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Manatū Ahu Matua

Aquaculture New Zealand

Options to Strengthen On-farm Biosecurity Management for Commercial and Non-commercial Aquaculture

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Prepared for the Aquaculture Unit
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Options to strengthen on-farm biosecurity management for commercial and non-commercial aquaculture.

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1 Executive Summary

Aquaculture facilities have an inherent risk of pest and pathogen introduction, exacerbation or spread. Biosecurity measures can be employed to effectively manage these risks.

People involved at any level of the aquaculture industry play a vital role to New Zealand's biosecurity system. Maintaining good on-farm biosecurity practices can minimise the potential impact of pests and pathogens to farms, sectors, the wider industry and New Zealand's aquatic environment. Following good biosecurity practices demonstrates to others that the New Zealand aquaculture industry is a responsible user of the aquatic environment, reduces impacts to markets, and ensures New Zealand's reputation for high environmental performance.

To assist the commercial and non-commercial aquaculture industry to strengthen their on-farm biosecurity practices, the Ministry for Primary Industries, in collaboration with Aquaculture New Zealand, have produced this technical document and associated reference material and templates. This information can be found on the MPI website www.mpi.govt.nz.

This document provides technical information, biosecurity objectives and best practice options to enable farmers to make informed decisions regarding their on-farm biosecurity management. The objectives and options are based on national and international "best practice" from both the regulatory and the aquaculture industry perspectives. These have been shown to successfully prevent or manage the introduction, exacerbation or spread of pests and pathogens on aquaculture facilities.

This document provides information to enable the uptake of effective on-farm biosecurity management, including:

- suggested options to strengthen on-farm biosecurity management;
- identification of many, but not all, of the risk organisms associated with the species within document scope; and
- ideas to help protect your business, sector, industry and the New Zealand aquatic environment.

This document does not set prescriptive measures, practices, rules or requirements on farmers.

Biosecurity measures adopted by farmers should be practical and fit for purpose. The options identified within this document represent a starting point for the implementation of general on-farm biosecurity procedures for each farm based on their own site-specific conditions. Ideally each individual biosecurity procedure should be implemented with the understanding that it will work within a wider biosecurity plan.

2 Glossary

Anthelmintic
A substance that destroys or expels parasitic worms in the gut.

Antibiotic
A substance produced by a living organism that is capable of inhibiting the growth or replication of bacteria.

Antibiotic resistance
The ability of bacteria to withstand exposure to an antibiotic.

Appropriate distance
Distance between aquaculture facilities taking into account water movement, occupancy of registered facilities, and relevant epidemiological studies.

Aquaculture

- (a) means the breeding, hatching, cultivating, rearing, or ongrowing of fish, aquatic life, or seaweed for harvest; and
- (b) includes the possession and ongrowing of harvestable spat; but
- (c) does not include an activity specified in paragraph (a) if the fish, aquatic life, or seaweed—
    - (i) is not in the exclusive and continuous possession or control of the fish farmer; or
    - (ii) cannot be distinguished or kept separate from naturally occurring fish, aquatic life, or seaweed.

Aquaculture facility
A facility used for the culture or enhanced production of fish species. Facility may be classified as open, semi-open, semi-closed or closed systems.

Aquatic animal health professional
A person who is authorised by the Competent Authority to carry out certain designated tasks in a territory and has the appropriate qualifications and training to perform the designated tasks.

Area-based management
A defined area in which aquaculture production and biosecurity processes are planned and co-ordinated to reduce the risks posed by pathogens, parasites and pests which can be present in the environment, in wild and farmed stock, and in other naturally occurring biota.

Audit
Independent examination to determine whether implemented activities comply with planned objectives.

Autotrophic
Capable of self-nourishment by using inorganic materials as nutrient sources and using photosynthesis or chemosynthesis as energy sources.

Benthic

On or in the seabed.

Biofouling
Unwanted accumulation of aquatic organisms on both natural and artificial substrates, including aquaculture stock and products (such as biofouling of mussel or oyster shells), artificial infrastructure (including vessel hulls, rudders, propellers and other hull appendages), internal seawater systems (including sea chests and pipe-work) or any submerged equipment used in the industry.

Biosecurity
A set of preventive measures designed to reduce the risk of transmission of pests and infectious diseases.

Biosecurity plan
A plan that identifies significant potential pathways for the introduction and spread of pests and infectious diseases into an aquaculture facility, and describes the measures which are being, or will be, applied to mitigate the risks to introduce and spread pests and disease. The plan should also describe how these measures are audited, with respect to both their implementation and their targeting, to ensure that the risks are regularly re-assessed and the measures adjusted accordingly.

Biosecurity risk
Likelihood of occurrence of an adverse event and magnitude of consequences to the facility, environment, human health or socio-cultural values.

Broodstock
An adult population of animals held until maturation to provide genetic material for the next generation.

"Bus stop" deliveries
The practice of delivering stock, typically smolts, to more than one location from a single supplier in one journey by transport vessel.

Carrier
An individual harbouring the specific organisms which can cause a disease. Carriers may be either clinical or subclinical.

Chemotherapeutic
A chemical substance used for the prevention or treatment of disease.

Cleaning
The process of removing material, mineral or organic matter from equipment, personnel and infrastructure.

Contingency plan
A documented work plan designed to ensure that all needed actions, requirements and resources are provided in order to be undertaken in the occurrence of an emergency situation (e.g. earthquake, storm damage, pest or disease incursion, flooding).

Critical control point
Any point within a process or area identified as being critical in limiting the spread of pests or diseases.

Decontamination
A combination of physical and chemical procedures that are used to remove soiling and inactivate the target disease organism. Includes all stages of cleaning and disinfection.

Defined area
For area-based management, this area should be specific to the locale taking into account water movement, occupancy of registered aquaculture facilities, and relevant epidemiological studies.

Depuration
To reduce the level of contaminants in live animals by the use of a managed aquatic environment as the treatment process.

Destocking
The process of removing some or all live-stock from an aquaculture facility.

Disease
A pathological condition that presents a group of signs indicating the existence of an abnormal histological or physiological entity.

Disease agent
A general term for a transmissible organism or other factor that causes an infectious disease.

Disease outbreak
Occurrence of disease in a group of animals, as opposed to individual cases.

Disinfectant
A substance which will destroy infective agents outside a living animal.

Disinfection
The application, after thorough cleaning, of procedures intended to destroy the infectious or parasitic agents of animal diseases, including zoonoses. Applies to aquaculture facilities, vehicles and other objects that may have been directly or indirectly contaminated.

Disposal
Sanitary removal of stock carcases, shells, equipment and associated material by burial, burning or some other process so as to prevent the spread of pests and disease.

Ectoparasite
A parasite that lives on the external surface of the host.

Effluent
Material flowing from a pipe or facility into a body of water.

Egg
A viable fertilised ovum of an aquatic animal. ‘Green eggs’ means newly fertilised ova of fish. ‘Eyed eggs’ means eggs of fish where the eyes of the embryo are visible and that the eggs may be transported.

Endoparasite
A parasite that lives within the host.

Enzootic
A disease which is present in an animal population at all times.

Epidemiological unit
A group of animals or plants that share approximately the same likelihood of exposure to a pathogen. This may be because they share a common environment (e.g. animals in a pond), or because of common management practices. It may apply to the stock on a particular farm or stock sharing a communal animal handling facility. The epidemiological relationship may differ from disease to disease, or even strain to strain of the pathogen.

Epizootic
Outbreak of disease attacking many animals in a population at the same time and rapidly spreading.

Extra-ovum
Outside the egg.

Fallowing
Practice of leaving a facility or epidemiological unit empty of stock for a period of time for disease management purposes.

Farm (aquaculture facility)
A facility for the rearing and growing of stock organisms. The collective structures licensed and required for the purposes of aquaculture, including growing area, walkways, barges, floats and living accommodations plus associated lines and anchors.

Finfish
All species of finfish of the classes Agnatha, Chondrichthyes, and Osteichthyes, at any stage of their life history.

Fingerling
A term commonly applied to young stages of salmonid fish.

Fomite
Any inanimate object (e.g. water, packing, boots, equipment) capable of spreading a pest or disease agent following contact with infected stock or contaminated water.

Gametes
The sperm or unfertilised eggs of aquatic animals that are held or transported separately prior to fertilisation.

Genetic enhancement
Genetic improvement that may result in better growth performance and domestication via selective breeding. Does not involve the insertion of any foreign genes into the genome of the animal. Selective breeding does not involve genetic engineering of specific DNA or artificial manipulation of genetic material with the intent of changing the genetic structure.

Growing area
An area, water body or facility where juveniles are grown to market size.

HACCP
Hazard Analysis and Critical Control Points. A risk analysis and control methodology originally developed for food safety assurance.

Harmful algal bloom
A phytoplankton bloom that causes negative impacts to other organisms via production of natural toxins, mechanical damage to other organisms, or by other means.

Hatchery
A facility for rearing stock from hatching.

Horizontal transmission
An infectious agent transmitted to a susceptible host or among individuals of the same generation via contact (the agent is either shed in the environment by an infected animal, or ingested).

Host
An organism that carries a parasite, disease or pathogen.

Hydrodynamics
The study of liquids in motion, including tidal and wind-driven currents in the sea and river flow.

Intra-ovum
Within the egg.

Intermediate host
The host in which a parasite undergoes a stage in its development.

Intertidal
The area of coastal zone between the high water and low water marks; subject to alternating periods of flooding and drying.

Live-stock
Any animal held under controlled conditions, may include fish and shellfish.

Monitoring
Routine collection of data for assessing the health status of a population.

Moribund
Nearly dead or obviously progressing towards death.

Movement control
Restrictions placed on the movement of live-stock, people and other things to prevent the spread of pests and diseases.

Multiple year class site
A site which contains more than one year class of stock.

Non-indigenous species

A species that does not originate in New Zealand and which has been introduced from other parts of the world by humans, either deliberately or accidentally.

Opportunistic pathogen
An organism capable of causing disease only when the host's resistance is lowered or when unusual circumstances favour its growth and development.

Parasite
An organism that lives in association and at the expense of another organism (the host), from which it derives nutrition.

Pathogen
A microorganism (e.g. bacterium, virus, fungus) capable of causing disease.

Pest
Aquatic organisms that may be problematic to aquaculture that are neither pathogens or parasites. Includes biofouling invertebrates, seaweeds and phytoplankton associated with harmful algal blooms.

Phytoplankton
Autotrophic component of plankton.

Pigging
The process of passing plugs or other structures through pipes to remove accumulations within pipes.

Plankton
Organisms living in water column that cannot swim against a current.

Quarantine
Maintaining a group of aquatic animals in isolation with no direct or indirect contact with other aquatic animals, to allow observation for a specified length of time and, if appropriate, testing and treatment, including proper treatment of the effluent waters.

Relaying
The harvesting of juvenile shellfish off-lease for culturing on lease or from one lease to another.

Restocking
The cultivation of fish or shellfish for introduction to both open and closed water bodies for the purpose of stock enhancement.

Risk
The likelihood of the occurrence and the likely magnitude of the biological and economic consequences of an adverse event or effect to animal or human health.

Rotation
A regime with a fallowing period of greater than one year.

Shellfish
Includes all species of the phylum Echinodermata and phylum Mollusca and all species of the class Crustacea at any stage of their life history, whether living or dead.

Single year class
Any group of fish stocked into a site over any six-month period. For marine species, a year class is defined by the calendar year of production of the juvenile fish.

Smolt
Young salmon at the stage when it adapts from fresh to sea water.

Smoltification
Physiological process by which a young salmon becomes able to move from fresh to sea water.

Spat
or "seed" refers to sets of the fertilised egg or larvae of shellfish. Spat then 'settle' onto suitable substrates.

Spat catching
Collection of juvenile shellfish (‘spat’) as they settle out of the water column and metamorphose from their planktonic larval form to their adult form.

Stock organism
A valuable aquatic animal or plant reared for commercial purposes.

Stocking density
Number of organisms stocked on a per unit of area or volume.

Subtidal
The zone lying below the low-tide mark but still shallow and close to shore.

Surveillance
The systematic ongoing collection, collation, and analysis of information related to animal health and the timely dissemination of information to those who need to know so that action can be taken.

Tidal excursion
The distance a particle (of water) will move over one tidal cycle.

Traceability
The ability to follow and track stock (and feed) through all stages of production, processing and distribution.

Transfer
The intentional movement of animals, gametes, animal products or equipment from one location to another.

Transgenic
Containing genetic material introduced from an unrelated organism by techniques of genetic engineering.

Transport vessel
A vessel or vehicle in which aquaculture stock can be transported dead or alive .

Unwanted organism
Defined in the Biosecurity Act 1993 as any organism the chief technical officer believes capable of causing unwanted harm to any natural and physical resources or human health. It also includes any new organism the Environmental Protection Authority has declined approval to import, or any organism specified in the Second Schedule of the Hazardous Substances and New Organisms Act 1996.

Vaccine
A preparation of an agent that resembles a live disease causing organism administered into the body to stimulate the production of antibodies.

Vector
The physical means, agent or mechanism which allows translocation of organisms (i.e. pests and pathogens) from one place to another.

Vertical transmission
The transmission of a pathogen within the contents of the gametes, i.e. from parents to offspring.

Vermin
Any rodents, birds, scavengers, unwanted domestic animals or insects that may carry pests and diseases or disrupt quarantine with their activities.

Veterinary health plan
A plan that covers areas of biosecurity, monitoring procedures, management and husbandry, and recording and reporting procedures to accomplish the following aims:

- the prevention of introduction and spread of disease and pests;
- the reduction and elimination of factors which predispose to disease and pests;
- the establishment of pest and disease prevention procedures;
- the reduction of pest and disease incidence;
- the maintenance of an environment and systems of management and husbandry which reflect best practice in terms of maintaining stock health and welfare;
- the establishment of monitoring and reporting structures ensuring adequate stock health; and
- surveillance, early warning of any potential health or welfare problem, rapid action and follow-up.

Veterinary medicine
Any substance, mixture of substances, or biological compound used or intended for use in the direct management of an animal

Vessel
A mobile structure of any type operating in the aquatic environment and includes floating craft, fixed and floating platforms, and floating production storage and off-loading units.

Virulence
The relative capability of a pathogen to produce disease.

Water quality
The measure of the condition of water relative to the requirements of one or more biotic species.

2.1 REFERENCES

The above definitions were adapted from:
BC Shellfish Growers Association (2013). Environmental management code of practice. 75 pp.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Department of Agriculture, Fisheries and Forestry (2008). *Operational procedures manual - decontamination* (Version 1.0). *In*: Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT. 122 pp.

European Food Safety Authority (2008). Scientific opinion of the panel on animal health and animal welfare on a request from the European Commission on the animal welfare aspects of husbandry systems for farmed trout. *The EFSA Journal* 796: 1-22.

Forrest B, Cahill P, Newcombe E and D Taylor (2014). *Marine pests and management concepts for shellfish aquaculture.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Institute, Nelson. 48 pp.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Meyer FP, Warren JW and TG Carey (Eds.) (1983). *A guide to integrated fish health management in the Great Lakes basin.* Great Lakes Fishery Commission, Michigan. Special Publication 83-2. 272 pp.

Morrisey D, Plew D and K Seaward (2011). *Aquaculture readiness data phase II.* Report prepared for the Ministry of Agriculture and Forestry, New Zealand. Technical Paper No.: 2011/68. 64 pp.

OIE (2014). *Aquatic animal health code.*
http://www.oie.int/en/international-standard-setting/aquatic-code/

3 Abbreviations

ACVM	Agricultural Compounds and Veterinary Medicines
AQNZ	Aquaculture New Zealand
ASC	Aquaculture Stewardship Council
ASP	Amnesic Shellfish Poisoning
ASTM	American Society for Testing and Materials
AVG	Abalone Viral Ganglioneuritis
BC	British Columbia (Canada)
BKD	Bacterial Kidney Disease
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
COP	Code of Good Practice
CT	Contact Time
DAFF	former Department of Agriculture, Fisheries and Forestry (Australian Government) now Department of Agriculture (Australian Government)
DNA	Deoxy-Ribonucleic Acid
DOC	Department of Conservation
DSP	Diarrhetic Shellfish Poisoning
EC	European Commission
EFSA	European Food Safety Authority
EHN	Epizootic Haematopoietic Necrosis
EPA	Environmental Protection Authority
EPA SA	Environmental Protection Authority South Australia
EU	European Union
FAO	Food and Agriculture Association (United Nations)
FISH	Fluorescent *In Situ* Hybridisation
GIS	Geographic Information System
HAB	Harmful Algal Bloom
HACCP	Hazard Analysis and Critical Control Point
HS	Hazardous Substances
HSMI	Heart and Skeletal Muscle Inflammation
ICES	International Council for the Exploration of the Sea
IHN	Infectious Haematopoietic Necrosis
IHNV	Infectious Haematopoietic Necrosis Virus
IHS	Import Health Standard
IPN	Infectious Pancreatic Necrosis
IPNV	Infectious Pancreatic Necrosis Virus
ISA	Infectious Salmon Anaemia
ISAV	Infectious Salmon Anaemia Virus
LC-MS	Liquid Chromatography - Mass Spectrometry
MAF	Ministry of Agriculture and Forestry (now MPI)
MAFBNZ	Ministry of Agriculture and Forestry Biosecurity New Zealand (now MPI)
MPI	Ministry for Primary Industries
NASA	National Aeronautics and Space Administration
NSP	Neurotoxic Shellfish Poisoning
NSPMMPI	National System for the Prevention and Management of Marine Pest Incursions
NSW	New South Wales (Australia)
OIE	World Organisation for Animal Health

OMV	*Oncorhynchus masou* Virus
OsHV-1	Ostreid Herpesvirus Microvariant 1
PD	Pancreas Disease
PSP	Paralytic Shellfish Poisoning
QACs	Quaternary Ammonium Compounds
RMA	Resource Management Act 1991
RNA	Ribonucleic Acid
RSPCA	Royal Society for the Prevention of Cruelty to Animals
SAV	Salmon Alpha Virus
SCAAH	Subcommittee on Aquatic Animal Health, Department of Agriculture and Water Resources, Australia
SINTEF	*Stiftelsen for industriell og teknisk forskning*
SOP	Standard Operating Procedures
USA	United States of America
US FDA	United States Food and Drug Administration
UV	Ultra Violet
VHP	Veterinary Health Plan
VHS	Viral Haemorrhagic Septicaemia
VHSV	Viral Haemorrhagic Septicaemia Virus

4 Introduction

4.1 DOCUMENT PURPOSE

The purpose of this document is to provide commercial and non-commercial aquaculture farmers with technical information, biosecurity objectives and best practice options to enable informed decisions to be made regarding their on-farm biosecurity management.

Application of best biosecurity practice in daily farm operations will assist farmers to protect their business, sector, industry, and the aquatic environment on which they depend.

4.1.1 Background

In 2014, commercial aquaculture generated an estimated $500 million for the New Zealand economy and employed more than 3000 people (C. Johnston, pers. comm.; http://aquaculture.org.nz/industry/overview/). Geographical isolation and border controls have kept New Zealand relatively free from many of the pests and pathogens that affect aquaculture production elsewhere in the world (e.g. http://www.oie.int/international-standard-setting/aquatic-code/access-online/; Bell *et al.* 2011). However, the introduction, exacerbation or spread of pests and pathogens remains an ongoing threat to New Zealand's aquaculture, fisheries and environment, as this can lead to losses in production, increased production costs and potential impacts to trade and tourism. These biosecurity risks can be managed through the implementation of border controls, aquatic users taking steps to prevent pest and pathogen spread, and farm operators using farm management practices, such as good husbandry and having on-farm biosecurity plans.

4.1.2 The project - *Identification of on-farm biosecurity management options for aquaculture*

Recent biosecurity related events, such as Pacific oyster mortalities due to ostreid herpesvirus microvariant 1, the incidence of *Perkinsus olseni* in paua, *Bonamia ostreae* in flat oysters and *Flavobacterium psychrophilum* in Chinook salmon, indicate that strengthening of aquaculture biosecurity practices may be required to support the sustainable growth of New Zealand's commercial and non-commercial aquaculture sectors.

To achieve this goal, the Ministry for Primary Industries (MPI) and Aquaculture New Zealand have collaborated on a project to provide options to enhance on-farm biosecurity protection for New Zealand's commercial and non-commercial aquaculture sectors. Maintaining good on-farm biosecurity practices can minimise the potential impact of pests and pathogens to farms, sectors, industry and New Zealand's environment. Following good biosecurity practices also demonstrates to others that the New Zealand aquaculture industry is a responsible user of the aquatic environment and ensures New Zealand's reputation for high environmental performance.

The project has three phases:

- Phase I - understanding practices, priorities and perceptions;
- Phase II - risk profiling (organism and pathway risk) and option identification; and
- Phase III - testing the options with industry before releasing for use to manage biological risk.

Phase I

To develop the on-farm biosecurity management options, it was first necessary to understand the current farming practices, on-farm biosecurity management, and concerns and perceptions of the farmers themselves. Coast and Catchment Ltd. were commissioned by MPI to carry out this research with in-kind support from Aquaculture New Zealand: "Managing Biosecurity Risk for Business Benefit: Aquaculture Biosecurity Practices Research".

Phase II

Using scientific literature and national and international codes of best practice, this phase of the project identified influences, pathways and vectors of biosecurity risk organisms onto, within and from aquaculture facilities. A biosecurity objective for each identified influence, pathway and vector was given, and potential preventive and management options of biosecurity best practice identified. These options were based on broad identifications of biosecurity risk organisms to New Zealand aquaculture species and other New Zealand core values (i.e. wild aquatic populations, ecosystem services), as well as examining core pathways that industry has some control over.

For each of New Zealand's major commercial and non-commercial aquaculture sectors, this included:

- the identification of the known pests and pathogens (nationally and internationally);
- the identification of knowledge gaps with respect to pests and pathogens;
- the means by which these pests and pathogens could enter production cycles; and
- the identification of options based on best practice to prevent or manage these pests and pathogens.

Phase II provided a technical guide to national and international "best practice" based on regulator and aquaculture industry perspectives, as at December 2014.

Phase III

Following input from the commercial and non-commercial aquaculture sectors, MPI has used the outputs of phases I and II to finalise the options into a product that can be used to inform on-farm biosecurity management. Uptake of these options may flow into updated industry environmental management systems, sustainable management frameworks, operational procedures and any future biosecurity planning whether voluntary or more formally agreed readiness and response measures as part of a Government Industry Agreement.

This reference document represents a key deliverable of the project. A user-friendly Aquaculture Biosecurity Handbook including a biosecurity plan template has also been developed as part of Phase III. The Aquaculture Biosecurity Handbook provides a set of simple tasks and objectives and recommended practices, that when followed, will assist farmers to strengthen their on-farm biosecurity management.

4.1.3 References

Bell A, Phillips S, Denny C, Georgiades E and D Kluza (2011). *Risk Analysis: Vessel Biofouling*. Ministry of Agriculture and Forestry Biosecurity New Zealand. 145 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf [Website accessed May 2014].

4.2 DOCUMENT SCOPE

Included within the scope of this document are the major aquaculture sectors in New Zealand[1]:

Finfish

- Chinook salmon (*Oncorhynchus tshawytscha*);
- Rainbow trout (*Oncorhynchus mykiss*) [2];
- Brown trout (*Salmo trutta*)[2];
- Kingfish (*Seriola lalandi lalandi*)[3]; and
- Hapuku (*Polyprion oxygeneios*)[3]

Shellfish

- Green-lipped mussels (*Perna canaliculus*);
- Pacific oysters (*Crassostrea gigas*);
- Flat oysters (*Ostrea chilensis*); and
- Paua (*Haliotis* sp.).

The present document does not attempt to cover all pests and pathogens of the in scope species but instead provides examples that may have important implications to the New Zealand industry and environment. This is intended to illustrate the utility of biosecurity best practice options that may be used to prevent or manage the introduction, exacerbation or spread of pests and pathogens and the benefits of employing such actions.

Much of the information within this document can be used to inform the biosecurity practices of farmers culturing other species not listed above (e.g. other finfish, shellfish, crustaceans and algae).

While many of the aspects listed below may influence on-farm biosecurity and are mentioned briefly, this document does not specifically consider aspects of:

- food safety;
- animal welfare;
- aquaculture processing facilities (i.e. scope is limited to production);
- risk associated with on-selling of aquaculture products or by-products to be used as bait;
- chemical or hazardous substance usage (outside of direct use for biosecurity purposes); or
- principles associated with re-stocking or re-seeding populations (e.g. genetic effects).

[1] The species in-scope have been selected based on their annual production levels and commercial, wild, and recreational fisheries importance. MPI evisages repeating the project with other aquaculture species such as eels, koura, amur, and whitebait.
[2] Commercial farming of trout is prohibited, however, Fish and Game New Zealand, the Department of Conservation and volunteer hatcheries produce significant quantities of trout for re-stocking purposes. Therefore, to ensure the associated risks of salmonid species that are farmed commercially or non-commercially, trout is included. Their inclusion will facilitate the development of appropriate recommendations for on-farm biosecurity management options to mitigate biosecurity and environmental risk.
[3] Not currently farmed but represents a species that may be farmed in the near future.

4.3 HOW TO USE THIS DOCUMENT

This document will enable members of New Zealand's commercial and non-commercial aquaculture sectors to develop and implement their own on-farm biosecurity plans. Application of best biosecurity practice in daily farm operations will assist the farmer to protect their business, industry, and the aquatic environment on which they depend.

The document was primarily developed with the specific aquaculture species in mind (**see Chapter 4.2 Document scope**). However, much of the information and principles presented can be adapted for use by any producer of aquatic life.

THIS DOCUMENT IS NOT DESIGNED TO BE READ FROM END-TO-END.

Section 5 provides a series of chapters on factors that may influence on-site biosecurity. Each chapter includes a biosecurity objective and options that can be followed to prevent,reduce, or manage pests and diseases. Some information and references may be repeated between chapters. The document has been designed so each chapter can be reviewed and amended with minimal disruption to the rest of the document.

The first chapter in **Section 5** highlights the importance of on-site biosecurity (**Chapter 5.1 Biosecurity (general)**) followed by a chapter on applying an integrated approach to biosecurity (**Chapter 5.2 Integrated approach to biosecurity**). These chapters illustrate the importance of biosecurity and demonstrate the principle that biosecurity is a series of measures implemented together rather than the application of one or two measures in isolation. These are important elements to understand when developing and implementing a biosecurity plan for your facility or business.

Chapter 5.3 (Identification of biosecurity hazards to New Zealand aquaculture) contains tables identifying pests and diseases that may be hazardous to the main sectors of the New Zealand aquaculture industry and trout producers. Although extensive, they are not definitive as a gap has been identified with respect to knowledge of pathogens and parasites that are already present in New Zealand. Generalised diagrams have been prepared that map the pathways for introduction and spread of pests and diseases for the industries within the scope of this document.

Each subsequent chapter is based on a specific topic that may influence on-site biosecurity. Chapters have been written so that they can be read as stand-alone guides regarding best biosecurity practice relevant to the chapter topic. Examples are used to help demonstrate the impacts of pests and diseases associated with the chapter topic and options to prevent or manage them are identified. There are thirty-three of these chapters, however, not all are relevant to each industry or facility type. For example, there are chapters specific to land-based facilities, offshore facilities, and finfish and shellfish aquaculture.

A biosecurity objective for each topic is given at the end of each chapter, as well as the associated high level options of biosecurity best practice. These are followed by a series of more detailed options based on current New Zealand and international best practice guidelines.

The take-home message from these chapters is that there are many organisms that can be hazardous to New Zealand's aquaculture industry and trout producers. Predicting the next pest or disease that may negatively impact production is problematic. Therefore the most efficient way to prevent impacts to your business, industry and the environment is to

proactively implement an on-farm biosecurity plan based on integrated practices that manage a wide range of organisms.

5 Biosecurity risks in aquaculture and their management

This section provides a series of reviews on factors that may influence on-site biosecurity. The options listed (and the programmes into which they are embedded) have been shown to be successful in preventing or managing pathogen and pest introduction and establishment on farms.

5.1 BIOSECURITY (GENERAL)

5.1.1 Introduction

Aquaculture sites have an inherent risk of pest and pathogen introduction, exacerbation or spread. However, biosecurity measures can be employed to manage these risks to an acceptable level (Peeler 2005; Johansen *et al*. 2011; Fitridge *et al*. 2012; Inglis *et al*. 2013). Good biosecurity practices can support animal welfare, farm productivity, environmental sustainability, product quality, trade and ultimately profitability (Aquaculture Stewardship Council 2012 a b c; Farm Animal Welfare Committee 2014; Subcommittee on Aquatic Animal Health (SCAAH) 2016).

The open design of offshore aquaculture sites and the input of seawater or freshwater into land-based systems represent a pathway for pathogen and pest introduction (Peeler *et al*. 2005; Johansen *et al*. 2011; Fitridge *et al*. 2012). The creation of densely farmed populations increases the likelihood of disease outbreaks (i.e. exacerbation), as stressed and weaker individuals within the farmed population are more susceptible to pathogens and parasites and may transmit the agents to healthy individuals (Handlinger *et al*. 2006; Robertsen 2011). Further, production infrastructure for aquaculture and, in the case of shellfish production the organisms themselves, provide a potential habitat for the settlement of biofouling organisms (Table 1; Bruno *et al*. 1987; Fitridge *et al*. 2012; Woods *et al*. 2012; Inglis *et al*. 2013).

Table 1: Pathways (i.e. entry points) associated with the introductions of pathogens and pests onto aquaculture facilities.

Pathway	References
Water	Hnath 1983b; Elston 1984; Diggles and Oliver 2005; Saksida 2006; Madsen and Dalsgaard 2008
Broodstock and stock introductions	Hnath 1983a; Warren 1983a; Elston 1984; Goggin and Lester 1995; Diggles and Oliver 2005; Heasman and Savva 2007
Stock movements	Egidius 1987; Elston 1993; Bower *et al*. 1994; Raynard *et al*. 2007; Inglis *et al*. 2013
Shared infrastructure, equipment and vessels	Howard 1994; Murray *et al*. 2002; McClure *et al*. 2005; Fitridge *et al*. 2012
Staff, contractors and visitors	Jarp *et al*. 1993; Vågsholm *et al*. 1994; Anon 2000
Wildlife	Olesen and Vestergård Jorgensen 1982; Anon 2005; Raynard *et al*. 2007
Feed	Warren 1983a; Warren 1983c; Elston 1984; Elston *et al*. 2008; Whittington *et al*. 2008

To reduce the likelihood of introduction of pathogens or pests onto a site there is a need to manage the potential pathways (SCAAH 2016). Application of general measures to manage pathways caters for the fact that the 'next' pest or pathogen may not be recognised (Anon

2003; Forrest *et al*. 2011; SCAAH 2016). For example, in Maine, USA the infectious salmon anaemia (ISA) management strategy promotes practices to reduce exposure and susceptibility to disease-causing situations in general (Gustafsen *et al*. 2007). Management of pathogen, pest, and, stress levels are on-going requirements of all intensive farming systems to ensure long-term profitability and sustainability (Handlinger *et al*. 2006; Yanong and Erlacher-Reid 2012).

The main goals of the implementation of biosecurity plans are to protect the facility and the surrounding environment from the introduction, exacerbation or spread of pathogens, parasites and pests (Subasinghe and Bondad-Reantaso 2006; Friedman and Renault 2007; Aquaculture Stewardship Council 2012; SCAAH 2016). As such, poor biosecurity increases the likelihood of spread of pathogens and pests between farms and from farmed to wild populations (Anon 2005; Raynard *et al*. 2007). For example, the major risk factors associated with ISA spread through Norway were proximity to other infected holdings and management practices that increased exposure to foreign biological material. The authors concluded that the spread of ISA was the result of poor biosecurity (Vågsholm *et al*. 1994).

5.1.2 Aquatic diseases

Marine and freshwater fish and shellfish including aquaculture production species are susceptible to a range of viral, bacterial, fungal, parasitic, nutritional and other non-infectious diseases. A number of infectious diseases have had significant consequences to aquaculture in multiple countries (OIE 2014; http://www.oie.int/international-standard-setting/aquatic-code/access-online/). However, other enzootic and management related diseases should not be over-looked in terms of their importance to animal welfare and aquaculture production (European Food Safety Authority (EFSA) 2008).

The interaction between three factors influences the occurrence of disease outbreaks in cultured aquatic animals, namely:

- the host;
- the environment; and
- the presence or absence of a disease agent (pathogen) (Snieszko 1973; Warren 1983b; EFSA 2008).

Many pathogens are ubiquitous in the environment and may be carried by the production stock themselves. However, the outbreak of clinical disease often depends on conditions of animal husbandry and the rearing environment (Snieszko 1973; Warren 1983b; EFSA 2008). Disease outbreaks may be an indicator of an underlying husbandry or environmental perturbation (EFSA 2008). Changes in the virulence of the pathogen can also facilitate the establishment and spread of clinical disease. There is increasing evidence that relatively unimportant bacterial pathogens can become highly virulent with the introduction of bacteriophages (i.e. viruses that infect bacteria; Austin *et al*. 2003).

The interaction between host, environment and pathogen can be illustrated as three overlapping circles (

Figure 1; Snieszko 1973). Circumstances that will result in the disease occurrence are represented by the common central area. Reductions in the influence of any of the three elements result in a corresponding decrease in the disease threat (Warren 1983b).

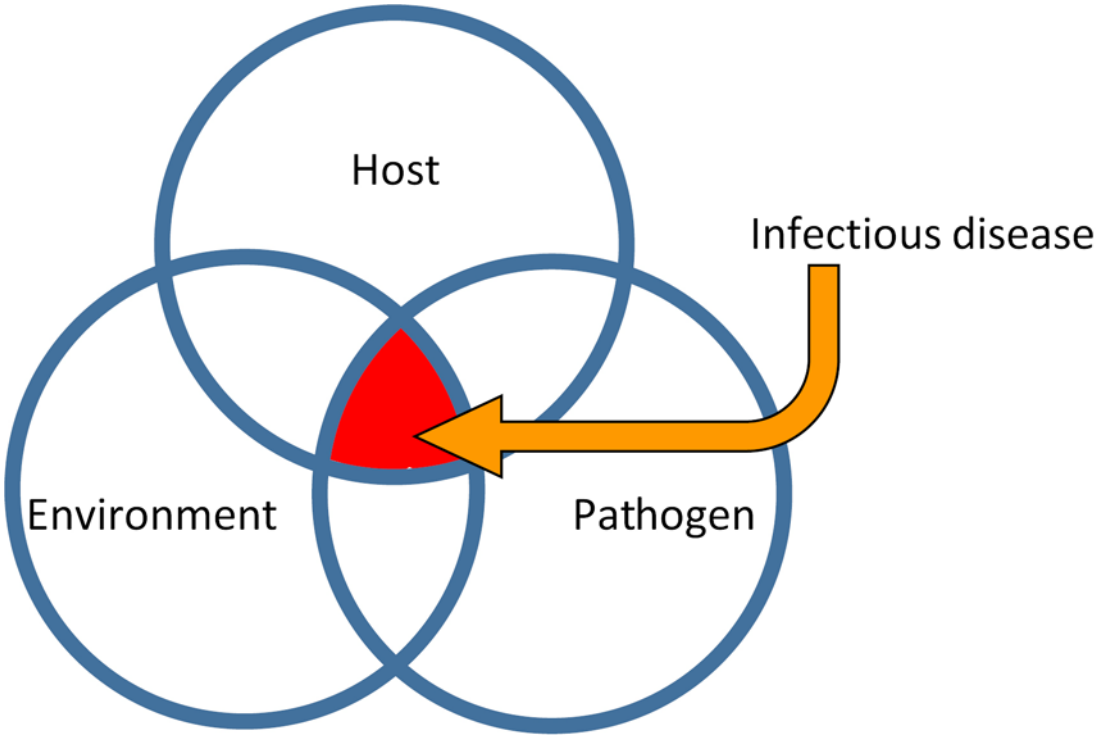

Figure 1: Host-environment-pathogen interrelationship with disease (Snieszko 1973).

The growth of aquaculture, as with other aquatic-based industries, can accelerate the spread of non-indigenous species including disease organisms and their secondary hosts. Biofouling associated with infrastructure, vessels and equipment is a major vector of these species.

5.1.3 Biofouling

Biofouling is a costly problem for the all users of the aquatic environment, including the aquaculture industry where it leads to increased maintenance and production losses (e.g. low growth and poorer quality) and animal welfare issues (Adams *et al*. 2011; Fitridge *et al*. 2012). Aquaculture production facilities and, in some circumstances, the production stock themselves, offer a large area of "new" habitat for a wide range of biofouling organisms or pest species (Zeldis *et al*. 2010; Fitridge *et al*. 2012).

Non-indigenous species can have a significant effect on the environment and the economy (Bell *et al*. 2011; National System for the Prevention and Management of Marine Pest Incursions (NSPMMPI) 2013). By the time a non-indigenous species is detected in an environment, the likelihood of successful eradication is minimal (Bell *et al*. 2011). Efforts should be focussed on prevention, containment and management (Bell *et al*. 2011; NSPMMPI 2013). The New Zealand aquaculture industry regards species that have an impact on business, regardless of origin, as pests (Sim-Smith *et al*. 2014). These can include sessile, mobile or waterborne organisms.

5.1.4 Preventive biosecurity

Once pests and pathogens enter and become established within a region, it is difficult to prevent them from entering a facility, especially offshore facilities (Mohan *et al*. 2008; Bell *et al*. 2011). Biosecurity is a set of preventive measures designed to reduce the risk of transmission of pests and infectious diseases. Biosecurity plans are recognised as an important tool for the prevention and management of the establishment and spread of pests and diseases (Friedman and Renault 2007; HDR Engineering Inc. 2010; *Code of Good Practice Management Group* 2011; NSPMMPI 2013; SCAAH 2016).

The main goals of implementation of biosecurity plans are to protect the facility and the surrounding environment from the introduction, exacerbation or spread of pathogens, pests and parasites (Subasinghe and Bondad-Reantaso 2006; Friedman and Renault 2007; Aquaculture Stewardship Council 2012abc; SCAAH 2016). Biosecurity best management practices should be simple, science-based, cost-effective and appropriate to their context (Mohan *et al.* 2008).

On-site and regional biosecurity plans are not new to aquaculture. In 1978, provincial veterinary authorities in Italy initiated a prophylactic plan to control viral haemorrhagic septicaemia in finfish similar to the policy practiced in Denmark since 1965 (Zanin *et al*. 1983). However, despite a strong incentive to protect aquaculture operations from the adverse effects of pests and pathogens, biosecurity plans and measures are often employed reactively. For example, adequate biosecurity measures were not implemented in Chile despite all other major salmon-producing countries being impacted by the ISA virus. As a result, Chilean salmon production was reduced by 75% between 2005 and 2010 due to infectious salmon anaemia outbreaks (Asche *et al*. 2009). Similarly, efforts were made by the Canadian salmon industry to increase biosecurity and isolate farms only after diagnosis of infectious haematopoietic necrosis virus was confirmed (Saksida 2006). In New Zealand, biosecurity measures on a paua farm were strengthened after the occurrence of *Perkinsus olseni* on the farm (Sim-Smith *et al*. 2014).

Implementation of good biosecurity practice is beneficial for industry because the cost can be low compared to the expected benefits on productivity and product quality. This is particularly the case when serious diseases can be excluded from farms or eradicated if they occur (SCAAH 2016). Although preventive measures are acknowledged as expensive (Anon 2003; Saksida 2006), a lack of biosecurity has resulted in considerable economic losses to aquaculture globally (Subasinghe and Bondad-Reantaso 2006). For example, the annual cost of outbreaks of infectious pancreatic necrosis to the Norwegian aquaculture industry has been estimated at approximately $USD 60 million. However, individual farm production losses possibly have more serious ramifications than be may indicated by the calculations of economic losses to the industry (Anon 2003). Projected losses (2007-2011) following the Chilean infectious salmon anaemia outbreak were estimated at approximately $1 billion (i.e. 50% of the economic value of the Chilean salmon industry) (Kibenge *et al*. 2012).

Bonamia ostreae along with *Marteilia refringens*, drastically reduced the French flat oyster production from 20,000 t in 1970 to less than 2,000 t after 1981. In 2001, about 1,650 t of flat oysters were marketed in France. Between 1980 and 1983, losses in France were estimated at about 20% of employment, US$ 240 million turn over and US$ 200 million of added value (Arzul *et al.* 2006). Production is now restricted to low levels with fewer people employed and the requirement of modified husbandry techniques (Arzul *et al.* 2006; Colluty and Mulcahy 2007). Overall, bonamiosis and marteiliosis have reduced European production of flat oysters from 29,595 t in 1961 to 5,921 t in 2000 (Culloty and Mulcahy 2007).

In recent times, the Scottish salmon aquaculture industry has recognised that sound measures would reduce costs and make their industry more competitive and successful (Stewart 1998). It has been identified that having biosecurity measures in place while designing a facility is typically less costly and easier to implement than trying the retrofit an existing facility (Freidman and Renault 2007).

Strengthened on-site biosecurity can:

- result in better stock health and improved stock performance;
- mitigate the transmission and amplification of pests and diseases within and between farms;
- allow for early pest and disease detection so that impacts can be reduced;
- supports claims of freedom from diseases that impact marketability and market access;
- be integrated with other farm quality control systems such as Hazard Analysis Critical Control Point (HACCP);
- facilitate translocation within and between jurisdictions;
- allow farms to meet international trade requirements (e.g. through health accreditation);
- minimise impacts of aquaculture on the surrounding environment, and be integrated with broader risk management planning such as workplace health and safety, animal welfare, food safety and environmental management (Aquaculture Stewardship Council 2012 a b c; Farm Animal Welfare Committee 2014; SCAAH 2016).

