mandatory reporting of a suspected or confirmed cases of resistance to anti-lice treatments (2009-08-18 No. 1095).
	Data management	• All information from samples submitted to the Norwegian Veterinary Institute is stored in the Veterinary Institute's Laboratory Information System and the data is used for the Fish Health Reports (Bang Jensen, 2016).
	Outputs	• Lice counts per region (Seafood Norway, 2016). • Total quantity of veterinary drugs used (Directorate of Fisheries, 2016a). • Annual fish health reports (Norwegian Veterinary Institute, no date-c). • A list of the companies that exceed lice thresholds (Hersoug, 2015).
	Use of outputs	–
	Consequences if disease is detected	• Treatment required: between Nov–Jun when this is more than 0.5 adult females per fish or more than 5 adult females and motile stages; or, between Jul–Oct when there is more than 2 adult females or more than 10 adult females and motile stages in a

NORWAY		single cage[94]. Treatment must be completed within 14 days of exceedance (2009-08-18 No. 1095, §5). • Exceeding maximum lice limits can result in reductions in maximum allowable biomass, slaughter of all fish at site, longer fallowing times, prohibition of smolt introduction, or prohibition of use of certain therapeutants (Standing Senate Committee on Fisheries and Oceans, 2015b). • Authorities can force treatment at the owners expense, close the farm, withdraw the licence, impose fines or send the owner to prison ((2009-08-18 No. 1095, §8–9). • Farmers that continue to exceed lice thresholds may have their maximum allowable biomass halved at the next licencing round (Hersoug, 2015).
	Cost to industry	• Sea lice control cost NOK$1–2.45/kg salmon produced in 2013 (P. Jensen in Nikitina, 2015). • In 2015, total sea lice control was estimated to be NOK$5 billion. This includes the cost of surveillance ($195 million), cleaner fish ($700 million), and therapeutants ($2.5 billion)[95] (Ramsden, 2016). • An estimated 240 labour hours were spent on counting lice numbers in 2015 (Ramsden, 2016).
	Cost to regulatory body	–
	Supporting material	–
	Implementation	1. A National Working Group comprising members of industry, regulatory authorities and researchers, was formed that had an advisory and coordinating role, and developed the National Action Plan. 2. The County Veterinarian's Office facilitated the formation of regional collaborative groups to coordinate treatment, data collection, and reporting by geographic region. 3. Legislation was introduced to allow the enforcement of sea lice regulations. 4. An Integrated Pest Management Plan was developed for sea lice (Ritchie & Boxaspen, 2011).
	Industry support	–
	Uptake of voluntary measures	• n/a.
	Compliance problems	–
	Incentives for compliance	• Farmers allowed to increase their maximum biomass by 5% if they had an average of ≤ 0.1 adult female lice per fish on their sites with a maximum of 2 medicated treatments per production cycle. Licensees are also required to pay NOK$1.5 million[96] to increase their biomass (Nikitina, 2015; Standing Senate Committee on Fisheries and Oceans, 2015b).
	Benefits	–
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

[94] No biological reason is given for these levels (Nikitina, 2015).
[95] NZ$859 million for total sea lice, NZ$33.5 million for monitoring, NZ$120 million for cleaner fish, NZ$429 million for therapeutants, at current exchange rates.
[96] NZ$258,000 at current exchange rates.

Table 27. Norway's surveillance and control programme for *Gyrodactylus salaris* and relevant aquatic health and disease regulations.

NORWAY	Cultured host species	Atlantic salmon and rainbow trout.
	Start date	Late 1970s.
	Regulatory authority	• Department for Fisheries and Aquaculture, Ministry of Trade, Industry and Fisheries. • Norwegian Food Safety Authority.
	Relevant legislation	• Aquaculture Operations Regulations 2008 (2008-06-17 No. 822).
	Objectives	• To detect and trace the spread of *G. salaris* to previously uninfected regions. • To document freedom from *G. salaris* in previously infected Norwegian rivers and farms after implementation of eradication measures.
	Diseases of most concern	• Infection with *G. salaris.*
	Sampling and data collection	• The Norwegian Veterinary Institute coordinates the surveillance programme and commissions the surveillance of uninfected natural waterways to other organisations such as County Environmental Departments and private companies. At least 30 wild fish are sampled per river per year. Fish are captured by electrofishing and preserved whole in 96% ethanol (Hytterød *et al.*, 2015a). In 2015, 2320 wild fish were tested for *G. salaris* (Sviland *et al.*, 2016). • The Norwegian Food Safety Authority collects 30 Atlantic salmon or 60 rainbow trout from every farm each year for *G. salaris* surveillance. All fins[97] are cut off and preserved in 96% ethanol (Hytterød *et al.*, 2015a). In 2015, 3651 farmed fish were tested for *G. salaris* (Sviland *et al.*, 2016). • All samples are sent to the Norwegian Veterinary Institute for examination (Hytterød *et al.*, 2015a). • In order to declare freedom from *G. salaris,* fish need to be examined for at least 5 years following eradication methods (Hytterød *et al.*, 2015b).
	Routine diagnostic tests	• Visual examination under stereo microscope for *Gyrodactylus* sp. The entire surface of wild salmon are examined for the parasite while only the fins of farmed salmon are examined. • If *Gyrodactylus* sp. are found the specimens are sent to the OIE reference laboratory for species determination by PCR and morphology (Hytterød *et al.*, 2015a).
	Mandatory requirements	• At least 30 fish are to be examined for *G. salaris* per year per farm (2008-06-17 No. 822, §50).
	Variable requirements	• None.
	Voluntary measures	• None.
	Reporting requirements	• Norwegian Veterinary Institute produces an annual report on the surveillance programme (Norwegian Veterinary Institute, no date-c).
	Data management	• All information from samples submitted to the Norwegian Veterinary Institute is stored in the Veterinary Institute's Laboratory Information System and the data is used for the fish health reports (Bang Jensen, 2016).
	Outputs	• Monthly and annual surveillance reports (Norwegian Veterinary Institute, no date-c). • Annual fish health report (Norwegian Veterinary Institute, no date-c).
	Use of outputs	
	Consequences if disease is detected	• All farmed fish shall be destroyed and the aquaculture facility shall be shut down and reconstructed. Specific disease prevention measures can also be imposed. • Wild fish are killed with rotenone, or treated with aluminium sulphate to kill *G. salaris* but not the hosts (Hytterød *et al.*, 2015a).
	Cost to industry	–
	Cost to regulatory body	–
	Supporting material	–
	Implementation	–

[97] Except for the adipose fin.

	Industry support	–
	Uptake of voluntary measures	• n/a.
	Compliance problems	–
	Incentives for compliance	–
	Benefits	–
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 28. Norway's hazard-specific surveillance programmes for viral haemorrhagic septicaemia, infectious haematopoietic necrosis, bacterial kidney disease, pancreas disease, piscine orthoreovirus, infectious salmon anaemia.

NORWAY	Cultured host species	Atlantic salmon and rainbow trout.
	Start date	• 2004 for VHS and IHN (Gjevre *et al.*, 2016a). • 2005–2011 for BKD (Nilsen *et al.*, 2012). • 2012 for pancreas disease (Gjevre *et al.*, 2013; Gjevre *et al.*, 2016c). • 2012 for surveillance of wild salmonids (various diseases) (Madhun *et al.*, 2016). • 2015 for piscine orthoreovirus[98] (Gjevre *et al.*, 2016b).
	Regulatory authority	• Department for Fisheries and Aquaculture, Ministry of Trade, Industry and Fisheries. • Norwegian Food Safety Authority.
	Relevant legislation	• n/a.
	Objectives	• To substantiate national disease-free status for trade purposes (Nilsen *et al.*, 2012; Gjevre *et al.*, 2016a). • To substantiate regional disease-free status for zonation purposes and the prevention of disease transmission (Gjevre *et al.*, 2016c). • Early detection and description of the prevalence and distribution of the disease (Gjevre *et al.*, 2013; Gjevre *et al.*, 2016b; Madhun *et al.*, 2016).
	Diseases of most concern	• Viral haemorrhagic septicaemia. • Infectious haematopoietic necrosis. • Bacterial kidney disease. • Pancreas disease. • Infection with piscine orthoreovirus. • Infectious salmon anaemia.
	Sampling and data collection	• VHS and IHN—Fish Health Services conduct around 6 routine health inspections per year per site. Additional inspections may be conducted during transfers of smolt to seawater or if mortality is higher than normal. Only fish with possible disease symptoms are sampled for diagnostic tests. Both salmon and trout samples are surveyed for VHS, while only salmon samples are surveyed for IHN. In 2015, ~1200 fish were tested for VHS and ~750 fish were tested for IHN (Gjevre *et al.*, 2016a). • BKD—Sampling is done in conjunction with VHS/IHN surveys. 30 fish from selected freshwater farms and seawater sites with broodstock are sampled each year (~2,000–5,000 tests/year). • Pancreas disease—Farmers within the surveillance zones 1 & 2 submit 20 recently dead fish to the authorities per month. For the rest of the country, the Food Safety Authority collects 30 fish biannually for testing. In 2015, ~3700 fish were tested for pancreas disease (Gjevre *et al.*, 2016c). • Piscine orthoreovirus—samples are collected by the Food Safety Authority as part of routine farm health inspections or disease investigations. In 2015, 680 fish were tested for piscine orthoreovirus (Gjevre *et al.*, 2016b).