The greatest benefits of biosecurity are achieved through preventive rather than reactive action (Hnath 1983ab; Warren 1983abc; Elston 1984; Elston 1993; Jarp *et al*. 1993; Bower *et al*. 1994; Danner and Merrill 2006; Robertsen 2011; SCAAH 2016). However, due to a variety of reasons, such as economics, logistics and production constraints, implementation of biosecurity measures are often taken after significant pest or pathogen events (Zanin *et al*. 1983; Hardy-Smith 2006; Saksida *et al.* 2006; Johansen *et al.* 2009; Asche *et al.* 2009). For example, in Chile preventive biosecurity measures (e.g. area management, increased inspection frequency) were only implemented after outbreaks of ISA despite several of the larger companies having first-hand experience of the impacts of this disease in Norway (Asche *et al.* 2009). The New Zealand salmon industry have not yet implemented biosecurity measures, such as year class separation, fallowing, area management, due to the following rationale: current disease free status, low likelihood of disease outbreaks in New Zealand Chinook salmon, production constraints, and difficulties obtaining consents for new growing and fallowing areas (New Zealand King Salmon Ltd. 2011; Sim-Smith and Forsythe 2013; Sim-Smith *et al.* 2014). This decision in conjunction with the ability to access more water space, a lack of biosecurity awareness and experience with diseases and their management may leave the New Zealand aquaculture industry vulnerable to incursions of novel pathogens, and to exacerbation of those already present (Castinel *et al.* 2013).

The implementation of preventive biosecurity in New Zealand aquaculture should take advantage of the lessons learned internationally (Asche *et al.* 2009). There is a strong incentive to ensure that pathogen, parasite or pest outbreaks do not occur, as they can have a significant economic impact (Asche *et al.* 2009; Forrest *et al.* 2011; Fitridge *et al.* 2012; Kibenge *et al.* 2012). Ultimately, implementation of on-site biosecurity should be viewed as insurance and requires both financial and intellectual investment as well as commitment (SCAAH 2016).

Aquaculture facilities should have general on-farm biosecurity procedures based on site-specific conditions (Aquaculture Stewardship Council 2012). These procedures will vary between facilities (depending on such factors as species farmed and growing systems) and should be based on a careful on-site audit, usually by an aquatic animal veterinarian or a qualified aquatic animal health expert (Subasinghe and Bondad-Reantaso 2006).

Understanding of biosecurity varies considerably within the aquaculture industry, as does an understanding of what actions are required to achieve adequate biosecurity (Hardy-Smith 2006). The following considerations are fundamental to any biosecurity programme:

- the prevention of introduction and spread of disease or pests (e.g. known health status of all animals entering a facility);
- the reduction and elimination of factors which predispose sites and live-stock to diseases or pests (e.g. farm location, farm structures);
- the establishment of procedures to prevent disease or pest introduction and establishment (e.g. control over movement of people, equipment and vessels);
- the reduction of disease or pest incidence (e.g. area management, year class separation, fallowing procedures);
- the maintenance of an environment, management systems and husbandry which reflect best practice in terms of maintaining animal health and welfare (e.g. water quality, animal handling, stocking density); and
- the establishment of standard monitoring and reporting procedures ensuring adequate animal health surveillance, early warning of any potential health or welfare problem, rapid action and follow-up (Zanin *et al.* 1983; Stewart 1998; Blaylock and Whelan 2004; Johnston and Jungalwalla no date; Culloty and Mulcahy 2007; Friedman and Renault 2007; Johansen *et al.* 2009; Province of New Brunswick 2009; Code of Good Practice Management Group 2011; Yanong and Erlacher-Reid 2012; SCAAH 2016).

Biosecurity measures can be significantly improved when co-ordinated by neighbouring farms in an area management approach (Anon 2000; Gustafsen *et al.* 2007; Midtlyng *et al.* 2011) or a sector level approach (SCAAH 2016).

5.1.5 Current biosecurity awareness within New Zealand commercial and non-commercial aquaculture sectors

Apart from identification and management of specific risks, there is a need for the New Zealand aquaculture industry to embrace biosecurity awareness (Castinel *et al.* 2013). Achieving this is dependent on:

- the availability of resources and framework for pathogen and pest surveillance;
- clarity of regulatory requirements such as having translocation policies in place;
- ongoing education; and
- knowledge capture and sharing regarding diseases and pests relevant to each sector of the New Zealand aquaculture industry (Handlinger *et al.* 2007; Sim-Smith *et al.* 2014).

Recent research showed that the majority of New Zealand aquaculture farmers were at least moderately concerned about preventing and managing pests and diseases (Sim-Smith *et al.* 2014). However, large variations in biosecurity practices occur within the industry and the high level of industry concern regarding pests and diseases is not always reflected in their biosecurity practices. For example, the majority of farmers believe that water is the most likely transmission vector of pests and diseases and that biosecurity measures to manage water-borne transmission are futile. These farmers appear to be unaware of biosecurity

measures e.g. area-based agreements and fallowing, employed overseas to manage the risk of introduction and establishment of pests and diseases.

The New Zealand aquaculture industry are concerned about the costs associated with the implementation of preventive biosecurity measures (Sim-Smith *et al.* 2014). However the costs associated with respect to losses in productivity, increased labour and reduced market access due to pests and diseases have been seldom considered.

Sim-Smith *et al.* (2014) identified better education of the aquaculture industry, particularly concerning the importance of preventive biosecurity practices, those methods that have successfully been used overseas and the identification of methods that farmers can implement as the key biosecurity needs of the New Zealand aquaculture industry.

5.1.6 Biosecurity plans and practices

Despite the many pathways through which a pathogen or non-indigenous species can be introduced to an aquaculture facility, there are some basic plans and practices that will help to minimise the likelihood of entry (HDR Engineering, Inc. 2010). However, the effectiveness of these plans and practices is reliant on their implementation. Auditing, inspection and compliance are crucial (HDR Engineering, Inc. 2010; Farm Animal Welfare Committee 2014). Enforcement alone has limited effect in ensuring the implementation of a biosecurity policies and plans (Handlinger 2007). To provide maximum gain, effort needs to be spent on communication and education so that the reasons for the inclusion of biosecurity practices in standard business operating systems are understood (Handlinger 2007; Sim-Smith *et al.* 2014).

Different production systems are likely to require different measures to control the biosecurity risks. Operators should take into account their facilities, operations and locations (NSPMMPI 2013; SCAAH 2016). However, the biosecurity principles upon which the measures are based should be the same. While some practices can be implemented on-site to achieve maximum biosecurity benefit, others may require co-operative implementation with other production facilities within a defined area (HDR Engineering, Inc. 2010).

Biosecurity practices should improve the biological, operational and economic performance of the facilities in which they are implemented. Good biosecurity practice should be as simple and low cost as possible to achieve the desired outcomes (SCAAH 2016).

5.1.7 Conclusions

Good operating practices and sound biosecurity reduce the risk of diseases and pests for the individual site and also help to minimise the risk of diseases and pests for neighbouring sites and the industry overall.

5.1.8 Options to strengthen on-farm biosecurity (general)

5.1.8.1 Objective

To provide effective control points to manage the risk of pest and pathogen transfer onto, within and from the facility.

5.1.8.2 High level options

The aquatic health professional should develop and implement a veterinary health plan (VHP) that accomplishes disease and pest prevention through biosecurity and, if needed, treatment. A biosecurity plan is an integral part of the VHP. The VHP should be updated regularly.

Facility biosecurity should be carried out under the direction of an appropriately qualified individual.

All facility inputs, throughputs and outputs (e.g. stock, people, equipment, vehicles, water and procedures) should be assessed for potential biosecurity risks.

Each facility should have access to a veterinarian of suitable experience to advise on stock health matters and medicine usage, and who is available to attend on short notice.

The facility should ensure compliance with all legal requirements for:

- disease testing;
- stock movements (including zoosanitary regulations of inbound and outbound transports);
- treatments for pests and diseases; and
- reporting to MPI in the instance of mortalities or presence of suspect exotic pest species (0800 80 99 66).

Facility staff should be trained in the application of biosecurity and health management procedures, as appropriate to each employee's job description. Documentation of this training should be recorded.

The biosecurity plan should be implemented at all times and actions taken be verifiable by record keeping (e.g. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/278578/Finfish_biosecurity_logbook.pdf).

5.1.8.3 Detailed options

The VHP should operate at two levels:

- at the facility location; and
- among neighbouring sites and aquaculture establishments within a defined management area.

The second level requires the establishment of an area-based management agreement in which facility operator's co-ordinate their activities with neighbouring facilities.

Facilities operating in the same local area should agree on a clear set of procedures and criteria that guide individual facilities on when and how they should share information on pest and disease incidents, stock performance and environmental conditions. These guidelines may also assist in reducing the likelihood of distribution of incorrect information.

The biosecurity plan should include written procedures for the diagnosis and treatment of disease in stock. This should include monitoring for enzootic parasitic, bacterial and viral infections.

The biosecurity plan should include written procedures for the identification and treatment of pest species. This should include identification guides and monitoring for pest species.

If used, pharmaceutical treatments should be based on authorisation of the aquatic health professional, who should be guided by the VHP and principles of best practice for the veterinary profession. The aquatic health professional should only prescribe medicines to treat diagnosed diseases in accordance with instructions on product labels and national regulations (where regulations exsist).

Records should be maintained for every application of pharmaceutical and other chemicals that include the date, compound used, reasons for use, dose, withholding time and harvest date.

Facilities should record data on disease and pest outbreaks and actions taken so this information can be made available to MPI.

5.1.9 References

Adams CM, Shumway SE, Whitlatch RB and T Getchis (2011). Biofouling in marine molluscan shellfish aquaculture: a survey assessing the business and economic implications of mitigation. *Journal of the World Aquaculture Society* 42(2): 242-252.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012a). *ACS abalone standard. Version 1.0.* January 2012. 42 pp.

Aquaculture Stewardship Council (2012b). *ACS bivalve standard. Version 1.0.* January 2012. 57 pp.

Aquaculture Stewardship Council (2012c). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Arzul I, Moissec L, Blanchet E, Garcia C, Francois C and J–P Joly (2006). *Bonamia ostreae* and *Ostrea edulis*: a stable host–parasite system in France? Proceedings of the 11th International Symposium on Veterinary Epidemiology and Economics. 5 pp.

Asche F, Hansen H, Tveteras R and S Tveterås (2009). The salmon disease crisis in Chile. *Marine Resource Economics* 24: 405-411.

Austin B, Pride AC and GA Rhodie (2003). Association of a bacteriophage with virulence in *Vibrio harveyi. Journal of Fish Diseases* 26: 55-58.

Bell A, Phillips S, Denny C, Georgiades E and D Kluza (2011). *Risk Analysis: Vessel Biofouling.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 145 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf [Website accessed May 2014].

Blaylock RB and DS Whelan (2004). *Fish health management for offshore aquaculture in the Gulf of Mexico. In*: Bridger CJ (Ed.) Efforts to develop a responsible offshore aquaculture industry in the Gulf of Mexico: A compendium of offshore aquaculture consortium research. Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, United States of America. pp. 129-161.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Bruno DW (1987). The risk to farmed Atlantic salmon, *Salmo salar* L., from marine mussels growing on net cages. *Bulletin of the European Association of Fish Pathologists* 7(5): 121-123.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Culloty SC and MF Mulcahy (2007). *Bonamia ostreae* in the native oyster *Ostrea edulis*. A review. *Marine Environmental Health Series* No. 29. 36 pp.

Danner GR and P Merrill (2006). *Disinfectants, disinfection and biosecurity in aquaculture. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 91-128.

Diggles BK and M Oliver (2005). *Diseases of cultured paua (Haliotis iris) in New Zealand. In*: P Walker, R Lester and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 275-287.

European Food Safety Authority (EFSA) (2008). Scientific opinion of the panel on animal health and animal welfare on a request from the European Commission on the animal welfare aspects of husbandry systems for farmed trout. *The EFSA Journal* 796: 1-22.

Egidius E (1987). *Import of furunculosis to Norway with Atlantic salmon smolts from Scotland.* Mariculture Committee Report no. C.M. 1987/F:8, International Council for the Exploration of the Sea (ICES). 8 pp.

Elston RA, Hasegawa H, Humphrey KL, Polyak IK and CC Hase (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119-134.

Elston RA (1993). Infectious diseases of the Pacific oyster, *Crassostrea gigas*. *Annual Review of Fish Diseases* 3: 259-276.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Friedman C and T Renault (2007). *Report on Australian herpes-like viral outbreak and field notes.* Report prepared for Western Abalone Divers Association of Victoria, Australia. 17 pp.

Goggin CL and RJG Lester (1995). *Perkinsus*, a protistan parasite of abalone in Australia: a review. *Marine Environmental Research* 46: 639-646.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Handlinger J, Bastianello S, Callinan R, Carson J, Creeper J, Deveney M, Forsyth WM, Freeman K, Hooper C, Jones B, Lancaster M, Landos M, Loh R, Oyay BS, Phillips P, Pyecroft S and F Stephens (2006). *Abalone aquaculture subprogram: a national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs.* FRDC project Report 2002/201, Tasmanian Aquaculture and Fisheries Institute, Hobart. 170 pp.

Handlinger J (2007). *Report to Western Abalone Divers Association of Victoria on the ganglioneuritis outbreak.* Report from Judith Handlinger Senior Veterinary Pathologist, Aquatic Animal Health, DPIW, Tasmania. Prepared for WADA, Victoria, Australia. 48 pp.

Hardy-Smith P (2006). *Biosecurity at the farm level - how to create a state of mind. In* Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 149-154.

HDR Engineering, Inc. (2010). *Illinois aquaculture biosecurity manual.* Prepared for Southern Illinois University Carbondale Fisheries and Illinois Aquaculture Center. 177 pp.

Heasman M and N Savva (2007). *Manual for intensive hatchery production of abalone. Theory and practice for year round, high density seed production of blacklip abalone* (*Haliotis rubra*). New South Wales Department of Primary Industries and Australian Government Fisheries Research and Development Corporation. 95 pp.

Hnath JG (1983a). *Hatchery disinfection and disposal of infected stocks. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great

Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 121-134.

Hnath JG (1983b). *Infectious pancreatic necrosis. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 169-174.

Howard AE (1994). The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. *Bulletin of the European Association of Fish Pathologists* 14(6): 211-212.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Jarp J, Tangen K, Willumsen FV, Djupvik HO and AM Tveit (1993). Risk factors for infection with *Aeromonas salmonicida* in Norwegian freshwater hatcheries. *Diseases of Aquatic Organisms* 17: 81-86.

Johansen L-H, Jensen I, Mikkelsen H, Bjorn P-A, Jansen PA and Ø Bergh (2011). Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. *Aquaculture* 315: 167-186.

Johansen R, Kongtorp RT, Bornø G, Skjelstad HR, Olsen AB, Flesjå K, Colquhoun D, Ørpetveir I, Hansen H, Garseth ÅH and B Hjeltnes (2009). *The health situation in farmed salmonids 2008*. National Veterinary Institute, Norway. 18 pp.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: Guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Kibenge FSB, Godoy MG, Fast M, Workenhe S and MJT Kibenge (2012). Countermeasures against viral diseases of farmed fish. *Antiviral Research* 95: 257-281.

Madsen L and I Dalsgaard (2008). Water recirculation and good management: potential methods to avoid disease outbreaks with *Flavobacterium psychrophilum*. *Journal of Fish Diseases* 31: 799-810.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Mohan CV, Phillips MJ, Bhat BV, Umesh NR and PA Padiyar (2008). Farm level plans and husbandry measures for aquatic animal disease emergencies. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 161-173.

Murray AG, Smith RJ and RM Stagg (2002). Shipping and the spread of infectious salmon anemia in Scottish aquaculture. *Emerging Infectious Diseases* 8: 1-5.

National System for the Prevention and Management of Marine Pest Incursions (2013). *National biofouling management guidelines for the aquaculture industry.* National System for the Prevention and Management of Marine Pest Incursions, Commonwealth of Australia, Canberra. 26 pp.

New Zealand King Salmon (2011). *NZ King Salmon Report.* 165 pp.

Olesen NJ and PE Vestergård Jorgensen (1982). Can and do herons serve as vectors for Egtved virus? *Bulletin of the European Association of Fish Pathology* 3: 48.

Peeler E (2005). *The role of risk analysis and epidemiology in the development of biosecurity for aquaculture. In*: Walker P Lester R and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 35-45.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Province of New Brunswick (2009). *New Brunswick marine aquaculture finfish health policy.* CNB 6496. 11 pp.

Robertsen B (2011). Can we get the upper hand on viral diseases in aquaculture of Atlantic salmon? *Aquaculture Research* 42: 125-131.

Saksida SM (2006). Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms* 72: 213-223.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Sim-Smith C and A Forsythe (2013). *Comparison of the international regulations and best management practices for marine fish farming.* Prepared for the Ministry of Primary Industries. NIWA client report no. AKL2013-013. 85 pp.

Snieszko SE (1973). Recent advances in scientific knowledge and developments pertaining to diseases of fishes. *Advances in Veterinary Science and Comparative Medicine* 17: 291-314.

Stewart JE (1998). *Sharing the waters: an evaluation of site fallowing, year separation and distances between sites for fish health purposes on Atlantic salmon farms.* Canadian Technical Reports in Fisheries and Aquatic Sciences 2218. 56 pp.

Subasinghe RP and MG Bondad-Reantaso (2006). *Biosecurity in aquaculture: international agreements and instruments, their compliance, prospects, and challenges for developing countries. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. pp. 149-154.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Vågsholm I, Djupvik HO, Willumsen FV, Tveit AM and K Tangen (1994). Infectious salmon anaemia (ISA) epidemiology in Norway. *Preventive Veterinary Medicine* 19: 277-290.

Warren JW (1983a). *Bacterial kidney disease. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 185-192.

Warren JW (1983b). *The nature of fish diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 7-14.

Warren JW (1983b). *Viral hemorrhagic septicaemia. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 175-180.

Whittington RJ, Crockford M, Jordan D and JB Jones (2008). Herpesvirus that caused epizootic mortality in 1995 and 19988 in pilchard *Sardinops sagax neopilchardicus* (Steindachner), in Australia is now endemic. *Journal of Fish Diseases* 31: 97-105.

Woods CMC, Floerl O and BJ Hayden (2012). Biofouling of Greenshell™ mussel (*Perna canaliculus*) farms: a preliminary assessment and potential implications for sustainable aquaculture practices. *Aquaculture International* 20: 537-557.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, Part 1: an overview.* Program in Fisheries and Aquatic Sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. 16 pp.

Zanin E, Allegretti M, Giorgetti, G and G Ceshia (1983). Initiation and appraisal of an official prophylactic policy against VHS in farmed trout in the Province of Trento, Italy. *Bulletin of the European Association of Fish Pathologists* 3: 5-6.

Zeldis J, Broekhuizen N, Forsythe A, Morrisey D and J Stenton-Dozey (2010). *Waikato marine finfish farming: production and ecological guidance.* NIWA Client Report: CHC2010-147 prepared for MFish Aquaculture Unit. 112 pp.

5.2 INTEGRATED APPROACH TO BIOSECURITY

The open design of offshore aquaculture sites and the input of seawater or freshwater into land-based systems may introduce pathogens and pests (Peeler 2005; Johansen *et al.* 2011; Fitridge *et al.* 2012).

To reduce the risk of introduction of pathogens and pests onto a site there is a need to manage the potential entry points. General biosecurity measures are encouraged as they manage 'undescribed' risks (Forrest *et al.* 2011). In Maine, USA the infectious salmon anaemia (ISA) management strategy promotes practices to reduce exposure and susceptibility to disease-causing situations in general (Gustafsen *et al.* 2007). Management of pathogen, pest and live-stock stress levels are essential on-going requirements of all intensive farming systems to ensure long-term profitability (Handlinger *et al.* 2006; Yanong and Erlacher-Reid 2012; **Chapter 5.1 Biosecurity (general); Chapter 5.13 Good husbandry**).

Given that there are multiple potential pathways and entry points onto a farm, application of an individual biosecurity measure in isolation is unlikely to sufficiently manage disease risks. On-site biosecurity is reliant on the implementation of a concerted approach via a biosecurity plan. For example, the effectiveness of on-site fallowing is reliant on a robust stock containment strategy as the presence of escaped stock from previous production cohorts constitutes a risk of re-infection of newly introduced stock (Wallace *et al.* 2011). To gain maximum preventive benefit, the individual measures implemented within a biosecurity plan should work synergistically. Thus, an integrated approach across the facility will address individual risks better and provide coverage for multiple risks (HDR Engineering, Inc. 2010).

Fallowing and year class separation, when coupled with area-based management, are effective measures to manage stock health (Stewart 1998). However, it is only when they are underpinned by sound farming practices (i.e. biosecurity and animal welfare plans) that their benefits can be fully realised (Stewart 1998; St-Hiliare *et al.* 2002). McMahon (2000) identified that the key elements of area-based management include agreed husbandry practices, annual and synchronous fallowing of sites, separation of generations, early harvest of two sea-winter fish and targeted sea lice treatment regimes of all facilities within the managed area.

However, area-based management plans can be rendered ineffective if stock, equipment or staff are being shared between management areas without proper biosecurity procedures, such as, stock health certification or cleaning and disinfection (Wheatley *et al.* 1995; Anon 2000; St-Hiliare *et al.* 2002). On a smaller scale, the benefits of physically separating on-farm populations (i.e. broodstock from progeny or within farm compartments) can be voided if staff do not follow correct sanitary procedures when working between those populations (Gavine *et al.* 2007; Department of Agriculture, Fisheries and Forestry (DAFF) 2008; Code of Good Practice Management Group 2011; OIE 2012).

Management of ISA in Maine, USA, includes year class separation, area-based management, supported by biosecurity measures which include ongoing surveillance and swift removal of infected cages. These measures are further underpinned by good husbandry to reduce the susceptibility of stock to disease (Gustafsen *et al.* 2007). Similarly, the control plans introduced in Norway to limit the spread of furunculosis, ISA and pancreas disease include multiple measures such as synchronised fallowing, increased focus on separation of different generations, transport restrictions, disease surveillance and vaccination (Johansen *et al.* 2009; Midtlyng *et al.* 2011). Similar recommendations were recently made to improve biosecurity best practice in New Zealand (Sim-Smith *et al.* 2014).

The following elements have been identified as essential to an area-based management agreement and thus provide an example of an integrated approach to biosecurity (Anon 2000; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012):

- agreement of the participants;
- clear statements of the objectives;
- definition of the area and the farms included (based on local hydrodynamic conditions); and
- agreement on the following specific issues:
    - general aspects of fish health and good husbandry;
    - health status of the management area including any official controls in place;
    - health status of stock to be introduced into the management area;
    - physical condition of stock to be introduced;
    - vaccines and vaccination regimes (where available);
    - veterinary input, including veterinary health plans and biosecurity plans;
    - fallowing plans and protocols;
    - year class separation;
    - adherence to agreed stocking densities;
    - movement of live stock;
    - removal and disposal of dead and moribund stock;
    - harvesting protocols;
    - escapee protocol;
    - exclusion and control of predators;
    - stock inspection and independent oversight of the operation;
    - records management including mortalities; and
    - information exchange and communication.

The choice and procedure for implementation of measures within biosecurity plans is dependent on facility design, the stock and life stage being produced, and the acceptable level of risk (HDR Engineering, Inc. 2010).

5.2.1 Conclusions

Biosecurity plans are recognised as an important tool for the prevention and management of the establishment and spread of pests and diseases.

The integrated approach to biosecurity plans is not restricted to individual facilities but often reliant on the agreement of a co-ordinated approach by farmers (e.g. area-based management). Good operating practices and sound biosecurity will reduce the risk of disease and pests for the individual site and help to minimise the risk of disease and pests for neighbouring sites and the industry overall.

5.2.2 Options for adopting an integrated approach to biosecurity

5.2.2.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility.

5.2.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

An integrated approach to biosecurity management measures should be adopted.

5.2.2.3 Detailed options

Please refer to the detailed biosecurity options listed in the other chapters of this document.

5.2.3 References

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Department of Agriculture, Fisheries and Forestry (DAFF) (2008). *Operational procedures manual - decontamination (Version 1.0). In*: Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT. 122 pp.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Gavine FM, Ingram BA, Hardy-Smith P and M Doroudi (2007). *Biosecurity control measures for abalone viral ganglioneuritis: a code of practice.* Prepared as part of FRDC Project No. 2006/243. 31 pp.

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Handlinger J, Bastianello S, Callinan R, Carson J, Creeper J, Deveney M, Forsyth WM, Freeman K, Hooper C, Jones B, Lancaster M, Landos M, Loh R, Oyay BS, Phillips P,

Pyecroft S and F Stephens (2006). *Abalone aquaculture subprogram: a national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs.* FRDC project Report 2002/201, Tasmanian Aquaculture and Fisheries Institute, Hobart. 170 pp.

HDR Engineering, Inc. (2010). *Illinois aquaculture biosecurity manual.* Prepared for Southern Illinois University Carbondale Fisheries and Illinois Aquaculture Center. 177 pp.

Johansen L-H, Jensen I, Mikkelsen H, Bjorn P-A, Jansen PA and Ø Bergh (2011). Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. *Aquaculture* 315: 167-186.

Johansen R, Kongtorp RT, Bornø G, Skjelstad HR, Olsen AB, Flesjå K, Colquhoun D, Ørpetveir I, Hansen H, Garseth ÅH and B Hjeltnes (2009). *The health situation in farmed salmonids 2008.* National Veterinary Institute, Norway. 18 pp.

McMahon T (2000). Regulation and monitoring of marine aquaculture in Ireland. *Journal of Applied Ichthyology* 16: 177-181.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

OIE (2012). *Manual of diagnostic tests for aquatic animals. Chapter 1.1.3. Methods for disinfection of aquaculture establishments.* 12 pp.

Peeler E (2005). *The role of risk analysis and epidemiology in the development of biosecurity for aquaculture. In*: Walker P, Lester R and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 35-45.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Stewart JE (1998). *Sharing the waters: an evaluation of site fallowing, year separation and distances between sites for fish health purposes on Atlantic salmon farms.* Canadian Technical Reports in Fisheries and Aquatic Sciences 2218. 56 pp.

St-Hilaire S, Ribble CS, Stephen C, Anderson E, Kurath G and ML Kent (2002). Epidemiological investigation of infectious hematopoietic necrosis virus in salt water net-pen reared Atlantic salmon in British Columbia, Canada. *Aquaculture* 212: 49-67.

Wallace IS, Munro LA, Kilbrun R, Hall M, Black J, Raynard RS and AG Murray (2011). *A report on the effectiveness of cage and farm-level fallowing for the control of bacterial kidney disease and sleeping disease on large cage-based trout farms in Scotland.* Scottish Marine and Freshwater Science Report. Volume 02, Number 10. 40 pp.

Wheatley SB, McLoughlin MF, Menzies FD and EA Goodall (1995). Site management factors influencing mortality rates in Atlantic salmon (*Salmo salar* L.) during marine production. *Aquaculture* 136: 195-207.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 16 pp.

5.3 IDENTIFICATION OF BIOSECURITY HAZARDS TO NEW ZEALAND AQUACULTURE

5.3.1 Pathogens and parasites

Pathogens and parasites that may be hazards to the New Zealand aquaculture industry have been tabulated (Tables 2-9). The tables presented are not exhaustive and do not attempt to cover all existing or potential pathogens and parasites associated with each of the cultured species. The intention is to illustrate the utility of biosecurity best practice options to prevent the introduction and spread of hazards (Subcommittee on Aquatic Animal Health (SCAAH) 2016).

Most of the pathogens and parasites listed can be preventively managed by a combination of measures including, but not limited to:

- treatment of in-take water;
- area-based management;
- population separation;
- stock health certification;
- broodstock testing;
- quarantine;
- egg disinfection;
- vaccination;
- fallowing;
- disinfection of facilities and equipment;
- year class separation;
- wildlife management;
- biofouling management;
- good husbandry; and
- feed certification.

A knowledge gap has been identified with respect to enzootic pathogens and parasites with the potential to impact the New Zealand aquaculture industry. The importance of enzootic pathogens and parasites relative to internationally listed diseases is illustrated by the most recent disease responses in New Zealand:
Perkinsus olseni (paua),
http://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=14615
and *Flavobacterium psychrophilum* (salmon; Anon 2013).

Table 2: Diseases of concern for rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Infectious pancreatic necrosis and other birnaviruses [Aquatic birnaviruses] (multiple agents)	Yes*	Horizontal and vertical (via eggs). May be spread via contaminated transport water, infected eggs and blood feeding parasites. Piscivorous birds are also known vectors.
	Epizootic haematopoietic necrosis [Epizootic haematopoietic necrosis virus]	No	Horizontal. May be carried on equipment including nets and boats, in fish (live or dead) used for bait. Piscivorous birds are also known vectors.
	Viral encephalopathy and retinopathy [Betanodaviruses] (multiple agents)	No	Horizontal and vertical.
	**Retroviral infection of salmon [Retrovirus]	No	Unknown. Horizontal transmission of the virus is possible, although this is believed to occur rarely. Oral transmission in tissue can also occur as can vertical transmission. Not easily transmitted in seawater.
	Infectious haematopoietic necrosis [Infectious haematopoietic necrosis virus]	No	Horizontal and vertical (via eggs). May be spread by the movement of infected fish or eggs, equipment, feed, water or birds.
	Viral haemorrhagic septicaemia [Viral haemorrhagic septicaemia virus]	No	Horizontal. May be spread by birds that have consumed infected fish, via blood-feeding vectors such as leeches, and on equipment that has been in contact with water from infected fish.
	Infection with *Oncorhynchus masou* virus [*Oncorhynchus masou* virus]	No	Horizontal.
	Pancreas disease [Salmon alpha virus]	No	Horizontal.
Bacterial	Bacterial kidney disease [*Renibacterium salmoninarum*]	No	Horizontally and vertical.
	Epitheliocystis [Gram negative, obligate intracellular bacteria. Aetiology currently putative, usually described as chlamydia-like or rickettsia-like] (multiple agents)	Yes*	Horizontal.
	Enteric redmouth [*Yersinia ruckeri*]	Yes	Horizontal. Vertical transmission (fish to egg) is suspected but is yet to be proven. Many other aquatic species are potential carriers but show no signs (e.g. some crustaceans, including freshwater crayfish). May be spread by contact with contaminated water, nets, and other materials used for

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
			handling fish.
	Infection with *Flavobacterium* spp. [*F. columnare, F. psychrophilum* *F. branchiophilum*] (multiple agents)	Yes*	Horizontal. *F. psychrophilum* is suspected to be vertically transmittted.
	Infection with *Tenacibaculum maritimum* [*Tenacibaculum maritimum*]	Yes	Horizontal.
	Infection with *Piscirickettsia salmonis* [*Piscirickettsia salmonis*]	No	Horizontal. Although *P. salmonis* has been isolated in reproductive organs of salmonids, vertical transmission has not been definitively demonstrated.
	Piscirickettsiosis [*Piscirickettsia*-like bacteria]	Yes*	Horizontal. Note: although *P. salmonis* has been isolated in reproductive organs of salmonids, vertical transmission has not been definitively demonstrated.
	Infection with *Streptococcus iniae* [*Streptococcus iniae*]	No	Horizontal.
	Furunculosis [*Aeromonas salmonicida* var *salmonicida*]	No	Horizontal. Vectors include birds and invertebrates, such as sea lice.
	Infection with atypical strains of *Aeromonas salmonicida* [*Aeromonas salmonicida*]	Yes***	Horizontal.
	Motile aeromonad septicaemia [*Aeromonas hydrophila*] (note: many *Aeromonas* species can cause disease and they have are taxonomically complex)	Yes	Horizontal.
	Infection with *Moritella viscosa* [*Moritella viscosa*]	No	Horizontal.
	Infection with *Lactococcus garvieae* [*Lactococcus garvieae*]	No	Horizontal.
	Infection with *Vibrio salmonicida* [*Vibrio salmonicida*]	No	Horizontal.
Chromistan	Epizootic ulcerative syndrome [*Aphanomyces invadans*]	No	Horizontal. Disease transmission is through zoospore transfer in water, direct contact between fish and skin contamination (penetration assisted by damage to skin).
Chromistan	Saprolegniasis	Yes*	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	[*Saprolegnia* spp.] (multiple agents)		
	Infection with *Ichthyophthirius multifiliis* [*Ichthyophthirius multifiliis*]	Yes	Horizontal.
Fungal	Microsporidial gill disease [*Loma salmonae*]	No	Horizontal.
Protozoan	*Ichthyophoniasis* [*Ichthyophonus hoferi*]	No	Horizontal.
	Sphaerothecum destruens	No	Horizontal transmission may occur when infected fish release parasites with bile, urine, and seminal and ovarian fluid during spawning.
	Amoebic gill disease [*Neoparamoeba* spp., usually *N. pemaquidensis*] (multiple agents)	Yes	Horizontal. *N. pemaquidensis* is an opportunistic pathogen that is normally free-living in seawater.
Metazoan	Infection with *Argulus foliaceus* [*Argulus foliaceus*]	No	Horizontal.
	Infection with *Gyrodactylus salaris* [*Gyrodactylus salaris*]	No	Horizontal and contact between infected and uninfected fish, or by contact between host fish and detached parasites on the substrate. The parasite is readily spread between farms and countries through the transport of infected fish.
	Whirling disease [*Myxobolus cerebralis*]	Yes	Horizontal direct via triactinomyxon infective stages carried through the water. The intermediate host, the worm *Tubifex tubifex*. May be spread by the stocking of infected fish through the alimentary tracts of fish-eating migratory birds.
	Nematode parasitism [Nematoda: Anisakidae Including *Anisakis* spp., *Hysterothylacium* spp., including *Hysterothylacium aduncum*] (multiple agents)	Yes*	Horizontal (uptake via food chain). Note: lifecyles and intermediate species are often unknown.

*Some pathogenic agents of this disease are found in New Zealand.
**Experimentally susceptible.
***Although an atypical strain of *Aeromonas salmonicida* has been isolated in New Zealand, it appears to be an environmental strain of no clinical significance.
Note 1: See Table 2 for additional diseases of concern if these species are to be reared in seawater.
Note 2: Atlantic salmon (*Salmo salar*) is the only species that have been shown to exhibit clinical signs of infectious salmon anaemia.

Table 3: Diseases of concern for Chinook salmon (*Oncorhynchus tshawytscha*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Infectious pancreatic necrosis and other birnaviruses [Aquatic birnaviruses] (multiple agents)	Yes*	Horizontal and vertical (via eggs). May be spread via contaminated transport water, infected eggs, and blood feeding parasites. Piscivorous birds are also known vectors
	Viral encephalopathy and retinopathy [Betanodaviruses] (multiple agents)	No	Horizontal and vertical.
	**Retroviral infection of salmon [Retrovirus]	No	Exact methods of transmission unknown. Horizontal transmission of the virus is possible, although this is believed to occur rarely. Oral transmission in tissue can also occur as can vertical transmission. Not easily transmitted in seawater.
	Infectious haematopoietic necrosis [Infectious haematopoietic necrosis virus]	No	Horizontal and vertical (via eggs). May be spread by the movement of infected fish or eggs, equipment, feed, water, or birds.
	Infectious salmon anaemia [Infectious salmon anaemia virus]***	No	Horizontal. Vertical transmission is suspected.
	Viral haemorrhagic septicaemia [Viral haemorrhagic septicaemia virus]	No	Horizontal. May be spread by birds that have consumed infected fish, via blood-feeding vectors, such as leeches, and on equipment that has been in contact with water from infected fish.
	Cardiomyopathy syndrome [Piscine myocarditis virus, totivirus]	No	Horizontal.
	Pancreas disease [Salmon alpha virus]	No	Horizontal.
	Heart and skeletal muscle inflammation [unknown, piscine orthoreovirus suspected]	No	Assumed horizontal.
Bacterial	Bacterial kidney disease [*Renibacterium salmoninarum*]	No	Horizontal and vertical (via eggs).
	Epitheliocystis [Gram negative, obligate intracellular bacteria. Usually described as chlamydia-like or rickettsia-like] (multiple agents)	Yes*	Horizontal.
	Enteric redmouth [*Yersinia ruckeri*]	Yes	Horizontal. Vertical transmission (fish to egg) is suspected. Many other aquatic species are potential carriers but show no signs (e.g. some crustaceans, including freshwater crayfish).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
			May be spread by contact with contaminated water, nets, and other materials used for handling fish.
	Infection with *Flavobacterium* spp. [*F. columnare, F. psychrophilum, F. branchiophilum*] (multiple agents)	Yes*	Horizontal. *F. psychrophilum* is suspected to be vertically transmittted.
	Infection with *Tenacibaculum maritimum* [*Tenacibaculum maritimum*]	Yes	Horizontal.
	Infection with *Moritella viscosa* [*Moritella viscosa*]	No	Horizontal.
	Infection with *Piscirickettsia salmonis* [*Piscirickettsia salmonis*]	No	Horizontal. Although *P. salmonis* has been isolated in reproductive organs of salmonids, vertical transmission has not been definitively demonstrated.
	Piscirickettsiosis [*Piscirickettsia*-like bacteria]	Yes*	Horizontal. Note: although *P. salmonis* has been isolated in reproductive organs of salmonids, vertical transmission has not been definitively demonstrated.
	Infection with *Lactococcus garvieae* [*Lactococcus garvieae*]	No	Horizontal.
	Infection with *Streptococcus iniae* [*Streptococcus iniae*]	No	Horizontal.
	Furunculosis [*Aeromonas salmonicida* var. *salmonicida*]	No	Horizontal Vectors include birds and invertebrates, such as sea lice.
	Infection with atypical strains of *Aeromonas salmonicida* [*Aeromonas salmonicida*]	Yes****	Horizontal.
	Motile aeromonad septicaemia [*Aeromonas hydrophila*] (note: many *Aeromonas* species can cause disease and they have are taxonomically complex)	Yes	Horizontal.
	Infection with *Listonella anguillarum* [*Listonella anguillarum*]	Yes	Horizontal.
	Infection with *Vibrio ordalii* [*Vibrio ordalii*]	Yes	Horizontal. Selectively infects the muscle and skin and may be able to actively penetrate the skin. It is also found in the gills, and digestive tract which may act as other portals of entry.
	Infection with	No	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	Vibrio salmonicida [*Vibrio salmonicida*]		
Chromistan	Saprolegniasis [*Saprolegnia* spp.] (multiple agents)	Yes*	Horizontal.
	Infection with *Ichthyophthirius multifiliis* [*Ichthyophthirius multifiliis*]	Yes	Horizontal.
Fungal	Microsporidial gill disease [*Loma salmonae*]	No	Horizontal.
Protozoan	*Ichthyophoniasis* [*Ichthyophonus hoferi*]	No	Horizontal.
	Sphaerothecum destruens	No	Horizontal.
	Amoebic gill disease [*Neoparamoeba* spp., usually *N. pemaquidensis*] (multiple agents)	Yes	Horizontal. *N. pemaquidensis* is an opportunistic pathogen that is normally free-living in seawater.
Metazoan	Sea lice infestation [*Abergasilus* spp., and *Caligus* spp.] (multiple agents)	Yes	Horizontal Adult parasites shed numerous eggs continuously. The eggs hatch into a free swimming nauplius which moults into a free swimming infectious copepodid that attaches to a suitable host.
	Infection with *Argulus foliaceus* [*Argulus foliaceus*]	No	Horizontal.
	Infection with *Parvicapsula* spp. [Genus *Parvicapsula*] (multiple agents)	No	Not known, possibly a direct lifecycle.
	Whirling disease [*Myxobolus cerebralis*]	Yes	Horizontal, direct via triactinomyxon infective stages carried through the water. The intermediate host, the worm *Tubifex tubifex*. May be spread by the stocking of infected fish through the alimentary tracts of fish-eating migratory birds.
	Nematode parasitism [Nematoda: Anisakidae Including *Anisakis* spp., *Hysterothylacium* spp., including *Hysterothylacium aduncum*] (multiple agents)	Yes*	Horizontal (uptake via food chain). Note: lifecyles and intermediate species are often unknown.

*Some pathogenic agents of this disease are found in New Zealand.

**Experimentally susceptible.
***Atlantic salmon (*Salmo salar*) is the only salmonid species that have yet been shown to exhibit clinical signs of infectious salmon anaemia. Chinook salmon (*O. tshawytscha*) is the only salmon farmed in New Zealand.
****Although an atypical strain of *Aeromonas salmonicida* has been isolated in New Zealand, it appears to be an environmental strain of no clinical significance.