[98] Previously known as virus Y.

NORWAY		• ISA in wild fish—regulatory authorities captured ~600 returning salmon and sampled gill tissues (Madhun *et al.*, 2016). • Most samples are sent to the Norwegian Veterinary Institute for diagnosis. Some pancreas disease samples are sent to an accredited, private laboratory (Gjevre *et al.*, 2016c; Madhun *et al.*, 2016).
	Routine diagnostic tests	• VHS—qRT-PCR with VHSV primers and probe from Jonstrup *et al.* (2013) (Gjevre *et al.*, 2016a). • IHN—qRT-PCR with IHNV primers and probe modified from Liu *et al.* (2008) (Gjevre *et al.*, 2016a). • BKD—Extracts of the tissues (mainly kidneys) are tested individually by a commercially available ELISA (BiosChile) utilising monoclonal antibodies specific for a bacterial surface protein. ELISA positive samples are then tested for the presence of the gene coding for this protein qRT-PCR (Nilsen *et al.*, 2012). • Pancreas disease—qRT-PCR. Positive samples are confirmed by histopathology (Gjevre *et al.*, 2016c). • Piscine orthoreovirus—qRT-PCR targeting the sigma 3 protein (Olsen *et al.*, 2015; Gjevre *et al.*, 2016b). • ISA in wild fish—qRT-PCR (detects both non-virulent HPR0 and virulent HPRΔ) (Madhun *et al.*, 2016).
	Mandatory requirements	• Farmers must permit authorities to inspect and sample their fish.
	Variable requirements	• None.
	Voluntary measures	• None.
	Reporting requirements	• Annual surveillance reports produced (Norwegian Veterinary Institute, no date-a).
	Data management	–
	Outputs	• The Norwegian Veterinary Institute provides reports on the surveillance programmes each year (e.g., Nilsen *et al.*, 2012; Gjevre *et al.*, 2016a). • Monthly surveillance reports for pancreas disease (Norwegian Veterinary Institute, 2016).
	Use of outputs	• Substantiation of freedom from disease for trade purposes (e.g., Gjevre *et al.*, 2016a). • Confirmation of disease eradication methods (e.g., Sviland *et al.*, 2016). • To substantiate regional disease-free status for zonation purposes and the prevention of disease transmission (e.g., Gjevre *et al.*, 2016c). • Description of the prevalence and distribution of the disease (e.g., Gjevre *et al.*, 2016b).
	Consequences if disease is detected	• Loss of freedom from disease status. For example, Norway lost its VHS-free status from 2007–2010 (Gjevre *et al.*, 2016a). • The Ministry may order the destruction of stock, decontamination of facilities, vehicles and equipment and fallowing of the farm when an infectious disease is found or suspected at the cost to the farmer (FDA, §23 & 25). • The Ministry may establish no-transfer zones during a disease outbreak (FDA, §26). • Breeding of animals from areas where notifiable diseases are present or suspected is prohibited, unless the licensee has a permit (2008-06-17 No. 819, §29). • Farms that have had a notifiable disease must be fallowed for a period prior to restocking (2008-06-17 No. 819, §34).
	Cost to industry	–
	Cost to regulatory body	–
	Supporting material	–
	Implementation	–
	Industry support	–
	Uptake of voluntary measures	• n/a.
	Compliance problems	–

	Incentives for compliance	–
	Benefits	–
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 29. Aquatic health and disease surveillance field and laboratory capabilities in Norway.

No. of farms in region	• 1069 finfish farms and 151 invertebrate farms (Directorate of Fisheries, 2016a).
Laboratory capabilities	
Organisation name	Norwegian Veterinary Institute.
No. of laboratories	6.
Laboratory capabilities	Research, full range of disease diagnostic services. A national reference laboratory for several diseases. ISO/IEC 17025 accredited.
No. staff & qualifications	Norwegian Veterinary Institute has approximately 350 employees. The following sections are listed under the laboratory services branch[99]: • 22 staff in bacteriology section; • 24 staff in immunology section; • 11 staff in substrate production section; • 9 staff in parasitology section; • 27 staff in virology section; • 27 staff in pathology section; • 14 staff in mycology section; • 22 staff in chemistry and toxicology (Norwegian Veterinary Institute, no date-b).
Staff responsibilities	Provide animal disease diagnostic services.
No. of tests per annum	In 2015, the Norwegian Veterinary Institute tested: • 680 fish for piscine orthoreovirus (Gjevre *et al.*, 2016b); • 2,320 wild fish and 3651 farmed fish for *G. salaris* (Sviland *et al.*, 2016); • 1,112 fish for VHS (Gjevre *et al.*, 2016a); • 609 fish were tested for IHN (Gjevre *et al.*, 2016a); • 3,712 fish for pancreas disease (Gjevre *et al.*, 2016c).
Field capabilities	
Organisation name	Norwegian Veterinary Institute.
No. staff & qualifications	The following sections are listed under the health surveillance branch[99]: • 23 staff in epidemiology section; • 25 staff in veterinary public health; • 30 staff in environmental and biosecurity measures.
Staff responsibilities	• Conduct routine farm inspections. • Investigate any outbreaks of notifiable diseases.
No. of farm visits per year	• Usually six per finfish farm (> 6,000 visits) (Gjevre *et al.*, 2016a).

[99] Note, this list includes staff that also work on terrestrial animals.

13.2.10 Scotland

Table 30. Scotland's fish and shellfish surveillance programme and relevant aquatic health and disease surveillance regulations.

SCOTLAND	Cultured host species	Salmonids, oysters, mussels.
	Start date	• The current programme started in 2010 following the introduction of EU Council Directive 2006/88/EC. This programme replace an existing active and hazard-specific surveillance programme that was undertaken to meet EU Council Directive 91/67/EEC. Prior to this, only passive surveillance and surveillance to meet export certification requirements was conducted (N. Purvis, Marine Scotland, pers. comm.).
	Regulatory authority	• Marine Scotland. • Fish Health Inspectorate (Marine Scotland).
	Relevant legislation	• Aquaculture and Fisheries (Scotland) Act 2007 (amended 2013) (AFSA): – The Fish Farming Businesses (Record Keeping) (Scotland) Order 2008 (2008 No. 326); – The Alien and Locally Absent Species in Aquaculture (Scotland) Regulations 2015 (2015 No. 103). • EU Council Directive 2006/88/EC. • Aquatic Animal Health (Scotland) Regulations 2009 (2009 No. 85).
	Objectives	• Ensuring satisfactory compliance with the legal requirements of EU Council Directive 2006/88/EC (N. Purvis, Marine Scotland, pers. comm.). • Safeguarding the health of aquatic animals in Scotland through appropriate measures placed to deal with listed and emerging diseases, preventing their introduction and ensuring adequate containment and eradication following any identified outbreaks (N. Purvis, Marine Scotland, pers. comm.).
	Diseases of most concern	• ISA (exotic). • VHS (exotic). • IHN (exotic). • Infection with *Marteilia refringens* (exotic). • Infection with OsHV-μvar. • BKD. • Infection with *Gyrodactylus salaris*. • Infection with *Bonamia ostreae* (The Scottish Government, 2014). • Diseases listed in Annex IV of EU Council Directive 2006/88/EC.
	Sampling and data collection	• Fully trained FHI staff who are appointed by the Scottish Ministers carry out scheduled farm health inspections and also inspect for sea lice. Diagnostic samples may be taken by FHI staff if there is evidence of elevated mortality, clinical signs of disease, or suspicion of the presence of a listed disease. Inspection frequency is risk-based with farms inspected every 1–4 years. Some inspections are unannounced (The Scottish Government, 2015c; N. Purvis, Marine Scotland, pers. comm.). • All *Ostrea edulis* farms are inspected by FHI staff annually and 30 oysters are collected for testing for *Bonamia ostreae* (The Scottish Government, 2014). • FHI staff conduct spot checks on imports and exports (The Scottish Government, 2015c). • FHI staff investigate reported disease outbreaks and unexplained mortality and take samples for testing. Staff respond immediately to reports of listed diseases, and within 1 day for reports of unexplained mortality (The Scottish Government, 2014). • All farms that have species susceptible to ISA, VHS, IHN and marteiliosis are inspected to meet statutory requirements (The Scottish Government, 2014). • FHI staff sample wild fish from all major catchment areas for disease to maintain disease-free status for ISA, VHS, IHN and marteiliosis (The Scottish Government, 2014; 2015c). • FHI staff conduct diagnostic testing for import/export health certificates (The Scottish Government, 2014). • Farmers and health professionals conduct passive surveillance between farm inspections (The Scottish Government, 2014).

SCOTLAND	Routine diagnostic tests	• Diagnostic tests used vary with species cultured and the disease signs. Methods follow the standards prescribed by the OIE. Histopathology examination, bacteriological culture and q-PCR are the typical screening tests used. Use of histopathology as a primary screening tool allows for the observation of emerging diseases (N. Purvis, Marine Scotland, pers. comm.). • Viruses: q-PCR screening for ISAV, VHSV, IHNV, salmonid alphavirus, and IPNV. Additional screening for amoebic gill disease, salmon gill pox virus, BKD, and ENH may be conducted on suspicion of these diseases. Virus culture may be conducted to support positive PCR results where methods and cell lines exist to culture those viruses (N. Purvis, Marine Scotland, pers. comm.; The Scottish Government, 2015a). • Parasites: fish are screened and observed for general parasites. Specific samples are taken for *G. salaris* (N. Purvis, Marine Scotland, pers. comm).
	Mandatory requirements	• Farmers must participate in area management agreements if their farm is located within an established management area (AFSA, pt 1, Ch. 1, §4A). • Farmers must permit the authorities to conduct farm inspections and to take samples from their farms (AFSA, pt 1, Ch. 1, §5A & 13). • Farmers must keep records of all stock transfers, mortalities, surveillance results, which must be publicly available (2009 No. 85, §6 & 13). • Farmers must keep records of staff training in parasite surveillance, the results of weekly parasite surveillance, any therapeutants administered and any anti-parasite control methods used for ≥ 3 years (2008 No. 326, §3). • Farmers must follow good biosecurity practices and comply with any surveillance requirements imposed by the authorities (2009 No. 85, §6). • Movement of alien or locally absent species requires a permit and may require a fish health certificate (2015 No. 103, §9).
	Variable requirements	• Inspections are risk-based. Farms that have the highest risk of spreading disease and culture susceptible species of listed diseases are inspected more frequently than low risk farms. High risk farms are inspected at least annually, medium risk farms are inspected biennially, and low risk farms are inspected every three years for finfish and every four years for shellfish (The Scottish Government, 2014; 2016b; N. Purvis, Marine Scotland, pers. comm.).
	Voluntary measures	• Reporting of sea lice levels above 3 parasites per fish. While farmers are legally required to control sea lice and keep records of sea lice counts, they are not legally required to report these counts to Marine Scotland (N. Purvis, Marine Scotland, pers. comm.). • Notifying the FHI of two consecutive failed sea lice treatments (< 50% lice removal) (The Scottish Government, 2014). • Notifying the FHI of mortality events that are below the notifiable limit (The Scottish Government, 2014). Code of good practice for Scottish finfish aquaculture (Scottish Salmon Producers Organisation, 2015): • Health of broodstock should be monitored for ≥ 3 months. • Fish health should be inspected daily by a qualified person. • Farmers should test all stripped fish for diseases (if non-destructive testing is possible), or should test at least 150 progeny from each batch of eggs. If diseases are present, the entire batch should be destroyed. National strategy for sea lice control (Scottish Salmon Producers Organisation, 2015): • Sea lice control and surveillance should be synchronised by farm management areas. • 25 fish should be monitored for lice per week. Results should be shared weekly with other farmers within the same management area. • Anti-lice treatments should be coordinated within management areas. Treatment is required when there are ≥ 0.5 adult female *L. salmonis* per fish between Feb–June, or ≥ 1 adult female *L. salmonis* per fish between Jul–Jan.

SCOTLAND		
	Reporting requirements	• Farmers are required to notify the authorities of the presence or suspected presence of any commercially damaging species (AFSA, §15). • Farmers must immediately notify the authorities of the presence or suspected presence of listed diseases or increased mortality (2009 No. 85, §23). However, the legislation does not specify the reportable mortality threshold. Industry and government have agreed upon a mortality reporting threshold for the various stages of salmonids farmed in freshwater (6% weekly from egg to first feeding; 3% weekly from first feeding to 5g; 1.5% weekly from 5 g to smelting) and seawater (weekly rate of 1.5% or 5-weekly rate of 6% for fish < 750 g; weekly rate of 1% or 5-weekly rate of 4% for fish > 750 g). Reporting in accordance with these levels is recognised as a voluntary agreement between government and industry (N. Purvis, Marine Scotland, pers. comm.).
	Data management	• A fish health database (Aquadat) is used by Marine Scotland to hold all farm registration details, transporting businesses, processing plants and non-commercial operations. The database also contains records of site inspections. Aquadat is used to place and manage and movement restrictions in the event of a notifiable disease outbreak. Aquadat is hosted by an external company and is provided to Marine Scotland for its exclusive use (N. Purvis, Marine Scotland, pers. comm.). • LIMS is used by Marine Scotland to manage diagnostic testing results and to ensure full traceability of samples (N. Purvis, Marine Scotland, pers. comm.).
	Outputs	• FHI publishes quarterly and annual reports that summarise all farm inspections conducted and the results of diagnostic tests (The Scottish Government, 2016a).
	Use of outputs	• Fish health reports provide surveillance feedback back to industry (N. Purvis, Marine Scotland, pers. comm.).
	Implementation	• Aquatic Animal Health Board considered the UK's aquatic surveillance requirements that involved full consultation with industry, policy makers, scientists and veterinarians. A workshop was held seeking opinions over risks associated with contracting and spreading disease. This information was fed into the development of the risk-based programme and the outcome rolled out through our surveillance activity (The Scottish Government, 2016b; N. Purvis, Marine Scotland, pers. comm.). • Development and implementation of the programme took 2–3 years of regular meetings and on-going development[100] (N. Purvis, Marine Scotland, pers. comm.).
	Consequences if disease is detected	• Farmers may be required to implement measures to control disease, disinfect equipment and destroy stock (AFSA, §16–17; 2009 No. 85, §30 & 33). • Farmers are not allowed to move stock or equipment when a listed disease is suspected or dispose of mortalities without permission (2009 No. 85, §24 & 29). • Staff may be prohibited from entering a designated area where a disease has been confirmed (The Scottish Government, 2015b). • Farms in the vicinity of a disease outbreak are put under surveillance (The Scottish Government, 2015a). • Farms infected by a listed disease must be destocked, cleaned, disinfected and fallowed prior to restocking (The Scottish Government, 2014).
	Cost to industry	• Industry pay for the cost of health certificates (The Scottish Government, 2015c). • Industry pay for the culling of fish and any staff time and costs associated with assisting with farm inspections (N. Purvis, Marine Scotland, pers. comm.).
	Cost to regulatory body	• Farm inspections and disease diagnostic services are provided to aquatic farmers free of charge (The Scottish Government, 2014; 2015c). • In 2017–18, farm inspections and collection of samples are estimated to cost £332,000, and laboratory costs and diagnostic testing is estimated to costs £392,000. This estimate includes the cost of sample processing, operating and servicing equipment, maintaining staff expertise, maintaining the standards obtained to meet external accreditation, participating in ring tests and maintaining the standards required to ensure the upkeep of our National Reference Laboratory status (N. Purvis, Marine Scotland, pers. comm.).
	Supporting material	• Surveillance frequency assessment forms for farmers to self-assess the disease risk of their site (The Scottish Government, 2016b). • Code of good practice for Scottish finfish aquaculture (Scottish Salmon Producers Organisation, 2015).
	Industry support	• Industry were generally supportive of the programme.

[100] The time period of 2–3 years does not reflect the total time spent on development.

SCOTLAND	Uptake of voluntary measures	–
	Compliance problems	• The majority of non-compliance issues detected are related to administrative and record keeping issues, many of which are not considered to be serious, but are a legal requirement under the current Directive. These can be quickly resolved through the issuing of advice and recommendations (N. Purvis, Marine Scotland, pers. comm.).
	Incentives for compliance	• None offered (N. Purvis, Marine Scotland, pers. comm.).
	Benefits	• Scotland has maintained its high health status during the lifetime of the programme, despite an outbreak of VHS in 2012 where control and eradication measures were implemented and the disease free status was regained following the removal of all susceptible species from the farms, the harvest of non-susceptible species (Atlantic salmon), and the completion of a fallow period commencing after the completion of cleaning and disinfection (N. Purvis, Marine Scotland, pers. comm.).
	Barriers to implementation	• No barriers to implementation known. • The frequency of site visits is constrained to some degree by economics. Inspection frequencies of 3–4 years can be too long for some sites, with FHI staff not kept up-to-date with the developments on some sites (N. Purvis, Marine Scotland, pers. comm.).
	Solutions	• New processes are typically brought in with a soft approach allowing industry to become aware of requirements and gradually meet these before enforcement action is taken (N. Purvis, Marine Scotland, pers. comm.). • Sites that are only inspected every 3–4 years are sometimes contacted by telephone to assess the current situation, development and confirm no problems or issues have been experienced (N. Purvis, Marine Scotland, pers. comm.).
	Abandoned processes	• None (N. Purvis, Marine Scotland, pers. comm.).

Table 31. Aquatic health and disease surveillance field and laboratory capabilities in Scotland.