Table 4: Diseases of concern for kingfish (*Seriola lalandi*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Infectious pancreatic necrosis and other birnaviruses [Aquatic birnaviruses] (multiple agents)	Yes*	Horizontal and vertical (via eggs). May be spread via contaminated transport water, infected eggs and blood feeding parasites. Piscivorous birds are also known vectors.
	Infection with yellowtail ascites virus [Yellowtail ascites virus]	No	Horizontal and vertical (via eggs).
	Infection with viral deformity virus [Viral deformity virus of yellowtail]	No	Horizontal and vertical (via eggs).
	Red sea bream iridoviral disease [Red sea bream iridovirus] (multiple agents)	No	Horizontal.
	Lymphocystis [Iridoviruses] (multiple agents)	No	Horizontal.
	Viral haemorrhagic septicaemia [Viral haemorrhagic septicaemia virus]	No	Horizontal. May be spread by birds that have consumed infected fish, via blood-feeding vectors such as leeches, and on equipment that has been in contact with water from infected fish.
	Infection with nodavirus [Nodavirus sp.]	No	Horizontal and vertical.
Bacterial	Epitheliocystis [Gram negative, obligate intracellular bacteria. Usually described as chlamydia-like or rickettsia-like] (multiple agents)	Yes*	Horizontal.
	Infection with *Tenacibaculum maritimum* [*Tenacibaculum maritimum*]	Yes	Horizontal.
	Infection with *Lactococcus garvieae* [*Lactococcus garvieae*]	No	Horizontal.
	Infection with *Streptococcus iniae* [*Streptococcus iniae*]	No	Horizontal.
	Infection with *Photobacterium damsela* subsp. *piscicida* [*Photobacterium damsela* subsp. *piscicida*]	No	Horizontal.
	Infection with *Listonella anguillarum* [*Listonella anguillarum*]	Yes	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	Infection with atypical strains of *Aeromonas salmonicida* [*Aeromonas salmonicida*]** (note: many *Aeromonas* species can cause disease and they have are taxonomically complex)	Yes	Horizontal.
	Vibriosis [*Vibrio* spp.] (multiple agents)	Yes*	Horizontal.
	Infection with *Vibrio ordalii* [*Vibrio ordalii*]	Yes	Horizontal. Selectively infects the muscle and skin and may be able to actively penetrate the skin. It is also found in the gills, and digestive tract which may act as other portals of entry.
	Norcardiosis [*Nocardia seriolae*]	No	Horizontal
	Piscirickettsiosis [*Piscirickettsia*-like bacteria]	Yes*	Horizontal. Note: although *P. salmonis* has been isolated in reproductive organs of salmonids, vertical transmission has not been definitively demonstrated.
Fungal	Beko disease [*Microsporidium seriolae*]	No	Horizontal (oral ingestion of spores).
Chromistan	Infection with *Cryptocaryon irritans* [*Cryptocaryon irritans*]	Yes	Horizontal.
	Infection with Scuticociliates. [Unidentified scuticociliates of the genera *Uronema*, *Miamiensis* or *Philasterides*] (multiple agents)	Yes*	Horizontal.
Protozoan	*Ichthyophoniasis* [*Ichthyophonus hoferi*]	No	Horizontal (oral ingestion).
Metazoan	Infection with *Mxyosporea* [e.g. *Myxidium* sp., *Kudoa* sp., *Unicapsula seriolae*, *Ceratomyxa seriolae*, *Ceratomya buri*, *Parvicapsula* spp.] (multiple agents)	Yes*	Horizontal. The lifecycles of the majority of marine myxosporeans are unknown.
	Infection with *Enteromyxum leei* [*Enteromyxum leei*]	No	Horizontal.
	Infection with *Benedenia* spp. [Ectoparasitic monogeneans of the genus	Yes	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	Benedenia] (multiple agents)		
	Infection with *Zeuxapta* spp. [Genus *Zeuxapta* including *Z. seriolae*, and *Z. japonica*] (multiple agents)	Yes	Horizontal.
	Infection with *Paradeontacylix* spp. [Genus *Paradeontacylix* spp.] (multiple agents)	Yes	Horizontal. Invertebrate intermediate host.
	Infection with *Philometra lateolabracis* [*Philometra lateolabracis*]	No	Not known, but an indirect life-cycle is likely, possibly including an intermediate crustacean host.
	Sea lice infestation [*Abergasilus* spp., and *Caligus* spp.] (multiple agents)	Yes*	Horizontal. Adult parasites shed numerous eggs continuously. The eggs hatch into a free swimming nauplius which moults into a free swimming infectious copepodid that attaches to a suitable host.
	Lernanthropus parasitism [*Lernanthropus* spp.] (multiple agents)	Yes*	Horizontal.
	Neobrachiella parasitism [*Neobrachiella* spp.] (multiple agents).	Yes*	Horizontal.
	Nematode parasitism [Nematoda: Anisakidae Including *Anisakis* spp., *Hysterothylacium* spp., including *Hysterothylacium aduncum Hysterothylacium seriolae*] (multiple agents)	Yes*	Horizontal (uptake via food chain). Note: lifecyles and intermediate species are often unknown.

*Some pathogenic agents of this disease are found in New Zealand.

Table 5: Diseases of concern for hapuku (*Polyprion oxygeneios*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Infectious pancreatic necrosis and other birnaviruses [Aquatic birnaviruses] (multiple agents)	Yes	Horizontal and vertical (via eggs). May be spread via contaminated transport water, infected eggs and blood feeding parasites. Piscivorous birds are also known vectors
	Red sea bream iridoviral disease [Red sea bream iridovirus] (multiple agents)	No	Horizontal.
	Viral encephalopathy and retinopathy [Betanodaviruses] (multiple agents)	No	Horizontal and vertical.
	Viral haemorrhagic septicaemia [Viral haemorrhagic septicaemia virus]	No	Horizontal. May be spread by birds that have consumed infected fish, via blood-feeding vectors such as leeches, and on equipment that has been in contact with water from infected fish.
Bacterial	Epitheliocystis [Gram negative, obligate intracellular bacteria. Usually described as chlamydia-like or rickettsia-like] (multiple agents)	Yes	Horizontal.
	Enteric redmouth [*Yersinia ruckeri*]	Yes	Horizontal. Vertical transmission (fish to egg) is suspected but is yet to be proven. Many other aquatic species are potential carriers but show no signs (e.g. some crustaceans, including freshwater crayfish). May be spread by contact with contaminated water, nets, and other materials used for handling fish.
	Infection with *Tenacibaculum maritimum* [*Tenacibaculum maritimum*]	Yes	Horizontal.
	Infection with *Moritella viscosa* [*Moritella viscosa*]	No	Horizontal.
	Infection with *Lactococcus garvieae* [*Lactococcus garvieae*]	No	Horizontal.
	Infection with *Streptococcus iniae* [*Streptococcus iniae*]	No	Horizontal.
	Infection with atypical strains of *Aeromonas salmonicida* [*Aeromonas salmonicida*]**	Yes	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	(note: many *Aeromonas* species can cause disease and they have are taxonomically complex)		
	Infection with *Photobacterium damsela* subsp. *piscicida* [*Photobacterium damsela* subsp. *piscicida*]	No	Horizontal.
	Infection with *Listonella anguillarum* [*Listonella anguillarum*]	Yes	Horizontal.
	Vibriosis [*Vibrio* spp.] (multiple agents)	Yes*	Horizontal.
	Infection with *Vibrio ordalii* [*Vibrio ordalii*]	Yes	Horizontal. Selectively infects the muscle and skin and may be able to actively penetrate the skin. It is also found in the gills, and digestive tract which may act as other portals of entry.
	Infection with *Vibrio ichthyoenteri* [*Vibrio ichthyoenteri*]		Horizontal.
	Piscirickettsiosis [*Piscirickettsia*-like bacteria]	Yes*	Horizontal. Note: although *P. salmonis* has been isolated in reproductive organs of salmonids, vertical transmission has not been definitively demonstrated.
Chromistan	Infection with *Cryptocaryon irritans* [*Cryptocaryon irritans*]	Yes	Horizontal.
	Infection with Scuticociliates. [Unidentified scuticociliates of the genera Uronema, Miamiensis or Philasterides]	Yes	Horizontal.
Protozoan	Ichthyophoniasis [*Ichthyophonus hoferi*]	No	Horizontal
Metazoan	Infection with *Mxyosporea* [e.g. *Myxidium* sp., *Ceratomyxa moenei, Parvicapsula* spp.] (multiple agents)	Yes*	Horizontal. The lifecycles of the majority of marine myxosporeans are unknown.
	Infection with *Enteromyxum leei* [*Enteromyxum leei*]	No	Horizontal.
	Infection with *Philometra lateolabracis* [*Philometra lateolabracis*]	No	Not known, but an indirect life-cycle is likely, possibly including an intermediate crustacean host.
	Sea lice infestation [*Abergasilus* ssp., and *Caligus* spp.]	Yes*	Horizontal. Adult parasites shed numerous eggs continuously.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	(multiple agents)		The eggs hatch into a free swimming nauplius which moults into a free swimming infectious copepodid that attaches to a suitable host.
	Copepod infestation [e.g. *Lepeophteirus polyprioni, Jusheyus shogunus*] (multiple agents)	Yes*	Horizontal.
	Neolepidapedon parasitism [*Neolepidapedon polyprioni*]	Yes	Horizontal. Unknown intermediate hosts
	Tubovesciula parasitism [*Tubovesciula angusticauda*]	Yes	Horizontal. Unknown intermediate hosts
	Allocotylophora parasitism [*Allocotylophora polyprionum*]	Yes	Horizontal.
	Hepatoxylon parasitism [*Hepatoxylon trichiuri*]	Yes	Horizontal.
	Nematode parasitism [Nematoda: *Anisakis* spp., *Ascarophis* sp., *Hysterothylacium* spp., including *Hysterothylacium aduncum* and *Cucullanus* sp.] (multiple agents)	Yes*	Horizontal (uptake via food chain). Note: lifecyles and intermediate species are often unknown.

*Some pathogenic agents of this disease are found in New Zealand.

**Although an atypical strain of *Aeromonas salmonicida* has been isolated in New Zealand, it appears to be an environmental strain of no clinical significance.

Table 6: Diseases of concern for Paua (*Haliotis iris*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Abalone viral ganglioneuritis [Abalone viral ganglioneuritis virus]	No	Vertical and horizontal.
Bacterial	Infection with *Xenohaliotis californiensis* [*Xenohaliotis californiensis*]	No	Horizontal.
	Pustule disease of abalone [Genus *Vibrio*, particularly *V. fluvialis* II, *V. harveyi* and *V. splendidus*] (multiple agents)	Yes*	Horizontal.
	Bacterial disease of abalone (not pustule disease) [Genus *Vibrio*, particularly *V. harveyi, V. carchariae,V. alginolyticus, V. parahaemolyticus* and *V. splendidus.* Other bacteria including *Clostridium lituseberense,* Flavobacterium-like bacteria and long *Flexibacter/Cytophaga-like* rod bacteria] (multiple agents)	Yes*	Horizontal.
	Brown ring disease [*Vibrio tapetis*]	No	Horizontal.
Fungal	Paua shell mycosis (multiple agents)	Yes*	Assumed horizontal.
Chromistan	Infection of the head and foot with *Labyrinthuloides haliotidis* [*Labyrinthuloides haliotidis*]	No	Assumed horizontal.
	Kidney coccidia of abalone [*Margolisiella* (=*Pseudoklossia*) *haliotis*, unindentified species of coccidia] (multiple agents)	Yes*	Horizontal.
	Paua haplosporidosis [undescribed haplosporidian]	Yes	Assumed horizontal. Failure to transmit the disease between paua in the laboratory suggests that an intermediate host is required for transmission.
	Infection with *Perkinsus olseni* [*Perkinsus olseni*]	Yes	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	Ciliates associated with abalone [*Mantoscyphidia* sp., *Scyphidia*-like and *Sphenophrya*-like ciliates] (multiple agents)	Yes*	Assumed horizontal.
Metazoan	Infection with *Boccardia* spp. [Annelids of the genus *Boccardia* including *Boccardia acus*, *B. knoxi*, and *B. chilensis*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle on mollusc shells.
	Infection with *Polydora* spp. [Annelids of the genus *Polydora*, including *P. websteri*, *P. cornuta*, *P. hoplura* and *P. haswelli*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle on mollusc shells.
	Sabellid polychaete infestation disease [*Terebrasabella heterouncinata*]	No	Horizontal.
	Nematode parasitism [*Echinocephalus pseudouncinatus*]	No	Horizontal.
	Trematode parasitism {unknown] Only incompletely developed juvenile stages of the parasite occur in abalone, the specific identities of the trematodes involved are not known. (multiple agents)	Yes*	Horizontal. Trematodes have a complex life cycle that includes different host groups, including bivalves, fish and birds.

*Some pathogenic agents of this disease are found in New Zealand.

Table 7: Diseases of concern for green-lipped mussels (*Perna canaliculus*) and blue mussels (*Mytilus galloprovincialis*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Digestive epithelial virosis [Small unenveloped RNA viruses] (multiple agents)	Yes*	Horizontal via the water column.
	[Infectious pancreatic necrosis-like virus and other aquatic birnaviruses] (multiple agents)	Yes*	Horizontal but vertical transmission may be possible.
Bacterial	Intracellular bacterial disease [Rickettsiales and/or Chlamydiales and/or an unidentified mycoplasma] (multiple agents)	Yes*	The most probable transmission route is horizontal via the water water column by means of direct contact.
	Vibriosis [*Vibrio* spp.] (multiple agents)	Yes*	Horizontal.
	Phototrophic endolith invasion of mussel shells [Species of cyanobacteria including: *Plectonema terebrans, Hyella caespitosa, Mastigocoleus testarum, Mastigocoleus* sp. and aggregated cyanobacterium *Pleurocapsa* sp.] (multiple agents)	Yes*	Horizontal.
Chromista	Kidney coccidia of mussels [*Pseudoklossia semiluna, Pseudoklossia pelseneeri*, unindentified species of coccidia] (multiple agents)	Yes*	Horizontal.
	Haplosporidiosis [*Haplospordian tumefacientis, Haplospordian* sp.] (multiple agents)	Yes*	Horizontal.
	Gregarine parasitism of mussels [*Nematopsis* spp., *Porospora* spp.] (multiple agents)	Yes*	Horizontal. Intermediate species may include crustaceans.
	Infection with *Trichodina* spp. [*Trichodina* spp.]	Yes*	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	(multiple agents)		
	Infection with *Perkinsus olseni* [*Perkinsus olseni*]	Yes	Horizontal. All life-stages are infective.
	Infection with *Marteilia refringens* [*Marteilia refringens*]	No	Horizontal. Several intermediate hosts or a free-living stage are thought to be required during the lifecycle of *M. refringens*. The copepod *Paracartia grani* is one intermediate host and may be involved in transmission of *M. refringens* between bivalves.
	Infection with apicomplexan parasite X (APX) [An unnamed apicomplexan parasite]	Yes	Probably a multihost life cycle. As only one stage of the life-cycle of these parasites occurs in bivalves, the APX parasite probably uses another host, possibly a terebellid polychaete worm.
	Infection with invasive ciliates (multiple agents)	Yes*	Horizontal.
Fungal	Mussel egg disease [*Steinhausia* sp. and *Steinhausia*-like microsporidia] (multiple agents)	No	Horizontal but vertical transmission is suspected.
Metazoan	Infection with *Boccardia* spp. [Annelids of the genus *Boccardia* including *Boccardia acus, B. knoxi*, and *B. chilensis*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle on mollusc shells.
	Infection with Platyhelminth flatworms. [Flatworms, including *Postenterogonia orbicularis, Urastoma cyprinae* and a member of the family Planoceridae] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to be drawn into filter feeding molluscs.
	Infection with *Polydora* spp. [Annelids of the genus *Polydora*, including *P. websteri, P. cornuta, P. hoplura* and *P. haswelli*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle on mollusc shells.
	Infection with trematodes. [Trematodes including *Cercaria* spp., *Protoeces* spp., *Bucephalus* spp.] (multiple agents)	Yes*	Horizontal. Trematodes have a complex life cycle that includes different host groups, such as bivalves, fish and birds.
	Red worm disease [*Mytilicola intestinalis, M. orientalis*]	No	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	(multiple agents)		
	Pinnotheres parasitism [*Pinnotheres novaezelandiae*]	Yes	Horizontal.
	Infection with shell-boring sponges [*Cliona* spp.] (multiple agents)	Yes*	Horizontal.

*Some pathogenic agents of this disease are found in New Zealand.

Table 8: Diseases of concern for oysters (*Crassostrea gigas*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Herpesvirus infection of oysters. [Ostreid herpesvirus microvariant 1]	Yes	Assumed horizontal but vertical transmission may also occur.
	Gill necrosis virus disease [An iridovirus-like virus]	No	Horizontal.
	Oyster velar virus disease [Icosahedral DNA, iridovirus-like virus]	No	Presumed horizontal.
	Digestive epithelial virosis [Small unenveloped RNA viruses] (multiple agents)	Yes*	Horizontal.
	Haemocytic infection virus disease of oysters [Icosahedral DNA virus]	No	Horizontal.
	Viral gametocytic hypertrophy of oysters [Papilloma-like virus]	No	Horizontal but vertical transmission may be possible.
	Infection with infectious pancreatic necrosis-like virus [Infectious pancreatic necrosis-like virus and other aquatic birnaviruses] (multiple agents)	Yes*	Horizontal but vertical transmission may be possible.
Bacterial	Intracellular bacterial disease [Rickettsiales and/or Chlamydiales or an unidentified mycoplasma] (multiple agents)	Yes*	Assumed horizontal.
	Infection with extracellular giant "Ricketsiae" of oysters [Pleomorphic prokaryotic microorganism but not in the family Rickettsiales]	No	Horizontal.
	Pacific oyster nocardiosis [*Nocardia crassostreae*]	No	Horizontal.
	Vibriosis [*Vibrio* spp.] (multiple agents)	Yes*	Horizontal.
	Hinge-ligament disease [*Cytophaga* spp.]	No	Horizontal.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	(multiple agents)		
Chromistan	Kidney coccidia of oysters [oyster kidney coccidians] (multiple agents)	No	Horizontal.
	Gregarine parasitism of oysters [*Nematopsis* spp.] (multiple agents)	Yes*	Horizontal. Intermediate species may include crustaceans.
	Infection with *Trichodina* spp. [*Trichodina* spp.] (multiple agents)	Yes*	Horizontal.
	Infection with *Haplosporidium nelsoni* [*Haplosporidium nelsoni, H. costale*] (multiple agents)	No	Assumed horizontal. Failure to transmit the disease between oysters in the laboratory suggests that an intermediate host is required for transmission.
	Infection with *Marteilioides chungmuensis.* [*Marteilioides chungmuensis*]	No	Mode of transmission is unknown; however, intermediate hosts may be involved in the life cycle of the disease.
	Infection with *Perkinsus marinus* [*Perkinsus marinus*]	No	Horizontal.
	Infection with invasive ciliates (multiple agents)	Yes*	Horizontal.
Fungal	Shell disease [*Ostracoblabe implexa*]	No	Horizontal.
	Oyster egg disease [*Microsporidian* sp.] (multiple agents)	No	Horizontal but vertical transmission is suspected.
Protozoan	Hexamitiasis of oysters [*Hexamita* spp.] (multiple agents)	Yes*	Horizontal.
Unknown	Infection with *Mikrocytos mackini.* [*Mikrocytos mackini*]	No	Assumed horizontal.
Metazoan	Infection with *Boccardia* spp. [Annelids of the genus *Boccardia* including *Boccardia acus, B. knoxi* and *B. chilensis*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle onto mollusc shells.
	Infection with Platyhelminth flatworms. [Flatworms, including *Postenterogonia*	Yes*	Horizontal. Planktonic dispersal allows larvae to be drawn into filter feeding molluscs.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	orbicularis, Urastoma cyprinae and a member of the family Planoceridae] (multiple agents)		
	Infection with *Polydora* spp. [Annelids of the genus *Polydora*, including *P. websteri, P. cornuta, P. hoplura* and *P. haswelli*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle onto mollusc shells.
	Red worm disease [*Mytilicola intestinalis*]	No	Horizontal.
	Nematode parasitism [Nematoda: *Echinocephalus* sp.] (multiple agents)	No	Horizontal . Note: lifecyles and intermediate species are often unknown.
	Infection with shell-boring sponges [*Cliona* spp.] (multiple agents)	Yes*	Horizontal .

*Some pathogenic agents of this disease are found in New Zealand.

Table 9: Diseases of concern for flat oysters (*Ostrea chilensis*).

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
Viral	Gill necrosis virus disease [An Iridovirus-like virus]	No	Horizontal.
	Herpes-like virus disease [Herpes-like virus]	Yes	Presumed horizontal but vertical transmission may also occur.
Bacterial	Intracellular bacterial disease [Rickettsiales and/or Chlamydiales or an unidentified mycoplasma] (multiple agents)	Yes*	Assumed horizontal.
	Vibriosis [*Vibrio* spp.] (multiple agents)	Yes*	Horizontal.
	Hinge-ligament disease [*Cytophaga* spp.] (multiple agents)	No	Horizontal.
	Nocardiosis [*Nocardia spp.*] (multiple agents)	No	Horizontal.
Fungal	Shell disease [*Ostracoblabe implexa*]	No	Horizontal.
	Microsporidiosis [Unidentified species currently placed in collective group *Microsporidium rapuae*]	Yes	Horizontal.
Chromistan	Infection with *Bonamia exitiosa* [*Bonamia exitiosa*]	Yes	Horizontal. Transmission is thought to occur from host to host via infective stages being carried along water currents between oyster beds.
	Infection with *Bonamia ostreae* [*Bonamia ostreae*]	Yes	Horizontal. Directly from host to host and indirectly between oyster beds via the water.
	Infection with other *Bonamia* species [Undescribed species of *Bonamia*]	No	Assumed horizontal.
	Infection with *Marteilia refringens* [*Marteilia refringens*]	No	Horizontal. Several intermediate hosts or a free-living stage are thought to be required during the lifecycle of *M. refringens.* The copepod *Paracartia grani* is one intermediate host and may be involved in transmission of *M. refringens* between bivalves.

Disease type	Disease name [pathogen]	Present in New Zealand	Transmission
	Infection with apicomplexan parasite X (APX) [An unnamed apicomplexan parasite]	Yes	Probably a multihost life cycle. As only one stage of the life-cycle of these parasites occurs in bivalves, the APX parasite probably uses another host, possibly a terebellid polychaete worm.
	Infection with invasive ciliates (multiple agents)	Yes*	Assumed horizontal.
	Infection with *Haplosporidium* (=*minchina*) [*Haplosporidium* (=*minchina*)]	No	Horizontal
Unknown	Infection with *Mikrocytos mackini.* [*Mikrocytos mackin*]	No	Assumed horizontal.
Metazoan	Infection with *Boccardia* spp. [Annelids of the genus *Boccardia* including *Boccardia acus, B. knoxi* and *B. chilensis*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle onto mollusc shells.
	Infection with Platyhelminth flatworms. [Flatworms, including *Postenterogonia orbicularis, Urastoma cyprinae* and a member of the family Planoceridae] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to be drawn into filter feeding molluscs.
	Infection with *Polydora* spp. [Annelids of the genus *Polydora*, including *P. websteri, P. cornuta, P. hoplura* and *P. haswelli*] (multiple agents)	Yes*	Horizontal. Planktonic dispersal allows larvae to settle onto mollusc shells.
	Infection with *Bucephalus* sp. (multiple agents)	Yes*	Horizontal. Bucephalids have a complex life cycle that includes different host groups, such as bivalves, fish and birds.

*Some pathogenic agents of this disease are found in New Zealand.

5.3.2 Pests

The New Zealand aquaculture industry regards species that have an impact on business, regardless of origin, as pests (Sim-Smith *et al.* 2014). These can include sessile, mobile or waterborne organisms.

In a recent survey, New Zealand freshwater salmonid producers were concerned about *Didymosphema geminata* and other microalgae and aquatic plants (Sim-Smith *et al.* 2014). Little is known about biofouling species in freshwater aquaculture facilities, although it is thought to consist of algae, diatoms and bryozoans (Dürr and Watson 2010).

On a global scale, biofouling of marine aquaculture organisms, infrastructure and equipment is dominated by mussels, ascidians, barnacles, hydroids, seaweeds and tubeworms (Dürr and Watson 2010).

Forrest *et al.* (2014) identified 58 pest species that have significant impacts on shellfish aquaculture. However, the authors also expressed difficulty in identifying the next pest to shellfish aquaculture and its occurrence in New Zealand. They recommend that biofouling management approaches need to be generic where possible, to capture a wide range of potential problem species (Forrest *et al.* 2014).

Broad groups of organisms of concern, i.e. pests and biofouling, have been identified for New Zealand marine-based aquaculture (Table 10). The table presented is not exhaustive and given the difficulties highlighted by Bell *et al.* (2011) and Forrest *et al.* (2014) in predicting the next pest, does not attempt to cover all existing or potential pest associated with each of the cultured species.

Table 10: Organism groups of concern for New Zealand marine-based aquaculture (Dürr and Watson 2010; Bell *et al.* 2011; Fitridge *et al.* 2014; Forrest *et al.* 2014; Sim-Smith *et al.* 2014).

Organism group	**Type of aquaculture species affected**
Amphipods	Finfish
Ascidians	Finfish, Mussel, Oyster, Paua
Barnacles	Finfish, Mussel, Oyster
Bivalves	Finfish, Mussel, Oyster, Paua
Bristleworms	Mussel, Oyster, Paua,
Bryozoans	Finfish, Mussel
Cnidarians	Finfish, Mussel, Oyster, Paua
Crab	Oyster
Flatworms	Mussel, Oyster
Gastropods	Oyster
Microalgae (harmful algal blooms)	Finfish, Mussel, Oysters, Paua
Macroalgae (seaweeds)	Finfish, Mussel, Oyster
Sea stars	Mussel; Oyster
Sponges	Finfish, Mussel, Oyster, Paua

5.3.3 Pathways

Understanding the risks to New Zealand aquaculture from existing or potential pathogens, parasites or pests requires the identification of pathways by which they may spread. The figures presented assist in the identification of potential risk sources and can be used to identify different preventive or management options (Figures 2-5; Zepeda *et al.* 2008).

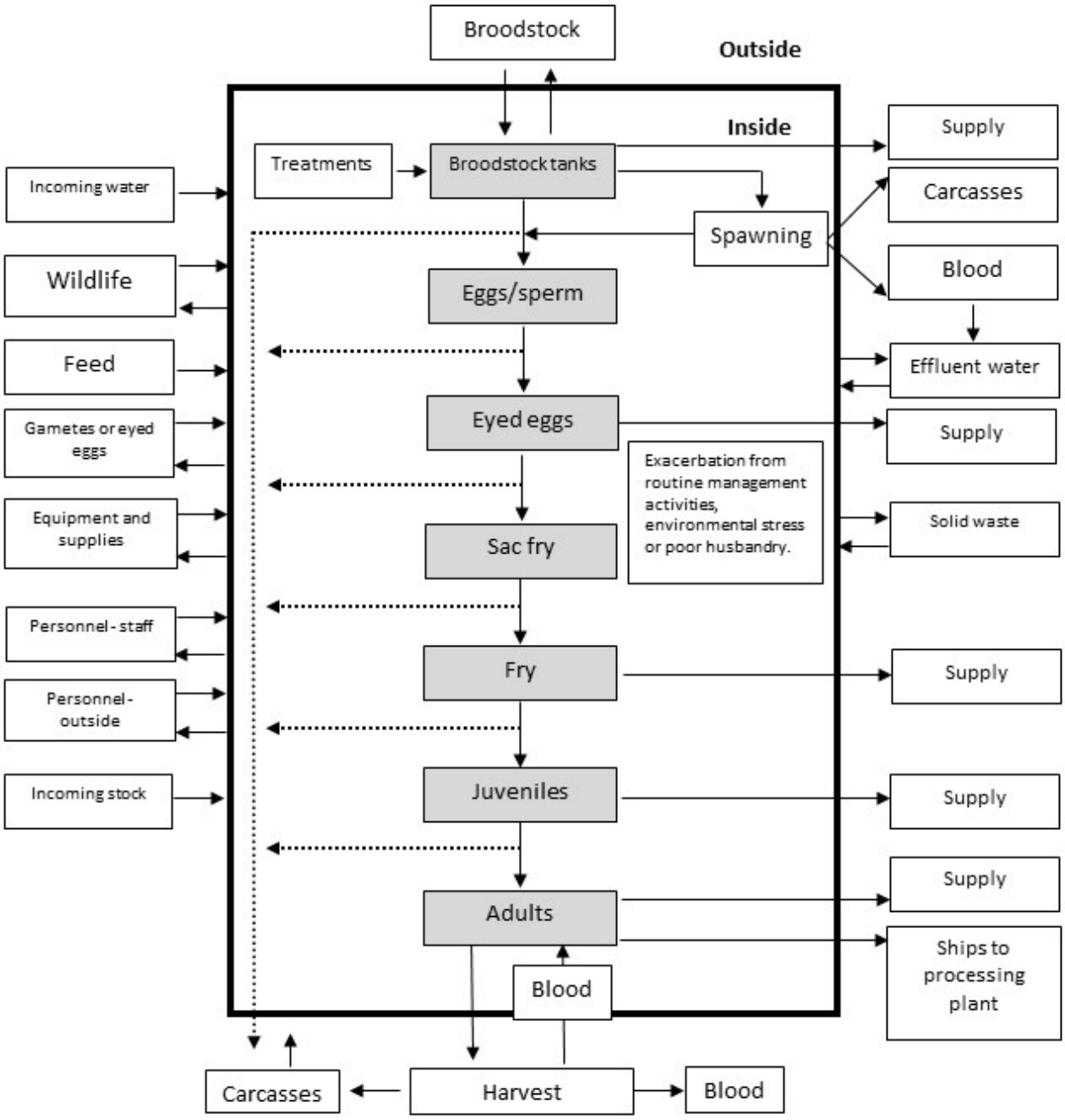

Figure 2: Pathways for potential introduction and spread of pests and pathogens into and from a finfish land-based hatchery or farm (modified from Zepeda *et al.* 2008).
The larger frame represents the farm. The population units are represented by grey boxes. The solid arrows going in and out of the larger frame represent potential sources of infection, and the discontinuous arrows indicate mortalities removed from the system. Hatchery production typically ends at supply of fry for on-growing elsewhere.

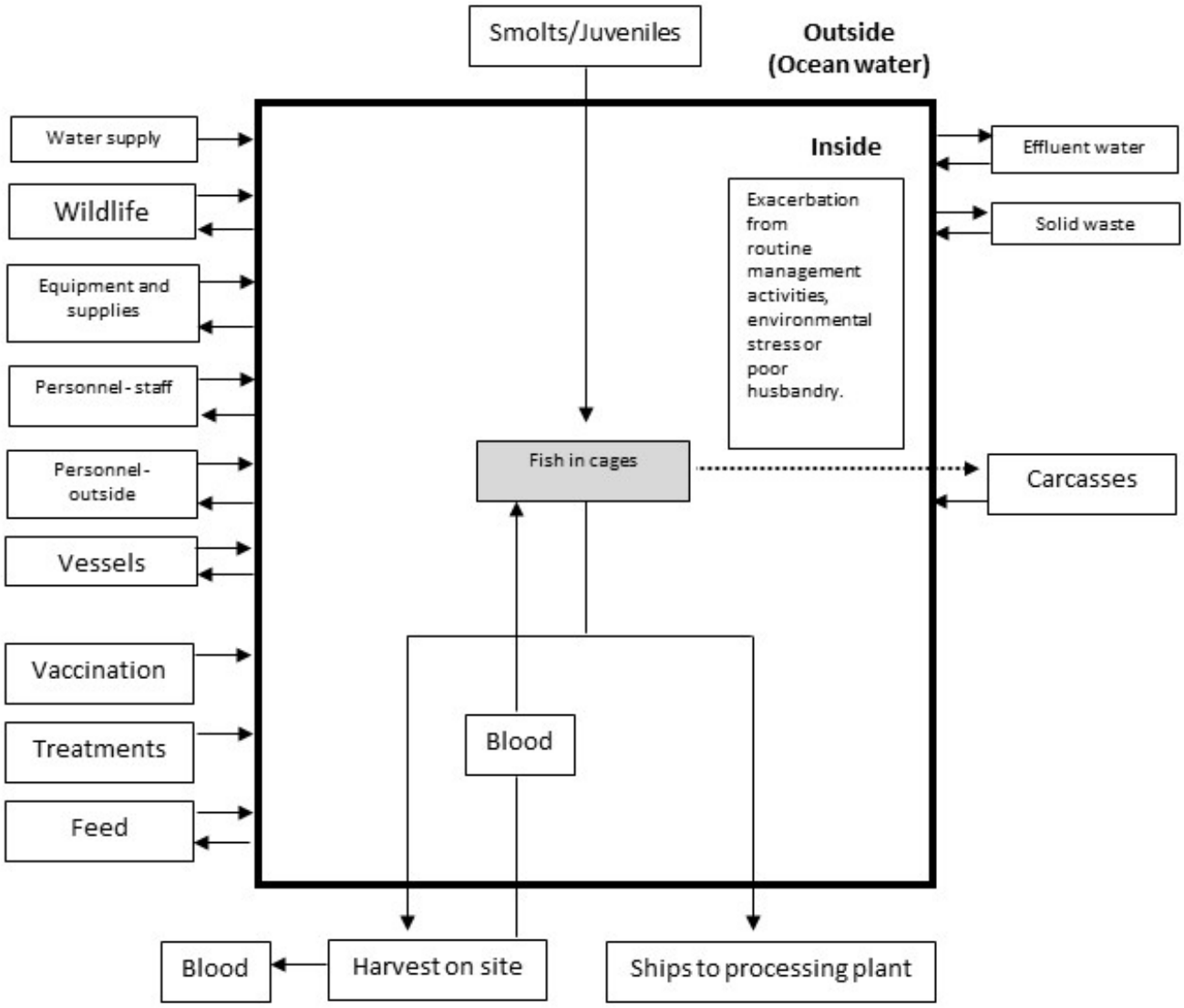

Figure 3: Pathways for potential introduction and spread of pathogens into and from an open water finfish farm (modified from Zepeda *et al.* 2008).
The larger frame represents the farm. The population units are represented by the grey box. The solid arrows going into and out of the larger frame represent potential sources of infection, and the discontinuous arrows indicate mortalities removed from the system.

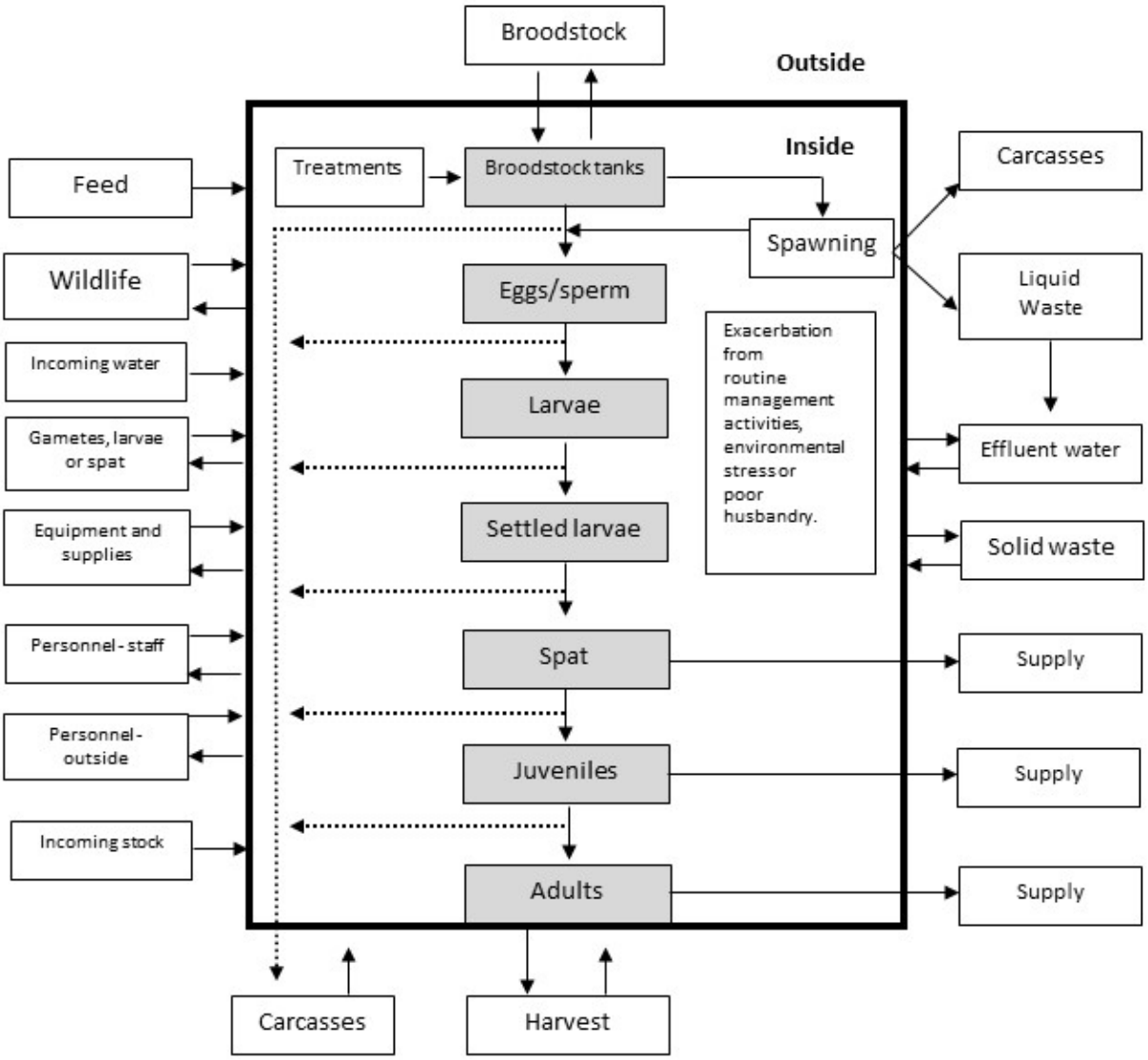

Figure 4: Pathways for potential introduction and spread of pathogens into and from a land-based shellfish hatchery or farm (modified from Zepeda *et al.* 2008).
The larger frame represents the farm. The population units are represented by grey boxes. The solid arrows going into and out of the larger frame represent potential sources of infection, and the discontinuous arrows indicate mortalities removed from the system. Hatchery production typically ends at supply of spat for on-growing elsewhere.

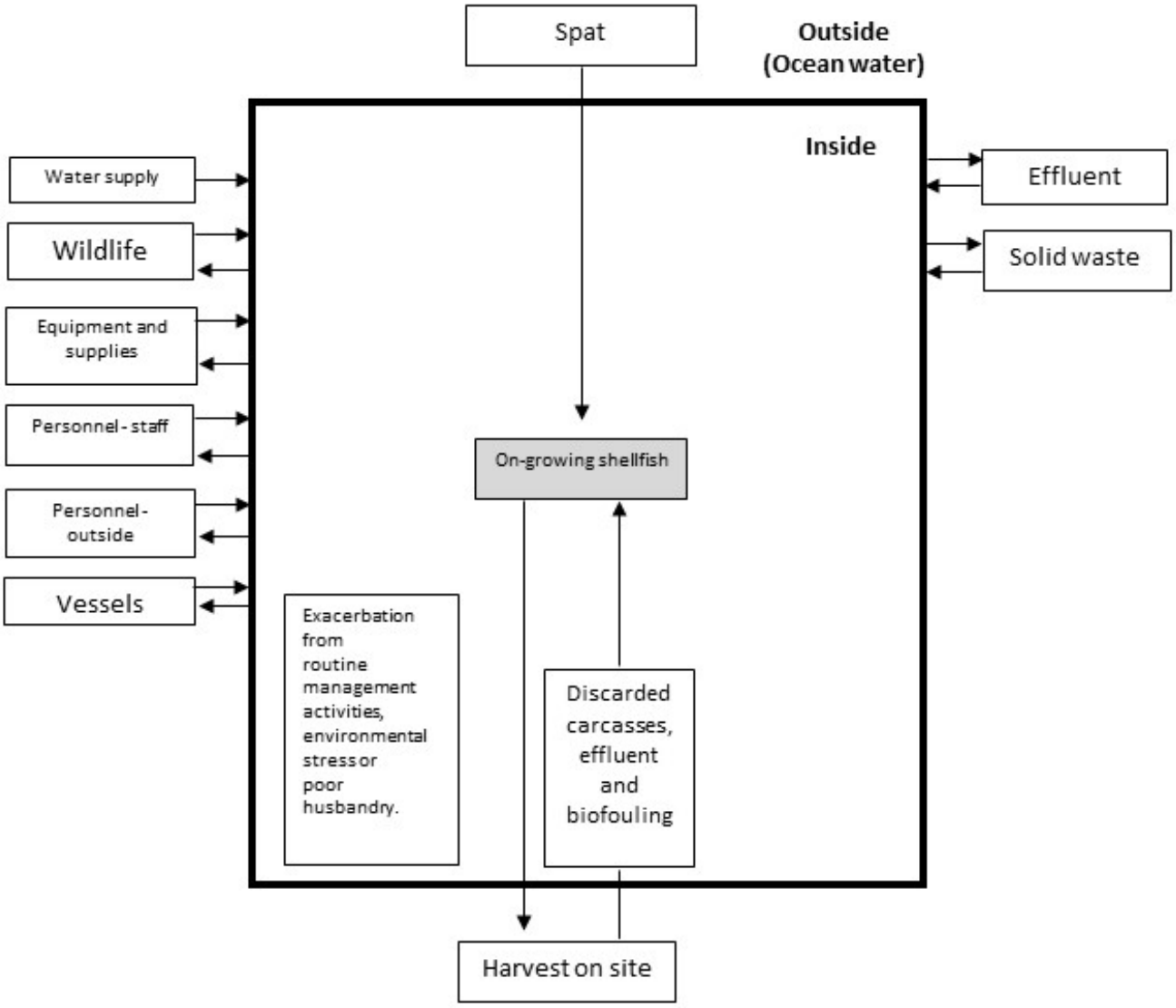

Figure 5: Pathways for potential introduction and spread of pests and pathogens in an open water shellfish farm (modified from Zepeda *et al.* 2008).
The larger frame represents the farm. The population units are represented by grey box. The solid arrows going into and out of the larger frame represent potential sources of infection. Mortalities are not typically removed from open water shellfish farms (Sim-Smith *et al.* 2014).

5.3.4 References

Andreou D; Gozlan RE; Stone D; Martin P; Bateman K; Feist SW (2011). *Sphaerothecum destruens* pathology in cyprinids. *Diseases of Aquatic Organisms* 95: 145-151.

Anon (2013). Animal health laboratory. *Surveillance* 40(3): 9-13.

Bell A, Phillips S, Denny C, Georgiades E and D Kluza (2011). *Risk Analysis: Vessel Biofouling.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 145 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf [Website accessed May 2014].