No. of farms in region	In 2015 there were: • 418 fish farms (254 Atlantic salmon farms, 87 Atlantic salmon hatcheries, 45 rainbow trout farms, 32 farms of other fish species) (Munro & Wallace, 2016a). • 335 shellfish sites (Munro & Wallace, 2016b).
Laboratory capabilities	
Organisation name	Fish Health Inspectorate Marine Laboratory, Aberdeen.
No. of laboratories	1
Laboratory capabilities	• A national reference laboratory for finfish, mollusc and crustacean diseases within the European Union. • Accredited by UK Accreditation Service (UKAS) to ISO:17020 and 17025 for inspection, sampling and laboratory analyses for virological, histopathological and molecular tests for VHS, ISA, IHN, spring viraema of carp and infections with *M. refringens* and *B. ostreae* (FVO, 2010; N. Purvis, Marine Scotland, pers. comm.). • All assays undergo 'benchtop' validation prior to being utilised in a diagnostic context, therefore, the analytical sensitivity and specificity of each assay is known. We have conducted several field/laboratory studies to calculate the diagnostic sensitivity and specificity of our testing regimes and have published peer-reviewed papers covering BKD, ISAV and salmon alphavirus screening (N. Purvis, Marine Scotland, pers. comm.).
No. staff & qualifications	• 5 laboratory staff (includes 1 histopathologist).
Staff responsibilities	• Provide disease diagnostic services for the aquaculture industry. • Provide diagnostic testing and issue health certifications for exports (The Scottish Government, 2014).
No. of tests per annum	• 55 diagnostic cases (disease investigations) conducted on average (N. Purvis, Marine Scotland, pers. comm.).
Field capabilities	
Organisation name	Fish Health Inspectorate.

No. staff & qualifications	• 1 operations manager, 3 technical managers, 13 fish health inspectors, 1 aquaculture planning coordinator, 1 aquaculture planning assistant, 1 administrator (The Scottish Government, 2014; N. Purvis, Marine Scotland, pers. comm.). • FHI staff are accredited to UKAS ISO:17020 standard for inspection and sampling of fish farm sites for fish diseases in accordance with EC Directive 2006/88 (The Scottish Government, 2015c).
Staff responsibilities	• Conduct farm inspections, sample fish for disease and therapeutant residues, provide regulatory advice (The Scottish Government, 2015c). • Investigate reported disease outbreaks and unexplained mortality (The Scottish Government, 2014). • Conduct disease surveillance of wild fish (The Scottish Government, 2015c). • Conduct spot checks on imports and exports (The Scottish Government, 2015c). • Conduct annual aquaculture production surveys (The Scottish Government, 2015c). • Monitor compliance with industry codes of practice (Marine Scotland, 2010).
No. of farm visits per year	• Approximately 360 farm inspections were conducted in 2016 (N. Purvis, Marine Scotland, pers. comm.).

13.2.11 Ireland

Table 32. Ireland's risk-based fish health surveillance programme and relevant aquatic health and disease surveillance regulations.

IRELAND	Cultured host species	Salmonids, Pacific oysters, mussels.
	Start date	Early 1990s. The current programme under EU Council Directive 2006/88/EC started in 2008 (Expert 2, pers. comm.).
	Regulatory authority	• Marine Institute.
	Relevant legislation	• EU Council Directive 2006/88/EC: – European Communities (Health of Aquaculture Animals and Products) Regulations 2008 (SI no. 261 of 2008); – European Communities (Health of Aquaculture Animals and Products (Amendment) Regulations 2010 (S.I. no. 398 of 2010) and 2011 (S.I. no. 430 of 2011).
	Objectives	• Early detection and prevention of spread of diseases.
	Diseases of most concern	• Infection with *G. salaris*, spring viraemia of carp, bacterial kidney disease (exotic). • Infection with OsHV-μvar (regionally exotic). • Diseases listed in Annex IV of EU Council Directive 2006/88/EC. • Pancreas disease, amoebic gill disease, infectious pancreatic necrosis, furunculosis, enteric redmouth disease, vibriosis, brown ring disease and withering syndrome (Marine Institute, 2016c; Expert 2, pers. comm.).
	Sampling and data collection	• Marine Institute staff or inspectors acting on behalf of the Marine Institute visit shellfish and finfish farms every 1–2 years, depending on risk. Farms are inspected and any moribund or dead fish are sampled for disease screening. If no moribund fish are present then 30 healthy animals may be sampled, depending on the annual work schedule. Inspectors also audit the farms records, biosecurity procedures and compliance with legislated requirements (Marine Institute, 2016j; Expert 2, pers. comm.). • Private health professionals also inspect and sample high risk finfish farms annually, and medium risk finfish farms biennially as part of the national risk-based health surveillance scheme (Marine Institute, 2016j). • Molluscs and marine finfish may also be sampled if unusual mortality is reported (Expert 2, pers. comm.). • All finfish hatcheries are sampled before smolts go to sea (Expert 2, pers. comm.).

IRELAND	Routine diagnostic tests	• Diseases that are routinely screened for include: IHN, VHS, ISA, koi herpesvirus, *B. ostreae, M. refringens, G. salaris*, spring viraemia of carp, bacterial kidney disease, pancreas disease, IPN, furunculosis, enteric redmouth disease, vibriosis, brown ring disease, withering syndrome (Ruane & Nunes, 2015 Marine Institute, 2016c). Some production diseases are also tested for (Expert 2, pers. comm.). • Diagnostic methods for diseases listed in EU Council Directive 2006/88/EC are stipulated in Decision 2015/1554.
	Mandatory requirements	• Movement of stock requires a permit (SI no. 261 of 2008, §4). Permit applications require a veterinary report that summarises the outcome of a clinical inspection of the fish which has taken place ≤ 1 month prior (IFA Aquaculture, 2011; Expert 2, pers. comm.). • When destined for disease free areas in Ireland, juvenile stock must come from certified disease-free hatcheries in approved health zones (IFA Aquaculture, 2011; Expert 2 pers. comm.). • Aquaculture farmers, processing businesses, holding facilities, put and take fisheries and quarantine facilities require a fish health authorisation permit (SI no. 261 of 2008, §17). • Farmers must maintain a record of all stock transfers, mortality and surveillance results for ≥ 5 years (SI no. 261 of 2008, §22). • Aquatic animal transporters must maintain records of mortality during transport, each facility visited, and details of any water exchange during the journey for ≥ 5 years (SI no. 261 of 2008, §22). • Farmers must prepare a fish health management plan that includes fish health surveillance, hygiene practices, emergency disease responses, biosecurity measures, and sampling of fish for disease (SI no. 261 of 2008, §23). • Any increase in mortality must be investigated by the company health professional (SI no. 261 of 2008, §9).
	Variable requirements	• Frequency of farm inspections is risk based. High risk finfish farms are inspected annually by both private health professionals and Marine Institute staff; medium risk farms are visited annually with visits alternating between private health professionals and Marine Institute staff; and, low risk farms are visited biennially by Marine Institute staff (Marine Institute, 2016j). • High risk shellfish farms are inspected annually by Marine Institute staff; medium risk farms are visited biennially by Marine Institute staff (Marine Institute, 2016j).
	Voluntary measures	A fish health code of practice for salmonid aquaculture in Ireland[101] (IFA Aquaculture, 2014): • each farm must retain a veterinary surgeon and have a veterinary health plan written in collaboration with the veterinary surgeon; • all stocks must be constantly monitored for health and welfare, and veterinary practitioners must be kept informed of the health status of stocks; • steps must be taken to identify the cause of any abnormal behaviour or mortality; • all farms must have a disease emergency response plan; • all staff should receive training in fish health and welfare. Farmed salmonid health handbook (IFA Aquaculture, 2011): • Fish in all net pens should be checked at least twice a week by farm staff, at least once per week by a trained biologist, and at least once every two months by a veterinarian. • If abnormal behaviour or appearance is noted, the surveillance frequency should be increased and a disease sampling programme implemented. • Fortnightly health screens should be conducted where 5 fish from at least 3 units are examined visually. If necessary, fish should be sampled for mucous, blood, bacterial swabs or internal organs. • A batch of 50–100 fish should be weighed monthly to assess growth and performance.
	Reporting requirements	• Farmers are required to immediately notify the authorities and the company health professional of the presence or suspected presence of listed diseases, or an increase in mortality (SI no. 261 of 2008, §9).

[101] All signatories to the code of practice must comply with the requirements outlined in the code of practice.

IRELAND	Data management	• The Marine Institute maintains and publishes registers of holders of fish health permits and fish transport permits (SI no. 261 of 2008, §18–19). Permit applications can be made online via the Marine Institute website (Marine Institute, 2015). • A database of surveillance results is jointly owned by the Marine Institute and the parent department. It can be accessed by approved government staff only (Expert 2, pers. comm.).
	Outputs	• An up-to-date register of all aquaculture business, wild enhancement facilities, processing plants that have been approved for sanitary slaughter, and aquaculture transporters (Marine Institute, 2016f).
	Use of outputs	• Used for contacting farmers during a disease outbreak.
	Consequences if disease is detected	• Movement of stock will be prohibited (SI no. 261 of 2008, §10). • Introduction of new stock or harvest of stock from a farm that has been declared infected is prohibited (SI no. 261 of 2008, §11). • The area around an infected farm is declared a containment zone (SI no. 261 of 2008, §12). • Stock in an infected farm may be destroyed (SI no. 261 of 2008, §14). • The farm may be ordered to be left to fallow for a specified period of time (SI no. 261 of 2008, §15).
	Cost to industry	• Time required for compliance, the cost of private veterinary visits and any costs associated with the provision of samples. There is also a potential cost to industry in the event of a disease outbreak that requires culling or implementation of disease control methods (Expert 2, pers. comm.).
	Cost to regulatory body	• Unavailable. The programme is taxpayer funded (Expert 2, pers. comm.).
	Supporting material	• The farmed salmon handbook (IFA Aquaculture, 2011). • A fish health code of practice for salmonid aquaculture in Ireland (IFA Aquaculture, 2014). • A fish health website (www.fishhealth.ie).
	Implementation	• Industry were consulted prior to implementation. Initial programme development took approximately 18 months and the programme is constantly refined (Expert 2, pers. comm.).
	Industry support	• Industry were supportive of programme development (Expert 2, pers. comm.).
	Uptake of voluntary measures	–
	Compliance problems	• Record keeping by mollusc farmers was inconsistent (Expert 2, pers. comm.).
	Incentives for compliance	• The biosecurity measures which are mandatory under the programme assist with disease prevention which incentivises compliance (Expert 2, pers. comm.).
	Benefits	• Disease prevention and control (Expert 2, pers. comm.).
	Barriers to implementation	• Lack of funding made implementation more difficult, but this has been overcome and the programme is fully implemented throughout the country (Expert 2, pers. comm.).
	Solutions	• The provision of a statutory record book to mollusc farmers to assist with record keeping. It is a mandatory requirement to complete the record book (Expert 2, pers. comm.).
	Abandoned processes	• Surveillance frequency of mussel farms and put and take fisheries has been decreased because, with a few exceptions, these two industries are deemed to be low risk (Expert 2, pers. comm.).

Table 33. Ireland's sea lice surveillance programme (DMNR, 2000).

IRELAND

Cultured host species	Salmonids.
Start date	• 1991
Regulatory authority	• Marine Institute.
Relevant legislation	• EU Council Directive 2006/88/EC: – European Communities (Health of Aquaculture Animals and Products) Regulations 2008 (SI no. 261 of 2008); – European Communities (Health of Aquaculture Animals and Products (Amendment) Regulations 2010 (S.I. no. 398 of 2010) and 2011 (S.I. no. 430 of 2011).
Objectives	• To provide an objective measurement of infestation levels on farms. • To investigate the nature of infestations. • To provide information to assist implementation and development of control and management strategies.
Diseases of most concern	• Infection with *L. salmonis*
Sampling and data collection	• Marine Institute staff sample fish fortnightly between Mar–May, and monthly for the rest of the year except for Dec–Jan, where inspection is once in the two month period (14 inspections per annum) (O'Donohoe *et al.*, 2009). • On each inspection, 20–60 fish will be sampled for each year class (half from a reference cage and half from a random cage), with 60 being the target number. If there are only two cages on the site, only one cage needs to be sampled (O'Donohoe *et al.*, 2009). • All lice are removed from anaesthetised fish and the seawater sieved. Lice are preserved in 70% alcohol and taken to the laboratory for identification and enumeration (O'Donohoe *et al.*, 2009). • Surveillance results are sent to farmers within 5–10 days of the inspection (O'Donohoe *et al.*, 2016). • Additional, follow up inspections may be conducted where required (O'Donohoe *et al.*, 2009).
Routine diagnostic tests	• Visual examination of lice under the microscope.
Mandatory requirements	• Marine finfish farmers must comply with the sea lice surveillance protocol (Jackson, 2011). • Farmers must operate according to the principles of Single Bay Management to synchronised anti-lice treatments and fallowing (DMNR, 2000; IFA Aquaculture, 2011).
Variable requirements	• Surveillance and treatment is not required if fish are about to be harvested, or by agreement with the authorities (IFA Aquaculture, 2011).
Voluntary measures	Farmed salmonid health handbook (IFA Aquaculture, 2011): • Fish should be sampled weekly for sea lice (in addition to surveillance conducted by the Marine Institute). Lice on 10 fish from 1/3 of the pens should be counted by staff training in lice surveillance.
Reporting requirements	• Government sends surveillance results to farmers within 5–10 days of the inspection (O'Donohoe *et al.*, 2016).
Data management	–
Outputs	• Surveillance results are circulated by the Marine Institute to all farmers, regulatory bodies and fishing associations each month. The Marine Institute also publishes an annual summary (O'Donohoe *et al.*, 2016). • Annual lice surveillance reports identifiable to the company (O'Donohoe *et al.*, 2016).
Use of outputs	–
Consequences if disease is detected	• Treatment is required if there are ≥ 0.5 egg-bearing females/fish between March to May or ≥ 2 egg-bearing females/fish for the rest of the year (ARTIB, 2008; IFA Aquaculture, 2011).
Cost to industry	–
Cost to regulatory body	• Marine Institute pays for the surveillance programme and conducting lice counts.
Supporting material	• A strategy for the improved pest control on Irish salmon farms (ARTIB, 2008). • Farmed salmonid health handbook (IFA Aquaculture, 2011).
Implementation	• 1991: Farms were monitored for sea lice to obtain an understanding of the infestation levels (Jackson, 2011).

IRELAND		• 1993: Sampling strategy was developed in consultation with national and international experts in the field and was been refined following feedback from industry and stakeholders (ARTIB, 2008). • 2000: The surveillance protocol was made mandatory for all marine finfish farms (Jackson, 2011). • 2007: A joint industry/government working group was established to identify sea lice management options in problematic areas (ARTIB, 2008).
	Industry support	• Industry support for the surveillance programme has been high. Industry co-operated with implementation of the sampling programme and provided advice for improvements to the programme (Jackson, 2011).
	Uptake of voluntary measures	–
	Compliance problems	–
	Incentives for compliance	–
	Benefits	• Frequent lice surveillance has facilitated early intervention and better sea lice control, resulting in lower lice numbers (O'Donohoe *et al.*, 2016).
	Barriers to implementation	–
	Solutions	–
	Abandoned processes	–

Table 34. Aquatic health and disease surveillance field and laboratory capabilities in Ireland.

No. of farms in region	• 20 salmonid farms (O'Donohoe *et al.*, 2016).
Laboratory capabilities	
Organisation name	Fish Health Unit, Marine Institute.
No. of laboratories	1
Laboratory capabilities	• The national reference laboratory for aquatic disease in Ireland. Responsible for developing, validating and implementing appropriate methods for the testing of fish and shellfish diseases (Marine Institute, 2016g). • Parasitology, histology, bacteriology, virology and molecular diagnostics (Marine Institute, 2016g). • Accredited to ISO 17025 standards for a number of diseases, including the diseases that are routinely screened for (Ruane & Nunes, 2015).
No. staff & qualifications	• 4 technicians, 6 scientists (Expert 2, pers. comm.).
Staff responsibilities	• Provide diagnostic testing according to approved methods. Ensure good quality control (Expert 2, pers. comm.).
No. of tests per annum	• In 2016, 3,000 molluscs and 4,500 finfish were tested for disease (Expert 2, pers. comm.).
Field capabilities	
Organisation name	Marine Institute.
No. staff & qualifications	• 3 field inspectors (Expert 2, pers. comm.).
Staff responsibilities	• Conduct, sea lice inspections. • Conduct fish health inspections.
No. of farm visits per year	• 212 sea lice inspection visits were conducted at 20 sites in 2015 (O'Donohoe *et al.*, 2016). • 250 farm inspections (Expert 2, pers. comm.).

13.3 SUMMARY OF THE SURVEILLANCE PROGRAMMES CONDUCTED IN THE REVIEWED COUNTRIES

Table 35. Surveillance type, programme objectives and main components.

Jurisdiction	Programme	Surveillance Type	Objectives	Main components	Sampling conducted by:
South Australia	Aquatic animal health.	Enhanced passive.	• Early detection.	• Government staff review laboratory results and veterinarian reports. • Farmers send samples for diagnostic testing prior to importation.	Industry.
	OsHV-µvar.	Hazard-specific.	• Early detection.	• Participating farmers collect spat samples in spring and autumn.	Industry.
Tasmania	OsHV-µvar.	Hazard-specific.	• Prevention of spread.	• Government staff collect samples in summer. • Farmers submit samples when unusual mortality is detected.	Industry and government.
	TSHSP.	Enhanced passive.	• Early detection.	• Farmers or fish health professionals (FHP) regularly check fish, moribund fish may be sampled for diagnostic testing.	Industry and fish health professional (FHP).
British Columbia	BCARP.	Hazard-specific.	• Early detection. • Prevention of spread.	• Government staff conducts farm inspections and collects samples approximately twice a year. • Farmers or FHP sample fish prior to transfers or when there is unusual mortality.	Government, industry and FHP.
	Sea lice.	Hazard-specific.	• Prevention of spread.	• Farmers sample fish for lice fortnightly to monthly . • Government staff conducts lice count audits approximately annually.	Industry and government.
New Brunswick	ISA control.	Hazard-specific.	• Early detection. • Prevention of spread.	• FHP collect samples of fish for diagnostic testing once every 2 months. • Government staff conducts farm inspections and collects samples once every 2 months. • FHP collect samples from spawning broodstock for diagnostic testing.	FHP and government.
	Sea lice.	Hazard-specific.	• Prevention of spread.	• Farmers sample fish for lice weekly to monthly, and before treatment. • Government staff conduct lice count audits approximately twice per year.	Industry and government.
	Shellfish health.	Hazard-specific.	• Early detection.	• Government staff collect samples twice a year.	Government.
Washington	Salmonid disease	Hazard-specific.	• Prevention of spread.	• FHP or government staff sample adults annually for viruses.	Government or FHP.