Bell AS, Yokoyama H, Aoki T, Takahashi M and K Maruyama (1999). Single and nested polymerase chain reaction assays for the detection of *Microsporidium seriolae* (Microspora), the causative agent of 'Beko'disease in yellowtail *Seriola quinqueradiata*. *Diseases of Aquatic Organisms* 37: 127-134.

Biering E. and ÅH Garseth (2012). Heart and skeletal muscle inflammation (HSMI) of farmed Atlantic salmon (*Salmo salar* L.) and the associated *Piscine reovirus* (PRV). ICES identification leaflets for diseases and parasites of fish and shellfish. Leaflet No. 58. 6 pp.

Biosecurity Australia (2002). *Import risk analysis (IRA) of non-viable bivalve molluscs.* Technical issues paper. Animal Biosecurity Policy Memorandum 2002/44, Australian Government. 55 pp.

Bower SM (2011). *Synopsis of infectious diseases and parasites of commercially exploited shellfish.* http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/index-eng.html [Website accessed December 2014].

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Department of Agriculture, Fisheries and Forrestry (2012). *Aquatic animal diseases significant to Australia: identification field guide, 4th edition.* Australian Government, Canberra.http://www.daff.gov.au/animal-plant-health/pests-diseases-weeds/aquatic-animal-diseases-significant-to-australia-identification-field-guide-4th-edition [Website accessed August 2014].

Diggles B (2011). *Environmental assessment report - disease risks.* Prepared for New Zealand King Salmon Ltd. by Digsfish Pathology Services Ltd. 68 pp.

Diggles B (2004). *Review of submissions on: import risk assessment;- juvenile yellowtail kingfish (Seriola lalandi) from Spencer Gulf aquaculture, South Australia.* Prepared for: Island Aquafarms Ltd. by Digsfish Pathology Services Ltd. 54 pp.

Diggles B (2002). *Import risk assessment: juvenile yellowtail kingfish (Seriola lalandi) from Spencer Gulf aquaculture, South Australia.* Prepared for: Island Aquafarms Ltd. NIWA Client Report WLG 2002/03. 54 pp.

Diggles BK and M Oliver (2005). *Diseases of cultured paua (Haliotis iris) in New Zealand. In*: P Walker, R Lester and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 275-287.

Diggles BK, Hine PM, Handley S and NC Boustead (2002). *A handbook of diseases of importance to aquaculture in New Zealand.* NIWA science and technology series No. 49. 200 pp.

Dürr S and DI Watson (2010). *Biofouling and antifouling in aquaculture. In*: Dürr S and JC Thomason (Eds.) Biofouling. Blackwell Publishing. pp. 267-287.

Fitridge I, Sievers M, Dempster T and MJ Keough (2014). *Tackling a critical industry bottleneck: developing methods to avoid, prevent and treat biofouling in mussel farms.* Report prepared by University of Melbourne for Fisheries Research and Development Corporation, Australia. 77 pp.

Forrest B, Cahill P, Newcombe E and D Taylor (2014). *Marine pests and management concepts for shellfish aquaculture.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Institute, Nelson. 48 pp.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Friedman CS, Grindley R and JA Keogh (1997). Isolation of a fungus from shell lesions of New Zealand abalone, *Haliotis iris* Martyn and *H. australis* Gmelin. *Molluscan Research* 18: 313-324.

Gozlan R E; Whipps C M; Andreou D; Arkush K D (2009). Identification of a rosette-like agent as *Sphaerothecum destruens*, a multi-fish pathogen. *Internal Journal of Parasitology* 39(10): 1055-1058.

Jones JB (1977). Natural history of the pea crab in Wellington Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 11(4): 667-676.

Jones SRM and SC Dawe (2002). *Ichthyophonus hoferi* (Plehn and Mulsow) in British Columbia stocks of Pacific herring, *Clupea pallasi* (Valenciennes) and its infectivity to chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). *Journal of Fish Diseases* 25(7): 415-421.

Hewitt GC and PM Hine (1972). Checklist of parasites of New Zealand fishes and of their hosts. *New Zealand Journal of Marine and Freshwater Research* 6(1-2): 69-114.

Hine PM (1997). Health status of commercially important molluscs in New Zealand. *Surveillance* 24(1): 25-28.

Hine PM, Jones JB and BK Diggles (2000). *A checklist of the parasites of New Zealand fishes, including previously unpublished records.* NIWA Technical Report 75. 96 pp.

Hutson KS, Ernst I and ID Whittington (2007). Risk assessment for metazoan parasites of yellowtail kingfish *Seriola lalandi* (Perciformes: Carangidae) in South Australian sea-cage aquaculture. *Aquaculture* 271: 85-99.

Kent ML and TT Poppe (1998). Diseases of seawater netpen-reared salmonid fishes. Department of Fisheries and Oceans, Pacific Biological Station, British Columbia. 137 pp.

Kesarcodi-Watson A, Miner P, Nicolas JL, and R Robert (2012). Protective effect of four potential probiotics against pathogen-challenge of the larvae of three bivalves: Pacific oyster (*Crassostrea gigas*), flat oyster (*Ostrea edulis*) and scallop (*Pecten maximus*). *Aquaculture* 344: 29-34.

Kesarcodi-Watson A, Kaspar H, Lategan MJ and L Gibson (2009). Two pathogens of Greenshell™ mussel larvae, *Perna canalicuus*: *Vibrio splendidus* and a *V. coralliilyticus/neptunis*-like isolate. *Journal of Fish Diseases* 32: 499-507.

Klimpel S and S Rückert (2005). Life cycle strategy of *Hysterothylacium aduncum* to become the most abundant anisakid fish nematode in the North Sea. *Parasitology Research* 97(2): 141-149.

Kocan R, Hershberger P, Sanders G and J Winton (2009). Effects of temperature on disease progression and swimming stamina in *Ichthyophonus*-infected rainbow trout, *Oncorhynchus mykiss* (Walbaum). *Journal of Fish Diseases* 32(10): 835-843.

Labrie L, Ng J, Tan Z, Komar C, Ho E and L Grisez (2008). *Nocardial infections in fish: an emerging problem in both freshwater and marine aquaculture systems in Asia. In*: Bondad-Reantaso MG, Mohan CV, Crumlish M and RP Subasinghe (Eds.). Diseases in Asian Aquaculture VI. Fish Health Section, Asian Fisheries Society, Manila. pp. 297-312.

OIE (2013). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.9 Infection with ostreid herpesvirus 1 microvariant.* 14 pp.

OIE (2012). *Manual of diagnostic tests for aquatic animals.* http://www.oie.int/international-standard-setting/aquatic-manual/access-online/
[Website accessed August 2014].

Read GB (2010). Comparison and history of *Polydora websteri* and *P. haswelli* (Polychaeta: Spionidae) as mud-blister worms in New Zealand shellfish. *New Zealand Journal of Marine and Freshwater Research* 44(2): 83-100.

Rückert S, Klimpel S, Al-Quraishy S, Mehlhorn H and HW Palm (2009). Transmission of fish parasites into grouper mariculture (Serranidae: *Epinephelus coiodes* (Hamilton, 1822)) in Lampung Bay, Indonesia. *Parasitology Research* 104: 523-532.

Saglam N (2013). Infection of *Hysterothylacium aduncum* (Nematoda: Anisakidae) in farmed rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792). *African Journal of Agricultural Research* 8(47): 5953-5957.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Smith PJ, McVeagh SM, Hulston D, Anderson SA and Y Gublin (2009). DNA identification of ciliates associated with disease outbreaks in a New Zealand marine fish hatchery. *Diseases of Aquatic Organisms* 86: 163-167.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Symonds JE, Walker SP, Pether S, Gublin Y, McQueen D, King A, Irvine GW, Setiawan AN, Forsythe JA and M Bruce (2014). Developing yellowtail kingfish (*Seriola lalandi*) and hapuku (*Polyprion oxygeneios*) for New Zealand aquaculture. *New Zealand Journal of Marine and Freshwater Research* 48(3): 371-384.

Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M and C Sim-Smith (2007). *A review of aquatic diseases of significance to New Zealand.* Final Research Report for MAF Biosecurity New Zealand. NIWA Project No. ZBS 2005-17. 461 pp.

Waterman PB and FYT Sin (1990). Occurrence of the marine tapeworms, *Hepatoxylon trichiuri* and *Hepatoxylon megacephalum*, in fishes from Kaikoura, New Zealand. *New Zealand Natural Sciences* 18: 71-73.

Webb S (2008). *Pathogens and parasites of mussels Mytilus galloprovincialis and Perna canialiculus: assessment of the threats faced by New Zealand aquaculture.* Cawthron Report No. 1334. 28 pp.

Whipps CM, Burton T, Watral VG, St Hilaire S and ML Kent (2005). Assessing the accuracy of a polymerase chain reaction test for *Ichthyophonus hoferi* in Yukon River chinook salmon *Oncorhynchus tshawytscha*. *Diseases of Aquatic Organisms* 68(2): 141-147.

Zepeda C, Jones JB and FJ Zagmutt (2008). Compartmentalisation in aquaculture production systems. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 229-241.

5.4 AREA-BASED MANAGEMENT

In New Zealand, marine farming takes place under a coastal permit as per a regional coastal plan. There are many instances where water is shared by a number of aquaculture production units. However, as farm densities within a locale increase so too does the risk of disease (Anon 2000). Scenarios modelled by Salama and Murray (2013) indicated that, when exposed to infectious salmon anaemia (ISA) virus, larger farms separated farther apart experience lower infection incidence than smaller farms located closer together.

Since many aquatic animal pathogens can survive outside their host, they can be transported to neighbouring farms that are connected by water currents without the presence of an infected host (Peeler 2005; Salama and Murray 2013). To manage the risk of widespread transport of aquatic animal pathogens, tools have been developed at the regional level in addition to tools for farm level biosecurity (Peeler 2005). "Area-based management" describes defined areas in which farmers plan and co-ordinate production and biosecurity processes to reduce the risks posed by pathogens and parasites which can be present in the environment, in wild and farmed stock, and in other naturally occurring biota (Anon 2000; Zepeda *et al.* 2008; Code of Good Practice Management Group 2011). In this context, the term "area" was used to describe a defined region around one or several farms. The term "zoning" has been used in a similar context (Midtlyng *et al.* 2011).

Area-based management has been utilised for some time in marine finfish aquaculture. Single bay management plans were developed at salmon farm locations in Ireland during the early-to-mid 1990s (McMahon 2000). Key elements of these include agreed husbandry practices, annual and synchronous fallowing of sites, separation of generations, early harvest of two sea-winter fish and targeted sea lice treatment regimes (McMahon 2000).

Farm proximity has been identified as a risk factor in the spread of aquatic animal diseases including ISA (McClure *et al.* 2005; Gustafson *et al.* 2007; Aldrin *et al.* 2010), pancreas disease (Kristoffersen *et al.* 2009; Aldrin *et al.* 2010) and parasitism, such as sea lice and monogeneans (Anon 2000; Chambers and Ernst 2005). Such disease outbreaks and their spread have resulted in the adoption of area-based management plans worldwide (Peeler 2005), for example, farm management areas (Scotland), bay management areas (Canada), and neighbourhoods (Chile) (Salama and Rabe 2013). Midtlyng *et al.* (2011) maintained that the "re-location to increase the distance between sites; and zoning and co-ordination between farmers within a zone" were among the most important measures to prevent horizontal transmission of both ISA and furunculosis in Norway. Implementation of these measures, in conjunction with vaccination, contributed to the reduced use of antibiotics used in Norwegian finfish production (Midtlyng *et al.* 2011).

The rationale behind the management of separated and discrete units within a wider area is to create an epidemiological 'firebreak', reducing the probability of infection spread from infected to susceptible sites (Green 2010). The further positioning of both farms and management areas needs to consider whether or not they may bridge these 'firebreaks' (Anon 2000; Midtlyng *et al.* 2011). In the case of ISA, distances > 5 km between sites (farms and processing facilities) appears to be effective in reducing the probability of disease transmission (Jarp and Karlson 1997; Anon 2000; McClure *et al.* 2005). With this in mind, the Norwegian Food Safety Authority currently enforces a 5 km restricted zone and a 10 km observation zone around ISA-infected farms (Aldrin *et al.* 2011).

To prevent the spread of disease, the locational guidelines of the Scottish Executive specify a minimum distance of 8 km between finfish farms, 3 km between finfish and shellfish farms and 1.5 km between shellfish farms (Anon 2005).

To mitigate the risk of spreading pancreas disease, the Norwegian coastline has been divided into two administrative units north and south of a 10 NM section of coastline with no fish farms. This section of coast is assumed to act as an efficient barrier between an endemic south region and a disease-free north region (Bang Jensen *et al.* 2012). In terms of parasites, Chambers and Ernst (2005) recommended that a distance > 8 km was required to separate down-current farms from the monogenean *Benedenia seriolae*.

It is important to note that the defined area for area-based management should be specific to the locale taking into account water movement, occupancy of registered farm sites and relevant epidemiological studies (Anon 2000; Peeler 2005; Aquaculture Stewardship Council 2012). Hydrographically defined farm management areas in Scotland have their origins in strategies for controlling furunculosis and sea lice (Anon 2000). However, area management boundaries are never perfectly sealed and infection may still be able to occur in a pathogen-free population (Murray 2013).

New Zealand King Salmon Ltd. acknowledge that a wide geographic spread of farms is a good management strategy in salmon farming areas where disease is prevalent (New Zealand King Salmon Ltd. 2011). However, New Zealand salmon farms are widely spread, particularly in areas where water currents are slower (New Zealand King Salmon Ltd. 2011). Sim-Smith *et al.* (2014) reported that the majority of New Zealand farmers contacted appeared unaware of area-based management to manage waterborne transmission of pathogens. However, six interviewees suggested that biosecurity in New Zealand should be managed in geographic zones rather than regional council boundaries (Sim-Smith *et al.* 2014).

Area-based management is included in various best practice production standards for finfish aquaculture (Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012). Area-based management is also included in best practice production standards for shellfish aquaculture (Global Aquaculture Alliance 2013). Sim-Smith *et al.* (2014) identified the need for establishment of appropriate geographical zones for biosecurity purposes in New Zealand. These should be sufficiently separated and align with hydrographic boundaries (Sim-Smith *et al.* 2014). They also recommend the implementation of routine disease testing of stock prior to transfers between areas.

The essential elements of an area-based management agreement should be documented as follows:

- agreement of the participants;
- clear statements of the objectives;
- definition of the area and the farms included (based on local hydrodynamic conditions);
- agreement on the following specific issues:
    - general aspects of stock health and good husbandry;
    - health status of the management area inc. any official control(s) in place;
    - health status of animals to be stocked into the management area;
    - physical condition of stock to be introduced;
    - vaccines and vaccination regimes (where available);
    - veterinary input including veterinary health plans and biosecurity plans;
    - fallowing plans and protocols;

- year class separation;
- adherence to agreed stocking densities;
- movement of live stock;
- dead stock removal and disposal;
- harvesting protocols;
- escapes;
- exclusion and control of predators;
- stock inspection and independent oversight of the operation;
- records management; and
- information exchange and communication (Anon 2000; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012).

5.4.1 Conclusions

Area-based management is an important tool for the prevention and management of disease establishment and spread. This is reliant on the agreement of a co-ordinated approach by farmers.

5.4.2 Options to aid the adoption of area-based management

5.4.2.1 Objective

To manage the risk of pest and pathogen transfer into areas of higher health status (i.e. disease or pest free areas).

5.4.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

A VHP should operate at two levels:

- at the facility location; and
- among neighbouring sites and aquaculture facilities within a defined area.

The second level requires the establishment of an area-based management agreement in which facility operator's co-ordinate their activities with neighbouring facilities.

Lease sites should be located to maintain epidemiological separation of populations with different health status (e.g. different year classes).

Within management areas, personnel, equipment, and personal protective equipment should be company and facility specific.

5.4.2.3 Detailed options

Synchronisation of biosecurity practices

Where movement between marine management areas is unavoidable, cleaning and disinfection should be in accordance with standard cleaning and disinfection protocols. To control pests and diseases at the local level, facilities should establish written agreements with other producers sharing the same defined area. These agreements should cover sanitary measures in their facilities and provide basis for co-ordination of the sanitary measures to be adopted by all the producers in the area in response to outbreaks of specified pests and pathogens.

Where there is more than one aquaculture facility in a particular defined area, fallowing should be pursued in the context of the area-based management process.

Facilities within a defined area should be fallowed synchronously on a single year class basis.

An exception to the foregoing requirement may be possible. Where this is the case, the undernoted conditions should be met:

- a documented risk assessment, which considers the risks to the company's own operations and to the operations of other companies within the area and in any adjacent area, should be undertaken and management systems adopted that effectively manage risks;
- this risk assessment should include detailed information on strategies to be followed for pathogen and parasite control in the absence of fallowing; and
- the plan should have the written agreement of all other companies within the management area.

Movements within an area-based management scheme

Where a single company occupies an area, movements of stock within that management area are acceptable.

Where more than one company occupies an area and a single year class of animals is stocked within it, movements within the area should be subject to written agreement between the companies occupying the area.

There is an increased risk in areas where more than one company operates or more than one year class is present or different species are being produced. In such cases, all movements within the area should be subject to a risk assessment and the written agreement of all the companies operating within that area. Management systems adopted should effectively manage the identified risks.

Where the source or destination of the stock is subject to official movement controls, permission must be granted by MPI before any movement takes place. Applications must be submitted, along with a risk assessment, to MPI in advance of the proposed stock movement.

Stock should receive a general health and biosecurity check from the supplier on the day of loading into a transport vessel and be in good health when loaded.

The number of different sources used to stock facilities should be kept to a minimum.

Movements between area-based management schemes

All activities in which transport vessels are used to transport stock between areas should be subject to documented risk assessment.

Risk assessments should take into account the type of activity and type of vessel (particularly whether it is open or closed valve), particularly where the intention is that:

- a transport vessel will deliver stock to one or more new or fallow sites in one area, and will then go on to deliver stock to a site or sites in another area;
- a transport vessel will deliver animals to a site already containing stock, and will then go on to deliver animals to a site or sites in another area; or
- a transport vessel will collect stock from a site or sites within one area, and then go on to collect stock from a site or sites within another area.

Stock movements between areas should take place with the written agreement of other facilities within the area into which the stock are to be moved.

Where the same company is the sole operator in two different areas, it is acceptable for this company to move stock from one area to another fallow area (subject to a risk assessment).

Where the source or destination of the stock is subject to official movement controls, permission must be granted by MPI before any movement takes place. Applications must be submitted, along with a risk assessment, to MPI in advance of the proposed stock movement.

Stock should receive a general health and biosecurity check on the day of loading into a transport vessel and be in good health when loaded. This check should be documented with copies retained by both the supplier and receiver.

The number of different sources of animals used to stock facilities should be kept to a minimum.

Placement of broodstock sites

New offshore or marine-linked land-based broodstock sites should be located an appropriate distance from any production facilities. If, through a risk assessment (which gives due consideration to relevant hydrodynamic information), it can be shown that the risk of spread of pathogens is acceptable, and all farmers within the management area agree, the establishment of such a site within the management area may be acceptable.

All new facilities should be located at an appropriate distance from existing broodstock sites.

5.4.3 References

Aldrin M, Lyngstad TM, Kristoffersen AB, Storvik B, Borgan Ø and PA Jansen (2011). Modelling the spread of infectious salmon anaemia among salmon farms based on seaway distances between farms and genetic relationships between infectious salmon anaemia virus isolates. *Journal of the Royal Society Interface* 8(62): 1346-1356.

Aldrin M, Storvik B, Frigessi A, Viljugrein H and PA Jansen (2010). A stochastic model for the assessment of the transmission pathways of heart and skeleton muscle inflammation, pancreas disease and infectious salmon anaemia in marine fish farms in Norway. *Preventive Veterinary Medicine* 93: 51-61.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012). *ASC salmon standard. Version 1.0.* June 2012. 103 pp.

Bang Jensen B, Kristoffersen AB, Myr C and E Brun (2012). Cohort study of effect of vaccination on pancreas disease in Norwegian salmon aquaculture. *Diseases of Aquatic Organisms* 102: 23-31.

Chambers CB and I Ernst (2005). Dispersal of the skin fluke *Benedenia seriolae* (Monogenia: Capsalidae) by tidal currents and implications for sea-cage farming of *Seriola* spp. *Aquaculture* 250: 60-69.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Green DM (2010). A strategic model for epidemic control in aquaculture. *Preventive Veterinary Medicine* 94: 119-127.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Jarp J and E Karlsen (1997). Infectious salmon anaemia (ISA) risk factors in seacultured Atlantic salmon *Salmo salar*. *Diseases of Aquatic Organisms* 28: 79-86.

Kristoffersen AB, Viljugrein H, Kongtorp RT, Brun E and PA Jansen (2009). Risk factors for pancreas disease (PD) outbreaks in farmed Atlantic salmon and rainbow trout in Norway during 2003-2007. *Preventive Veterinary Medicine* 90: 127-136.

McMahon T (2000). Regulation and monitoring of marine aquaculture in Ireland. *Journal of Applied Ichthyology* 16: 177-181.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Murray AG (2013). Implications of leaky boundaries for compartmentalised control of pathogens: a modelling case study for bacterial kidney disease in Scottish salmon aquaculture. *Ecological Modelling* 250: 177-182.

New Zealand King Salmon (2011). *NZ King Salmon Report.* 165 pp.

Peeler E (2005). *The role of risk analysis and epidemiology in the development of biosecurity for aquaculture. In*: Walker P Lester R and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 35-45.

Salama NKG and AG Murray (2013). A comparison of modelling approaches to assess the transmission of pathogens between Scottish fish farms: the role of hydrodynamics and site biomass. *Preventive Veterinary Medicine* 108: 285-293.

Salama NKG and B Rabe (2013). Developing models for investigating the environmental transmission of disease causing agents within open-cage salmon aquaculture. *Aquaculture Environment Interactions* 4: 91-115.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Zepeda C, Jones JB and FJ Zagmutt (2008). Compartmentalisation in aquaculture production systems. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 229-241.

5.5 AUDITING

The effectiveness of biosecurity plans is reliant on their proper implementation (HDR Engineering, Inc. 2010). Along with documented standard operating procedures and good records management, facility auditing, both internal and independent, can be used to ensure and verify that biosecurity plans are being adhered to and thus limit the potential for production losses (HDR Engineering, Inc. 2010; Subcommittee on Aquatic Animal Health (SCAAH) 2016; **Chapter 5.25 Record keeping and traceability**).

Internal auditing of aquaculture production facilities can identify weaknesses in biosecurity plans and allow them to evolve and adapt (i.e. adaptive management) to maintain biosecurity best practice as risks change over time (Hinrichsen 2007; HDR Engineering, Inc. 2010). Nevertheless, it is good practice to arrange for periodic independent audits by suitably qualified aquatic health professionals (Hinrichsen 2007).

Independent audits can assist in the identification of sources, vectors and potential pest and disease agents (Maine Aquaculture Association 2002). Audit frequency can be increased for consistently poor performers which place neighbouring facilities, the industry and the environment at risk (Maine Aquaculture Association 2002; **Chapter 5.4 Area-based management; Chapter 5.1 Biosecurity (general)**).

Independent auditing of biosecurity plans (or adopted codes of practice (COP)) can be used to provide assurance to industry, consumers, other stakeholders and the general public that the facility is a responsible user of the aquatic environment (Code of Good Practice Management Group 2011).

A biosecurity audit can have several objectives, including:

- ensuring the proper implementation of biosecurity plans;
- ensuring the maintenance of appropriate, up-to-date records;
- ensuring the traceability of aquaculture stock (e.g. for epidemiology purposes);
- determining the effectiveness of measures specified in the biosecurity plans;
- assisting in the update of biosecurity plans (e.g. identification of weaknesses in existing standards as risks change over time); and
- assisting in communication between the aquaculture facility, industry, authorities, and stakeholders (Maine Aquaculture Association 2002; Hinrichsen 2007; HDR Engineering, Inc. 2010; SCAAH 2016).

The salmon, mussel and oyster industries have codes of practices that address aspects of on-site biosecurity (Aquaculture New Zealand (AQNZ) 2007ab; New Zealand Salmon Farmers Association 2009). All members of the New Zealand Salmon Farmers Association must comply with the salmon industry COP however this is not subject to external auditing (Sim-Smith *et al.* 2014).

AQNZ (2007a) committed to developing an auditing system to support the implementation of their COPs:
"AQNZ will use audit results to identify how well the industry is performing against the targets and objectives contained in this Code. Where results show that targets contained in this Code are not being met, AQNZ will (where possible) implement additional actions to achieve targets. AQNZ will also use auditing outcomes to update future revisions of this Code."

Compliance with the mussel and oyster farmers COP remains voluntary although, participants are audited by AQNZ and the list of complying participants is publicly available (Sim-Smith *et al.* 2014). Four farmers interviewed by Sim-Smith *et al.* (2014) reported that while they were aware of the COPs, they had not read them. All three COPs are in the process of being revised.

Sim-Smith *et al.* (2014) also recommended the biosecurity certification and auditing of hatcheries to minimise the distribution of pests and diseases.

5.5.1 Conclusions

The proper implementation of biosecurity plans is key to their effectiveness. Facility auditing, both internal and independent, can be used to ensure and verify that biosecurity plans are being adhered to and thus limit the potential for production losses

The importance of independent auditing is paramount to the preventive management of pests and diseases. This may be achieved through on-farm contracting of suitably qualified aquatic health professionals with a complementary Government auditing programme (**Chapter 5.23 Preventive practices (surveillance and vaccination)**).

5.5.2 Options to aid on-farm auditing

5.5.2.1 Objective

To ensure the facility biosecurity plan continues to address biosecurity risks effectively and efficiently.

5.5.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

The biosecurity plan should be implemented at all times and actions taken be verifiable by record keeping (e.g. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/278578/Finfish_biosecurity_logbook.pdf).

The facility biosecurity plan should include a schedule for routine review and identify any triggers for extraordinary review.

Audit of the facility biosecurity plan should be conducted to ensure it is being implemented effectively.

5.5.2.3 Detailed options

Facilities should have a suitably qualified staff member to audit the implementation of biosecurity plans. This person should be mandated with the authority to take immediate action as required. Responsibilities should include:

- ensuring that the other employees are aware of their roles and responsibilities under these plans;

- monitoring the implementation of best practices under these plans;
- informing all parties of aspects or conditions that could result in unacceptable biosecurity risk so that these may be addressed as required;
- documenting and maintaining records for all matters pertaining to the implementation of these plans; and
- updating of these plans.

Facilities should undergo a yearly independent audit of their biosecurity plans. The agent should be a certified veterinarian (or equivalent) and the audit should be conducted using approved and accepted procedures.

5.5.3 References

Aquaculture New Zealand (2007a). *Greenshell™ mussel industry environmental code of practice.* New Zealand Mussel Industry Council Limited, 1999 (Revised, June 2007 by Aquaculture New Zealand). 82 pp.

Aquaculture New Zealand (2007b). *New Zealand oyster industry code of practice.* 51 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

HDR Engineering, Inc. (2010). *Illinois aquaculture biosecurity manual.* Prepared for Southern Illinois University Carbondale Fisheries and Illinois Aquaculture Center. 177 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Maine Aquaculture Association (2002). *Recommended code of practice for aquaculture in Maine.* 35 pp.

New Zealand Salmon Farmers Association Inc (2009). *Finfish aquaculture environmental code of practice. Version 2.* Date of issue: 22 Dec 2009. Nelson, New Zealand. 26 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

5.6 BIOFOULING MANAGEMENT (FINFISH)

5.6.1 General

Surface biofouling occurs when biofouling organisms encounter a surface in a state that is suitable for attachment. Complex interactions take place between abiotic and biotic factors. These interactions include the season of first submersion, length of submersion, surface type and light availability (Terlizzi and Faimali 2010). 'Pioneering' macrofoulers typically include green filamentous algae, barnacles, tubeworms and bryozoans (Hilliard *et al.* 2006; Lewis and Coutts 2010).

Hilliard *et al.* (2006) suggested the following common successional pattern in coastal waters:

- primary slime layer with grey and green tinges that vary with diatom content and light;
- gossamer-like amphipod tubes (dependent on season and level of water movement);
- filamentous green algae that can develop into waterline or transom beards providing shelter to amphipods and other clinging biota;
- encrusting bryozoans;
- tubeworms, barnacles, turfing red algae, hydroids, erect bryozoans, ectocarpoid brown algae;
- mussels, oysters, encrusting sponges, sea anemones and sea squirts; and
- larger mobile forms, including errant polychaetes, crabs, whelks, nudibranchs, crinoids and territorial fishes.

In temperate environments, the intensity of recruitment of biofouling organisms tends to be seasonal and limited during colder periods of the year (Floerl *et al.* 2010). However, diverse biofouling assemblages can develop on surfaces in temperate marine environments within four weeks (Floerl *et al.* 2010). Even after short periods of immersion (1-2 weeks) large abundances of well-known biofouling groups such as barnacles, bryozoans, and tubeworms, can occur (Floerl *et al.* 2010).

The production infrastructure for aquaculture provides a habitat for the settlement of biofouling organisms (Bruno 1987; Fitridge *et al.* 2012; Inglis *et al.* 2013). Typically, the biofouling on aquaculture infrastructure is dominated by sessile, suspension-feeding organisms, including barnacles, bivalves, bryozoans, polychaetes, ascidians, hydroids, sponges and algae (Bruno 1987; New Zealand King Salmon Ltd. 2011; Fitridge *et al.* 2012; Woods *et al.* 2012).

Substantial economic costs to industry, conservatively estimated at between 5 and 10% of production costs, are associated with biofouling control. This illustrates the need for effective preventive technologies and mitigation methods (Fitridge *et al.* 2012). Several incursions of non-indigenous biofouling organisms into New Zealand have also affected production and costs to the aquaculture industry or have had the potential to do so (Bell *et al.* 2011; Woods et al. 2012; Inglis *et al.* 2013). These include the ascidians *Styela clava, Didemnum vexillum, Ciona intestinalis* and *Eudistoma elongatum,* macroalgae *Undaria pinnatifida,* and the tubeworm *Sabella spallanzanii*.

Biofouling organisms may also harbour pathogens whose spread may be facilitated by activities within the aquaculture industry (Meyers 1984; Olafsen *et al.* 2001; Anon 2005; Fitridge *et al.* 2012; Inglis *et al.* 2013).

The establishment and transfer of biofouling species is associated with the aquaculture industry via:

- the provision of habitat on production structures;
- industry associated vessels;
- movements of mobile structures;
- movement of spat, seed-stock or adult product and associated equipment;
- deployment and retrieval of equipment; and
- waste discharged from processing facilities (Inglis *et al.* 2013).

A range of vessel types are used by the New Zealand aquaculture industry including mussel harvesters and seeding vessels, tug boats, finfish transporters, barges, small launches, water taxis and dinghies (Inglis *et al.* 2013). The amount of biofouling present on the submerged vessel surfaces is dependent on their operating profile, the antifouling measures employed and the vessel maintenance schedule (Bell *et al.* 2011).

In addition, movements of aquaculture stock and equipment represent significant pathways for the translocation of biofouling and associated "hitchhiker" organisms (Inglis *et al.* 2013).

The codes of practice (COP) developed for each of the three main New Zealand industries (mussel, salmon and oyster) attempt to address the problem of biofouling and non-indigenous species to varying degrees (Aquaculture New Zealand 2007a; Aquaculture New Zealand 2007b; New Zealand Salmon Farmers Association 2009).

Recently, Sim-Smith *et al.* (2014) investigated the concerns and perceptions of biofouling species on New Zealand aquaculture. The majority of respondents were at least moderately concerned about managing pest species on their farms (Sim-Smith *et al.* 2014).

In terms of production of freshwater salmonids, didymo (*Didymosphenia geminata),* other microalgae and aquatic plant species were of concern (Sim-Smith *et al.* 2014). The majority of questionnaire respondents checked for the presence of pest species on their farms at least monthly, with half of the questionnaire respondents removing biofouling from their farms at least quarterly. The majority of respondents that do remove biofouling species leave the waste to disperse through the water on-site (Sim-Smith *et al.* 2014).

Many of the known methods used overseas to manage the risk of pest entry (e.g. influent water treatment, division of facilities into discrete units) were considered by New Zealand freshwater farmers to be either impractical or unnecessary (Sim-Smith *et al.* 2014). The results from the seawater salmonid industry indicated that they share equipment and vessels between farms (Sim-Smith *et al.* 2014).

5.6.2 Impacts to finfish aquaculture

The impacts of biofouling on finfish aquaculture are typically associated with infrastructure resulting in:

- restriction of water exchange;
- increased disease risk; and
- deformation of cages and structures (Fitridge *et al.* 2012).

5.6.2.1 Restriction of water exchange

Net occlusion can lead to poor water quality within the cages (e.g. lowered dissolved oxygen levels and restricted elimination of wastes) (Bruno 1987; Braithwaite *et al.* 2007; New Zealand King Salmon Ltd. 2011; Fitridge *et al.* 2012).

5.6.2.2 Increased disease risk

Poor water quality, as a result of the restriction of water exchange, may increase stock vulnerability to pathogens due to the physiological changes associated with chronic stress (Meyer 1991; Georgiadis *et al.* 2001; Johnston and Jungalwalla no date). In South Australia, a build up of polychaete worms (alternate host for sanguinicolid worms) in the nutrient rich detritus under cages has been implicated in increased tuna mortalities due to *Cardicola* sp. infection (Cribb *et al.* 2011). There have also been instances where the fouling organisms themselves have had direct impacts by their settlement on the finfish produced. For example, the attachment of mussels to the gill epithelium of Atlantic salmon leading to mortalities and a failure to thrive (Bruno 1987).

Filter feeding organisms take in particles (including viruses and bacteria) suspended in seawater or adsorbed onto the surfaces of organic and inorganic solids. These invertebrates may serve as vectors for transmission of fish pathogens, for example, horizontal transmission of *A. salmonicida* has been demonstrated through co-habitation studies of molluscs and salmonid species (Bjørshol *et al.*, pers. comm. in Mortensen 2000; Starliper and Morrison 2001; Starliper 2005)**.** Further, infectious pancreatic necrosis virus (IPNV) has been isolated from both scallops *Pecten maximus* (Mortensen *et al.* 1992) and mussels *Mytilus edulis* (Mortensen 1993). IPNV has been found to accumulate in shellfish at titres similar to those observed in clinically infected fish (two to three hundred fold greater than those in seawater or wild fish) (FRS unpub data in Raynard *et al.* 2007). Although, little is known about the release of viruses from invertebrate reservoirs (Raynard *et al.* 2007), Mortensen (2000) suggests that bivalves should still be considered potential vectors of fish pathogenic viruses. Further, Anon (2003) concluded that the presence or abundance of carrier shellfish may influence the risk of IPNV transfer to susceptible fish species. They concluded that fouling should be regularly removed as a precautionary measure (Anon 2003). However, not all pathogens may be as transferred by filter feeding biofouling, for example, Skår and Mortensen (2007) concluded that mussels are not a likely reservoir host or vector for infectious salmon anaemia virus, as the virus is rapidly inactivated by them.

The occurrence of finfish pathogens in common bivalves indicates that these organisms may introduce finfish diseases when transported to other waters (Meyers 1984; Mortensen *et al.* 1992; McAllister and Owens 1995; Mortensen 2000; Olafsen 2001; Anon 2003; Anon 2005). Bivalves are well known components of biofouling assemblages on both vessels (Bell *et al.* 2011) and aquaculture infrastructure (New Zealand King Salmon Ltd. 2011; Woods *et al.* 2012). Howard (1994) recorded an instance whereby a possible transfer of an aquatic molluscan disease (*Bonamia ostreae*) occurred via the biofouling of concrete barges. These barges had been moored in the centre of the area of the original *Bonamia* outbreak in England and had live molluscs on them upon arrival at the destination. The recipient area had no previous history of the disease or any reason to receive live oyster transfers for aquaculture purposes (Howard 1994). It has been speculated that *B. ostreae* has previously been spread via vessel biofouling in the Netherlands and Ireland (Van Banning 1991; Culloty and Mulcahy 2007).

Further molluscan biofouling on vessels hulls has been suggested to be the pathway for introduction of ostreid herpesvirus microvariant 1 into Australia (Fisheries Research and

Development Corporation 2011). This disease halved Pacific oyster production in New Zealand (Johnston 2014). The spread of the oyster parasite *Marteilioides chungmuensis* has also been associated with vessel biofouling due to its restriction to wharves in the ports of Darwin (Australia), and Eureka (USA) (Tubbs *et al.* 2007).

5.6.2.3 Deformation of structures

The extra weight imposed by fouling may lead to cage deformation and structural fatigue or failure which contributes to maintenance costs (Braithwaite *et al.* 2007; New Zealand King Salmon Ltd. 2011; Fitridge *et al.* 2012). Such impacts to infrastructure may also increase the likelihood of fish escapes, for example, reports by fish farming companies to the Norwegian Directorate of Fisheries during the period from September 2006 to December 2009 indicate that the majority of Atlantic salmon escapes were due to structural failures of equipment (Jensen *et al.* 2010). Structural fatigue was indicated as a component of these failures (Jensen *et al.* 2010).

5.6.3 Control

Commercial fish farm operations usually employ a multifaceted approach to controlling net fouling as reviewed by Fitridge *et al.* (2012). These approaches include:

- net changing and cleaning;
- application of antifouling paints; and
- biological control measures.

5.6.3.1 Net changing and cleaning

As the "grower nets" for holding salmon in the sea pens are not typically treated with antifouling products they need to be cleaned approximately once a month (New Zealand King Salmon Ltd. 2011). Automated *in situ* cleaning of nets is in widespread global use (e.g. Tasmania, Norway) (Fitridge *et al.* 2012; Inglis *et al.* 2013). In New Zealand, New Zealand King Salmon Ltd. have an *in situ* in-water cleaning system that employs high-pressure water-blasting and rotating discs. This system is used to clean their larger and newer grower nets (New Zealand King Salmon Ltd. 2011). Alternatively, nets are spread and lifted above the water, water-blasted and left to dry (New Zealand King Salmon Ltd. 2011). The biofouling removed from the nets is not contained, the discharge of which is covered under the resource consent (New Zealand King Salmon Ltd. 2011; Inglis *et al.* 2013).

Practices that return viable fouling organisms removed from the structures into the environment may contribute to subsequent fouling problems (Inglis *et al.* 2013). Ideally disposal of waste material to an approved site on land, as per the oyster industry (Aquaculture New Zealand 2007b), should occur. However, the practicalities of this need to be explored (Inglis *et al.* 2013).

Land based treatment facilities should contain and separate solids from liquids for disposal (National System for the Prevention and Management of Marine Pest Incursions (NSPMMPI) 2013). Untreated waste should not be returned to the marine environment at a location different to where biofouling was acquired (NSPMMPI 2013).

Predator nets, typically coated in a copper-based antifouling paint, are processed by New Zealand King Salmon Ltd. through a mussel crusher to remove the larger biofouling

organisms (New Zealand King Salmon Ltd. 2011). The remaining biofouling is removed following drying on land. However, *in-situ* cleaning of predator nets may occur when:

- fouling impacts on water flow through the sea pens;
- unexpected fouling has added dangerous levels of weight to the nets; or
- prior to moving farms locally for fallowing purposes (New Zealand King Salmon Ltd. 2011; Mark Gillard, New Zealand King Salmon Ltd, pers. comm. in Inglis *et al.* 2013).

Although in the case of the latter not all biofouling is removed, it is not economically viable to remove the entire farm from the water to clean it prior to local movement (Mark Gillard, New Zealand King Salmon Ltd., pers. comm. in Inglis *et al.* 2013).

For non-local movements, NSPMMPI (2013) recommend that all net cages and other equipment be soaked in fresh water for at least two hours or washed in a specialised net-washing machine. This should be followed by at least 12 hours of air drying (NSPMMPI 2013). Similarly, Inglis *et al.* (2013) recommend that manual cleaning is followed by desiccation or disinfection prior to movements outside the local production area.

The Scottish finfish code of practice (Code of Good Practice Management Group 2011) recommends that all removable items, including cage nets, should be cleaned and disinfected before being moved to another location. A fallow period of at least four weeks before reuse is also recommended (Code of Good Practice Management Group 2011). These recommendations also appear to cover the risk of pathogen spread.

Net changing requires a large number of nets, staff and infrastructure. The process can reduce net life-span or necessitate repairs. Frequent net changes may result in disturbance to feeding regimes, reduced growth rates and stock losses (Fitridge *et al.* 2012).

5.6.3.2 Evaluation of cleaning options

High pressure washing

High pressure water blasting is a feasible, low cost method of treating some forms of biofouling on infrastructure, however is not 100% effective at removing all biofouling organisms (Inglis *et al.* 2013). Higher pressures (at least 2000 psi for 2 seconds at 100 mm distance) may be required to dislodge biofouling material from fissures and crevices in addition to difficult to remove biofouling (e.g. *U. pinnatifida* gametophytes) (Inglis *et al.* 2013; NSPMMPI 2013). Organisms capable of regeneration (e.g. *D. vexillum*) may be spread as a result of the creation of large numbers of fragments (Inglis *et al.* 2013).

Some of the remaining fragments from *in situ* cleaning can quickly regenerate into reproductively viable organisms (Forrest *et al.* 2011). *In situ* cleaning can also trigger larval release leading to the rapid recolonisation of structures (Fitridge *et al.* 2012). As such, additional treatment methods may be required (e.g. desiccation, chemical disinfection) (NSPMMPI 2013). Removal of infrastructure and equipment from the water prior to treatment is the most effective method to contain pest organisms and fragments (NSPMMPI 2013).