Jurisdiction	Programme	Surveillance Type	Objectives	Main components	Sampling conducted by:
	control policy.			• FHP or government staff inspect fish monthly between spawning and release of juveniles. • FHP or government staff sample fish once every 3 years for whirling disease. • FHP or government staff sample fish for viruses prior to transfers.	
Washington	Shellfish disease.	Hazard-specific.	• Prevention of spread.	• Industry submit samples for diagnostic testing prior to import into state, prior to export, and prior to some intrastate movements of stock. • Industry submit samples for annual disease-free certification of hatcheries. • Government staff conduct site inspections of hatcheries, wet-holding facilities and quarantine facilities.	Industry and government.
Maine	USDA ISA control.	Hazard-specific.	• Early detection. • Prevention of spread.	• FHP sample fish at least monthly for ISA and at least annually for other targeted diseases. • FHP sample broodstock annually within 30 days of spawning. • FHP conduct annual farm inspections. • Government staff conduct annual biosecurity audits.	FHP and government.
	Fish health.	Enhanced passive	• Early detection.	• Laboratory results and FHP reports are reviewed for certain diseases of concern. • Industry submit samples for diagnostic testing prior to importation.	FHP and government.
Alaska	Fish and shellfish health and disease control policy.	Hazard-specific.	• Prevention of spread.	• Farmers submit finfish samples prior to transfers or release. • Farmers submit shellfish samples prior to transfers and annually for disease-free certification. • Government staff conduct farm inspections at least biennially.	Industry.
Norway	Fish health.	Active & hazard-specific.	• Early detection. • Prevention of spread. • Substantiation of freedom from disease.	• Government staff conduct farm inspections 4–12 times per year. Fish showing disease symptoms are sampled. • Government staff sample fish prior to release into the wild. • Government staff sample wild caught broodstock for BKD, furunculosis and IPN. • Government staff sample wild fish to substantiate freedom from disease for certain diseases.	Government.
	Sea lice	Hazard-specific.	• Prevention of spread.	• Farmers monitor fish for lice every fortnight. • Government staff conduct farm audits to check lice counts.	Industry and government.

Jurisdiction	Programme	Surveillance Type	Objectives	Main components	Sampling conducted by:
Scotland	Fish and shellfish health.	Active & hazard-specific.	• Early detection. • Prevention of spread. • Substantiation of freedom from disease.	• Government staff conduct farm inspections every 1–3 years. Inspection frequency is risk based. During an audit fish are sampled for disease. • Government staff sample wild fish to substantiate freedom from disease for certain diseases.	Government.
	Sea lice.	Hazard-specific.	• Prevention of spread.	• Farmers monitor fish for lice every week. • Government staff conduct lice count audits every 1–3 years as part of the farm inspection.	Industry and government.
Ireland	Fish and shellfish health.	Active & hazard-specific.	• Early detection. • Prevention of spread. • Substantiation of freedom from disease.	• Government staff conduct farm inspections every 1–2 years. Inspection frequency is risk based. Moribund fish are sampled. • FHP also conduct farm inspections every 1–2 years for medium to high risk farms. • Government staff sample hatcheries prior to smolts going to sea. • Government staff sample wild fish to substantiate freedom from disease for certain diseases.	Government and FHP.
	Sea lice.	Hazard-specific.	• Prevention of spread.	• Government staff sample fish for lice 14 times per year on every farm.	Government.

Table 36. Summary of the mandatory and variable requirements of the regular surveillance programmes conducted in the reviewed countries, and any recommended voluntary surveillance measures.

Jurisdiction	Mandatory requirements	Variable requirements	Voluntary measures
South Australia	• Immediate requirement to report listed diseases and elevated mortality. • Imports & releases must be disease-free. • Recording of transfers, mortalities and therapeutants used.	• None.	• Participation in the OsHV-µvar surveillance programme.
Tasmania	• Immediate requirement to report listed or unknown diseases and elevated mortality. • Imports must be disease-free.	• None.	• Participation in TSHSP, Macquarie Harbour fish health management plan and Pacific oyster health surveillance programme. • Monthly bacterial tests for finfish. • Requirement for a fish health management plan. • Monitoring of water parameters and fish condition. • Disease-free certification prior to transfer between biosecurity zones. • Other companies to be notified of a disease outbreak.
British Columbia	• Immediate requirement to report listed diseases and elevated mortality. • Approximately biannual inspections and diagnostic testing for finfish. • Fortnightly to monthly sea lice counts. • Transfers and releases require a permit and must be disease-free. • Reporting of diagnostic testing, transfers, therapeutants used, sea lice counts and mortalities. • Requirement for a fish health management plan. • Monitoring of water parameters and fish condition.	• Conditions of the fish health management plans varies among companies. • Lice sampling may be skipped during stressful environmental conditions.	• Disease-screening prior to spawning. • Lice sampling when there is 2 or less stocked pens.
New Brunswick	• Immediate requirement to report diseases of commercial significance. • Finfish diagnostic testing every month. • Weekly to monthly sea lice counts. • Farm inspections. • Transfers requires a permit and disease-free certification. • Requirement for a sea lice management plan.	• Frequency of lice monitoring is dependent on water temperature.	• None.

Jurisdiction	Mandatory requirements	Variable requirements	Voluntary measures
	• Reporting of site visits, samples submitted, unexplained mortality, diagnostic results, sea lice counts and therapeutants used. • Recording of transfers, mortality and diseases. • Broodstock sites must have DFO's fish health certification.		
Washington	• Immediate requirement to report listed diseases or elevated mortality. • Annual virus testing for finfish broodstock. • Testing for whirling disease once every 3 years. • Transfers and releases required a permit and virus-free certification. • Imports require disease-free certification. • Fish heath checked monthly from spawn to release. • Requirement for a disease management plan. • Recording of diagnostic testing and transfers.	• Level of diagnostic testing prior to transfers depends on level of disease risk.	• Participation in the shellfish high health programme.
Maine	• Immediate requirement to report listed diseases. • Annual diagnostic testing and farm inspections for finfish. • Diagnostic testing of broodstock around spawning. • Monthly sampling for ISA. Marine salmon farmers must participate in the ISA surveillance programme. • Wild fish must be quarantined and tested for diseases. • Imports and releases require a permit and disease-free certification. • Hatchery stock must be certified disease-free. • Reporting of therapeutants used, vaccination and transfers. • Recording of transfers, harvest, mortalities and diagnostic testing.	• Number of fish tested for bacterial diseases depends on the results of the previous 3 years. • Frequency of ISA sampling depends on the infection history. • Monthly ISA surveillance may be skipped if fish are to be harvested.	• None.
Alaska	• Immediate requirement to report listed diseases or elevated mortality. • Farm inspections at least biennially. • Transfers and releases require a permit and disease-free certification. • Shellfish may only be imported for certified disease-free hatcheries. • Requirement for a hatchery management plan.	• If transfers are within the state the farm may supply a disease history of the donor site rather than live samples. • Requirement for diagnostic testing is dependent on culture species and disease status of receiving waters. • Frequency of farm inspections is dependent on the farm's disease history.	• Diagnostic testing the year prior to transfer to establish a disease history.

Jurisdiction	Mandatory requirements	Variable requirements	Voluntary measures
	• Reporting of production, stock acquisition, transfers, mortality and inventory.		
Norway	• Immediate requirement to report diseases or elevated mortality. • Farm inspections and diagnostic testing 4–12 times per year. • Diagnostic testing prior to release. • Diagnostic testing prior to leaving the hatchery or farm. • Diagnostic testing of wild salmonids. • Fortnightly lice counts. • Daily inspections of finfish and weekly inspections of shellfish by farmer. • Farmers must have suitable aquaculture training. • Requirement for an emergency disease plan. • Records of biomass, diagnostic testing, mortality, therapeutants used, environmental monitoring. • Vaccination against furunculosis and vibriosis. • Elevated mortality or suspected disease must be investigated by a health professional. • Reporting of density, transfers, fallow periods, mortality, biomass, harvest and feed consumption.	• Frequency of inspections depends on the number of fish, species and life-stage cultured.	• None.
Scotland	• Immediate requirement to report listed diseases, commercially damaging species or elevated mortality. • Farm inspections and diagnostic testing every 1–3 years. • Weekly lice counts. • Transfers require a permit and may require disease-free certification. • Participation in AMAs. • Recording of transfers, mortalities, diagnostic testing, staff training in lice surveillance, lice counts, therapeutants used.	• Frequency of inspections is risk-based.	• Reporting of mortality events below the notifiable limit. • Reporting of two consecutive failed sea lice treatments. • Adherence to the code of good practice for Scottish finfish aquaculture. • Adherence to the national strategy for sea lice control.
Ireland	• Immediate requirement to report listed diseases or elevated mortality. • Farm inspections and diagnostic testing every 1–2 years. • Fortnightly to monthly lice counts. • Transfers require a permit and disease-free certification. • Juveniles must be obtained from certified disease-free hatcheries.	• Frequency of inspections is risk-based. • Lice counts are not required if fish are about to be harvested.	• Disease emergency plan. • Staff to be trained in fish health and welfare. • Regular stock checks by farm staff, biologists and veterinarians. • Weekly lice counts. • Adherence to a fish health code of practice for salmonid aquaculture in Ireland.