Desiccation

Marine organisms have a wide range of tolerances to aerial exposure, thus the efficacy desiccation varies and depends on factors such as exposure duration, temperature, humidity and sunlight (Hilliard *et al.* 2006; Inglis *et al.* 2013; NSPMMPI 2013). Biofouling extent may also influence treatment efficacy as large fouling masses can retain moisture extending the survival of organisms within the biomass (Inglis *et al.* 2013).

Ideal conditions consisting of high ambient temperatures, low humidity, direct sunlight, and complete exposure to air will render most marine organisms non-viable within 7 days (NSPMMPI 2013). However, Hilliard *et al.* (2006) recommend at least 21 days is required to ensure that all organisms die. In agreement, MPI recommends that prior to movement, equipment should be removed from the water for a month to thoroughly air-dry. During this time ropes and equipment should be laid out in a manner that allows all surfaces to dry completely (MPI 2013).

Organisms are likely to re-establish and be translocated if dried fouled structures are returned to the water without fouling removal. For example, macroalgae, including *U. pinnatifida*, release spores following periods of desiccation (Inglis *et al.* 2013).

Heat treatment

The efficacy of heat treatment is dependent on the temperature achieved, fouling mass and exposure duration. For example, soft bodied organisms may be treated at moderate temperatures (e.g. 30-40°C), whereas hard shelled organisms (e.g. barnacles and bivalves) and resistant life-stages will require hotter treatments (50-70°C) (Inglis *et al.* 2013). Heat treatment is more effective if there is a large difference between the surrounding and treatment temperatures. Therefore, heat treatment appears to be more effective during winter as pests are conditioned to colder temperatures (NSPMMPI 2013). The Scottish finfish COP recommended protocol for heat treatment of nets is immersion of the entire net to a temperature of more than 65°C for at least 10 minutes. However, heat treatment of nylon nets above 71°C can significantly affect their breaking strain (Code of Good Practice Management Group 2011).

Application of heat treatment is suitable for simple, uniform structures. Treatment of complex surfaces can be time consuming and costly due to practical difficulties in maintaining the required temperature (Inglis *et al.* 2012; Inglis *et al.* 2013).

Freshwater treatment

The use of osmotic shock (e.g. freshwater solutions) has been recommended as an effective marine biofouling treatment option by both New Zealand and Australian government agencies (MPI 2013; NSPMMPI 2013). MPI recommend that prior to equipment transfers equipment be soaked in freshwater for 72 hours. For some equipment, such as ropes, it is important that fresh water is replaced after 12 hours to ensure the water does not remain brackish (MPI 2013). Biofouling species that are susceptible to changes in salinity can be treated by immersion in freshwater for 12 hours (NSPMMPI 2013). Previous studies have shown that mortality of all biofouling species on vessels following immersion in freshwater is difficult and time consuming (Brock *et al.* 1999; Davidson *et al.* 2008). Inglis *et al.* (2012) estimated that it may take up to 14 days to achieve 100 % mortality.

Chemical treatment

Decisions regarding use of chemical treatments must consider the efficacy, costs (including regulatory compliance), environmental impact and impacts on stock production and marketability (Inglis *et al.* 2013). Treatment efficacy will vary according to the type of organism being targeted and the treatment type, concentration and duration (Inglis *et al.* 2013).

Investigations into methods for treating biofouling organisms have generally examined four chemicals:

- acetic acid;
- hydrated lime;
- sodium hypochlorite; and
- alkaline ammonia (Forrest *et al.* 2007; Inglis *et al.* 2013; MPI 2013; Fitridge *et al.* 2014).

For example, prior to equipment transfer MPI recommend either of the following practices to manage the risk of transfer of biofouling species:

- soak the item in a 2% bleach and freshwater solution for 30 minutes; or
- soak the item in a 4% acetic acid and freshwater solution for 10 minutes (MPI 2013).

Disinfection procedures for equipment are a standard practice used globally in the aquaculture industry to prevent the spread of microbial pathogens. Many of these procedures will also be useful in reducing the risk of transfer of fouling macroorganisms (Inglis *et al.* 2013). For example, prior to equipment transfer MPI recommend immersion for 30 minutes in a 2% Decon 90 detergent and freshwater solution (MPI 2013).

Antifouling paints

A range of antifouling products may be used to prevent or reduce biofouling on farm infrastructure (e.g. farm barges, cage pontoons), vessels and nets (New Zealand King Salmon Ltd. 2011; Inglis *et al.* 2013; Morrisey *et al.* 2013). Copper-based antifouling paints are the most widely used in marine finfish aquaculture (Burridge *et al.* 2010; New Zealand King Salmon Ltd. 2011; Inglis *et al.* 2013).

In temperate regions, copper-based antifouling paints have been shown to be effective during periods of high fouling pressure (i.e. summer) and offer > 6 months protection (Braithwaite *et al.* 2007; Fitridge *et al.* 2012). While elevated copper concentrations inside antifouled pens have been reported, industry best practice dictates that nets should be seasoned for 1 month prior to the introduction of fish (Fitridge *et al.* 2012). The Aquaculture Stewardship Council (2012) recommends not cleaning copper treated nets in the aquatic environment and requires that land-based cleaning facilities have the appropriate effluent treatment in place.

A perception also exists regarding the use of biocidal antifouling paints being at odds with the ‘clean and green’ marketing perspective that often accompanies products of marine aquaculture (Fitridge *et al.* 2012). New Zealand King Salmon Ltd. (2011) is investigating the reduction or stopping of antifouling paint use on predator nets.

For vessels, correct choice, application and maintenance of antifouling paints can minimise biofouling. Application and maintenance should follow the manufacturer’s instructions and take the vessel operating profile into account. Maintenance includes regular inspection and

removal of biofouling in dry-docking facilities or by in-water cleaning as appropriate (Bell *et al.* 2011; Inglis *et al.* 2013; Morrisey *et al.* 2013).

Vessels (< 45 m) used for marine aquaculture are likely to be required to comply with the safe ship management requirements provided under Maritime Rule Part 21 Section 2 (Maritime New Zealand 2011a). According to Rule 46.17, this includes out-of-water inspections of the hull and external fittings below the waterline at intervals not exceeding 2 years (Maritime New Zealand 2011b). Although these inspections concern the structural integrity and safety of the vessel, some biofouling is likely to be removed to allow a thorough inspection. As such, these inspections may provide the opportunity to clean and antifoul the vessels as appropriate (Inglis *et al.* 2013).

Biological control

Attempts to use herbivorous fish or invertebrates have been largely small-scale or experimental in nature and have achieved variable results (Fitridge *et al.* 2012; Inglis *et al.* 2013).

5.6.4 Land-based farms

New Zealand land-based marine farms and hatcheries typically have seawater intakes and discharges which are under the consent of regional authorities. These consents vary in terms of treatment at intake and discharge (Inglis *et al.* 2013).

NSPMMPI (2013) recommends that seawater intakes at hatcheries meet or exceed a minimum filtration level of 20 µm. The larval stages of most biofouling organisms will be excluded by this level of filtration (McClary and Nelligan 2001; Morrisey *et al.* 2013; NSPMMPI 2013).

Vectors for transport of fouling organisms into and out of land-based marine aquaculture include:

- collection and translocation of broodstock;
- acquisition and discharge of waters that contain harmful organisms;
- transfer of aquatic life or equipment from one fish farm to another farm;
- transfer of stock or equipment to marine grow-out farms; and
- disposal or releasing of unwanted material into the wild (Inglis *et al.* 2013).

The vectors for transport of fouling organisms into and out of land-based freshwater aquaculture facilities are similar to those listed above for land-based marine aquaculture. In terms of production of freshwater salmonids in New Zealand, didymo (*D. geminata),* other microalgae and aquatic plant species appeared to be the pest species of concern (Sim-Smith *et al.* 2014).

Didymo was first reported in the Lower Waiau River in 2004. It is now found in over 150 South Island rivers, but not yet in the North Island (http://www.biosecurity.govt.nz/pests/didymo). To combat the spread of didymo and other freshwater pests MPI have released various guides for the cleaning of gear and equipment based on the principles of "check, clean and dry" (http://www.biosecurity.govt.nz/cleaning). Further, some producers of freshwater salmonids treat eggs from didymo-positive areas before transfer to didymo-negative areas (Sim-Smith *et al.* 2014).

The risk posed by New Zealand land-based facilities with respect to the translocation of biofouling or pest organisms is unknown. However, existing approval processes through Department of Conservation and MPI for stock transfers to and from these facilities and for effluent and waste discharge into the environment could be strengthened. Effective risk management plans should be developed during the consent process to minimise the risk (Inglis *et al.* 2013).

5.6.5 Conclusions

Biofouling of infrastructure, vessels and live-stock is recognised as having the potential for wide ranging impacts to finfish aquaculture. Management actions are required to minimise the risks to and from the aquaculture industry and the environment.

5.6.6 Options to minimise the risks associated with biofouling

5.6.6.1 Objective

To manage the risk of transferring pests and pathogens onto, within and from the facility via equipment, structures, vehicles and vessels, etc.

5.6.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All facility inputs, throughputs and outputs (e.g. stock, equipment, staff, procedures, vehicles and vessels) should be assessed for potential biosecurity risks.

Aggregation of fouling organisms on or near production units should be limited.

Procedures and infrastructure should be in place to clean and disinfect stock, equipment, vehicles or vessels. All gear and structures should be cleaned before transfer between facilities, management areas or regions. Cleaning should be to a standard that ensures that biofouling species (and their propagules within) are eliminated. These should incorporate a staged approach relative to risk.

MPI should be contacted (0800 80 99 66) in all instances where an unfamiliar species is encountered. If possible, samples of these organisms should be collected for identification. Disposal of exotic or unwanted marine species should follow relevant protocols, as specified by the jurisdiction.

5.6.6.3 Detailed options

General biosecurity

Facilities should be aware of the locally important, invasive, rare and endangered species and record organisms observed at the facility location (e.g. date, identification, abundance).

Notable occurrences of biofouling organisms should be recorded and documented (e.g. date, identification, photographs).

Facility staff should be trained to monitor for and identify biofouling or pest organisms when they are inspecting live-stock and inspecting and cleaning, structures, equipment and vessels, etc.

Facility structures and equipment should undergo regular maintenance and cleaning to manage the occurrence of biofouling.

Shorelines or river banks adjacent to facilities should be monitored for occurrence of new and established non-indigenous species. MPI should be contacted (0800 80 99 66) in all instances where an unfamiliar species is encountered.

Any materials and equipment (e.g. floats, nets, anchors) that is no longer required should be removed from the environment.

The amount of organic material discarded into the environment should be minimised.

Materials and equipment should be cleaned onshore and fouling materials disposed of in an appropriate land based facility.

Biofouling should not be permitted to build-up on pen nets to a level that impairs water flow through the mesh.

Nets should be checked often for damage, holes or excessive biofouling. Remedial action should be taken immediately to rectify any problems.

Clean netting coated with an antifoulant in line with the New Zealand antifouling and in-water cleaning guidelines, regional council requirements and any criteria the Environmental Protection Authority sets.

Recoat equipment with antifoulant before re-use in accordance with New Zealand antifouling and in-water cleaning guidelines, regional council requirements and any criteria the Environmental Protection Authority sets.

Hatchery produced stock for transfer to grow-out facilities or re-stocking around New Zealand should be managed to reduce the risk of transfer of biofouling organisms.

Biosecurity attestation of hatcheries, land-based facilities and wild broodstock should be put in place due to the potential to spread pest organisms quickly to multiple locations.

Land-based facilties

Facilities should have effective systems to prevent the entry of aquatic macro-organisms.

Intake water for facilities should meet or exceed a minimum filtration level of 20 µm.

Inlet and outlet pipes should be widely separated to avoid recirculation of effluent.

Inlet and outlet piping should be designed so that they can be cleaned (pigged) from the outside into the facility rather than the effluent being discharged into the environment.

Culture units, intake and discharge pipes should be cleaned regularly to prevent the build-up of organic matter and fouling organisms.

Grates for inlet and outlet in pipes and tanks should be inspected regularly for holes or fouling. Remedial action should be taken immediately if needed.

Settlement tanks and ponds should be regularly treated to kill biofouling.

Methods of removal

Removal of biofouling organisms should be achieved via methods, such as:

- desiccation in air;
- freshwater immersion (e.g. marine species);
- brine immersion;
- combined treatment (e.g. freshwater treatment followed by desiccation in air);
- high pressure blasting (e.g. freshwater, salt water, hot water);
- separation of liquids and solids from biofouling waste;
- chemical treatment (e.g. chlorine, hydrogen peroxide);
- heat treatment;
- manual control (e.g. gear should be cleaned frequently when fouling is slight rather than waiting until the fouling is difficult to control); or
- onshore cleaning (e.g. fouling material should be disposed of in an approved manner, such as landfill or other public disposal facility).

Vehicle and equipment disinfection

Trucks, hauling tanks, pumps, nets, buckets, waders, or anything that may come in contact with the delivery site water should be inspected, cleaned and disinfected prior to coming back on the facility.

The vehicles for transporting fish, eggs or gametes, by land, air or water, should be washed and disinfected by trained personnel before and after each transport.

All fixtures and fittings (e.g. aeration equipment, pipe-work) should be dismantled and disinfected.

Vehicles should be designed and constructed so as not to cause contamination of fish contained within them.

Surfaces coming into contact with the fish should be made of corrosion-resistant material that is smooth and easy to clean and disinfect.

Reusable plastic boxes or pallets should be maintained in good condition (i.e. minimal abrasions and scratches) and cleaned and disinfected after use.

Boxes or pallets made from material that is difficult to clean and disinfect (e.g. porous material) should be for ‘single use’ only.

Boxes or pallets returned to the distribution or holding yard, together with those which may have been contaminated in transit, should be kept in a designated dirty area for disinfection or disposal. Documented evidence of disinfection should be obtained from the transport company.

Fit cleaned nets, where possible, before towing net pens between facilities or to land-based harvest facilities.

Diving equipment

Where possible, each site should have its own diving equipment.

Where divers are operating on different production areas or sites, documented cleaning and disinfection procedures should be followed before and after diving work takes place.

Facilities should check and record the fact that cleaning and disinfection procedures have been followed before and after diving takes place.

Dirty and disinfected diving suits and equipment should be kept separate at all times.

Vessel biofouling

Hull cleaning, antifouling and vessel maintenance

An antifouling coating supplier should be contacted for advice on the selection of the most appropriate coating system, based on:

- vessel operating location;
- vessel type and operating conditions; and
- vessel construction (e.g. wood, steel, aluminium).

Antifouling products should be applied and removed at designated onshore facilities.

Procedure for applying and removing antifouling products should be in accordance with manufacturer's instructions and follow regional council regulations and the New Zealand antifouling and in-water cleaning guidelines.

The hull should be regularly maintained, according to the antifouling paint manufacturer's instructions, to prevent the build-up of macrofouling.

Biological matter removed during hull cleaning should be contained or collected, and treated and disposed of at onshore facilities. If conducting hull servicing independently, the relevant permits to discard biological matter should be obtained.

Antifouling should be renewed according to the minimum frequency recommended by the paint manufacturer.

The effectiveness of antifouling coatings on vessels should be regularly monitored and if necessary the hull should be cleaned and the antifouling re-applied.

Unpainted surfaces should be regularly inspected.

If unpainted surfaces (e.g. echo sounders) are fouled, any biological matter should be removed and disposed of at onshore disposal facilities.

Preventive treatment should be applied to unpainted surfaces, for example, commercially available greases or other specified coatings can be applied to surfaces, such as propellers, to help keep them clean.

Vessels that have been stationary for periods of 30 days or more and have not been cleaned or antifouled within the previous six months should be inspected for exotic or unwanted species prior to relocating. All exotic or unwanted species found during the inspection should be removed from the hull before departure and disposed of.

Records of any hull maintenance and antifouling coatings applied should be maintained. Records may include antifouling product invoices (e.g. paint brand and type), place and date of application, date of renewal and a record of any official inspection carried out (e.g. at survey).

All vessels

Facility vessels should have (appropriate to the size of the vessel):

- unwanted and exotic species identification charts;
- sealable plastic bags or other sample containers to hold suspect specimens removed from equipment, crop or vessels; and
- instructions on how and where to send samples.

Facility staff should be trained to monitor for and identify unwanted or exotic species when they are inspecting and cleaning live-stock, vessels and equipment. MPI should be contacted (0800 80 99 66) in all instances where an unfamiliar species is encountered.

Transport vessels

Hull inspections of transport and accommodation vessels should occur at monthly intervals.

Where possible, niche areas should be physically covered to discourage the establishment of biofouling.

The use of sealed cooling systems in vessels should be adopted.

Vessels moving from site to site should be inspected for fouling before each departure.

Transport vessel live holding systems and engine cooling systems should be flushed and disinfected before each transport.

Maintaining trailered vessels onshore

Entangled or attached biological matter (e.g. seaweeds) should be removed from the vessel and trailer.

The outboard and hull fixtures that could harbour potential unwanted or exotic species (e.g. trim outboard down to let water out of the gearbox housing) should be monitored.

Mooring lines that have biofouling attached should be cleaned and dried.

Warps and anchors should be cleaned of biological matter, mud and sand.

Anchor and chain wells and lockers should be cleaned.

Marine vessels should be rinsed inside and out with freshwater, drained and allowed to dry prior to moving to another location.

Freshwater vessels should be rinsed inside and out, drained and allowed to dry prior to moving to another location.

Live tanks and wells for pests or biological matter should be cleaned and disinfected.

Any biological matter, including known unwanted or exotic species, should be disposed of in bins or to landfill so that it cannot be returned to the water.

Maintaining non-trailered vessels and vessels that have raw water internal water systems

The hull should be regularly maintained, according to the antifouling paint manufacturer's instructions, to prevent the build-up of macrofouling.

For marine vessels, treat internal water systems by cleaning intake and outlet points and by periodic flooding with freshwater or approved biocides prior to moving between regions.

For freshwater vessels, treat internal water systems by cleaning intake and outlet points and by periodic chemical treatment by approved biocides prior to moving between regions.

Conduct hull cleaning at a designated onshore facility (e.g. marina or slipway with waste trapping facilities).

Dispose all biological matter that is removed from the vessel at onshore facilities so that it cannot be returned to the water.

Potential refuge space that could harbour unwanted or exotic species should be regularly inspected, cleaned, and where possible, allow to dry (e.g. live well, anchors, anchor and chain wells, propellers, sacrificial anodes, strainer boxes, around external keel pipes, raw water intakes, sea chests).

Mooring lines that have biofouling attached should be cleaned and dried.

Warps and anchors should be cleaned of biological matter, mud and sand as they are hauled.

Waste

All facility waste, including materials, equipment, should not be disposed of into the consent area or into water. Disposal should occur at an approved disposal site on land.

Biofouling on the lease superstructure should be collected and returned to shore for disposal.

All wastes from culling activities conducted on leases should be returned to land for processing or disposal.

Facilities should minimise discharge (including drop-off) of fragments of gear and equipment.

Facility staff should be trained in the application of waste collection and disposal procedures, as appropriate to each employee's job description.

Where applicable, the facility should obtain all resource consents for any wastes under the Resource Management Act 1991 (RMA).

All collected waste should be stored in covered, leak proof, scavenger, vermin and bird proof containers.

5.6.7 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Aquaculture New Zealand (2007a). *Greenshell™ mussel industry environmental code of practice.* New Zealand Mussel Industry Council Limited, 1999 (Revised, June 2007 by Aquaculture New Zealand). 82 pp.

Aquaculture New Zealand (2007b). *New Zealand oyster industry code of practice.* 51 pp.

Aquaculture Stewardship Council (2012). *ASC salmon standard. Version 1.0.* June 2012. 103 pp.

Bell A, Phillips S, Denny C, Georgiades E and D Kluza (2011). *Risk Analysis: Vessel Biofouling.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 145 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf [Website accessed May 2014].

Braithwaite RA, Carrascosa MCC and LA McEvoy (2007). Biofouling of salmon cage netting and the efficacy of a typical copper-based antifoulant. *Aquaculture* 262: 219-226.

Brock R, Bailey-Brock JH and J Goody (1999). A case study of efficacy of freshwater immersion in controlling introduction of alien marine fouling communities: the USS Missouri. *Pacific Science* 53:223-231.

Bruno DW (1987). The risk to farmed Atlantic salmon, *Salmo salar* L., from marine mussels growing on net cages. *Bulletin of the European Association of Fish Pathologists* 7(5): 121-123.

Burridge L, Weis JS, Cabello F, Pizarro J and K Bostick (2010). Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. *Aquaculture* 306: 7-23.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Cribb TH, Adlard RD, Hayward CJ, Bott NJ, Ellis D, Evans D and BF Nowak (2011). The life cycle of *Cardicola forsteri* (Trematoda: Aporocotylidae), a pathogen of ranched southern bluefin tuna, *Thunnus maccoyi*. *International Journal of Parasitology* 41: 861-870.

Culloty SC and MF Mulcahy (2007). *Bonamia ostreae* in the native oyster *Ostrea edulis*. A review. *Marine Environmental Health Series* No. 29. 36 pp.

Davidson IC, McCann LD, Fofonoff PW, Sytsma MD and GM Ruiz (2008). The potential for hull-mediated species transfers by obsolete ships on their final voyages. *Diversity and Distributions* 14(3):518-529.

Fisheries Research and Development Corporation (2011). *Final Report, OsHV-1 μ-var International Workshop, Cairns Queensland 9-10 July 2011*. FRDC Report. 53 pp.

Fitridge I, Sievers M, Dempster T and MJ Keough (2014). *Tackling a critical industry bottleneck: developing methods to avoid, prevent and treat biofouling in mussel farms.* Report prepared by University of Melbourne for Fisheries Research and Development Corporation, Australia. 77 pp.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Floerl O, Wilkens S and C Woods (2010). *Temporal development of biofouling assemblages.* NIWA Client Report No. CHC2012-103. Prepared for the Department of Agriculture, Fisheries and Forestry. 47 pp.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Forrest BM, Hopkins GA, Dodgshun TJ and JPA Gardiner (2007). Efficacy of acetic acid treatments in the management of marine biofouling. *Aquaculture* 262: 319-332.

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Hilliard R, Polglaze J and I LeProvost (2006). *Review and evaluation of the biofouling protocol for vessels less than 25 m in length.* URS Australia Pty Ltd. report for the Australian Quarantine and Inspection Service, Canberra, Australia. Report no. R1216, 149 pp.

Howard AE (1994). The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. *Bulletin of the European Association of Fish Pathologists* 14(6): 211-212.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for

Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Inglis G, O Floerl and C Woods (2012). *Scenarios of vessel fouling risk and their management: an evaluation of options.* MAF Biosecurity New Zealand Technical Paper. Ministry of Agriculture and Forestry, New Zealand. 122 pp.

Jensen Ø, Dempster T, Thorstad EB, Uglem I and A Fredheim (2010). Escape of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions* 1: 71-83.

Johnston CJ (2014). *Statement of evidence on behalf of fisheries submitters before the Environmental Protection Authority.* 4 April 2014. 14 pp.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Lewis JA and ADM Coutts (2010). *Biofouling invasions. In*: Dürr S and JC Thomason (Eds.) Biofouling. Blackwell Publishing. pp. 348-365.

Maritime New Zealand (2011a). *Part 21: Safe ship management systems.* Maritime rules - MNZ Consolidation. Maritime New Zealand, Wellington. 21 pp.

Maritime New Zealand (2011b). *Part 46: Surveys, certification and maintenance.* Maritime rules - MNZ Consolidation. Maritime New Zealand, Wellington. 12 pp.

McAllister PE and WJ Owens (1995). Assessment of the virulence of fish and molluscan isolates of infectious pancreatic necrosis virus for salmonid fish by challenge of brook trout, *Salvelinus fontinalis* (Mitchill). *Journal of Fish Diseases* 18: 97-103.

McClary DJ and RJ Nelligan (2001). *Alternate biosecurity management tools for vector threats: technical guidelines for acceptable hull cleaning facilities.* A report prepared for Ministry of Fisheries project no. ZBS2000/03. Kingett Mitchell and Associates Ltd, Auckland. 29 pp.

Meyer FP (1991). Aquaculture disease and health management. *Journal of Animal Science* 69: 4201-4208.

Meyers TR (1984). Marine bivalve molluscs as reservoirs of viral finfish pathogens: significance to marine and anadromous finfish aquaculture. *Marine Fisheries Review* 46(3): 14-17.

Ministry for Primary Industries (2013). *Biosecurity information for aquaculture industries.* New Zealand Government. 1 pp.

Morrisey D, Gadd J, Page M, Floerl O, Woods C, Lewis J, Bell A and E Georgiades (2013). *In-water cleaning of vessels - biosecurity and chemical contamination risks.* MPI Technical Paper No: 2013/11. Ministry for Primary Industries, Wellington. 265 pp.

Mortensen S (2000). Scallop introduction and transfers, from an animal health point of view. *Aquaculture International* 8: 123-138.

Mortensen SH (1993). Passage of infectious pancreatic necrosis virus (IPNV) through invertebrates in an aquatic food chain. *Diseases of Aquatic Organisms* 16: 41-45.

Mortensen SH, Bechere E, Le Gall G and E Mialhe (1992). Persistence of infectious pancreatic necrosis virus (IPNV) in scallops *Pecten maximus*. *Diseases of Aquatic Organisms* 12: 221-227.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

New Zealand Salmon Farmers Association Inc (2009). *Finfish aquaculture environmental code of practice. Version 2.* Date of issue: 22 Dec 2009. Nelson, New Zealand. 26 pp.

National System for the Prevention and Management of Marine Pest Incursions (2013). *National biofouling management guidelines for the aquaculture industry*. National System for the Prevention and Management of Marine Pest Incursions, Commonwealth of Australia, Canberra. 26 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Skår CK and S Mortensen (2007). Fate of infectious salmon anaemia virus (ISAV) in experimentally challenged blue mussels *Mytilus edulis*. *Disease of Aquatic Organisms* 74:1-6.

Starliper CE (2005). Quarantine of *Aeromonas salmonicida*-harbouring ebonyshell mussels (*Fusconaia ebena*) prevents transmission of the pathogen to brook trout (*Salvelinus fontinalis*). *Journal of Shellfish Research* 24(2): 573-578.

Starliper CE and P Morrison (1999). Bacterial pathogen contagion studies among freshwater bivalves and salmonid fishes. *Journal of Shellfish Research* 19(1): 251-258.

Terlizzi A and M Faimali (2010). *Fouling on artificial substrata*. *In*: Dürr S and JC Thomason (Eds.) Biofouling. Blackwell Publishing. pp. 170-184.

Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M and C Sim-Smith (2007). *A review of aquatic diseases of significance to New Zealand.* Final Research Report for MAF Biosecurity New Zealand. NIWA Project No. ZBS 2005-17. 461 pp.

Van Banning P (1991). Observations on bonamiasis in the stock of European flat oyster, *Ostrea edulis*, in the Netherlands, with special reference to the recent developments in Lake Grevelingen. *Aquaculture* 93: 205–211.

Woods CMC, Floerl O and BJ Hayden (2012). Biofouling of Greenshell™ mussel (*Perna canaliculus*) farms: a preliminary assessment and potential implications for sustainable aquaculture practices. *Aquaculture International* 20: 537-557.

5.7 BIOFOULING MANAGEMENT (SHELLFISH)

5.7.1 General

Surface biofouling occurs when biofouling organisms encounter a surface in a state that is suitable for attachment. Complex interactions take place between abiotic and biotic factors. These interactions include the season of first submersion, length of submersion, surface type and light availability (Terlizzi and Faimali 2010). 'Pioneering' macrofoulers typically include green filamentous algae, barnacles, tubeworms and bryozoans (Hilliard *et al.* 2006; Lewis and Coutts 2010).

Hilliard *et al.* (2006) suggested the following common successional pattern in coastal waters:

- primary slime layer with grey and green tinges that vary with diatom content and light;
- gossamer-like amphipod tubes (dependent on season and level of water movement);
- filamentous green algae that can develop into waterline or transom beards providing shelter to amphipods and other clinging biota;
- encrusting bryozoans;
- tubeworms, barnacles, turfing red algae, hydroids, erect bryozoans, ectocarpoid brown algae;
- mussels, oysters, encrusting sponges, sea anemones and sea squirts; and
- larger mobile forms, including errant polychaetes, crabs, whelks, nudibranchs, crinoids and territorial fishes.

In temperate environments, the intensity of recruitment of biofouling organisms tends to be seasonal and limited during colder periods of the year (Floerl *et al.* 2010). However, diverse biofouling assemblages can develop on surfaces in temperate marine environments within four weeks (Floerl *et al.* 2010). Even after short periods of immersion (1-2 weeks) large abundances of well-known biofouling groups such as barnacles, bryozoans, and tubeworms, can occur (Floerl *et al.* 2010).

The production infrastructure for aquaculture and, in the case of shellfish production the organisms themselves, provide a habitat for the settlement of biofouling organisms (Bruno 1987; Fitridge *et al.* 2012; Woods *et al.* 2012; Inglis *et al.* 2013). Typically, the biofouling on aquaculture infrastructure is dominated by sessile, suspension-feeding organisms, including barnacles, bivalves, bryozoans, polychaetes, ascidians, hydroids, sponges and algae (Bruno 1987; New Zealand King Salmon Ltd. 2011; Fitridge *et al.* 2012; Woods *et al.* 2012).

Substantial economic costs to industry, conservatively estimated at between 5 and 10% of production costs, are associated with biofouling control. This illustrates the need for effective preventive technologies and mitigation methods (Fitridge *et al.* 2012). Several incursions of non-indigenous biofouling organisms into New Zealand have also affected production and costs to the aquaculture industry or have had the potential to do so (Bell *et al.* 2011; Woods et al. 2012; Inglis *et al.* 2013). These include the ascidians *Styela clava, Didemnum vexillum, Ciona intestinalis* and *Eudistoma elongatum,* macroalgae *Undaria pinnatifida,* and the tubeworm *Sabella spallanzanii*.

These organisms may also harbour pathogens whose spread may be facilitated by activities within the aquaculture industry (Meyers 1984; Olafsen *et al.* 2001; Anon 2005; Fitridge *et al.* 2012; Inglis *et al.* 2013).

The establishment and transfer of biofouling species is associated with the aquaculture industry via:

- the provision of habitat on production structures;
- industry associated vessels;
- movements of mobile structures;
- movement of spat, seed-stock or adult product and associated equipment;
- deployment and retrieval of equipment; and
- waste discharged from processing facilities (Inglis *et al.* 2013).

A range of vessel types are used by the New Zealand aquaculture industry including mussel harvesters and seeding vessels, tug boats, finfish transporters, barges, small launches, water taxis and dinghies (Inglis *et al.* 2013). The amount of biofouling present on the submerged vessel surfaces is dependent on their operating profile, the antifouling measures employed and the vessel maintenance schedule (Bell *et al.* 2011).

In addition, movements of aquaculture stock and equipment represent significant pathways for the translocation of biofouling and associated "hitchhiker" organisms (Inglis *et al.* 2013). For example, shellfish stock movements have been implicated in invasive species transfer, including slipper limpets (*Crepidula fornicata*), Atlantic oyster drills (*Urosalpinx cinerea*), the ascidians (*D. vexillum* and *S. clava*) and macroalgae (*U. pinnatifida* and *S. muticum*) (Inglis *et al.* 2013).

The codes of practice (COP) developed for each of the three main New Zealand industries (mussel, salmon and oyster) attempt to address the problem of biofouling and non-indigenous species to varying degrees (Aquaculture New Zealand 2007a; Aquaculture New Zealand 2007b; New Zealand Salmon Farmers Association 2009).

Recently, Sim-Smith *et al.* (2014) investigated the concerns and perceptions of biofouling (pest) species on New Zealand aquaculture. The majority of respondents from the mussel, oyster and paua industries were at least moderately concerned about managing biofouling on their farms.

Most mussel farmers surveyed only remove biofouling from their farms at re-seeding or harvesting (Sim-Smith *et al.* 2014). This material is typically cleaned on-site and disposed of in the sea. Some of these farmers appear only concerned with the impact of biofouling on product marketability, that is, those species that could not be removed by "tumblers".

By contrast, almost half of oyster farm respondents stated that biofouling is removed at least quarterly . This material is either left to disperse through the water on-site or disposed of in landfill. The majority of oyster farmers interviewed viewed biofouling as a nuisance that only resulted in increased labour costs during harvest. However, some farmers were concerned that these species compete for food and reduce stock growth. While some farmers appear to be engaged in activities to manage the risk of pest entry, exacerbation and transfer, overall the majority of Pacific oyster farmers do little to intentionally manage the biosecurity risk to their farms.

After a recent event on a paua farm there was an increase in biosecurity awareness (Sim-Smith *et al.* 2014). On-farm biosecurity procedures now include treatment of influent and effluent water, isolation and quarantine of incoming stock and manual removal of pest species.

Although, the impacts of biofouling on shellfish production is a significant global management issue, little direct information exists on these impacts and costs (Fitridge *et al.* 2014; Forrest *et al.* 2014). Few New Zealand shellfish farmers appear to know the cost of pests (biofouling) to their business (Sim-Smith *et al.* 2014). For example, only one mussel farmer stated that biofouling species can decrease the productivity of a line by 75%. Therefore, Sim-Smith *et al.* (2014) recommend outlining the costs of biofouling to the industry is likely to increase the willingness of farmers to implement biosecurity measures.

The presence of the fouling organisms *Ciona intestinalis, S. clava* and *Ectopleura crocea* in Port Phillip Bay, Australia was found to reduce mussel shell growth by 1 mm per month and flesh weight by 8-21%, even at low- to medium-fouling levels (Fitridge *et al.* 2014). Such impacts will result in economic losses by reducing the quantity of edible product and increasing the on-growing time (Fitridge *et al.* 2014). Adams *et al.* (2011) found that managing biofouling costs shellfish farmers on average, 15% of their total operating costs (excluding any loss in productivity) in the USA.

Forrest *et al.* (2014) identified 58 pest species that have significant impacts on shellfish aquaculture globally. The authors also highlighted the difficulty in identifying the next pest to shellfish aquaculture and its occurrence in New Zealand. To capture a wide range of potential problem species, they recommended that biofouling management approaches need to be generic where possible (Forrest *et al.* 2014).

Forrest *et al.* (2014) identified the following approaches for managing pest species:

- effective management of pathway risk based on the management of vessels, gear and stock movements; and,
- on-farm "passive surveillance" to assist with the timely detection of newly established species.

However, there is a clear need for the development of more effective tools for on-farm pest management (Forrest *et al.* 2014).

Similarly, Fitridge *et al.* (2014) identified monitoring of biofouling settlement throughout the growing season. Further, the authors recommended caution regarding choice of farm or spat collection location (Fitridge *et al.* 2014).

5.7.2 Impacts to shellfish aquaculture

Aquaculture stock and associated production equipment are known vectors for the spread of biofouling organisms both domestically and internationally. For example, transfers of mussel seed-stock have been implicated in the spread of *U. pinnatifida* and *D. vexillum* in New Zealand (Inglis *et al.* 2013).

The main impacts of biofouling are on the cultured stock as biofouling has detrimental effects on shellfish growth and condition as well as appearance, marketability and production costs (Bell *et al.* 2011; Fitridge *et al.* 2012; Woods *et al.* 2012; Fitridge *et al.* 2014; Forrest *et al.* 2014). Biofouling also negatively impacts on infrastructure (Fitridge *et al.* 2012; Woods *et al.* 2012).

The main impacts of biofouling on shellfish aquaculture can be summarised as:

- physical damage of stock;
- mechanical interference of stock;
- competition between fouling species and stock;

- increased disease risk; and,
- deformation and maintenance of infrastructure (Fitridge *et al.* 2012; Johnston 2014; Fitridge *et al.* 2014).

5.7.2.1 Physical damage

Damage to stock can be caused by shell boring organisms (e.g. *Polydora* spp., *Cliona* spp.) or by calcareous organisms growing on the shell surface (e.g. barnacles, bivalves). Impacts include slower growth, mortality, increased processing costs or reduced marketability (Bell *et al.* 2011; Sanford Ltd. 2011; Fitridge *et al.* 2012; Forrest *et al.* 2014).

5.7.2.2 Mechanical interference

Interference of shell function by biofouling (e.g. algae, ascidians, barnacles, bivalves) can negatively affect feeding ability and increase susceptibility to predators (Fitridge *et al.* 2012). The weight of fouling can also result in spat or crop loss from mussel lines (Forrest *et al.* 2014).

5.7.2.3 Competition

Biofouling (e.g. ascidians, bivalves, cnidarians) can provide competition for resources thus impacting stock growth and condition (Bell *et al.* 2011; Fitridge *et al.* 2012; Woods *et al.* 2012).

5.7.2.4 Environmental modification

Colonisation of culture infrastructure can lead to reduced water flow, waste build-up, decreased oxygen levels and reduced food availability (e.g. ascidians, barnacles, bivalves, cnidarians) (Fitridge *et al.* 2012). The New Zealand mussel industry typically discards biofouling into the environment. This can represent significant episodic localised benthic biodeposition (Woods *et al.* 2012). Further, the spread of non-indigenous organisms can have permanent impacts on surrounding ecosystems (Bell *et al.* 2011; Fitridge *et al.* 2012).

5.7.2.5 Disease risk

Poor water quality, as a result of the restriction of water exchange, may increase vulnerability of aquaculture stock to pathogens due to the physiological changes associated with chronic stress (Meyer 1991; Georgiadis *et al.* 2001; Johnston and Jungalwalla no date).

Bivalves are well known components of biofouling assemblages on both vessels (Bell *et al.* 2011) and aquaculture infrastructure (New Zealand King Salmon Ltd. 2011; Woods *et al.* 2012). Howard (1994) recorded an instance whereby a possible transfer of an aquatic molluscan disease (*Bonamia ostreae*) occurred via the biofouling of concrete barges. These barges had been moored in the centre of the area of the original *Bonamia* outbreak in England and had live molluscs on them upon arrival at the destination. The recipient area had no previous history of the disease or any reason to receive live oyster transfers for aquaculture purposes (Howard 1994). It has been speculated that *B. ostreae* has previously been spread via vessel biofouling in the Netherlands and Ireland (Van Banning 1991; Culloty and Mulcahy 2007).

Molluscan biofouling on vessels hulls has been suggested to be the pathway for introduction of ostreid herpesvirus microvariant 1 into Australia (Fisheries Research and Development Corporation 2011). This disease halved Pacific oyster production in New Zealand (Johnston 2014). The spread of the oyster parasite *Marteilioides chungmuensis* has also been associated with vessel biofouling due to its restriction to wharves in the ports of Darwin (Australia), and Eureka (USA) (Tubbs *et al.* 2007).

5.7.2.6 Infrastructure

Increased biomass (e.g. algae, ascidians, bivalves) on stock and equipment can lead to greater production costs associated with extra maintenance requirements and loss of stock and equipment (Bell *et al.* 2011; Fitridge *et al.* 2012; Forrest *et al.* 2014). After six months, biofouling organisms on average comprised 54% of the total mussel rope biomass (Woods *et al.* 2012).

5.7.3 Control

Methods to avoid mitigate or prevent the effects of biofouling in shellfish culture include:

- avoidance;
- physical removal;
- desiccation;
- heat treatment;
- freshwater treatment (e.g. for marine biofouling);
- chemical treatment;
- biological control;
- physical barriers; and
- antifouling paints (Bell *et al.* 2011; Fitridge *et al.* 2012; Woods *et al.* 2012; Inglis *et al.* 2013; National System for the Prevention and Management of Marine Pest Incursions (NSPMMPI) 2013; Fitridge *et al.* 2014; Forrest and Fletcher 2015).

Measures to mitigate the spread of harmful marine organisms (including species associated with biofouling) have recently been reviewed by Inglis *et al.* (2013) and Forrest and Fletcher (2015).

5.7.3.1 Avoidance

Avoidance can be an effective strategy to prevent or minimise the larval recruitment of fouling organisms in regions where fouling is predictable and seasonal (e.g. sinking of spat or seed lines to lower depths to avoid periods of heavy recruitment by blue mussels) (Fitridge *et al.* 2012; Inglis et al 2013). This practice may not be effective at reducing long term fouling biomass (Fitridge *et al.* 2012). Fitridge *et al*. (2014) recommend further investigation of depth as a tool to mitigate biofouling, as well as the effects of depth on mussel on-growing.

5.7.3.2 Physical removal

Physical removal is the preferred industry practice to remove biofouling from both live-stock and equipment associated with live-stock transfer (Inglis *et al.* 2013). Methods of fouling removal and their frequency are dictated by the fouling composition or intensity (Fitridge *et al.* 2012). The development of effective and inexpensive technology to remove biofouling is fundamental to shellfish culture.

Manual methods

The New Zealand shellfish industry has cleaning processes for spat and stock to reduce biofouling. To restrict the transport of biofouling species, the mussel industry has a voluntary COP for seed-stock that requires mechanical stripping, de-clumping, washing and sorting of mussels during re-seeding (Aquaculture New Zealand 2007a). This significantly reduces the biomass of biofouling that is transported with re-seed mussels onto new lines (Woods *et al.* 2012). Although this procedure greatly reduces macrofouling, it is less effective against resistant microscopic life-stages of some organisms (e.g. *U. pinnatifida* spores). Prior to inter-zone transfer, operators must ensure the seed meets specific criteria outlined in the code of practice, and also complete an Interzone Mussel Seed Transfer Declaration (Aquaculture New Zealand 2007a; Inglis *et al.* 2013).

During mussel harvesting biofouling organisms are removed from both floats and backbone ropes and returned to the sea in the consented farm area (Woods *et al.* 2012; Inglis *et al.* 2013). The cleaned floats are turned over to expose the biofouling to the air and the sun for at least 3 days. Backbone lines are also exposed to sun and air at this time. Infrastructure and equipment that is not required are typically taken onshore, washed down with freshwater and dried for at least 3 days prior movement to different areas (Inglis *et al.* 2013).