Jurisdiction	Mandatory requirements	Variable requirements	Voluntary measures
	• Recording of transfers, mortality, and diagnostic testing. • Requirement for a fish health management plan. • Increase in mortality must be investigated by a health professional.		

13.4 INTERVIEW QUESTIONS FOR INTERNATIONAL DISEASE EXPERTS

1. What is your role?
2. Are you happy for your comments to be cited in the report, or would you prefer that your comments remain anonymous?

Description of the surveillance programme

3. When did the programme start and what are the objectives of the surveillance programme?
4. How does the programme work?
    a) Sample/information collection—who collects the samples, what samples need to be collected, how often are the samples collected (periodic or risk based), how many farms are sampled per annum, what is the rationale behind the sampling regime?
    b) Are there any variable or voluntary requirements to the programme?
    c) Diagnostic testing—what diseases are tested for, what diagnostic methods are used, are there any limitations (specificity, sensitivity etc.) to the type of tests conducted, how many tests are conducted per farm, can the programme capture emerging diseases or risks?
    d) Site inspections—are site inspections conducted? If so, who are they conducted by, when and how often are they conducted, and what are the qualifications of the inspector?
    e) Data management—how is the data stored, who manages the database, who owns the database, who can access it, how is the data reported, how is the data used, confidentiality issues?

Implementation of the surveillance programme

5. How was the programme implemented throughout the region?
6. Were industry involved in the development of the programme?
7. How long did it take to develop and implement the programme?
8. Which parts were mandatory and which were voluntary, if any?
9. How supportive were the farmers to the surveillance programme?
10. Were any incentives offered to farmers to increase compliance?
11. Were there any barriers to implementation? If so, how they were overcome?
12. Were there any processes that were implemented but then abandoned? If so, why?
13. Do/did you have any problems with compliance? If so, how are/were they overcome?
14. Do you have any programme recommendations if starting over again?

Benefits and outcomes of the surveillance programme

15. Have there been any measurable benefits of the programme?
16. Is there any evidence that the outcomes of the surveillance programme are:
17. less beneficial that expected?

18. Successful in certain locations but not others?
19. What other procedures have been implemented that improve health and disease management? e.g., area-based management, fallowing, single year class management.

Economic cost of implementing the surveillance programme for the regulatory authority

20. Do you know what the cost of implementing the programme was in terms of:
    a) Costs and time required for consultation and programme development?
    b) Resources required for any necessary legislative changes?
21. Do you know what the compliance costs are for both farmers and the regulatory authorities in terms of:
    a) Cost of sample collections, tests and farm inspections?
    b) Labour required by farmers to comply with programme costs?
    c) Cost of running surveillance programme and reporting?
    d) Disposal and disinfection costs if a disease outbreak occurs?
    e) Implementation of emergency disease response plan?
22. How are the costs of the surveillance programme covered?
    a) Industry levies
    b) User pay fees
    c) Taxpayer funded
    d) Other
23. How many laboratories and staff are required to run the surveillance programme?
    a) Farm inspectors?
    b) Lab technicians?
    c) Scientists/pathologists?
24. What are your laboratory capabilities?
25. How many tests do you conduct per annum under the programme?
26. What are your staff responsibilities?
    a) In the field?
    b) In the laboratory?
27. How many farm inspections do you conduct per annum under the programme?

13.5 DISEASES OF CONCERN FOR THE NEW ZEALAND SALMON INDUSTRY

Table 37. Definition of risk analysis categories used to describe consequences of establishment of disease agents (from Diggles, 2016).

Consequences	Definition
Extreme	Establishment of disease would cause substantial biological and economic harm at a regional or national level, and/or cause serious and irreversible environmental harm.
High	Establishment of disease would have serious biological consequences (high mortality or morbidity) and would not be amenable to control or eradication. Such diseases would significantly harm economic performance at a regional level and/or cause serious environmental harm which is most likely irreversible.
Moderate	Establishment of disease would cause significant biological consequences (significant mortality or morbidity) and may not be amenable to control or eradication. Such diseases could harm economic performance at a regional level on an ongoing basis and/or may cause significant environmental effects, which may or may not be irreversible.
Low	Establishment of disease would have moderate biological consequences and would normally be amenable to control or eradication. Such diseases may harm economic performance at a local level for some period and/or may cause some environmental effects, which would not be serious or irreversible.
Very low	Establishment of disease would have mild biological consequences and would be amenable to control or eradication. Such diseases may harm economic performance at a local level for a short period and/or may cause some minor environmental effects, which would not be serious or irreversible
Negligible	Establishment of disease would have no significant biological consequences and would require no management. The disease would not affect economic performance at any level and would not cause any detectable environmental effects.

Table 38. Diseases of concern to Chinook salmon, their presence in New Zealand, and the consequences of establishment of the disease[102] on salmon should it occur in New Zealand (Table adapted from Georgiades et al. (2016).

Disease name [pathogen]	Disease type	NZ or OIE notifiable	Presence in NZ Chinook salmon		Notes on occurrence	Consequences of disease	References
			Pathogen	Disease			
ENDEMIC DISEASES							
Infectious pancreatic necrosis and other birnaviruses [Aquatic birnaviruses] (multiple agents)	Viral	NZ (exotic strains)	Yes	No	Some pathogenic agents of this disease are found in NZ but NZ strains appear to be non-pathogenic to salmon. Local strains have been isolated from multiple wild species. Occurs at low prevalence in South Island marine environments. Chinook salmon appear to be not susceptible to IPN.	Very low	Parisot *et al.* (1963); Davies *et al.* (2010); Diggles (2016)
Enteric redmouth/Yersiniosis [*Yersinia ruckeri*]	Bacterial	NZ (exotic strains)	Yes	No enteric redmouth; Yes yersiniosis.	NZ strain doesn't cause enteric redmouth, but a milder version of the disease, called yersiniosis. Local strain is widespread in freshwater. Also occurs in seawater. Mainly occurs in stressed or injured fish.	Moderate for enteric redmouth, very low for yersiniosis.	Diggles *et al.* (2002); Tubbs *et al.* (2007)
Epitheliocystis [Gram negative, obligate intracellular bacteria. Usually described as chlamydia-like or rickettsia-like] (multiple agents)	Bacterial	No	Yes	Yes	Some pathogenic agents of this disease are found in NZ. Occurs in both freshwater and seawater. Mainly occurs in stressed fish.	Very low	Kent *et al.*, 1998; Tubbs *et al.* (2007)
Infection with atypical strains of *Aeromonas salmonicida* [*Aeromonas salmonicida*]	Bacterial	No	No	No	Occurs in both freshwater and seawater. Recorded in lamprey and trout in NZ. Virulance depends on strain. NZ strain appears to be of no clinical significance.	Very low	Diggles (2016); Georgiades *et al.* (2016)
Infection with *Flavobacterium* spp. [*F. columnare, F. psychrophilum*[103], *F. branchiophilum*] (multiple agents)	Bacterial	No	Yes	Yes	Some pathogenic agents of this disease found in NZ. *Flavobacterium* spp. are widespread in freshwater. Multiple host species. Typically occurs in stressed fry.	Very low	Bingham (2015); Diggles (2016)

[102] Categories used to describe the consequences of establishment of disease follow the criteria given in Diggles (2016) (Table 37).
[103] Agent of bacterial gill disease.

Disease name [pathogen]	Disease type	NZ or OIE notifiable	Presence in NZ Chinook salmon		Notes on occurrence	Consequences of disease	References
			Pathogen	Disease			
Infection with *Listonella anguillarum*[104] [*Listonella anguillarum*]	Bacterial	No	Yes	No	Widespread in marine and brackish waters. Multiple host species. Can be highly virulent for young fish held at high densities.	Very low	Powell and Loutit (1990); Tubbs *et al.* (2007)
Nocardiosis [*Nocardia* sp.]	Bacteria	No	Yes	Yes	Occurs in freshwater. Caused 3.5% cumulative mortality over one month. Only occurred in one pen and did not spread to other pens in the farm.	Very low	Brosnahan *et al.* (2017)
Infection with rickettsia-like organisms[105] [*Piscirickettsia*-like bacteria]	Bacteria	No	Yes	Yes	Primarily found in seawater but may survive in freshwater. Mortality mainly occurs in stressed fish.	Moderate	Diggles (2016)
Infection with *Tenacibaculum maritimum* [*Tenacibaculum maritimum*]	Bacterial	No	Yes	Yes	Opportunisitic pathogen, widespread in seawater, occurs naturally on wild fish in the absence of disease. Only causes disease in stressed or injured fish, can cause high mortalities at high culture densities. Multiple host species.	Low	Tubbs *et al.* (2007); Diggles (2012); MPI (2015)
Infection with *Vibrio ordalii* [*Vibrio ordalii*]	Bacterial	No	Yes	Yes	Opportunisitic pathogen, widespread in seawater, occurs in stressed or injured fish, multiple host species. Can cause high mortalites in juvenile fish reared at high densities.	Low	Tubbs *et al.* (2007); Diggles (2012)
Motile aeromonad septicaemia [*Aeromonas hydrophila*][106]	Bacterial	No	Yes	No	Occurs in freshwater. Virulance varies greatly with strain and environmental conditions.	Very low	Tubbs *et al.* (2007)
Saprolegniasis [*Saprolegnia* spp.] (multiple agents)	Chromistan	No	Yes	Yes	Some pathogenic agents of this disease are widespread in freshwater in NZ. Occurs in stressed or injured fish.	Very low	Diggles (2016)
Infection with *Ichthyophthirius multifiliis* [*Ichthyophthirius multifiliis*]	Chromistan	No	Yes	Yes	Ubiquitous in freshwater. Occurs in stressed or injured fish. Heavy infestations can quickly lead to epizootics if untreated.	Low	Diggles (2016)
Amoebic gill disease [*Neoparamoeba* spp., usually *N.*	Protozoan	No	Yes	Yes	Opportunistic pathogen that is normally free-living in seawater. Disease typically only occurs in stressed fish. Chinook salmon	Negligible	Munday *et al.* (2001); Young *et al.* (2008);

[104] Previously *Vibrio anguillarum.*
[105] Designated as an unwanted organism in New Zealand.
[106] Many *Aeromonas* species can cause disease and they are taxonomically complex.