The New Zealand oyster industry COP (Aquaculture New Zealand 2007b) gives guidance regarding the removal of biofouling from posts and rails during harvesting or re-stocking. Farmers are required to dispose of farm waste to an approved land-based site. Washing-down of crops (with seawater) may be used to prevent crop siltation and mudworm infestation (Aquaculture New Zealand 2007b; Inglis *et al.* 2013).

In general, manual removal methods for biofouling do not remove all organisms (Forrest and Fletcher 2015). Organism fragments (e.g. *D. vexillum*; *S. spallanzanii*) or microscopic resistant stages (e.g. *U. pinnatifida* spores) may require additional treatment methods (e.g. desiccation, chemical disinfection) (NSPMMPI 2013).

Practices that return viable fouling organisms removed from the structures into the environment may contribute to subsequent fouling problems (Inglis *et al.* 2013; Forrest and Fletcher 2015). Ideally disposal of waste material to an approved site on land, as per the oyster industry (Aquaculture New Zealand 2007b), should occur. However, the practicalities of this need to be explored (Inglis *et al.* 2013).

Power washing

High pressure water blasting is a feasible, low cost method of treating some forms of biofouling on shellfish live-stock and infrastructure without affecting stock quality, although it does not remove all biofouling organisms (Inglis *et al.* 2013). Higher pressures (at least 2000 psi for 2 seconds at 100 mm distance) may be required to dislodge biofouling material from fissures and crevices in addition to difficult to remove biofouling (e.g. *U. pinnatifida* gametophytes) (Inglis *et al.* 2013; NSPMMPI 2013). Further, organisms capable of regeneration from fragments (e.g. *D. vexillum*; *S. spallanzanii*) may be spread as a result of the creation of large numbers of fragments (Inglis *et al.* 2013). Some of the remaining fragments from *in situ* cleaning can quickly regenerate into reproductively viable organisms (Forrest *et al.* 2011). *In situ* cleaning can also trigger larval release leading to the rapid recolonisation of structures (Fitridge *et al.* 2012). Removal of stock and equipment from the water prior to treatment is the most effective method with respect to containment of pest organisms and fragments (NSPMMPI 2013).

Manual cleaning by high-pressure water-blasting, followed by desiccation or disinfection should be considered for infrastructure and equipment prior to movements outside the local production area (Inglis *et al.* 2013).

Land based treatment facilities should contain and separate solids from liquids for appropriate disposal (NSPMMPI 2013). Untreated waste should not be returned to the marine environment at a location different to where biofouling was acquired (NSPMMPI 2013).

5.7.3.3 Desiccation

Marine organisms have a wide range of tolerances to aerial exposure, as such the efficacy desiccation varies and is dependent on factors such as exposure duration, temperature, humidity and sunlight (Hilliard *et al.* 2006; Inglis *et al.* 2013; NSPMMPI 2013). Biofouling extent may also influence treatment efficacy as large fouling masses can retain moisture extending the survival of organisms within the biomass (Inglis *et al.* 2013).

Conditions of high ambient temperatures, low humidity, direct sunlight, and complete exposure to air will render most marine organisms non-viable within 7 days (NSPMMPI 2013). Prior to equipment transfer to other regions, the internal policy of Sanford Ltd. is removal from the water, manual cleaning and desiccation for 2 weeks (Ted Cully, Sanford Ltd., pers. comm. in Inglis *et al.* 2013). However, Hilliard *et al.* (2006) recommend at least 21 days is required to ensure that all organisms die. In agreement, MPI recommends that prior to movement, equipment should be removed from the water for a month to thoroughly air-dry. During this time it should be ensured that ropes and equipment are laid out in a manner that allows all surfaces to dry completely (MPI 2013).

Organisms are likely to re-establish and be translocated if dried fouled structures are returned to the water without fouling removal. For example, macroalgae, including *U. pinnatifida*, release spores following periods of desiccation (Inglis *et al.* 2013).

In terms of live-stock fouling, aerial exposure is a cheap and feasible option for biofouling treatment on mussels and oysters due to their general greater tolerance of emersion than soft-bodied organisms. Extended emersion can, however, cause increased mortality of sensitive shellfish species or lifestages (Inglis *et al.* 2013; NSPMMPI 2013; Forrest and Fletcher 2015).

Air-drying can be an effective treatment for hitchhiker organisms, for example, this treatment is used to reduce mudworm infestations in oysters and abalone (Inglis *et al.* 2013).

5.7.3.4 Heat treatment

Heat treatment can be successful at killing particular fouling species without harming culture stock (Fitridge *et al.* 2014). The efficacy of heat treatment is dependent on the temperature achieved, fouling mass and exposure duration. For example, soft bodied organisms may be treated at moderate temperatures (e.g. 30-40°C), whereas hard shelled organisms (e.g. barnacles and bivalves) and resistant life-stages will require hotter treatments (50-70°C) (Inglis *et al.* 2013). Heat treatment is generally more effective if there is a large difference between the surrounding and treatment temperatures. Therefore, heat treatment appears to be more effective during winter as pests are conditioned to colder temperatures (NSPMMPI 2013). The Scottish finfish COP recommended protocol for heat treatment of nets is immersion of the entire net to a temperature of more than 65°C for at least 10 minutes. However, heat treatment of nylon nets above 71°C can significantly affect their breaking strain (Code of Good Practice Management Group 2011).

Application of heat treatment is suited to simple, uniform structures. Treatment of complex surfaces can be time consuming and costly due to practical difficulties in maintaining the required temperature (Inglis *et al.* 2012; Inglis *et al.* 2013).

In terms of live-stock fouling, heat treatment is a cheap and feasible option for mussels and oysters due to their general tolerance of heat relative to soft-bodied organisms. For example, in Australia, some oyster farmers treat their stock at 82°C for 3 seconds to reduce over-catch and eliminate some biofouling species (NSPMMPI 2013). However, treatment can result in increased mortality of juvenile live-stock and of other more sensitive shellfish species (e.g. abalone) (Inglis *et al.* 2013; Forrest and Fletcher 2015).

5.7.3.5 Freshwater treatment

The use of osmotic shock (e.g. freshwater solutions) has been recommended as an effective marine biofouling treatment option by both New Zealand and Australian government agencies (MPI 2013; NSPMMPI 2013). MPI recommend that prior to equipment transfers that the equipment be soaked in freshwater for 72 hours. For some equipment, such as ropes, it is important that fresh water is replaced after 12 hours to ensure the water does not remain brackish (MPI 2013). Biofouling species that are susceptible to changes in salinity can be treated by immersion in freshwater for 12 hours (NSPMMPI 2013). Depending on what is being treated, the volume of freshwater required may be difficult to acquire in remote locations (Forrest and Fletcher 2015). Previous studies have shown that mortality of all biofouling species on vessels following immersion in freshwater is difficult and time consuming (Brock *et al.* 1999; Davidson *et al.* 2008). Inglis *et al.* (2012) estimated that it may take up to 14 days to achieve 100 % mortality.

5.7.3.6 Chemical treatment

Decisions regarding use of chemical treatments must consider the efficacy, costs (including regulatory compliance), environmental impact and impacts on stock production and marketability (Inglis *et al.* 2013). A variety of chemical treatments have been examined to treat different fouling and hitchhiker organisms on aquaculture stock. Treatment efficacy will vary according to the type of organism being targeted and the treatment type, concentration and duration (Inglis *et al.* 2013).

Investigations into methods for treating biofouling organisms have generally examined four chemicals:

- acetic acid;
- hydrated lime;
- sodium hypochlorite; and,
- alkaline ammonia (Forrest *et al.* 2007; Inglis *et al.* 2013; MPI 2013; Fitridge *et al.* 2014; Forrest and Fletcher 2015).

For example, prior to equipment transfer MPI recommend either of the following practices to manage the risk of transfer of biofouling species:

- soak the item in a 2% bleach and freshwater solution for 30 minutes; or
- soak the item in a 4% acetic acid and freshwater solution for 10 minutes (MPI 2013).

Fitridge *et al.* (2014) found that acetic acid at the appropriate concentration can be successful at killing particular fouling species without harming culture stock.

Disinfection procedures for equipment are a standard practice used globally in the aquaculture industry to prevent the spread of microbial pathogens. Many of these procedures will also be useful in reducing the risk of transfer of fouling macroorganisms (Inglis *et al.* 2013). For example, prior to equipment transfer MPI recommend immersion for 30 minutes in a 2% Decon 90 detergent and freshwater solution (MPI 2013).

5.7.3.7 Biocontrol

Biocontrol in large scale shellfish production is not widely practiced. Examples from oyster culture include the use of periwinkles, crabs and sea urchins (Fitridge *et al.* 2012).

5.7.3.8 Shell coatings

A biodegradable, wax-based, impervious, non-toxic coating, was successful in treating oysters heavily infected with boring sponges (Fitridge *et al.* 2012). Similarly, a wax coating is also recommended to treat abalone broodstock infested with mudworms (Heasman and Savva 2007).

5.7.3.9 Antifouling paints

A range of antifouling products may be used to prevent or reduce biofouling on farm infrastructure (e.g. farm barges, pontoons) and associated vessels (Bell *et al.* 2011; Inglis *et al.* 2013). Copper-based antifouling paints are the most widely used in marine aquaculture (Burridge *et al.* 2010; Inglis *et al.* 2013). In temperate regions, such paints have been shown to be effective during periods of high fouling pressure (i.e. summer) and offer > six months protection (Braithwaite *et al.* 2007; Fitridge *et al.* 2012). Copper antifouling paints are not widely used in shellfish aquaculture as copper has known impacts on developing invertebrates (i.e. it is an effective biocide), and can be bioaccumulated in shellfish tissues (Fitridge *et al.* 2012).

For vessels, correct choice, application and maintenance of antifouling paints can minimise biofouling. Application and maintenance should follow the manufacturer's instructions and take the vessel operating profile into account. Maintenance includes regular inspection and removal of biofouling in dry-docking facilities or by in-water cleaning as appropriate (Bell *et al.* 2011; Inglis *et al.* 2013; Morrisey *et al.* 2013).

Vessels (< 45 m) used for marine aquaculture are likely to be required to comply with the safe ship management requirements provided under Maritime Rule Part 21 Section 2 (Maritime New Zealand 2011a). According to Rule 46.17, this includes out-of-water inspections of the hull and external fittings below the waterline at intervals not exceeding 2 years (Maritime New Zealand 2011b). Although these inspections concern the structural integrity and safety of the vessel, biofouling is likely to be removed to allow a thorough inspection. Thus these inspections provide an opportunity to clean and antifoul the vessels as appropriate (Inglis *et al.* 2013).

5.7.4 Land-based farms

New Zealand land-based marine farms and hatcheries typically have seawater intakes and discharges which are under the consent of regional authorities. These consents vary in terms of treatment at intake and discharge (Inglis *et al.* 2013).

NSPMMPI (2013) recommends that seawater intakes at hatcheries meet or exceeds a minimum filtration level of 20 µm. The larval stages of most biofouling organisms will be excluded by this level of filtration (McClary and Nelligan 2001; Morrisey *et al.* 2013; NSPMMPI 2013).

Vectors for transport of fouling organisms into and out of land-based marine aquaculture include:

- collection and translocation of broodstock;
- acquisition and discharge of waters that contain harmful organisms;
- transfer of aquatic life from one farm to another farm;
- transfer of stock to marine grow-out farms; and,
- disposal or release of unwanted stock or material (e.g. mollusc shells) into the wild (Inglis *et al.* 2013).

The level of risk posed by New Zealand land-based marine facilities with respect to the translocation of biofouling organisms is unknown. However, existing approval processes for stock transfers to and from these facilities and for effluent and waste discharge into marine environments could be strengthened. Ideally, effective risk management plans should be developed during the consent process to minimise the risk (Inglis *et al.* 2013).

5.7.5 Conclusions

Biofouling of infrastructure, vessels and live-stock is recognised as having the potential for wide ranging impacts to shellfish aquaculture. Management actions are required to minimise the risks to and from the aquaculture industry and the environment.

5.7.6 Options to minimise the risks associated with biofouling

5.7.6.1 Objective

To manage the risk of transferring pests and pathogens onto, within and from the facility via equipment, structures, vehicles and vessels, etc.

5.7.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All facility inputs, throughputs and outputs (e.g. stock, equipment, staff, procedures, vehicles and vessels) should be assessed for potential biosecurity risks.

Aggregation of fouling organisms on or near production units should be limited.

Procedures and infrastructure should be in place to clean and disinfect stock, equipment, vehicles or vessels. All gear and structures should be cleaned before transfer between facilities, management areas or regions. Cleaning should be to a standard that ensures that biofouling species (and their propagules within) are eliminated. These should incorporate a staged approach relative to risk.

MPI should be contacted (0800 80 99 66) in all instances where an unfamiliar species is encountered. If possible, samples of these organisms should be collected for identification.

Disposal of exotic or unwanted marine species should follow relevant protocols, as specified by the jurisdiction.

5.7.6.3 Detailed options

General biosecurity

Facilities should be aware of the locally important, invasive, rare and endangered species and record organisms observed at the facility location (e.g. date, identification, abundance).

Notable occurrences of biofouling organisms should be documented and recorded (e.g. date, identification, photographs).

Facility staff should be trained to monitor for and identify marine pests when they are inspecting and cleaning live-stock, equipment, structures and vessels, etc.

Facility structures and equipment should undergo regular maintenance and cleaning to manage the occurrence of biofouling.

Coastlines adjacent to facilities should be monitored for occurrence of new and established non-indigenous species. MPI should be contacted (0800 80 99 66) in all instances where an unfamiliar species is encountered.

Biofouling should not build-up to a level that impairs water flow.

Floats and ropes should be cleaned of biofouling during harvesting. Floats should be turned over after harvest to expose the fouled surface to the sun.

Any materials and equipment (e.g. floats, ropes, droppers, anchors) that is no longer required should be removed from the marine environment.

The amount of organic material discarded into the environment should be minimised.

Materials and equipment should be cleaned on shore and fouling materials disposed of in an appropriate land based facility.

Where the use of biocidal antifouling paints is approved, the application of these substances should be carried out in an approved facility.

Seed should be carefully inspected to prevent the introduction of small predators or unwanted species with the seed and document organisms removed (date and identification).

Hatchery production of spat for transfer to grow-out facilities around New Zealand should be managed to reduce the risk of transfer of biofouling organisms.

Land-based production of stock for re-stocking around New Zealand should be investigated to reduce the risk of transfer of biofouling organisms.

Biosecurity attestation of hatcheries, land-based facilities and wild spat should be put in place due to the potential to spread pest organisms quickly to multiple locations.

Land-based facilities

The facilities should have effective systems to prevent the entry of aquatic macro-organisms.

Intake water for hatcheries should meet or exceed a minimum filtration level of 20 µm.

Inlet and outlet pipes should be widely separated to avoid recirculation of effluent.

Inlet and outlet piping should be designed so that they can be cleaned (pigged) from the outside into the facility rather than the effluent being discharged into the environment.

Culture units, intake and discharge pipes should be cleaned regularly to prevent the build-up of organic matter and fouling organisms.

Grates for inlet and outlet pipes and tanks should be inspected regularly for holes or fouling. Remedial action should be taken immediately to rectify any unsatisfactory situation.

Settlement tanks and ponds should be regularly treated to kill biofouling.

Broodstock

All new broodstock should be cleaned and treated for biofouling and potential parasitic infestations.

Methods of removal

Removal of biofouling organisms should be achieved via methods, such as:

- desiccation in air;
- freshwater immersion (e.g. for marine biofouling);
- brine immersion;
- combined treatment (e.g. freshwater treatment followed by desiccation in air);
- high pressure blasting (freshwater, salt water, hot water);
- separation of liquids and solids from biofouling waste;
- chemical treatment (e.g. chlorine, hydrogen peroxide);
- heat treatment;
- manual control (e.g. gear should be cleaned frequently when fouling is slight rather than waiting until the fouling is difficult to control); or
- onshore cleaning (e.g. fouling material should be disposed of in an approved manner, such as landfill or other public disposal facility).

Vessel biofouling

Hull cleaning, antifouling and vessel maintenance

An antifouling coating supplier should be contacted for advice on the selection of the most appropriate coating system, based on:

- vessel operating location;
- vessel type and operating conditions; and
- vessel construction (e.g. wood, steel, aluminium).

Antifouling products should be applied and removed at designated onshore facilities

Procedure for applying and removing antifouling products should be in accordance with manufacturer's instructions and follow regional council regulations and the New Zealand antifouling and in-water cleaning guidelines.

The hull should be regularly maintained, according to the antifouling paint manufacturer's instructions, to prevent the build-up of macrofouling.

Biological matter removed during hull cleaning should be contained or collected, and treated and disposed of at onshore facilities. If conducting hull servicing independently, the relevant permits to discard biological matter should be obtained.

Antifouling should be renewed according to the minimum frequency recommended by the paint manufacturer.

The effectiveness of antifouling coatings on vessels should be regularly monitored and if necessary the hull should be cleaned and the antifouling re-applied.

Unpainted surfaces should be regularly inspected.

If unpainted surfaces (e.g. echo sounders) are fouled, any biological matter should be removed and disposed of at onshore disposal facilities.

Preventive treatment should be applied to unpainted surfaces, for example, commercially available greases or other specified coatings can be applied to surfaces, such as propellers, to help keep them clean.

Vessels that have been stationary for periods of 30 days or more and have not been cleaned or antifouled within the previous six months should be inspected for exotic or pest species prior to relocating. All exotic or unwanted species found during the inspection should be removed from the hull before departure and disposed of.

Records of any hull maintenance and antifouling coatings applied should be kept. Records may include antifouling product invoices (e.g. paint brand and type), place and date of application, date of renewal and a record of any official inspection carried out (e.g. at survey).

All vessels

Facility vessels should have (as appropriate to the vessel size):

- unwanted and exotic species identification charts;
- sealable plastic bags or other sample containers to hold suspect specimens removed from equipment, crop or vessels; and
- instructions on how and where to send samples.

Transport vessels

Hull inspections of transport and accommodation vessels should occur at monthly intervals.

Where possible, niche areas should be physically covered to discourage the establishment of biofouling.

The use of sealed cooling systems in vessels should be adopted.

Vessels moving from site to site should be inspected for fouling before each departure.

Transport vessel live holding systems and engine cooling systems should be flushed and disinfected before each transport.

Maintaining trailered vessels onshore

Entangled or attached biological matter (e.g. seaweeds) should be removed from the vessel and trailer.

The outboard and hull fixtures that could harbour potential marine pests (e.g. trim outboard down to let water out of the gearbox housing) should be monitored.

Mooring lines that have biofouling attached should be cleaned and dried.

Warps and anchors should be cleaned of biological matter, mud and sand.

Anchor and chain wells and lockers should be cleaned.

Vessels should be rinsed inside and out with freshwater, drained and allowed to dry prior to moving to another location.

Live tanks and wells for marine pests or biological matter should be cleaned and disinfected.

Any biological matter, including known marine pests, should be disposed of in bins or to landfill so that it cannot be returned to the water.

Maintaining non-trailered vessels and vessels that have raw water internal water systems

The hull should be regularly maintained, according to the antifouling paint manufacturer's instructions, to prevent the build-up of macrofouling.

Treat internal water systems by cleaning intake and outlet points and by periodic flooding with freshwater or approved biocide prior to moving between regions.

Conduct hull cleaning at a designated onshore facility (e.g. marina or slipway with waste trapping facilities).

Dispose all biological matter that is removed from the vessel at onshore facilities so that it cannot be returned to the water.

Potential refuge space that could harbour marine pests should be regularly inspected, cleaned, and where possible, allow to dry (e.g. live well, anchors, anchor and chain wells, propellers, sacrificial anodes, strainer boxes, around external keel pipes, raw water intakes, sea chests).

Mooring lines that have biofouling attached should be cleaned and dried.

Warps and anchors should be cleaned of biological matter, mud and sand as they are hauled.

Sorting and harvesting

Vessel skippers should ensure that during harvest of the crop and the removal of equipment that crews are made aware of the possible presence of exotic or unwanted marine species and be instructed in the approved removal and storage processes.

During harvests lifting crews should be vigilant for unwanted or exotic species on lines as they are removed from the sea. Any specimens located should be removed and stored in the appropriate containers for later identification or disposal.

Floats and ropes should be cleaned during harvesting.

Turn cleaned floats over after harvest to expose the fouled surface to the sun.

During sorting and grading at sea, any unfamiliar, unwanted or exotic organisms should be removed from the wastewater and stored later for identification or disposal.

Discharge of organic material (as well as sediment and shell) via washwater during harvest although generally authorised under resource consent should be minimised.

Stock transfers

All spat, seed, gamete or egg transfers should be authorised by the MPI.

Facilities should be aware of regulations for movement controls of stock for preventive management and control of pest species.

Seed, spat or stock purchased should only be obtained from nurseries or hatcheries that have accurate and verifiable records.

All seed transferred should be declumped, thoroughly washed, and dispatched as single seed.

All seed product harvested for transfer between zones should be thoroughly washed at the harvesting stage.

Final visual inspection of the seed should be at the conveyer belt on the harvest or to ensure that there are no macrofouling species present.

All material used (e.g. bags, shell) in the aquatic environment are sterilised and sanitised (e.g. dried or cleaned on an upland site) prior to transfer to a new area.

Any unfamiliar organisms or any notifiable organisms should be reported to the MPI pest and disease hotline 0800 80 99 66.

Vehicle and equipment disinfection

Any vehicles or equipment that may come in contact with the delivery site water should be inspected, cleaned and disinfected prior to coming back on the facility.

The vehicles for transporting shellfish, spat, seed, eggs or gametes, by land, air or water, should be washed and disinfected by trained personnel before and after each transport.

All fixtures and fittings (e.g. aeration equipment, pipe-work) should be dismantled and disinfected.

Vehicles should be designed and constructed so as not to cause contamination of shellfish contained within them.

Surfaces coming into contact with the shellfish should be made of corrosion-resistant material that is smooth and easy to clean and disinfect.

Reusable plastic boxes or pallets should be maintained in good condition (i.e. minimal abrasions and scratches) and cleaned and disinfected after use.

Boxes or pallets made from material that is difficult to clean and disinfect (e.g. porous material) should be for 'single use' only.

Boxes or pallets returned to the distribution or holding yard, together with those which may have been contaminated in transit, should be kept in a designated dirty area for disinfection or disposal.

Documented evidence of disinfection should be obtained from the transport company.

Diving equipment

Where possible, each site should have its own diving equipment.

Where divers are operating on different production areas or sites, documented cleaning and disinfection procedures should be followed before and after diving work takes place.

Facilities should check and record the fact that cleaning and disinfection procedures have been followed before and after diving takes place.

Dirty and disinfected diving suits and equipment should be kept separate at all times.

Waste

Facility waste, including stock, shells, materials, equipment, should not be disposed of into the consent area or into coastal waters. Disposal should occur at an approved disposal site on land.

All wastes from culling activities conducted on leases should be returned to shore for processing or disposal.

Facilities should minimise discharge (including drop-off) of mature shell and fragments of gear and equipment.

Biofouling on the lease superstructure should be collected and returned to shore for disposal if possible.

Facilities should keep the foreshore and sea bed within the consent area free of production debris and stock.

Broken shellfish and empty shells should be kept well separated from marketable shellfish to prevent contamination. All collected waste should be stored in covered, leak proof and scavenger proof containers.

Waste disposal should be carried out daily to prevent scavengers, flies, and odours.

Facility staff should be trained in the application of waste collection and disposal procedures, as appropriate to each employee's job description.

Where applicable, the facility should obtain all resource consents for any wastes under the Resource Management Act 1991 (RMA).

Large scale mortality events may require resource consent prior to dumping. Facilities will dispose of mortalities according to their licence conditions. All attempts should be made to dispose of the mortalities so as to avoid adverse environmental effects.

5.7.7 References

Adams CM, Shumway SE, Whitlatch RB and T Getchis (2011). Biofouling in marine molluscan shellfish aquaculture: a survey assessing the business and economic implications of mitigation. *Journal of the World Aquaculture Society* 42(2): 242-252.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Aquaculture New Zealand (2007a). *Greenshell™ mussel industry environmental code of practice.* New Zealand Mussel Industry Council Limited, 1999 (Revised, June 2007 by Aquaculture New Zealand). 82 pp.

Aquaculture New Zealand (2007b). *New Zealand oyster industry code of practice.* 51 pp.

Bell A, Phillips S, Denny C, Georgiades E and D Kluza (2011.) *Risk Analysis: Vessel Biofouling.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 145 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf

Braithwaite RA, Carrascosa MCC and LA McEvoy (2007). Biofouling of salmon cage netting and the efficacy of a typical copper-based antifoulant. *Aquaculture* 262: 219-226.

Brock R, Bailey-Brock JH and J Goody (1999). A case study of efficacy of freshwater immersion in controlling introduction of alien marine fouling communities: the USS Missouri. *Pacific Science* 53:223-231.

Bruno DW (1987). The risk to farmed Atlantic salmon, *Salmo salar* L., from marine mussels growing on net cages. *Bulletin of the European Association of Fish Pathologists* 7(5): 121-123.

Burridge L, Weis JS, Cabello F, Pizarro J and K Bostick (2010). Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. *Aquaculture* 306: 7-23.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Culloty SC and MF Mulcahy (2007). *Bonamia ostreae* in the native oyster *Ostrea edulis.* A review. *Marine Environmental Health Series* No. 29. 36 pp.

Davidson IC, McCann LD, Fofonoff PW, Sytsma MD and GM Ruiz (2008). The potential for hull-mediated species transfers by obsolete ships on their final voyages. *Diversity and Distributions* 14(3):518-529.

Fisheries Research and Development Corporation (2011). *Final Report, OsHV-1 μ-var International Workshop, Cairns Queensland 9-10 July 2011*. FRDC Report. 53 pp.

Fitridge I, Sievers M, Dempster T and MJ Keough (2014). *Tackling a critical industry bottleneck: developing methods to avoid, prevent and treat biofouling in mussel farms.* Report prepared by University of Melbourne for Fisheries Research and Development Corporation, Australia. 77 pp.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Floerl O, Wilkens S and C Woods (2010). *Temporal development of biofouling assemblages.* NIWA Client Report No. CHC2012-103. Prepared for the Department of Agriculture, Fisheries and Forestry. 47 pp.

Forrest B and L Fletcher (2015). *Managing biosecurity risk pathways in shellfish aquaculture: options for biofouling.* Prepared for the Ministry of Business, Innovation and Employment. Contract CAW1315. Cawthron Report no. 2624. 39 pp.

Forrest B, Cahill P, Newcombe E and D Taylor (2014). *Marine pests and management concepts for shellfish aquaculture.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Institute, Nelson. 48 pp.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Forrest BM, Hopkins GA, Dodgshun TJ and JPA Gardiner (2007). Efficacy of acetic acid treatments in the management of marine biofouling. *Aquaculture* 262: 319-332.

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Heasman M and N Savva (2007). *Manual for intensive hatchery production of abalone. Theory and practice for year round, high density seed production of blacklip abalone* (*Haliotis rubra*). New South Wales Department of Primary Industries and Australian Government Fisheries Research and Development Corporation. 95 pp.

Hilliard R, Polglaze J and I LeProvost (2006). *Review and evaluation of the biofouling protocol for vessels less than 25 m in length.* URS Australia Pty Ltd. report for the Australian Quarantine and Inspection Service, Canberra, Australia. Report no. R1216. 149 pp.

Howard AE (1994). The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. *Bulletin of the European Association of Fish Pathologists* 14(6): 211-212.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Inglis G, O Floerl and C Woods (2012). *Scenarios of vessel fouling risk and their management: An evaluation of options.* MAF Biosecurity New Zealand Technical Paper. Ministry of Agriculture and Forestry, New Zealand. 122 pp.

Johnston CJ (2014). *Statement of evidence on behalf of fisheries submitters before the Environmental Protection Authority.* 4 April 2014. 14 pp.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Lewis JA and ADM Coutts (2010). *Biofouling invasions. In*: Dürr S and JC Thomason (Eds.) Biofouling. Blackwell Publishing. pp. 348-365.

Maritime New Zealand (2011a). *Part 21: Safe ship management systems.* Maritime rules - MNZ Consolidation. Maritime New Zealand, Wellington. 21 pp.

Maritime New Zealand (2011b). *Part 46: Surveys, certification and maintenance.* Maritime rules - MNZ Consolidation. Maritime New Zealand, Wellington. 12 pp.

McClary DJ and RJ Nelligan (2001). *Alternate biosecurity management tools for vector threats: technical guidelines for acceptable hull cleaning facilities.* Report prepared for Ministry of Fisheries. Kingett, Mitchell and Associates Ltd, Auckland. Project no. ZBS2000/03. 29 pp.

Meyer FP (1991). Aquaculture disease and health management. *Journal of Animal Science* 69: 4201-4208.

Meyers TR (1984). Marine bivalve molluscs as reservoirs of viral finfish pathogens: significance to marine and anadromous finfish aquaculture. *Marine Fisheries Review* 46(3): 14-17.

Ministry for Primary Industries (2013). *Biosecurity information for aquaculture industries.* New Zealand Government. 1 pp.

Morrisey D, Gadd J, Page M, Floerl O, Woods C, Lewis J, Bell A and E Georgiades (2013). *In-water cleaning of vessels - biosecurity and chemical contamination risks.* MPI Technical Paper No: 2013/11. Ministry for Primary Industries, Wellington. 265 pp.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

New Zealand Salmon Farmers Association Inc (2009). *Finfish aquaculture environmental code of practice. Version 2.* Date of issue: 22 Dec 2009. Nelson, New Zealand. 26 pp.

National System for the Prevention and Management of Marine Pest Incursions (2013). *National biofouling management guidelines for the aquaculture industry.* National System for the Prevention and Management of Marine Pest Incursions, Commonwealth of Australia, Canberra. 26 pp.

Sanford Ltd. (2011). *Annual Report 2011.* Auckland, New Zealand. 88 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Terlizzi A and M Faimali (2010). *Fouling on artificial substrata. In*: Dürr S and JC Thomason (Eds.) Biofouling. Blackwell Publishing. pp. 170-184.

Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M and C Sim-Smith (2007). *A review of aquatic diseases of significance to New Zealand.* Final Research Report for MAF Biosecurity New Zealand. NIWA Project No. ZBS 2005-17. 461 pp.

Van Banning P (1991). Observations on bonamiasis in the stock of European flat oyster, *Ostrea edulis*, in the Netherlands, with special reference to the recent developments in Lake Grevelingen. *Aquaculture* 93: 205–211.

Woods CMC, Floerl O and BJ Hayden (2012). *Biofouling of Greenshell™ mussel (Perna canaliculus) farms: a preliminary assessment and potential implications for sustainable aquaculture practices. Aquaculture International* 20: 537-557.

5.8 CLEANING AND DISINFECTION

Cleaning and disinfection are central components of pathogen risk reduction and disease control for the aquaculture industry (Responsible Use of Medicines in Agriculture Alliance (RUMA) 2006; Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) 2008; OIE 2012). Cleaning and disinfection are typically used for:

- personal hygiene;
- reduction of spoilage;
- reduction of pests/fouling organisms (**Chapter 5.33 Wildlife management; Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish)**);
- reduction of odours;
- routine practice designed to exclude specific diseases;
- routine sanitary measures to reduce within farm disease incidence; or
- disease eradication (Tatterson and Windsor 1977; OIE 2012).

Cleaning differs from disinfection in that a clean surface is not necessarily sterile (Tatterson and Windsor 1977). As the efficacy of disinfectants is reduced in the presence of organic matter, mineral deposits and debris, surfaces need to be cleaned for effective disinfection (Tatterson and Windsor 1977).

Cleaning and disinfection typically involves a combination of physical and chemical procedures applied to the target area. In general, disinfectants are used to reduce or prevent transmission of pathogens on eggs (**Chapter 5.29 Stock origin and gamete production**) as well as decontamination of equipment, structures, raceways and other fomites (Corbeil *et al.* 2012; OIE 2012). As many aquatic diseases can be introduced into farms or released into the environment, disinfection of in-flow and effluent water is often included in land-based biosecurity plans (Sippel 1983; Corbeil *et al.* 2012; OIE 2012).

The importance of cleaning and disinfection has been long known to the aquaculture industry. For example, by 1974, viral hemorrhagic septicaemia had spread to the majority of the 540 trout farms in Denmark. Within three years, approximately 380 of these farms had been registered as free of the disease through the application of a rigorous disinfection programme (Hnath 1983).

Similarly, the 1980 infectious haematopoietic necrosis outbreak in Alaskan sockeye salmon resulted in the production of guidelines and criteria for disease control. These criteria included:

- ensuring supplies of virus-free water;
- rigorous disinfection procedures;
- separation of eggs and fry during incubation and rearing; and
- immediate destruction of infected stock followed by disinfection to contain within hatchery virus spread and to prevent environmental exposure (Meyers 2010).

Infectious salmon anaemia (ISA) outbreaks in Norway, Canada and Scotland indicate that the risk of virus transfer is associated with the use of shared, unsterilised equipment, including the use of the same personnel on several sites (Anon 2000; **Chapter 5.21 On-site management of staff and visitors**).

Cleaning and disinfection procedures have successfully managed outbreaks of oyster velar viral disease in affected hatcheries (Elston 1993). Such procedures included immediate sterilisation of affected tanks and the discard of contaminated larvae.

Contaminated vessels and equipment has been highlighted to be a potential source of *Bonamia ostreae* spread in The Netherlands (Van Banning 1991), England (Howard 1994) and Ireland (Culloty and Mulcahy 2007).

Disinfection protocols for vessels, equipment and structures have been used to prevent pathogen transfer in finfish (Zanin *et al.* 1983; Anon 2000; Anon 2003; Burridge *et al.* 2010; Code of Good Practice Management Group 2011) and molluscs (Elston 1984; Elston 1993; Bower *et al.* 1994; Diggles and Oliver 2005; Elston *et al.* 2008).

Although the use of chemical disinfectants is primarily to manage the risk of pathogen transfer, many of these disinfectants will also reduce risks associated with spread of macro-organisms (Inglis *et al.* 2013).

Recent research showed that the majority of New Zealand aquaculture farmers were at least moderately concerned about preventing and managing pests and diseases (Sim-Smith *et al.* 2014). However, large variations in biosecurity practices occur within the industry and the high level of industry concern regarding pests and diseases is not always reflected in their biosecurity practices.

Commercial salmonid farms (freshwater and marine) have biosecurity measures that include routine disinfection of equipment, however protocols regarding equipment disinfection differ among farms. For example, one farm requires disinfection of all shared equipment whilst another farm only requires disinfection following a mortality event (Sim-Smith *et al.* 2014).

Despite comprehensive standard operating procedures (SOPs) regarding biosecurity often existing within larger aquaculture companies. For example, a number of farmers admitted that adherence to SOPs regarding regular cleaning and disinfection of equipment and prevention of non-disinfected equipment between sites was variable (Sim-Smith *et al.* 2014).

Except in Stewart Island, New Zealand mussel and oyster farms employ few biosecurity measures, thus equipment is rarely cleaned and disinfected (Sim-Smith *et al.* 2014). This is despite moderate to high level of concern about pests and diseases, and the recent ostreid herpesvirus microvariant 1 (OsHV-1) outbreak in the oyster industry in 2009. One paua farm that had experienced a disease outbreak in 2013 improved their biosecurity practices to include the regular cleaning and disinfection of equipment (Sim-Smith *et al.* 2014).

Successful disinfection is reliant on the consideration of several factors, including:

- the target organisms;
- the degree of disinfection required;
- the nature and composition of the surface;
- adequate cleaning prior to disinfection;
- item or device to be treated,
- concentration of the chemical required;
- the contact time required;
- temperature and pH;
- turbidity, particulate concentration (water);
- cost;

- safety;
- ease of use;
- risk of residue(s) in the final animal product; and
- appropriate disposal of waste products (Huguenin and Colt 2002; Blaylock and Whelan 2004; Danner and Merrill 2006; RUMA 2006; OIE 2012).

Improper disinfection has previously been linked to disease outbreaks in marine aquaculture (Gustafsen *et al.* 2007). Ineffective disinfection is often attributed to:

- inadequate cleaning prior to disinfection;
- inappropriate disinfecting agents being employed; or
- inadequate contact time with the disinfecting agent (Blaylock and Whelan 2004; Danner and Merrill 2006; DAFF 2008).

The disinfection process can be broken down into a series of specific tasks that address the risks identified (e.g. disinfection of dive equipment or the treatment of discharge water) (DAFF 2008). Tasks will vary in complexity depending on the size and type of equipment involved (DAFF 2008).

DAFF (2008) note that disinfection strategies used during an emergency response should only differ from those used as part of typical farm operating procedures in terms of the selection, application and resource allocation.

Basic disinfection protocols include:

- removal of all aquatic animals from the equipment, structures, facilities to be disinfected (i.e. cleaning);
- elimination of all organic matter adhering to the surfaces to be disinfected;
- the use of the disinfection agent; and
- neutralisation/rinsing of the disinfection agent (OIE 2012).

5.8.1 Cleaning

Effective disinfection is reliant on thorough cleaning beforehand, as this:

- significantly reduces pathogen loading;
- removes the gross contamination/organic matter that may reduce the activity of chemical disinfectants; and
- removes chemical residues (Tatterson and Windsor 1977; Blaylock and Whelan 2004; DAFF 2008; Meyers 2010; OIE 2012).

Cleaning agent is a term used to describe a wide range of substances that assist cleaning; detergents are the most common followed by jellies (for vertical surfaces) and abrasive powders (Table 11; Tatterson and Windsor 1977).

Cleaning for disinfection purposes can be broken down into the following processes:

- initial cleaning;
- wet washing;
- rinsing;
- drying; and
- inspection (Danner and Merrill 2006; Meyers 2010; OIE 2012).

5.8.1.1 Initial cleaning

All gross contamination should be removed (e.g. dirt, dust). Surfaces may not be visibly clean as some organic matter may be tightly adhered (Anon 2000; Blaylock and Whelan 2004; Danner and Merrill 2006).

5.8.1.2 Washing

All exposed surfaces should be cleaned at a minimum with water and an abrasive scrubbing surface. The use of a cleaning agent can assist in the break down of any tightly adhered biofilm/organic material present. The cleaning agent used should be appropriate to the type of contamination present and the type of surface from which it is to be removed (Tatterson and Windsor 1977). Attention should be paid to surface irregularities (e.g. cracks, junctions, joints, mechanical items). Surfaces will be visibly clean following this step (Anon 2000; Danner and Merrill 2006). The value of a thorough scrubbing and use of soap cannot be over-emphasised. Water blasting and steam cleaning may also be appropriate.

5.8.1.3 Rinsing

All traces of the cleaning agents used should be removed as they can be incompatible with the chemical disinfectants applied (Danner and Merrill 2006; DAFF 2008).

5.8.1.4 Drying

The rinsed surfaces should be dried. Equipment or structures that are clean and dry are generally free of viable pathogens as the majority of fish pathogens (notably with the exception of infectious pancreatic necrosis virus (IPNV)) are killed by drying (Meyers 2010). Failure to dry surfaces will dilute the disinfectant applied (Danner and Merrill 2006)

5.8.1.5 Inspection

A careful inspection of all surfaces should be conducted to ensure that all organic matter has been removed. Areas that do not meet inspection should be re-cleaned (Danner and Merrill 2006).

Table 11: Characteristics of common cleaning agents and wetting compounds (DAFF 2008).

Compound	Application	Advantages	Disadvantages	Examples
Mild alkaline detergents	Primarily used for particulate matter or sediment accumulation Also useful for oily build-ups and protein accumulations	Useful as a general detergent May have chlorine added to enhance protein breakdown capability Produces pH of 8.4	High concentrations can be irritant Mildly corrosive May be difficult to rinse	Sodium carbonate Sodium sesquicarbonate
Strong alkaline detergents	Excellent for oily build-ups and protein accumulations and biofilms Also useful for particulate matter or sediment accumulation	Provide good saponification Have good foaming characteristics, which may be used to prolong contact time on vertical surfaces High pH aids removal and has some biocidal characteristics May have chlorine added to enhance protein breakdown	Corrosive to some metals, in particular soft alloys and aluminium Irritant to skin and mucous membranes Interact with calcium and magnesium ions in hard waters to produce soap scums that may be difficult to rinse Inefficient at deflocculation and emulsification	Sodium hydroxide Sodium orthosilicate Sodium sesquisilicate
Organic acid compounds	Mineral accumulations and for other inorganic acid-soluble substances	Removes inorganic precipitates and other acid-soluble substances Extremely effective in cleaning aluminium Less corrosive than alkalis Easily rinsed from surfaces	Mildly corrosive Inhibited by various organic nitrogen compounds	Acetic acid Citric acid Oxalic acid
Inorganic acid compounds	Mineral accumulations	Highly efficient at removing mineral deposits produced by marine or hard waters Some biocidal effect through low pH Effective at softening water Can be combined with other agents to enhance penetrating ability	Corrosive to metals Irritant to eyes, skin and mucous membranes	Phosphoric acid Sulfamic acid Nitric acid

Compound	Application	Advantages	Disadvantages	Examples
		Easily rinsed from surfaces		
Nonionic surfactants	Excellent detergents for oils; therefore effective on oily build-ups and some protein accumulations Useful for particulate matter or sediment accumulation	Compatible with most other cleaning compounds Very good wetting characteristics Good dispersing and detergent action	May be sensitive to acids	Polyethenoxyethers
Cationic surfactants	Some wetting effect, but not recommended for general cleaning purposes	Good biocidal characteristics	Relatively poor penetration capability Must not be used with anionic compounds	Quaternary ammonium compounds
Anionic surfactants	Effective against oils, fats and waxes Useful on some oily build-ups and protein accumulations. Also useful on absorbent or pitted material	Can be used under acid or alkaline conditions Good penetration characteristics Compatible with acid or alkaline cleaners and may have a synergistic effect	Some types foam excessively Must not be used with cationic compounds	Soaps Sulfated alcohols Sulfated hydrocarbons

5.8.2 Disinfection

Types of commonly used disinfecting agents include:

- oxidising agents;
- pH modifiers (alkalis and acids);
- aldehydes;
- biguanides;
- alcohol;
- quaternary ammonium compounds (QACs);
- ultraviolet (UV) irradiation;
- heat;
- drying;
- high temperatures; and
- sunlight (DAFF 2008; Yanong and Erlacher-Reid 2012).

Disinfectants vary in their effectiveness against specific disease organisms. Although standard doses will kill many pathogens, for some organisms specific conditions, doses and/or contact times may be required (Table 12; Table 13; DAFF 2008; Yanong and Erlacher-Reid 2012).

Table 12: Disinfectant application and recommended doses (DAFF 2008).

Disinfecting agent	Application	Pathogens	Recommended dose	Comments
Hypochlorite solutions (sodium hypochlorite or calcium hypochlorite)	Treatment of clean, hard surfaces	All pathogens	Minimum 30 mg/L available chlorine	Use as a general disinfecting solution
	Treatment of water (assuming low organic loading)	All pathogens	Minimum 30 mg/L available chlorine Maintain a minimum of 5 mg/L of residual chlorine	Hold for a minimum of 24 hours to inactivate Test chlorine level before discharge or neutralise with thiosulfate Less active in the presence of high levels of organic matter Re-dose if necessary
	Treatment of net pens	All pathogens	Initial dose of 1000 mg/L available chlorine Maintain a minimum of 5 mg/L of residual chlorine	Thoroughly mix to ensure even distribution Immerse for a minimum of 6 hours
	Dip treatment of absorbent material such as dip nets, clothing, ropes or absorbent surfaces	All pathogens	Solution of > 200 mg/L available chlorine	Allow time to completely saturate plus a further 2 minutes (minimum) Rinse items in fresh water or neutralise with thiosulfate
	Treatment of tanks, floors and walls in culture facilities	All pathogens	Spray with a solution > 1500 mg/L available chlorine	Leave solution for 2 hours, then rinse to free any remaining soils Tanks should be filled with freshwater and dosed with 200 mg/L available chlorine Leave for 24 hours in the case of whirling disease
Chloramine-T	Treatment of water	Bacteria, viruses, fungi	20 mg/L of chloramine-T (or as per manufacturer's instructions)	Hold for a minimum of 24 hours Test chlorine level before discharge or neutralise with thiosulfate Concentrations and doses vary between products
	Treatment of previously cleaned hard surfaces	Bacteria, viruses, fungi	20 mg/L of chloramine-T (or as per manufacturer's instructions)	Hold for a minimum of 24 hours

Disinfecting agent	Application	Pathogens	Recommended dose	Comments
				Test chlorine level before discharge or neutralise with thiosulfate Concentrations and doses vary between products
	Footbaths	Bacteria, viruses, fungi	50 g/L of chloramine-T (or as per manufacturer's instructions)	Concentrations and doses vary between products
	Treatment of hard surfaces	All pathogens	1% solution for > 60 minutes (or as per manufacturer's instructions)	Concentrations and doses vary between products
Peracetic acid	Treatment of porous surfaces	All pathogens	2% solution for > 60 minutes (or as per manufacturer's instructions)	Concentrations and doses vary between products
	Treatment of waste slurries (high organic matter)	All pathogens	40 L concentrate solution/1000 L	Contact time > 1 hour May cause excessive foaming and tank overflow in presence of high levels of protein
Monosulfate compounds	Treatment of hard surfaces	All pathogens	10 g/L (or as per manufacturer's instructions)	Application rate of 400 mL/m^2 for > 10 minutes Concentrations and doses vary between products
	Treatment of porous surfaces	All pathogens	20 g/L (or as per manufacturer's instructions)	Application rate of 400 mL/m^2 for > 10 minutes Concentrations and doses vary between products
	Footbaths	All pathogens	50 g/L (or as per manufacturer's instructions)	Remove all organic matter on footwear before immersion Immersion time > 1 minute Replace solution daily in areas of heavy use; every 4 days in areas of light use Concentrations and doses vary between products
Chlorine dioxide	Treatment of water	All pathogens	As per manufacturer's instructions	Can produce volatile fumes when first activated
	Treatment of hard surfaces	All pathogens	As per manufacturer's instructions	Can produce volatile fumes when first activated
Iodophors	Treatment of hard surfaces	Bacteria, viruses, fungi	> 200 mg/L available iodine	Apply to surface 1-2 minutes
	Spray disinfection of equipment	Bacteria, viruses, fungi	> 100 mg/L available iodine	Apply to previously cleaned and dried equipment.

Disinfecting agent	Application	Pathogens	Recommended dose	Comments
	Footbaths	Bacteria, viruses, fungi	> 200 mg/L available iodine	Clean boots before disinfection Replace daily in high-use areas, or when solution has lost colour
	Use as a hand or skin wash, or on angling or other delicate equipment	Bacteria, viruses, fungi	> 200 mg/L available iodine	Povidone-iodine solution only, do not use acidified iodine solutions
	Treatment of water	Bacteria, viruses, fungi	30 mg/L available iodine, left for 12 hours	Treat with thiosulfate before release
Calcium oxide	Earthen-based ponds	All pathogens	0.5 kg/m^2 for 1 month	Repeat dose on at least two occasions in wet areas or in event of flooding
Sodium hydroxide	Treatment of concrete or cracked surfaces of appropriate materials	All pathogens	Applied as a mixture with CaOH and Teepol	NaOH generally sold as pellets Repeat dose on at least two occasions in wet areas or in event of flooding May also be used as a 0.2% solution as a cleaning agent for equipment Teepol (wetting agent) enhances penetration through soil and into concrete
	Treatment of appropriate surfaces where high organic loading may be a problem	Viral pathogens on suitable Surfaces	Applied as a solution of 20 g/L NaOH for > 10 minutes	
	Treatment of wastewater	All pathogens	At a rate to achieve pH > 12 for 24 hours	
	Treatment of waste slurries (high organic matter)	All pathogens	50% (wt/vol) solution at a rate of 30 L/1000 L of slurry	Dose should achieve a pH of > 12 Treat for >4 days
Calcium hydroxide	Treatment of waste slurries (high organic matter)	All pathogens	40% (wt/vol) solution at a rate of 60 L/1000 L of slurry	Dose should achieve a pH of > 12 Treat for > 4 days
Glutaraldehyde	Treatment of small items or those subject to corrosion	All pathogens	2% (wt/vol) for 30 minutes	Available as concentrate solution
Formalin solution	Treatment of hard or porous surfaces	All pathogens	8% (vol/vol) for 30 minutes	Available as 40% solution Dilute 1:12 for use Use only in well-ventilated areas
	Foot baths	All pathogens	8% (vol/vol) for 30 minutes	Available as 40% solution

Disinfecting agent	Application	Pathogens	Recommended dose	Comments
				Dilute 1:12 for use Use only in well-ventilated areas
	Treatment of waste slurries (high organic matter)	All pathogens	40 L formalin solution/1000 L (40%)	Must be distributed evenly
	Treatment of pipelines or sewage channels (*in situ*)	All pathogens	300 mL of commercial grade formalin solution/10 L of water	Completely fill pipeline with disinfecting solution and leave for 24 hours
Quaternary ammonium compounds	Use on skin or delicate items	Some bacteria, some viruses	1 mg/L for > 1 minute	Limited range of efficacy
	Use on hard surfaces	Some bacteria, some viruses	2 mg/L for > 15 minutes	Limited range of efficacy
Heat	Treatment of wastewater	Most pathogens Enveloped viruses and some bacteria may be resistant	60°C for 10 minutes 70°C for 6 minutes 75°C for 5 minutes 80°C for 4 minutes	
	Treatment of hard surfaces and equipment	Most pathogens Enveloped viruses and some bacteria may be resistant	Steam cleaning at 115-130°C for 5 minutes	Difficult to regulate, best used as an adjunct to other disinfection methods Especially suitable for treatment of transport tanks
Desiccation and light	Earthen tanks	Most pathogens	Dry for > 3 months at an average temperature of > 18°C	Drying period can be reduced if combined with an appropriate chemical disinfectant Use drying and sunlight as a general adjunct to all disinfection if possible
UV light	Treatment of wastewater	Viruses, bacteria, Fungi	> 25 mJ/cm^2	Requires pre-treatment with chemical precipitation or filtration
	Treatment of water	*Myxosporidean* species spores	> 35 mJ/cm^2	May requires pre-treatment with chemical precipitation or filtration
Ozone	Treatment of water	All pathogens	1 mg/L for > 1 minute	

Note: Levels recommended in this table come from a number of sources and have been provided here as a general guide. Since the disinfecting capability of disinfecting agents will vary depending on the conditions, concentrations and contact times given should be viewed as minimum acceptable levels for decontamination purposes.

Table 13: Advantages and disadvantages of specific disinfecting agents (DAFF 2008; Code of Good Practice Management Group 2011; Yanong 2012; Yanong and Erlacher-Reid 2012).

Agent	Advantages	Disadvantages
Hypochlorite solutions	Wide spectrum of activity - effective against bacteria, fungi, viruses, protozoa and spores Rapid disinfecting action Easily rinsed from surfaces Wide temperature tolerance Not affected by hard water unless pH is high Low toxicity at dilute concentrations Easy to use Relatively low cost Readily available	Rapid degradation of working solutions Degradation of concentrate solutions over time Readily inactivated by organic matter Significantly affected by pH, with loss of activity above pH 8.5 No wetting capability Irritates mucus membranes, eyes, and skin in high concentrations Corrosive to metals May damage silicone sealants Damaging to nets over time
Chloramine-T	Effective against a wide range of organisms, although data on specific fish pathogens is limited Less affected by organic matter than hypochlorite solutions Less corrosive and irritating than hypochlorite solutions Concentrate powder is very stable More stable in solution than other chlorine-liberating agents Effective against biofilms Wide temperature tolerance	Limited specific data on effects on fish pathogens More expensive than hypochlorite solutions Requires longer contact times than hypochlorite solutions Some preparations are fine powders that are highly irritant to respiratory tracts Activity reduced by high pH Activity reduced by hard water Irritates mucus membranes, eyes, and skin in high concentrations Corrosive to metals May damage silicone sealants Damaging to nets over time
Stabilised chlorine dioxide solutions	Highly effective disinfectant, with greater activity than hypochlorite solutions Not affected by high levels of organic matter in comparison to other chlorine liberating compounds Effective over a wide pH range (up to pH 10) Effective against biofilms Un-activated solutions are relatively stable Wide temperature tolerance	Gives off toxic fumes when first activated Strong oxidising potential means that chlorine dioxide has similar corrosive characteristics to hypochlorite solutions Working solutions are unstable, especially in the presence of sunlight and elevated temperature Irritates mucus membranes, eyes, and skin in high concentrations Corrosive to metals May damage silicone sealants Damaging to nets over time
Iodophors	Excellent broad-spectrum antimicrobial activity, with good activity against bacteria, fungi, viruses and protozoa, as well as bacterial and fungal spores Less affected by organic material than chlorine compounds Remains active in the presence of organic matter, provided pH does not rise above 4	Treatment of spores and non-enveloped viruses require longer contact times Acidic solutions may be corrosive and are not recommended for concrete surfaces or metals Can cause staining under some circumstances

Agent	Advantages	Disadvantages
	More stable than chlorine solutions Lower corrosive qualities and less irritancy than chlorine, alkaline or peroxygen compounds Working solutions easy to monitor, as brown colour disappears when iodine is exhausted Mild acidic nature prevents film formation and makes it easy to rinse off. Wide temperature range (10-40°C) Moderate to good wetting ability, dependent on formulation	Can produce iodine gas if used at temperatures above 50°C Activity is reduced by hard water and very high levels of organic matter, particularly under alkaline conditions Acidified iodophors have some corrosive qualities Comparatively expensive
Alkaline compounds	Effective against a wide range of pathogens, particularly viruses Not affected by the presence of organic matter Useful in the disinfection of pond bases Useful for the decontamination of carcasses and organic matter in burial pits Good wetting ability Relatively cheap and available in bulk Wide temperature tolerance (some loss at low temperatures) Effective against mineral deposits	Corrosive on metallic structures, especially aluminium and soft metal alloys Irritant to skin and mucous membranes Sodium hydroxide and calcium oxide are highly corrosive and irritants Use requires experience and appropriate personal protective equipment Run-off into waterways should be avoided May be corrosive to metal and painted surfaces Very slow acting compared with oxidising agents
Acid compounds	Can be used as adjuncts to other compatible disinfecting agents, such as iodophors, where they produce optimal pH and enhance penetration or rinsing qualities May be mixed with anionic detergents to enhance sanitising capabilities Not affected by the presence of organic matter Good wetting ability Wide temperature tolerance (some loss at low temperatures) Effective against mineral deposits	Can be highly corrosive and irritant to skin and mucous membranes Slow acting Often needs to be combined with other forms of treatment May be corrosive to metal and painted surfaces
Peroxygen compounds	Wide spectrum of activity Remain effective at low temperatures Fast acting Effective sporicides Effective in the presence of organic matter. Effective over a wide pH range, but most effective in weak acid solutions Wide temperature tolerance Relatively non-toxic	Concentrated peracid solutions are relatively unstable (1-2% activity loss per month) Working solutions must be replaced every 2-3 days Corrosive to metals, including steel, if left in contact for prolonged periods Inhibited by copper, iron, manganese and chloride ions Relatively high cost
Aldehydes	Wide spectrum of activity Generally non-corrosive Generally not affected by organic matter Formalin is relatively cheap	Slow acting Significant workplace safety concerns, depending on use and presentation; produce vapours that are irritant to skin, eyes, respiratory tracts and mucous membranes Formaldehyde gas is highly irritant and potentially deadly

Agent	Advantages	Disadvantages
		Moderate temperature tolerance (gives off fumes at high temperatures) Glutaraldehyde is expensive
Biguanides	Do not irritate tissues (commonly used as skin disinfectants) Disinfectant for delicate materials Less sensitive to presence of organic material than chlorine and iodophors	Not effective in hard or alkaline water Less active against most types of pathogens than many other disinfectants Activity affected by pH Activity can be affected in the presence of moisturisers and detergents
Quarternary ammonium compounds	Odourless, non-corrosive and non-irritant Low toxicity to mammals Wetting properties (good penetration of porous surfaces) Wide pH range (pH 3-10.5) Stable at higher temperatures Not generally affected by organic matter May be used to combine cleaning and disinfection stages (where appropriate)	Variable and selective biocidal activity Not effective against spores Use limited to freshwater situations (inhibited by hard water and anionic detergents) Maintains a residual effect that may be toxic to aquatic animals Inhibited by low temperatures, anionic detergents and wetting agents
Ultra-violet radiation	Important role in the ongoing treatment of water entering or leaving facilities Functions over a range of temperatures, pressures and pH Alternative to potential environmental contamination from chemical disinfectants	Affected by suspended solids, water flow rates and water clarity (may require flocculation and filtration systems) Ineffectiveness against a number of pathogens, particularly non-enveloped viruses (e.g. IPN)
Ozone	Highly efficient at disinfecting water Important role in the ongoing treatment of water entering or leaving facilities Effective against a wide range of fish viruses, including non-enveloped viruses Enhances water clarity	Can be consumed by organic matter rendering treatment ineffective Highly toxic, must be removed from the water before the water returns to the system Can be hazardous to human health
Heat	Temperatures of 80 to 100°C for 10 minutes kills all active microorganisms Excellent supplementary method for equipment decontamination	Spores may require much longer exposure periods Difficult to maintain exposure temperature and time for practical disinfection purposes (significant loss of temperature between the unit and the treatment area) Often needs to be combined with other forms of treatment Treatment > 71°C can alter breaking strain of nylon nets.
Desiccation/ Sunlight	Can be effective, exposure time will vary depending upon intensity, temperature, etc Can help reduce pathogen numbers Good final stage of the decontamination process Leaving equipment to dry in areas exposed to sunlight is an effective adjunct to other disinfection processes Practical applications for dry heat include the use of heat rooms for diving	Little research conducted regarding effective exposure times Spores, cysts or eggs may survive treatment Complete drying may not be possible due to high humidity

Agent	Advantages	Disadvantages
	equipment to ensure that suits and other delicate equipment are thoroughly dried at the end of each day	

Depending on how they are to be used or promoted disinfectants, sterilisers and sanitisers may be subject to the Agricultural Compounds and Veterinary Medicines (ACVM) Act 2011. However, in general disinfectants, sterilisers and sanitisers are likely to be exempt from registration via:

- own use provisions; or
- sterilisers, sanitisers, and disinfectants exempt category.

See:
http://www.legislation.govt.nz/regulation/public/2011/0327/latest/DLM3982848.html?search=ts_regulation_Agricultural++Compounds_resel&p=1&sr=1

For procedures for decontamination of equipment and infrastructure refer to DAFF (2008), Code of Good Practice Management Group (2011) and OIE (2012).

5.8.3 Conclusions

Good cleaning and disinfection practices reduce the risk of on-site pathogen transfer and also help to minimise the risk of pathogen transfer between neighbouring sites and between management areas.

5.8.4 Options to aid on-site cleaning and disinfection

5.8.4.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility.

5.8.4.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Procedures addressing on-site sanitation should be in place and available for review. These procedures should cover, but are not limited to, standard operating procedures for cleaning and disinfection of facilities and equipment, personal protective gear, and minimising risks of pest and pathogen transfer.

Separate equipment should be assigned for use in production units of different health status. Where equipment must be used in multiple production units it should be cleaned and disinfected prior to movement between units.

Within management areas, personnel, equipment, and personal protective equipment should be site or at least company specific.

Where movement between management areas is unavoidable, cleaning and disinfection should be in accordance with standard disinfection protocols.

5.8.4.3 Detailed options

For specific procedures for decontamination of infrastructure and equipment refer to DAFF (2008), Code of Good Practice Management Group (2011) and OIE (2012).

Cleaning and disinfection (general)

Facility staff should be trained in the cleaning and disinfection procedures of the facility, as appropriate to each employee's job description. Documentation of this training should be recorded.

Structures and equipment should be designed in such a way as to be capable of being cleaned and disinfected.

Each site should have its own equipment to minimise pest and pathogen transfer between units.

A single-batch system should be used where each tank, pond or site has only stock of the same age or batch. The stock in each separate area should be harvested completely, and the area (including pens, nets, tanks, equipment, etc) cleaned, disinfected and dried before restocking.

Chemicals, cleaning agents, disinfectants or other substances should be used according to their intended purpose and to the manufacturer's instructions.

Wherever possible, structures or equipment should always be removed from the water for cleaning and disinfection.

Where equipment and structures must be drained prior to cleaning and disinfection, the safe disposal of infected water should be taken into account.

Any ancillary equipment associated with structures, such as feeders, aerators or lights, should be removed for separate cleaning and disinfection.

Where installations cannot be cleaned onshore or dismantled, the underwater section should be cleaned and disinfected by divers.

Cleaning and disinfection (land-based facilities)

Floors should be of such material that can be cleaned and disinfected (e.g. not dirt).

Structures, tanks and raceways should be of such material that can be cleaned and disinfected.

All culture units (including broodstock units) should have a written cleaning, disinfection and fallowing plan.

A single-batch system should be used where each tank, pond or site has only stock of the same age or batch. The stock in each separate area should be harvested completely, and the area (including pens, nets, tanks, equipment, etc) cleaned, disinfected and dried before restocking. For example, hatchery and broodstock tanks (i.e. tanks for broodstock maturation, mating, spawning, larval rearing and indoor nurseries) should be cleaned, disinfected and dried between uses.

Each culture unit (or group of culture units within one area) should have its own equipment to minimise pathogen and pest transfer between units.

Culture units, intake and discharge pipes should be cleaned regularly to prevent the build-up of organic matter and fouling organisms. The frequency of disinfection will vary according to stock turnover.

All land-based pipes and wastewater channels should be cleaned regularly and disinfected to limit the formation of biofilms and the accumulation of organic matter. During cleaning, the pipe-work should be drained and external fouling removed.

Inlet and outlet piping should be designed so that they can be cleaned (pigged) from the outside into the facility rather than the effluent being discharged into the environment.

Pipes, outlet channels and settlement tanks and ponds should be regularly cleaned to ensure that no organisms are established in these areas.

Settlement tanks and ponds should be regularly treated to kill escaped stock.

Equipment

All the equipment used for feeding, cleaning, and for removal of stock should be unique to each culture unit.

Modules, floating store rooms, and automatic feeding systems, should be cleaned and disinfected before re-location.

In freshwater on-growing areas, personnel, equipment and personal protective equipment should be site specific.

Where movement between freshwater on-growing areas is unavoidable, cleaning and disinfection should, as far as is reasonably practicable, be in accordance with standard disinfection protocols.

Equipment should be cleaned in a location and manner that allows the effective collection of solid waste (e.g. biofouling and sludge) and wastewater.

Informed choices should be made regarding materials to be used at the facility. For example, when considering cleaning and disinfection, porous materials are difficult to disinfect.

Documentation of material and equipment disinfection should be maintained.

Where vaccination equipment is brought on-site:

- the supplier should provide proof that the equipment has been disinfected;
- the equipment should be disinfected before and after use; and
- disinfection records should be maintained.

Nets

Nets should not be changed from one facility to another.

Nets that have not been cleaned and disinfected after being submerged in a body of water should not be re-immersed into another body of water.

The transfer of nets from and towards onshore washing stations should be carried out using the appropriate watertight compartments or packaging.

The cleaning and disinfection process should guarantee the elimination of all elements adhering to the nets.

Where treatment of nets cannot be achieved, nets should be destroyed by incineration or disposed of in approved landfill sites.

Documentation of material and equipment disinfection should be maintained.

Stock handling

The equipment used for stock handling and grading should be kept clean and disinfected between uses.

The vehicles, live holding systems of transport vessels, etc, for transporting stock, eggs or gametes, by land, air or water, should be washed and disinfected before and after each transport.

All fixtures and fittings (e.g. aeration equipment, pipe-work) should be dismantled, cleaned and disinfected.

Vehicles should be designed and constructed so as not to cause contamination of stock contained within them.

Vehicles, hauling tanks, pumps, nets, buckets, waders, or anything that may come in contact with the delivery site water should be inspected, cleaned and disinfected prior to coming back on the facility.

Surfaces coming into contact with the stock should be made of corrosion-resistant material that is smooth and easy to clean and disinfect.

Reusable plastic boxes or pallets should be disinfected after use.

Boxes or pallets of material difficult to clean and disinfect (e.g. porous) should be for ‘single use’ only.

Boxes or pallets returned to the distribution or holding yard, together with those which may have been contaminated in transit, should be kept in a designated dirty area for disinfection or disposal.

Documented evidence of disinfection should be obtained from the transport company.

Documentation of material and equipment disinfection should be maintained.

Vehicles

Facilities should ensure that the following requirements are met:

- only vehicles that serve the facility should be given access to the production areas or transit zones for determined purposes only; temporary service vehicles, visiting vehicles or staff vehicles should not have access to these areas;

- the facility should request a "disinfection certificate" or similar, before a transport vehicle is given access to the production units. The certificate should confirm that the vehicle's tanks into which the aquatic animals will be loaded have been cleaned and disinfected;
- all people entering with a vehicle should follow the cleaning and disinfection protocols established for the facility;
- vehicles and containers that serve more than one centre should be cleaned and disinfected after each centre visited, and the "disinfection certificate" or similar that accredits the procedure should be requested periodically;
- a register of all the vehicles that enter the facility or transit zones should be kept. The register should at least contain the following information:
    - date;
    - hour;
    - company;
    - reason for the visit;
    - name of the driver;
    - last facility visited; and
- vehicles for different services should not enter the facility at the same time, especially vehicles used for the collection of dead aquatic animals.

Diving equipment

Where divers are operating on different production areas or sites, documented cleaning and disinfection procedures should be followed before and after diving work takes place.

Facilities should check and record the fact that cleaning and disinfection procedures have been followed before and after diving takes place.

Dirty and disinfected diving suits and equipment should be kept separate at all times.

Vessels

Vessels operating between management areas should be cleaned and disinfected down to and including the water line prior to leaving.

Vessels operating within confirmed infected management areas should be subject to a risk assessment prior to entering areas of lower risk. Where a vessel has not been dry-docked, cleaned and disinfected before entering areas of lower risk, the facility operator(s) in the recipient area should agree to the vessels' entry (based on the risk assessment conducted). The route to the dry-dock should be chosen to minimise contact with other facilities and management areas.

Trailered vessels

Cleaning and disinfection should take place at an onshore site where contamination will not enter waterways.

The following surfaces should be cleaned and disinfected:

- all external surfaces of the vessel;
- all internal seawater systems (e.g. pipe-work, sea chests, bilge); and
- all equipment (e.g. mooring lines, life jackets, wet-weather clothing and fenders).

Non-trailered vessels

All external surfaces of the vessel above the water line should be cleaned and disinfected.

Upon return to shore, internal seawater systems should be drained, cleaned and disinfected. The vessel should be dry-docked, the hull cleaned and fresh antifouling paint applied.

For vessels that cannot be dry-docked, the hull should be encapsulated and soaked with the addition of a disinfecting solution for the period required to render pests and pathogens non-viable.

5.8.5 References

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Blaylock RB and DS Whelan (2004). *Fish health management for offshore aquaculture in the Gulf of Mexico. In*: Bridger CJ (Ed.) Efforts to develop a responsible offshore aquaculture industry in the Gulf of Mexico: A compendium of offshore aquaculture consortium research. Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, United States of America. pp. 129-161.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Burridge L, Weis JS, Cabello F, Pizarro J and K Bostick (2010). Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. *Aquaculture* 306: 7-23.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Corbeil S, Williams LM, Bergfield J and M StJ Crane (2012). Abalone herpes virus stability in sea water and susceptibility to chemical disinfectants. *Aquaculture* 326-329: 20-26.

Culloty SC and MF Mulcahy (2007). *Bonamia ostreae* in the native oyster *Ostrea edulis*. A review. *Marine Environmental Health Series* No. 29. 36 pp.

Danner GR and P Merrill (2006). *Disinfectants, disinfection and biosecurity in aquaculture. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 91-128.

Department of Agriculture, Fisheries and Forestry (2008). *Operational procedures manual - decontamination (Version 1.0). In*: Australian Aquatic Veterinary Emergency Plan

(AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT. 122 pp.

Diggles BK and M Oliver (2005). *Diseases of cultured paua (Haliotis iris) in New Zealand. In*: P Walker, R Lester and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 275-287.

Elston RA, Hasegawa H, Humphrey KL, Polyak IK and CC Hase (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119-134.

Elston RA (1993). Infectious diseases of the Pacific oyster, *Crassostrea gigas*. *Annual Review of Fish Diseases* 3: 259-276.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Hnath JG (1983). *Hatchery disinfection and disposal of infected stocks. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp 121-134.

Howard AE (1994). The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. *Bulletin of the European Association of Fish Pathologists* 14(6): 211–212.

Huguenin JE and J Colt (2002). *Design and operating guide for aquaculture seawater systems. Second Edition.* Elsevier, Amsterdam. pp 183-192.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01, Juneau, Alaska. 57 pp.

OIE (2012). *Manual of diagnostic tests for aquatic animals. Chapter 1.1.3. Methods for disinfection of aquaculture establishments.* 12 pp.

Responsible Use of Medicines in Agriculture Alliance (2006). *Responsible use of vaccines and vaccination in fish production. Responsible use of medicines in agriculture alliance (RUMA) guidelines.* Supported by the National Office of Animals Health. Hertfordshire, United Kingdom. 24 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Sippel AJ (1983). *Water supply sanitation. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 49-58.

Tatterson IN and ML Windsor (1977). *Cleaning in the fishing industry.* Ministry of Agriculture and Food. Torry Advisory Note No. 45 (revised). Torry Research Station, Aberdeen, Scotland. http://www.fao.org/wairdocs/tan/x5922e/x5922e01.htm [Website accessed May 2014].

Van Banning P (1991). Observations on bonamiasis in the stock of European flat oyster, *Ostrea edulis*, in the Netherlands, with special reference to the recent developments in Lake Grevelingen. *Aquaculture* 93: 205–211.

Yanong RPE (2012). *Biosecurity in aquaculture, part 2: recirculating aquaculture systems.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 9 pp

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Publication No. 4707. 16 pp.

Zanin E, Allegretti M, Giorgetti, G and G Ceshia (1983). Initiation and appraisal of an official prophylactic policy against VHS in farmed trout in the Province of Trento, Italy. *Bulletin of the European Association of Fish Pathologists* 3: 5-6.

5.9 CONTINGENCY PLANS

Contingency plans provide a description of all the actions to be undertaken in the event of an emergency situation. Although effective contingency plans have been identified as essential in combating disease outbreaks (Bondad-Reantaso and Arthur 2008; Oidtmann *et al.* 2011; Subcommittee on Aquatic Animal Health (SCAAH) 2016), aquaculture facilities need a suite of contingency plans that consider both non-infectious and infectious emergency situations (Barg 2005; Subasinghe 2005). Plans should be in place to cover events where there is catastrophic damage to structures that could impact on animal welfare, containment or affect the environment (Code of Best Practice Management Group 2011; Farm Animal Welfare Committee 2014a).

Many contingency plans will have interrelated components. A contingency plan for stock containment may include extreme weather, fire, stock transfers, predators, theft and equipment failure (Hinrichsen 2007; Anon 2013). The plan should also identify and take into account consequences to underpin decision making, for example, whether the escaped stock or gametes will survive in the wild (Hawkins and Jones 2002).

To enable efficient implementation, contingency plans should be prepared and agreed upon in advance of the emergency situation (Håstein *et al.* 1999). For example, the emergency culling of stock may involve stock at all stages of the production cycle, and can occur on sites where harvesting equipment is not typically present (e.g. hatcheries) (Farm Animal Welfare Committee 2014b). The emergency culling of stock may be necessary in circumstances, such as:

- the detection of a notifiable disease;
- irreparable failure of a production facility;
- outbreak of a serious untreatable disease or harmful algal bloom; or
- contamination of water supply (e.g. human pathogens, oil spill) (Subasinghe 2005; Farm Animal Welfare Committee 2014b).

The preparation of contingency plans reduces the impact of surprise and loss of time as it requires familiarisation of the emergency situation through the assessment of risks, identification of uncertainties, definition of priorities, and response strategies (Subasinghe 2005). Contingency plans for aquaculture need to be site and facility specific due to the difference in site variability, stock production and management techniques (Donovan 2006). Such plans should describe actions to be undertaken in the event of emergency situations. Plans that contain biosecurity considerations include but are not limited to:

- Storm damage;
- Flooding;
- Fire;
- Earthquake;
- Tsunami;
- Chemical/oil spill;
- Water supply (e.g. availability) (Munro and Waddell 1984; **Chapter 5.32 Water treatment**);
- Pest incursion (**Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish)**);
- Water quality (**Chapter 5.13 Good husbandry; Chapter 5.32 Water treatment**);
- Contaminated effluent water (**Chapter 5.32 Water treatment**);

- Mass mortalities (**Chapter 5.26 Removal and disposal of dead and moribund stock**);
- Emergency culling (**Chapter 5.17 Harvest (finfish); Chapter 5.18 Harvest (shellfish)**);
- Emergency cleaning and disinfection (**Chapter 5.8 Cleaning and disinfection);**
- Mass escape (**Chapter 5.28 Stock containment**);
- Harmful algal bloom (**Chapter 5.15 Harmful algal blooms 1: marine; Chapter 5.16 Harmful algal blooms 2: freshwater**);
- Jellyfish swarm (**Chapter 5.19 Jellyfish**); and
- Licensed use of veterinary medicines, therapeutic agents (**Chapter 5.23 Preventive practices (surveillance and vaccination); Chapter 5.24 Reactive measures for disease management (veterinary medicines)**).

Generic examples of the actions that may be contained in plans for various contingencies are plentiful (e.g. Barg 2005; Subasinghe 2005; Hinrichsen 2007; BC Shellfish Growers Association 2013). Donovan (2006) suggests the inclusion of performance and reporting criteria, as well as corrective actions.

Contingency plans that influence on-site biosecurity should be developed under the guidance of a veterinarian or aquatic health professional (Farm Animal Welfare Committee 2014a). When a problem is identified, all staff should be aware of the appropriate course of action (HDR Engineering, Inc. 2010). Contingency plans should be tested periodically to ensure that they remain fit for purpose (Oidtmann *et al.* 2011).

5.9.1 Conclusions

The preparation and implementation of contingency plans are crucial to maintaining on-farm biosecurity. Therefore, contingency plans are essential to ensure on-going viability of aquaculture facilities as they enable the recovery from emergency situations in the minimum time with minimal cost and disruption to production.

5.9.2 Options to aid the adoption of contingency plans

5.9.2.1 Objective

To ensure contingency plans are developed and understood to minimise the impact of emergency incidents that relate directly or indirectly to facility biosecurity.

5.9.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

The facility biosecurity plan should include contingencies for the response to a suspected emergency biosecurity incident.

The facility biosecurity plan should include contingencies for the response to emergency incidents that have biosecurity consequences.

Contingency plans should be developed under the guidance of a veterinarian or an appropriately qualified aquatic health professional.

All facility staff should understand the facility's contingency plans and their own role in the event of an emergency.

5.9.2.3 Detailed options

Contingency plans should provide information regarding the staff required to undertake the control measures, their responsibilities and instructions on the chain of command.
Contingency plans should therefore include:

- clearly defined triggers to identify an emergency incident and for activation of the emergency protocols (e.g. a certain level of unexplained mortality or presence of a suspected or confirmed pathogen or exotic pest);
- immediate actions required by staff when an incident is suspected. This may include enhanced biosecurity, securing areas to prevent access, and cessation of any activity such as feeding, maintenance, or movement of staff, equipment or stock;
- guidance on observations that should be made to define the circumstances of the incident (e.g. the number of tanks affected, disease signs observed, the proportion of stock affected);
- procedures for reporting of the incident to farm management and the facility's veterinarian (including the farms legal reporting obligations to MPI);
- guidelines for collection of diagnostic specimens and for transporting specimens to the diagnostic laboratory;
- procedures for destruction and disposal of large volumes of diseased or dead stock (e.g. large scale mortality events may require resource consent prior to stock disposal);
- appropriate disposal and decontamination protocols; and
- emergency contact details of staff and external authorities (e.g. MPI's pest and disease hotline 0800 80 99 66).

Staff should be able to recognise indicators of reduced stock welfare, including abnormal behaviour, physical injury and signs of disease, and take specified action in the event that such indicators are apparent.

Staff protocols should be in place for contacting appropriate health professionals and/or calling MPI's pest and diseases hotline (0800 80 99 66) when unusual stock sickness or mortalities are experienced.

Facilities should consider regular, at least annual, testing and review of their contingency plans.

Staff necessary for the undertaking of contingency plans should be regularly trained to ensure contingency preparedness.

Equipment necessary for the undertaking of contingency plans should be regularly checked for readiness according to relevant legislation.

5.9.3 References

Anon (2013). *Environmental code of practice for the sustainable management of Western Australia's abalone aquaculture industry.* Published by Aquaculture Council of Western Australia and Government of Western Australia, Department of Fisheries. 42 pp.

Barg U (2005). *World inventory of fisheries. Prevention of emergencies. Issues Fact Sheets. In* FAO Fisheries and Aquaculture Department [online]. Rome. http://www.fao.org/fishery/topic/12365/152817/en [Website accessed 12 August 2014].

BC Shellfish Growers Association (2013). *Environmental management code of practice.* 75 pp.

Bondad-Reantaso MG and JR Arthur (2008). *Pathogen risk analysis for aquaculture production. In*: MG Bondad-Reantaso, JR Arthur and RP Subasinghe (Eds.) Understanding and applying risk analysis in aquaculture. FAO Fisheries and Aquaculture Technical Paper. No. 519. Rome, FAO. pp. 27-46.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Donovan DJ (2006). *Industry environmental codes of best practice for freshwater finfish aquaculture.* Prepared by Kuruma Australia Pty Ltd. for the Department of Primary Industries and Fisheries and the Queensland Finfish Aquaculture Industry. 31 pp.

Farm Animal Welfare Committee (2014a). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Farm Animal Welfare Committee (2014b). *Opinion on the welfare of farmed fish at the time of killing.* Department for the Environment Food and Rural Affairs (United Kingdom). 36 pp.

Håstein T, Hill BJ and JR Winton (1999). Successful aquatic animal disease emergency programmes. *Revue Scientifique et Technique de L'office International des Epizooties* 18: 214-227.

Hawkins CD and JB Jones (2002). Larval escape through abalone culture effluent systems an analysis of the risk. *Journal of Shellfish Research* 21: 805-809.

HDR Engineering, Inc. (2010). *Illinois aquaculture biosecurity manual.* Prepared for Southern Illinois University Carbondale Fisheries and Illinois Aquaculture Center. 177 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

Oidtmann B, Thrush MA, Denham KL and EL Peeler (2011). International and national biosecurity strategies in aquatic animal health. *Aquaculture* 320: 22-33.

Subasinghe R (2005). *Aquaculture topics and activities. Emergencies in aquaculture: disease outbreaks. In* FAO Fisheries and Aquaculture Department [online]. Rome. http://www.fao.org/fishery/topic/12366/en [Website accessed 12 August 2014].

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

5.10 FACILITY DESIGN AND STRUCTURES

The design and construction of facilities, and structures within them, should consider the safety of employees, stock and the environment (Hinrichsen 2007). Due to the artificial situation created by aquaculture, a facility should aim to create the best (least stressful) stock rearing conditions possible (Westers 1983). The farming environment increases the likelihood of disease outbreaks as stressed and weaker individuals are more susceptible to pathogens/parasites and may transmit the agents to healthy individuals (Handlinger *et al.* 2006; Robertsen 2011). The conditions experienced by stock are determined by factors including: site selection, water supply characteristics, facility design, and animal husbandry (Warren 1983b; Westers 1983; Munro and Waddell 1984; New South Wales Department of Primary Industries 2006; Massachusetts Shellfish Growers 2009; **Chapter 5.13 Good husbandry**).

The design and construction stages of aquaculture facilities offer the greatest opportunity to influence the rearing environment and therefore stock health planning (Westers 1983) and biosecurity (Subcommittee on Aquatic Animal Health (SCAAH) 2016). Consideration of biosecurity during these stages should ease its implementation as opposed to retrofitting biosecurity considerations to existing facilities (Freidman and Renault 2007). For example, concrete raceways offer many advantages over earthen ponds in terms of disease prevention and management (Warren 1983ab). Further, consideration of secondary water supplies and their treatment may prevent problems from occurring when the primary supply is unavailable. For example, an outbreak of furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*) occurred in a facility following the use of untreated river water when its normal loch supply free of migratory fish was inadequate (Munro and Waddell 1984; **Chapter 5.9 Contingency plans**). A proactive approach to biosecurity planning during facility design and construction typically results in long-term cost savings (Goldthwaite and Carey 1983; Freidman and Renault 2007). Facility design should involve input from an aquatic health professional (Farm Animal Welfare Committee 2014). Changes to facilities and infrastructure should be considered in the context of the biosecurity plan (SCAAH 2016).

The design of aquaculture facilities and how they are managed can have far reaching effects on biosecurity (Warren 1983ab; Westers 1983; Thoney and Hargis Jr 1991; Donovan 2006; SCAAH 2016). For example:

- poor facility design may result in animal stress making them more susceptible to diseases (Thoney and Hargis Jr 1991; **Chapter 5.13 Good husbandry**);
- poor choice of materials may mean that the facility cannot function (e.g. copper piping within hatcheries) or be adequately sanitised (i.e. washed down and disinfected) (**Chapter 5.8 Cleaning and disinfection**);
- inclusion of quarantine facilities, as appropriate, is important for controlling pathogen introduction and spread (Meyers 2010; **Chapter 5.29 Stock origin and gamete production**);
- hatchery biosecurity is paramount as hatcheries often act as hubs of infection not only at the individual farm level but also in a national and international context (Georgiadis *et al.* 2001; Anon 2005; **Chapter 5.29 Stock origin and gamete production**);
- creation of barriers between within farm compartments and epidemiological separation of on-site stocks are used to prevent pathogen (and pest) transfer (Warren 1983b; Yoshimizu 2009; **Chapter 5.21 On-site management of staff and visitors; Chapter 5.22 Population separation within land-based facilities**); and

- inclement weather can exacerbate the risks associated with the on-site harvest of fish, therefore contingencies need to be adapted for heavy rainfall (e.g. containment of blood water) and rough seas (e.g. appropriate and secure moorings) to mitigate the contamination and containment risks (Anon 2000; Anon 2003) (**Chapter 5.17 Harvest (finfish); Chapter 5.18 Harvest (shellfish)**).

5.10.1 Offshore structures

Stock are typically the most valuable assets on an aquaculture farm, therefore considerable efforts are made to limit their escape (Anon 2000). In Norway, escape events are largely caused by technical and operational equipment failures (Jensen *et al.* 2010). Similarly, the investigation of the 2006 Te Pangu salmon farm escape event found that the mooring failure was predominantly due to uneven tensioning on the moorings occurring over time (New Zealand King Salmon Ltd. 2011). Effective containment of farmed stock is dependent on the selection of appropriate installations and holding facilities and their maintenance (Code of Good Practice Management Group 2011*)*. Care should also be taken that all the aids to navigation are visible at all times and stages of the farming operation (Maritime New Zealand 2005). Correct facility construction has financial benefits with respect to cost savings associated with less maintenance and lower incidences of unexpected construction failures (Donovan 2006; vom Berg 2008; **Chapter 5.28 Stock containment**).