Disease name [pathogen]	Disease type	NZ or OIE notifiable	Presence in NZ Chinook salmon		Notes on occurrence	Consequences of disease	References
			Pathogen	Disease			
pemaquidensis] (multiple agents)					appear to be resistant to the disease. Gill lesions found on fish but mortality in NZ is rare.		Tubbs *et al.* (2010); Diggles (2016)
Nodular gill disease [*Cochliopodia*-like spp., freshwater amoebae] (multiple agents)	Protozoan	No	Yes	Yes	Associated with disease and mortality in juvenile Chinook salmon held in freshwater. Cannot survive in seawater.	Very low	Tubbs *et al.* (2010); Diggles (2016)
Nematode parasitism [Nematoda: Anisakidae. Including *Anisakis* spp., *Hysterothylacium* spp., including *Hysterothylacium aduncum*] (multiple agents)	Metazoan (Nematoda)	No	Yes	No	Some pathogenic agents of this disease are found in NZ in brackish and marine waters.	Negligible	Diggles (2016)
Whirling disease [*Myxobolus cerebralis*]	Metazoan (Myxozoa)	NZ	Yes	No	Found in freshwater in South Island. Clinical disease has not been recorded in NZ.	Very low	Boustead (1993); Diggles (2016)
Sea lice infestation [*Abergasilus* spp., and *Caligus* spp.] (multiple agents)	Metazoan (Crustacea)	No	Yes	No	No recorded infestation of Chinook salmon but *Caligus* spp. are host generalists and are known to infest other species of fish in NZ.	Very low	Diggles (2016)
Infection with *Paenodes nemaformis* [*Paenodes nemaformis*]	Metazoan (Crustacea)	No	Yes	Yes	Found in freshwater. One record of this copepod in Chinook salmon.	Negligible	Boustead (1982)
Infection with *Cirolana* sp. [*Cirolana* sp.]	Metazoan (Crustacea)	No	Yes	Yes	One record of this isopod in the mouth of a wild salmon.	Negligible	Boustead (1982)
EXOTIC DISEASES							
Cardiomyopathy syndrome [Piscine myocarditis virus, totivirus]	Viral	No	No	No	No published records could be found of this disease in Chinook salmon. One unpublished record was found.	Unknown	Poppe & Ferguson unpubl. in Brun *et al.* (2003)
Heart and skeletal muscle inflammation [unknown, piscine orthoreovirus suspected]	Viral	No	No	No	Virus has been isolated from wild Chinook salmon in North America, but appears to be of low pathogenicity and there are no records of disease occuring.	Unknown	Garver *et al.* (2016); DFO (2017b)

Disease name [pathogen]	Disease type	NZ or OIE notifiable	Presence in NZ Chinook salmon		Notes on occurrence	Consequences of disease	References
			Pathogen	Disease			
Infectious haematopoietic necrosis [Infectious haematopoietic necrosis virus]	Viral	NZ & OIE	No	No	Occurs in freshwater.	High	Tubbs *et al.* (2007)
Infectious salmon anaemia [Infectious salmon anaemia virus]	Viral	NZ & OIE	No	No	No cases of ISA have been reported from Chinook salmon but Chinook salmon have been experimentally infected with ISAV (no clinical signs of disease but the virus was re-isolated from infected fish).	Moderate	Rolland and Winton (2003)
Pancreas disease [Salmon alpha virus]	Viral	OIE	No	No	No records could be found of this disease occuring in Chinook salmon but it does affect brown and rainbow trout.	High	OIE, 2016a
Retroviral infection of salmon [Retrovirus]	Viral	No	No	No	Occurs in seawater. Usually chronic, low level mortalities.	Low	Tubbs *et al.* (2007)
Viral encephalopathy and retinopathy [Betanodaviruses] (multiple agents)	Viral	No	No	No	Mainly occurs in seawater but has been found in freshwater. Numerous host species but has not been naturally recorded in salmonids. Atlantic salmon have been experimentally infected.	Very low	Korsnes *et al.* (2005); Doan *et al.* (2017)
Viral haemorrhagic septicaemia [Viral haemorrhagic septicaemia virus]	Viral	NZ & OIE	No	No	Both marine and freshwater strains exist.	High	Biosecurity NZ (2005); Tubbs *et al.* (2007)
Infection with *Streptococcus iniae* [*Streptococcus iniae*]	Bacterial	No	No	No	Occurs in both freshwater and seawater. Can cause disease in humans. Can cause high mortalities in juveniles fish cultured at high densities.	Low	Biosecurity NZ (2005); Tubbs *et al.* (2007)
Bacterial kidney disease [*Renibacterium salmoninarum*]	Bacterial	NZ	No	No	Occurs in both marine and freshwater. Chinook salmon are particularly susceptible. Typically a chronic disease condition.	Moderate	Tubbs *et al.* (2007); BC Centre for Aquatic Health Sciences (2010)
Enteric septicaemia of catfish [*Edwardsiella ictaluri*]	Bacterial	No	No	No	Occurs in freshwater. Outbreaks occur at temperatures between 17–28°C, which is higher than optimum culture temperatures for Chinook salmon. Chinook salmon have been experimentally infected but no records of natural infection.	Very low	Baxa *et al.* (1990); Biosecurity NZ (2005)
Furunculosis	Bacterial	NZ	No	No	Occurs in both marine and freshwater. Variable virulance, mortalities can be high, partilcularly in young fish.	Moderate	Novotny, 1978; Tubbs *et al.* (2007)

Disease name [pathogen]	Disease type	NZ or OIE notifiable	Presence in NZ Chinook salmon		Notes on occurrence	Consequences of disease	References
			Pathogen	Disease			
[*Aeromonas salmonicida* var. *salmonicida*]							
Infection with *Vibrio salmonicida* [*Vibrio salmonicida*]	Bacterial	No	No	No	Occurs in seawater. Chinook salmon appears to be less suceptible to *V. salmonicida* than other salmon species.	Low	Tubbs *et al.* (2007); Meyers *et al.* (2008)
Infection with *Lactococcus garvieae* [*Lactococcus garvieae*]	Bacterial	No	No	No	Occurs in both marine and freshwater. Opportunistic pathogen, typcially occurs in stressed fish. Can cause high mortality in sub-optimal conditions. Multiple host species. Virulance depends on the strain.	Low	Tubbs *et al.* (2007)
Infection with *Moritella viscosa* [*Moritella viscosa*]	Bacterial	No	No	No	Occurs in seawater. Mortality is usually < 10%. No records could be found of this disease occuring in Chinook salmon.	Very low	Tubbs *et al.* (2007)
Infection with *Piscirickettsia salmonis* [*Piscirickettsia salmonis*]	Bacterial	No	No	No	Occurs in both freshwater and seawater. Chinook salmon are particularly susceptible.	Moderate	Tubbs *et al.* (2007)
Microsporidial gill disease [*Loma salmonae*]	Fungal	No	No	No	Occurs in freshwater but disease can persist in seawater. Chinook salmon are particularly sucesptible. Can cause significant economic losses.	Moderate	Shaw *et al.* (2000)
Ichthyophoniasis [*Ichthyophonus hoferi*]	Protozoan	No	No	No	Occurs in seawater, multiple host species. Has been found in 10–30% of wild Chinook salmon from Alaska. Effects on salmon health are poorly understood but it is associated with mortality and reduced fillet quality.	Low	Kahler *et al.* (2007); Dehn *et al.* (2010)
Infection with *Sphaerothecum destruens* [*Sphaerothecum destruens*]	Protozoan	No	No	No	Occurs in freshwater. Has been found in < 32% of wild Chinook salmon in USA. Mortality is typically chronic but can cause > 80% mortality in Chinook salmon.	Low	Harrell *et al.* (1986); Arkush *et al.* (1998)
Infection with *Argulus foliaceus* [*Argulus foliaceus*]	Metazoan (Crustacea)	No	No	No	Occurs in freshwater. Multiple host species.	Very low	Biosecurity NZ (2005); Tubbs *et al.* (2007)
Infection with *Parvicapsula* spp. [Genus *Parvicapsula*] (multiple agents)	Metazoan (Myxozoa)	No	No	No	Occurs in freshwater. Prevalance is < 80% in wild Chinook salmon in North America but disease signs are low. Disease is usually chronic.	Very low	Jones *et al.*, 2003; Tubbs *et al.* (2007); Bolick *et al.* (2013)

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