5.10.2 Positioning

Facility design should prevent the introduction of disease (and pest) organisms (Westers 1983). While this may not be possible in open water systems, these facilities should aim to reduce the pathogen load.

Traditionally, sea cages have been positioned in rows in-line with current direction to permit operational efficiencies, efficient mooring and maintenance of net-pen shape. However, such positioning has impacts upon water flow, oxygen supply and the waste removal (Jensen *et al.* 2010). This layout also enhances transmission of pathogens and parasites between cages. For example, infection rates of kingfish (*Seriola lalandi*) by the monogenean *Benedenia seriolae* were found to be higher at sites inline rather than perpendicular with current direction (Chambers and Ernst 2005). The strategic positioning of farms and cages can limit parasite population growth, resulting in extension of the interval between stressful and costly parasite treatments (Chambers and Ernst 2005). Due to these benefits, present-day cage arrangements (Norway) have moved towards positioning cage grid mooring systems perpendicular to the dominant current direction (Jensen *et al.* 2010).

5.10.3 Conclusions

Consideration of biosecurity during the design and construction stages of aquaculture facilities is crucial in influencing the rearing environment, stock health planning and the implementation of best biosecurity practices. This typically results in long-term cost savings for the facility.

5.10.4 Options to minimise the risks associated with facility design and structures

5.10.4.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility.

5.10.4.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

The design, construction, installation and maintenance of structures and equipment should be done so as to:

- be capable of the function it was designed for;
- be capable of dealing with the adverse weather and other environmental conditions likely to be experienced on the site (e.g. flooding);
- ensure the containment of facility stocks;
- allow the inspection of all stock; and
- allow the regular removal of moribund or dead animals.

The facility should have a secure perimeter fence or otherwise well-defined boundary, establishing a clearly defined biosecurity zone.

5.10.4.3 Detailed options

Options (general)

Facilities should obtain required approvals prior to structures being placed on the site.

Facility structures should be located within the boundaries designated within their approvals.

Facilities should be located away from navigational channels.

The facility should be adequately marked to warn navigators of the potential obstruction and reduce the risk of collision.

Floating structures and shallow submerged items should be clearly marked and maintained in an orderly and grouped fashion to reduce accidents during normal and adverse visibility conditions.

Critical structures and equipment should be designed to withstand the conditions expected in its geographical location. Specific requirements should include:

- mooring and anchoring systems for facilities should be fit for purpose and should maintain the correct position of the facility during all stages of the growing and harvesting operation; and
- pumps and generators for land-based facilities are capable of continuous provision of water.

Specifications and other design records for critical structures and equipment, including moorings, anchors, cages, long-lines nets, ponds and tanks should be documented and recorded.

Facilities and holding units, including inlets and outlets, should be designed in such a way as to minimise wildlife entry and stock escapes.

Regular inspections of structures and equipment should be documented and implemented to ensure they are sound and operating correctly. Inspection records should be maintained.

Routine maintenance programmes to ensure that the structures and equipment are maintained in a manner that assures operational integrity should be documented and implemented. All maintenance should be documented.

The placement of production units (e.g. tanks, cages, long-lines, enclosures), should be considered with a view to optimising biosecurity and stock welfare conditions.

The position, design and construction of facility should consider the interaction with wildlife, including minimisation of attraction, and the exclusion of predators (e.g. birds, seals) and scavengers (e.g. birds, cats, dogs, rats) at the planning stage.

Equipment and structures should be of such material that can be cleaned and disinfected.

Each site should have its own equipment to minimise pathogen and pest transfer.

Contingency plans should be in place to cover events where there is catastrophic damage to structures that could impact on biosecurity.

Prior to expansion of any facility or addition of new structures, a biosecurity assessment of the proposed change should be undertaken.

Procedures to be followed in the selection and installation of culture units and production systems should be documented.

The design specifications of culture units, along with evidence that they are suitable for the purpose and are correctly installed should be documented and retained.

Culture and production systems should be inspected and approved by suitably qualified and experienced people.

All non-natural materials (e.g. nets, floats, ropes, droppers, anchors) that are no longer required should be recovered.

Equipment and structures should be kept clean and encrusting by biofouling organisms should be limited.

Facilities should be aware of, and consider the implementation of, technological advances in aquaculture structures and equipment that may improve biosecurity.

The facility should be secured in such a way to restrict the entry of unauthorised personnel.

Land-based facilties

All production units (e.g. sheds, ponds, tanks, raceways) should have a unique and permanent identifier.

Facilities and equipment should be of such material that can be cleaned and disinfected (e.g. floors should not be dirt).

Facilities (e.g. tanks, ponds and raceways) should be designed and constructed to allow for complete drainage and drying.

Facilities (e.g. tanks, ponds and raceways) should have adequate overflow capability and flood protection (e.g. by means of stabilised spillways).

Facilities (e.g. tanks, ponds and raceways) should have systems that allow for early detection of rising water levels that could cause flooding.

Outflows should not directly empty water onto floors (i.e. cross contamination through foot traffic should be limited).

Routine maintenance programmes to ensure that the structures and equipment are maintained in a manner that assures operational integrity should be documented and implemented.

Where earthen ponds and dams are used, the inner walls should be of a suitable slope to prevent internal erosion and collapse. Furthermore, the effects of surface wind and wave erosion should be combated by means of vegetation establishment or stone packing.

Trees and other large plants should not be allowed to grow on the retaining walls of earthen ponds and dams as their roots may weaken the structure.

To prevent structure destabilisation of earthen ponds and dams, adequate control measures should be put into place to prevent animals burrowing into the retaining walls.

Aeration apparatus (e.g. agitators, paddlewheels), pumps and water inlets should be placed and managed so as to prevent internal erosion of earthen ponds and dams.

To prevent structure destabilisation of earthen ponds and dams, access points for personnel should be included in the design.

Offshore facilties

Specifications and other design records for critical structures and equipment, including moorings, anchors, cages and nets should be documented and recorded.

Structures and equipment should be maintained in a manner that assures operational integrity. Maintenance records should be maintained. Inspection and maintenance records should at least include:

- Records of the checks on aids to navigation;
- Records of checks on structural integrity, mooring lines, anchoring systems, etc, together with any maintenance carried out;
- Records of surveys and underwater checks; and
- Records of checks on the position of the facility.

All aids to navigation should be visible at all times and stages of the production.

Service barges and vessels should be designed and maintained to withstand local weather conditions.

Moorings and anchors

Facilities should have documented procedures to be followed in the selection and installation of moorings and anchors.

Facilities should hold on record the design specifications of mooring and anchoring systems, along with evidence that they are suitable for the purpose and are correctly installed.

Facilities should maintain evidence of the competence of staff involved in the design, installation and maintenance of mooring and anchoring systems.

Rearing, mooring and anchoring components should be inspected in accordance with a documented standard operating procedure and a documented inspection plan which is based on risk assessment.

Finfish - nets

The placement of enclosures should be considered with a view to minimising biosecurity risk:

- rows or arrays of nets should be positioned perpendicular to the current.

The design, quality and standard of manufacture of nets should take account of the conditions likely to be experienced on the site and include an adequate safety margin.

Nets should be adequately tensioned to minimise distortion.

Nets should carry an identification tag.

Nets should be treated with UV inhibitor and stored away from direct sunlight when not in use, to minimise deterioration in strength.

Nets should be of a mesh size, quality and strength suitable for their purpose.

The net mesh size should be such that it is capable of containing all fish when new stock is introduced to fresh or saltwater pen sites.

Facilities should demonstrate an awareness of the minimum fish size supplied at smolt input and at other relevant times.

Netting used in the construction of enclosures should present a smooth, non-abrasive surface to the fish.

Net depth should be sufficient to ensure that the net base does not come into contact with the sea bed.

Nets should be tested at a predetermined frequency and in accordance with a test procedure which is based on manufacturer's advice.

Systems used to attach nets to pens (including net weighting where this is used) should be inspected as frequently as possible.

Nets should be inspected as frequently as possible for damage, holes or excessive biofouling, and inspection records maintained. Appropriate action should be taken immediately to rectify any problems.

Immediate remedial action should be taken where damage to nets and any associated fittings has occurred (or the potential for damage to occur is apparent).

An inventory should be kept of all nets, which includes information on supplier, date of manufacture, date of purchase, location, history of testing and history of antifouling application.

Shellfish - mussels

Warp and backbone ropes should be of sufficient specification and condition to prevent breaking under prevailing environmental conditions.

Extra floats should be added to lines as necessary during mussel holding and production stages to offset any weight increases (e.g. biofouling).

Each buoy should be permanently branded with company's identification mark. Each corner of the facility structures and the middle of each of the seaward most and landward most longlines should be marked with an orange buoy of minimum diameter 0.5 metres.

Raised bottom culture activities should be clearly marked.

Shellfish - oysters

Structures should be constructed and positioned to maintain tidal and current flows and minimise the potential for silting such as:

- racks and lines should be orientated with the run of the tide except where the prevailing weather conditions may dictate another orientation;
- racks and lines should be spaced sufficiently apart;
- a rack should not excessively loaded;
- rails and lines supporting the crop at an appropriate height above the inter-tidal sea bed to avoid silting unless the site is not liable to siltation;
- the spacing of sticks on rails should allow good water flow; and
- double (above and below) layers of crop are not recommended.

Facility structures and gear should be kept in good order and repair and operated to minimise gear and oysters dropped to the seabed, thus preventing siltation and increasing the waters biomass that can lead to additional stress to farmed stock.

Access lanes through the facility should be constructed to ensure that servicing needs can be met at all stages of the tide and in all weather conditions. The placement and width of access lanes will vary from facility to facility.

Posts marking the facility area should be painted a colour for maximum day and night visibility, and repainted at regular intervals as required. Thus reducing risk of damage from vessels that may lead to stock losses.

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Raised bottom culture activities should be clearly marked.

5.10.5 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Chambers CB and I Ernst (2005). Dispersal of the skin fluke *Benedenia seriolae* (Monogenia: Capsalidae) by tidal currents and implications for sea-cage farming of *Seriola* spp. *Aquaculture* 250: 60-69.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Donovan DJ (2006). *Industry environmental codes of best practice for freshwater finfish aquaculture.* Prepared by Kuruma Australia Pty Ltd. for the Department of Primary Industries and Fisheries and the Queensland Finfish Aquaculture Industry. 31 pp.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Friedman C and T Renault (2007). *Report on Australian herpes-like viral outbreak and field notes.* Report prepared for Western Abalone Divers Association of Victoria, Australia. 17 pp.

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Goldthwaite DB and TG Carey (1983). *Planning a fish health program for hatchery management. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Special Publication 83-2. pp. 23-26.

Handlinger J, Bastianello S, Callinan R, Carson J, Creeper J, Deveney M, Forsyth WM, Freeman K, Hooper C, Jones B, Lancaster M, Landos M, Loh R, Oyay BS, Phillips P, Pyecroft S and F Stephens (2006). *Abalone aquaculture subprogram: a national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs.* FRDC project Report 2002/201, Tasmanian Aquaculture and Fisheries Institute, Hobart. 170 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the

Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Jensen Ø, Dempster T, Thorstad EB, Uglem I and A Fredheim (2010). Escape of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions* 1: 71-83.

Maritime New Zealand (2005). *Guidelines for aquaculture management areas and marine farms.* 19 pp.

Massachusetts Shellfish Growers (2009). *In*: Leavitt DF (Ed.) *Best management practices for the shellfish culture industry in Southeastern Massachusetts.* Version 09-04a. 100 pp.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

New South Wales Department of Primary Industries (2006). *The NSW oyster industry sustainable aquaculture strategy.* 64 pp.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

Robertsen B (2011). Can we get the upper hand on viral diseases in aquaculture of Atlantic salmon? *Aquaculture Research* 42: 125-131.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Thoney DA and WJ Hargis Jr (1991). Monogenea (Platyhelminthes) as hazards for fish in confinement. *Annual Review of Fish Diseases* 1: 133-153.

vom Berg F (2008). *Finfish aquaculture in Western Australia: final ESD risk assessment report for sea-cage and land-based finfish aquaculture.* Government of Western Australia Department of Fisheries. Fisheries Management Paper No. 229. 158 pp.

Warren JW (1983a). *The nature of fish diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 7-14.

Warren JW (1983b). *Synthesis of a fish health management program. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 151-158.

Westers H (1983). *Considerations in hatchery design for the prevention of diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 29-36.

Yoshimizu M (2009). Control strategy for viral diseases of salmonid fish, flounders and shrimp at hatchery and seed production facility in Japan. *Fish Pathology* 44(1): 9-13.

5.11 FALLOWING

Site fallowing has recognised benefits within stock health optimisation strategies in terms of management of both disease and the environment (Wheatley *et al.* 1995; Stewart 1998; Anon 2000; Anon 2005; Code of Good Practice Management Group 2011; New Zealand King Salmon Ltd. 2011; OIE 2013). Improvements in on-site biosecurity, including fallowing and year class separation, have reportedly increased the survival of smolts after transfer from ~60% to ~90% depending upon the year and location (Stewart 1998).

Fallowing reduces the probability of transferring infection to the next production generation and/or to neighbouring populations (Midtlyng *et al.* 2011). It is often carried out as a regular disease management measure, especially before re-stocking a site (OIE 2013). Fallowing creates a break in the disease cycle because pathogen survival is limited by the reduction in host biomass (Wheatley *et al.* 1995; Anon 2000; Munro and Wallace 2012). The effectiveness of fallowing is dependent on the pathogen's environmental persistence following a reduction in host biomass and the length of the fallowing period (Anon 2000; Werkman *et al.* 2011).

5.11.1 Effectiveness of site fallowing

Fallowing was introduced more than 30 years ago as part of the management strategy for furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*) in Scottish salmon aquaculture. Industry research at the time observed that the removal of all fish from a farm for a period of weeks, followed by equipment disinfection, could allow the introduction of disease free smolts without disease recurrence (Anon 2000). Fallowing was a key element of the voluntary single bay management plans developed and implemented in Irish salmon farms during the early-to-mid 1990s (McMahon 2000). Irish farms that employed fallowing reported reductions in mortalities attributed to vibriosis and pancreas disease. In fallowed farms, total year class mortality was 19.6% compared with 30.1% in farms that did not (Anon 2000). In British Columbia, Canada, a secondary outbreak of infectious haematopoietic necrosis (IHN) was associated with farms that did not practice year class separation with fallowing prior to re-stocking. As a result, new smolts were exposed to salmon that had survived the original IHN outbreak that may have acted as carriers of the virus (St-Hilaire *et al.* 2000; Saksida 2006).

In Scotland, fallowing is routinely used to manage diseases such as furunculosis, infectious salmon anaemia (ISA) and infectious pancreatic necrosis (IPN) (Table 14; Anon 2000; Werkman *et al.* 2011; Munro and Wallace 2013). Where farms are commonly fallowed after every cycle, site history of IPN infection has not been shown to be a significant risk factor for recurrence (Werkman *et al.* 2011).

Table 14: Number of Scottish seawater cage sites employing a fallow period during 2003-2012 (Munro and Wallace 2013).

Year	Fallow Period						Total Number of Sites
	0 weeks	<4 weeks	4-8 weeks	9-26 weeks	27-51 weeks	52 weeks	
2003	95	14	68	80	40	29	326
2004	82	9	52	95	42	35	315
2005	75	11	36	86	37	33	278

Year	Fallow Period						Total Number of Sites
	0 weeks	<4 weeks	4-8 weeks	9-26 weeks	27-51 weeks	52 weeks	
2006	67	10	44	74	37	20	252
2007	67	16	41	61	38	24	247
2008	53	16	28	92	40	28	257
2009	51	3	30	86	46	37	253
2010	53	8	26	83	41	36	247
2011	60	10	31	85	27	39	252
2012	58	4	31	97	28	37	255

In Norway, "mandatory fallowing between year classes" was among the most important measures to prevent horizontal transmission of both ISA and furunculosis (Midtlyng *et al.* 2011). Implementation of these measures contributes to the reduction in the amount of antibiotics used in Norwegian finfish production (Midtlyng *et al.* 2011).

In terms of reducing parasite (sea lice) loads, Grant and Treasurer (1993) maintain that incoming smolts are more likely to become rapidly infested on mixed year class sites. As such, year class separation and fallowing are recognised as important strategies for managing salmon parasites (e.g. *Lepeophtheirus salmonis*) (Bron *et al.* 1993; Grant and Treasurer 1993). However, Bron *et al.* (1993) observed the effectiveness of fallowing to be dependent on the parasite species (e.g. fallowing did not restrict the abundance of *Caligus elongatum*).

By contrast, Wallace *et al.* (2011) recently presented two case studies that demonstrated the failure of fallowing to control *Renibacterium salmoninarum* and salmon alpha virus (SAV) at the cage and farm levels, respectively. It was found that cage-level fallowing would not be an effective option in eliminating or even partially controlling these diseases as they are easily spread by horizontal transmission between cages (Wallace *et al.* 2011).

In the case of farm-level fallowing, the detection of *R. salmoninarum* and the observation of pathology consistent with an SAV infection implied that re-infection either came from the source fish (or perhaps birds in contact with infected farms) or that a reservoir exists in wild or escaped fish or the local environment (Wallace *et al.* 2011).

Fallowing may be ineffective if not accompanied by other biosecurity practices or if the lifecycle of the organism is unknown. For example, more stringent screening of populations at the source farms could at least substantially reduce the risks of re-infection via this route leaving the possibilities of local reservoirs to be considered (Wallace *et al.* 2011). Van Banning (1988) reported *Bonamia ostreae* infection remains present on oyster beds and that oysters became infected when relayed to areas that were cleared (see also Bucke *et al.* 1984) and remained fallow for a number of years (Van Banning 1991). It is not known if any residual oysters were present in the aforementioned fallow area and if they might have contributed to ongoing infection. However, as residual oyster numbers appeared to be low, a macro–invertebrate or zooplankton species was suggested to play a role as *B. ostreae* carrier or reservoir (Lynch *et al.* 2006).

R. salmoninarum, was eliminated from a Scottish trout hatchery on a tank-by-tank basis through effective on-site compartmentalisation and the maintenance of good internal biosecurity practices (Murray *et al.* 2012).

The New Zealand salmon industry have not yet implemented routine site fallowing citing disease free status, low likelihood of disease outbreaks in New Zealand Chinook salmon, production constraints, and difficulties obtaining consents for new growing and fallowing areas (New Zealand King Salmon Ltd. 2011; Sim-Smith and Forsythe 2013; Sim-Smith *et al.* 2014). However, as this may leave the New Zealand aquaculture industry vulnerable to incursions of novel pathogens, and to exacerbation of those already present, the New Zealand salmon industry may take a more conservative biosecurity approach in the future (New Zealand King Salmon Ltd. 2011; Castinel *et al.* 2013).

Recent research showed that the majority of New Zealand's aquaculture farmers were at least moderately concerned about preventing and managing pests and diseases (Sim-Smith *et al.* 2014). However, large variations in biosecurity practices occur within the industry and the high level of industry concern regarding pests and diseases is not always reflected in their biosecurity practices. For example, the majority of farmers believe that water is the most likely transmission vector of pests and diseases and that biosecurity measures to manage water-borne transmission are futile. These farmers appear to be unaware of biosecurity measures (e.g. area-based agreements and fallowing), employed overseas to manage the risk of introduction and establishment of diseases.

Sim-Smith *et al.* (2014) identified a lack of allocated farm space as a barrier to preventing the uptake and implementation of site fallowing and year class separation. However, industry are concerned about the costs associated with the implementation of preventive biosecurity measures. Interestingly, the costs associated with respect to losses in productivity, increased labour and reduced market access due to diseases have been seldom considered.

5.11.2 Cost considerations associated with site fallowing

The greatest benefits of biosecurity are achieved through preventive rather than reactive action as avoidance is often the most effective, and at times the only, control measure (Hnath 1983; Warren 1983ab; Elston 1984; Elston 1993; Jarp *et al.* 1993; Bower *et al.* 1994; Danner and Merrill 2006; Robertsen 2011). However, due to a variety of reasons, such as economics, logistics and production constraints, implementation of biosecurity measures are often taken after significant pest and pathogen events (Zanin *et al.* 1983; Hardy-Smith 2006; Saksida 2006; Johansen *et al.* 2009; Asche *et al.* 2009). For example, in Chile preventive biosecurity measures (e.g. area management, fallowing, increased inspection frequency) were only implemented after outbreaks of ISA despite several of the larger companies having first-hand experience of the impacts of this disease in Norway (Asche *et al.* 2009; Kibenge *et al.* 2012). There is a strong incentive to ensure that pathogen, parasite or pest outbreaks do not occur, as they can have a significant economic impact (Asche *et al.* 2009; Forrest *et al.* 2011; Fitridge *et al.* 2012; Kibenge *et al.* 2012).

Account should be taken of the likely beneficial effects of fallowing in proportion to the economic costs involved (OIE 2013). Fallowing is seen as an expensive preventive measure whose results might only occur in the long-term with wide spread adoption (Saksida 2006; New Zealand King Salmon Ltd. 2011; Wallace *et al.* 2011). However, the economic impact of outbreaks and movement restrictions may be much greater. For example, projected economic losses following the 2007–2011 Chilean ISA outbreaks are estimated to be $1 billion (i.e. 50% of the economic value of the Chilean industry). Full recovery is not expected before 2013 (Kibenge *et al.* 2012). In Scotland a small number of rainbow trout farms have become chronically infected with *R. salmoninarum* due to a policy of continuous stocking and now have long-term movement restrictions applied to their stock (Wallace *et al.* 2011).

A perceived restriction with respect to site fallowing is that multiple sites are required to maintain production (Stewart 1998; Anon 2000). In Norway each farm must have an alternate site and in Scotland farms routinely have 3 to 4 sites through which production can be rotated (Stewart 1998). However, account should be taken of the likely beneficial effects of fallowing (both in terms of stock health and environmental management) in proportion to the economic costs involved (OIE 2013). Facilities that practice continuous production are likely to experience a higher probability of infection than those who implement site fallowing, provided that input stocks are adequately screened (Wallace *et al.* 2011).

5.11.3 Co-ordinated approach (Chapter 5.2 Integrated approach to biosecurity)

Site fallowing is seldom applied in isolation as a management measure, and is typically applied as part of an area-based management approach with other biosecurity measures such as year class separation, containment (prevention of escapes), site cleaning and disinfection, and health screening of stocks (Stewart 1998; Anon 2000; Anon 2005; Code of Good Practice Management Group 2011; Wallace *et al.* 2011). The effectiveness of fallowing strategies can be reduced by the presence of escaped reservoirs, which may constitute a re-infection risk following the re-stocking of a fallowed farm (Wallace *et al.* 2011).

Synchronisation of fallowing as part of an area-based management approach creates an absence of hosts over a wider area, reducing the potential disease risk/severity on a marine farm (Anon 2000; Anon 2005; Code of Good Practice Management Group 2011; Aquaculture Stewardship Council 2012). Werkman *et al.* (2011) demonstrated the potential benefits of having epidemiologically isolated management areas and applying synchronised fallowing. Rapid removal of local spread by synchronised fallowing can also increase the likelihood of successfully eradicating a disease epidemic (Werkman *et al.* 2011).

5.11.4 Length of fallow period

Given the costs associated with fallowing, questions often arise regarding the length of the fallowing period (Midtlyng *et al.* 2011). The fallowing periods for pathogens and parasites of Atlantic salmon recorded in the literature tend to range from one to six months dependent on the type of pathogen and the environment (Grant and Treasurer 1993; Stewart 1998; Håstein *et al.* 1999; Anon 2000; Olivares and Marshall 2010). In 2012, more than 60% of Scottish seawater cage sites employed a fallow period longer than eight weeks (Munro and Wallace 2013).

The code of practice for Scottish finfish aquaculture recommends that the minimum fallow period should be four weeks at the end of each cycle (Code of Good Practice Management Group 2011). However, longer fallowing periods may be required depending on the site infection status and the degree of disinfection that has taken place. For example, in the event that a farm is infected with a List I or List II notifiable disease[4], cages to remain on site may be left *in situ* for the three to six months following cleaning and disinfection down to and including the waterline (Code of Good Practice Management Group 2011).

In terms of sediment remediation, the appropriate fallowing period remains poorly understood.

[4]List I diseases are exotic to the EU and must be eradicated from any place in which they are found.
List II diseases are present in certain parts of the EU but not in others and are capable of having a severe economic impact.
http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/aquaculture/diseases/notifiableDisease

5.11.5 Conclusions

Site fallowing is recognised as an important disease preventive measure, particularly when used in combination with other management measures (e.g. site cleaning and disinfection, year class separation, stock screening, area-based management).

As fallowing is said to create a break in the disease cycle, alternative approaches that achieve the same aim may be appropriate.

5.11.6 Options to aid the adoption of site fallowing

5.11.6.1 Objective

To manage the risk of pathogen transfer between different growing cycles of production stock (i.e. to break the disease cycle).

5.11.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All culture units (including broodstock units) should have a written cleaning, disinfection and fallowing plan.

All production sites should be fallowed annually for a minimum of four weeks and all equipment on site cleaned and disinfected.

Where there is more than one aquaculture facility in a management area, fallowing should be part of the area management process (i.e. fallowing is applied synchronously).

A single-batch system should be used where each tank, pond or site has only stock of the same age or batch. The stock in each tank, pond or site should be harvested completely, and the tank, pond or site drained and dried before the next batch of fish is stocked.

Where they are able, companies should use site rotation, fallowing each site for one full production cycle.

5.11.6.3 Detailed options

Area-based management and fallowing

Facilities within a defined area should be fallowed synchronously on a single year class basis.

An exception to the foregoing requirement may be possible. Where this is the case, the undernoted conditions should be met:

- a documented risk assessment, which considers the risks to the company's own operations and to the operations of other companies within the area and in any adjacent area, should be undertaken and management systems adopted that effectively manages risks;

- this risk assessment should include detailed information on strategies to be followed for pathogen and parasite control in the absence of fallowing; and
- the plan should have the written agreement of all other companies within the management area.

Fallowing and new finfish species

Multiple year class production may be required in the case of new marine finfish species.

In all cases, multiple year class production should only be undertaken following a documented risk assessment.

If more than one year class of marine species is to be cultured on a facility, this should not occur for more than six years. Thereafter:

- facilities should adhere to the provisions of a written fallowing plan;
- a minimum fallow period of 4 weeks should be applied at the end of each cycle;
- pens, nets, equipment, etc, should be cleaned and disinfected before the site is restocked with fish; and
- disinfection should be conducted to a satisfactory level to inactivate pathogens posing significant risk.

5.11.7 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012). *ASC salmon standard. Version 1.0*. June 2012. 103 pp.

Asche F, Hansen H, Tveteras R and S Tveterås (2009). The salmon disease crisis in Chile. *Marine Resource Economics* 24: 405-411.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Bron, JE, Sommerville C, Wootten R and GH Rae (1993). Fallowing of marine Atlantic salmon, *Salmo salar* L., farms as a method for the control of sea lice, *Lepeophtheirus salmonis* (Kroyer, 1837). *Journal of Fish Diseases* 16: 487-493.

Bucke D, Hepper D, Key D and RCA Bannister (1984). A report on *Bonamia ostreae* in *Ostrea edulis* in the UK. *International Council for Exploration of the Sea* CM K9 7 pp.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Danner GR and P Merrill (2006). *Disinfectants, disinfection and biosecurity in aquaculture. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 91-128.

Elston RA (1993). Infectious diseases of the Pacific oyster, *Crassostrea gigas*. *Annual Review of Fish Diseases* 3: 259-276.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Grant AN and J Treasurer (1993). *The effects of fallowing on caligid infestations in farmed Atlantic salmon (Salmo salar L.) in Scotland. In*: Boxshall GA and D Defaye (Eds.) Pathogens of wild and farmed fish: sea lice. Ellis Horwood, London. pp. 255-260.

Hardy-Smith P (2006). *Biosecurity at the farm level - how to create a state of mind. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 149-154.

Håstein T, Hill BJ and JR Winton (1999). Successful aquatic animal disease emergency programmes. *Revue Scientifique et Technique de L'office International des Epizooties* 18: 214-227.

Jarp J, Tangen K, Willumsen FV, Djupvik HO and AM Tveit (1993). Risk factors for infection with *Aeromonas salmonicida* in Norwegian freshwater hatcheries. *Diseases of Aquatic Organisms* 17: 81 - 86.

Johansen R, Kongtorp RT, Bornø G, Skjelstad HR, Olsen AB, Flesjå K, Colquhoun D, Ørpetveir I, Hansen H, Garseth ÅH and B Hjeltnes (2009). *The health situation in farmed salmonids 2008.* National Veterinary Institute, Norway. 18 pp.

Kibenge FSB, Godoy MG, Fast M, Workenhe S and MJT Kibenge (2012). Countermeasures against viral diseases of farmed fish. *Antiviral Research* 95: 257-281.

Lynch SA, Armitage DV, Wylde S, Mulcahy MF and SC Culloty (2006). Inventory of benthic macroinvertebrates and zooplankton in several European *Bonamia ostreae*–endemic areas and their possible role in the life cycle of this parasite. *Marine Biology* 149: 1477–1487.

McMahon T (2000). Regulation and monitoring of marine aquaculture in Ireland. *Journal of Applied Ichthyology* 16: 177-181.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Munro LA and IS Wallace (2013). *Scottish fish farm production survey 2012.* Marine Scotland Science. The Scottish Government. 49 pp.

Murray AG, Munro LA, Wallace IS, Allan CET, Peeler EJ and MA Thrush (2012). Epidemiology of *Renibacterium salmoninarum* in Scotland and the potential for compartmentalised management of salmon and trout farming areas. *Aquaculture* 324-325: 1-13.

New Zealand King Salmon (2011). *NZ King Salmon Report.* 165 pp.

OIE (2013). *Aquatic animal health code. Chapter 4.5. Fallowing in aquaculture.* 2 pp.

Olivares J and S Marshall (2010). Determination of minimal concentration of *Piscirickettsia salmonis* in water columns to establish a fallowing period in salmon farms. *Journal of Fish Diseases* 33: 261-266.

Robertsen B (2011). Can we get the upper hand on viral diseases in aquaculture of Atlantic salmon? *Aquaculture Research* 42: 125-131.

Saksida SM (2006). Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms* 72: 213-223.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Sim-Smith C and A Forsythe (2013). *Comparison of the international regulations and best management practices for marine fish farming.* Prepared for the Ministry of Primary Industries. NIWA client report no. AKL2013-013. 85 pp.

Stewart JE (1998). *Sharing the waters: an evaluation of site fallowing, year separation and distances between sites for fish health purposes on Atlantic salmon farms.* Canadian Technical Reports in Fisheries and Aquatic Sciences 2218. 56 pp.

St-Hilaire S (2000). *Epidemiology of infectious hematopoietic necrosis disease in net-pen reared Atlantic salmon in British Columbia, Canada.* PhD thesis, University of Guelph. 225 pp.

Van Banning P (1991). Observations on bonamiasis in the stock of European flat oyster, *Ostrea edulis*, in the Netherlands, with special reference to the recent developments in Lake Grevelingen. *Aquaculture* 93: 205–211.

Van Banning P (1988). Management strategies to control diseases in the Dutch culture of edible oysters. *American Fisheries Society Special Publication* 18: 243–245.

Wallace IS, Munro LA, Kilbrun R, Hall M, Black J, Raynard RS and AG Murray (2011). *A report on the effectiveness of cage and farm-level fallowing for the control of bacterial kidney disease and sleeping disease on large cage-based trout farms in Scotland.* Scottish Marine and Freshwater Science Report. Volume 02, Number 10. 40 pp.

Warren JW (1983). *Bacterial kidney disease. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. pp. 185-192.

Werkman M, Green DM, Murray AG and JF Turnbull (2011). The effectiveness of fallowing strategies in disease control in salmon aquaculture assessed with an SIS model. *Preventive Veterinary Medicine* 98: 64-73.

Wheatley SB, McLoughlin MF, Menzies FD and EA Goodall (1995). Site management factors influencing mortality rates in Atlantic salmon (*Salmo salar* L.) during marine production. *Aquaculture* 136: 195-207.

Zanin E, Allegretti M, Giorgetti, G and G Ceshia (1983). Initiation and appraisal of an official prophylactic policy against VHS in farmed trout in the Province of Trento, Italy. *Bulletin of the European Association of Fish Pathologists* 3: 5-6.

5.12 FEEDS AND FEEDING

Animal feeds are subject to the Agricultural Compounds and Veterinary Medicines (ACVM) (Exemptions and Prohibited Substances) Regulations 2011 which specify requirements on animal feeds and other agricultural compounds exempted from registration under the ACVM Act: http://www.foodsafety.govt.nz/industry/acvm/petfood-stock-feed-supplements/

Diet and feeding can affect susceptibility to both infectious and non-infectious diseases (Cho 1983; Meyer 1991; Anon 2005; Gavine *et al.* 2007; Code of Good Practice Management Group 2011).

Numerous variables influence the nutritional requirements of the production stock including, but not limited to, species farmed, life stage, type of culture and environment (Hinrichsen 2007). Food safety requirements, consumer requirements and the sustainability of feed components are also important factors for consideration (Code of Good Practice Management Group 2011).

Upgrading of feed quality, performance and feeding techniques were some of the key factors identified leading to the reduction in the number of smolts transferred per tonne of salmon harvested (Stewart 1998). However, despite these advances in aquaculture feed production (Stewart 1998; Aquaculture Stewardship Council 2012a; Aquaculture Stewardship Council 2012b), nutritional imbalances continue to cause health problems in aquaculture stock (Warren 1983a). A recent disease epidemic in yellowtail kingfish (*Seriola lalandi*) was resolved following dietary taurine supplementation (Clean Seas 2013; Huynh and Landos 2013).

The culture of carnivorous fish often utilises fish meal as the primary protein source (Penn *et al.* 2011). Alternative protein sources, such as soybeans, have been investigated, but have limited application because of negative effects at high concentrations (Krogdahl *et al.* 2003; Penn *et al.* 2011). Krogdahl *et al.* (2003) found a correlation between soybean inclusion in Atlantic salmon feed and the relative severity of the morphological changes in the distal intestine and apparent digestive and absorptive dysfunction. Penn *et al.* (2011) observed that feeding Atlantic salmon a pea protein concentrate at high inclusion (350 g/kg) resulted in similar effects to that observed to feeding a soybean diet.

Recently, a semi-commercial trial of yellowtail kingfish culture in the Marlborough Sounds, New Zealand was unsuccessful, in part due to cold water temperatures and the absence of winter diet formulations (Zeldis *et al.* 2010).

Improper feed storage may lead to nutrient breakdown, resulting in nutritional deficiencies in stock (Heasman and Savva 2007; Yanong and Erlacher-Reid 2012). Improper storage can also lead to contamination by pests (rats, mice, insects) and growth of bacteria and/or fungi (Heasman and Savva 2007; Yanong and Erlacher-Reid 2012). Formulated feeds should be stored appropriately (according to the manufacturer's instructions) and have a rapid turnover to avoid deterioration associated with extended storage times (Heasman and Savva 2007).

Live foods (e.g. algae, brine shrimp, copepods, oligochaetes, rotifers) may also be a source of pathogen transfer (Elston 1984; Olafsen 2001; Lowers and Bartholomew 2003; Elston *et al.* 2008; Yanong and Erlacher-Reid 2012). In 2006 and 2007, outbreaks of vibriosis (*Vibrio tubiashii*) in North American shellfish hatcheries included the contamination of on-site algal cultures (Elston *et al.* 2008). Persistent contamination of these cultures may contribute to the

chronic occurrence of vibriosis in shellfish hatcheries and nurseries (Elston *et al.* 2008). However, a variety of methods exist for reducing pathogen loads in live feed cultures (Elston *et al.* 2008; Yanong and Erlacher-Reid 2012).

Some land-based abalone farms depend on the collection of wild seaweeds to supplement the pelleted diets of their stock (Aquaculture Stewardship Council 2012a). However, wild seaweed may act as a vector for parasites, pests, diseases and associated organisms (Aquaculture Stewardship Council 2012a). In Tasmania and South Africa the presence of sessile single-celled coccidia-like parasites attached to gut epithelial cells were associated with stock fed wild seaweed (Handlinger *et al.* 2006).

Pathogens may also be spread to farmed and wild stock if dead fish are used as feed (or bait) (Goodwin *et al.* 2004; Anon 2005). This was observed more than 50 years ago with the transmission of viral haemorrhagic septicaemia (VHS) through feeding raw infected fish to healthy fish (Warren 1983b). The highest risk of reintroducing VHS from the marine environment to freshwater reared rainbow trout is now recognised to be feeding with raw marine fish (Raynard *et al.* 2007). Imported frozen fish fed to tuna has been implicated in the introduction of pilchard herpes virus to Australia, which resulted in mass mortalities of wild pilchards (Whittington *et al.* 2008). In another example, farmed *Seriola quinqueradiata* fed raw fish became infected with a larval cestode, *Callotetrarhynchus nipponica*, which reduced product marketability. The parasite was observed to disappear from farm sites following the replacement of raw fish with frozen food (Ogawa 1996).

Feeding to satiation is also important for disease management, as excesses of feed waste can affect water quality, deplete oxygen levels, cause gill damage, and provide an excellent medium for growth of opportunistic bacteria and fungi (Cho 1983; Olafsen 2001; Hinrichsen 2007). *Aeromonas salmonicida* subsp. *salmonicida* has been demonstrated to be associated with organic wastes and fish feed (Raynard *et al.* 2007). Further, fouling of tanks with feed has been previously linked to disease outbreak of epizootic haematopoietic necrosis virus in rainbow trout (OIE 2012).

Withdrawal of feed prior to handling and transport is used to reduce metabolism, oxygen demand and waste production. This action results in better water quality during crowding and transport, and improved food hygiene during processing (Farm Animal Welfare Committee 2014).

Recent research investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors. Freshwater salmonid farmers were shown to monitor feeding rate at least weekly by the majority of questionnaire respondents while feed wastage are generally monitored only occasionally. By contrast, the seawater salmonid farmers monitored feeding rate and feed wastage at least weekly. Some aquaculture research organisations feed their stock locally-caught frozen food, and one research facility did not treat the water used for rearing microalgae to be used as feed for cultured shellfish (Sim-Smith *et al.* 2014).

5.12.1 Conclusions

The selection of feeds and feeding regimes is critical to the welfare of aquaculture stock. The consideration of biosecurity with respect to feeds and feeding regimes can reduce disease and pest risk for both the individual site and the industry overall.

5.12.2 Options to minimise the risks associated with feeds and feeding

5.12.2.1 Objectives

To manage the risk of feed transferring pests and pathogens onto, within and from the facility. To manage the risk of feeding exacerbating the impacts of pests and pathogens within the facility.

5.12.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

The biosecurity risk of feeds and feeding procedures should be considered and appropriate actions taken to manage any identified risks.

Where aquatic organisms are to be used to feed stock, these should be pasteurised, irradiated or otherwise processed to a standard which ensures a microbiologically safe product.

Unless the above precautions are taken, aquaculture stock should not be fed to other aquaculture stock.

5.12.2.3 Detailed options

Feeds

A standard operating procedure (SOP) for feed quality and handling should be developed which covers aspects of feeding, quality, feed storage, handling and distribution. The following information should be recorded within the SOP:

- reception of each feed shipment to verify that it meets required quality specifications such as pellet size, type of diet, percentage of fines, proximal analysis, medication (as applicable) and weight;
- amount of feed (weight) that comes into the facility and the date of arrival of each shipment;
- shipments of feed from one site to another and the supporting documentation for the movements;
- physical control of inventory of stocks held in the warehouse;
- the amount, diet and pellet size of the feed given daily to the stock; and
- weekly checking of the calibration of weighing equipment and automatic and semi-automatic feeders (as applicable).

It should be ensured through labelling information or documentary assurance that feeds have been formulated specifically for the species, environment, feeding systems, and the life stage of the species that are being fed.

In the event that there is not a specifically-designated commercial diet available, advice should be sought from feed suppliers or independent stock nutrition experts as to the most appropriate type of feed to use.

Feed delivery and storage systems should be secure, and properly designed and maintained to:

- prevent spoilage and contamination;

- prevent wildlife and pest access;
- be protected from the environment and any other contaminants;
- maintain feed integrity; and
- prevent catastrophic loss.

Feeding

Facilities should have a written feed administration and management plan, which includes the following points:

- feeding the correct feed and feed size for the stock;
- feeding the correct amount of feed to any population of stock, in the proper manner and over the correct period(s) of the day;
- regular monitoring of feed conversion efficiency (following sample weighing), and assessment of whether feeding protocols and guidelines to assist facility personnel are effective; and
- procedures for incidence of non-compliance.

Feeding should be managed within the carrying capacity of the production system.

Water quality monitoring should be correlated and checked against feeding rates and production biomass so that adjustments can be made to the feeding programme.

Facility staff involved in feed delivery should undergo relevant training.

Facility staff should monitor and record feeding behaviours to review feed management and delivery in response to any changes or abnormality. If feeding is not active it may be necessary to suspend, delay or modify the feeding programme.

Water current speed, flow rate, turbidity, barometric pressure, oxygen levels, wind, territorial behaviour and other factors may influence feeding and thus the feeding strategy should be flexible and adaptive to ensure optimal intake and minimal wastage.

The oldest shipments of feed in the warehouse should be used first, as based on dated records of receipt (i.e. first in - first out).

Before transport or harvest, feed should be withheld to reduce metabolic rate and the excretion of waste products, and to eliminate the presence of food and faecal material in the gut at harvest, thus minimising the risk of microbiological contamination during processing.

5.12.3 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Aquaculture Stewardship Council (2012a). *ACS abalone standard. Version 1.0.* January 2012. 42 pp.

Aquaculture Stewardship Council (2012b). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Cho CY (1983). *Nutrition and fish health. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 63-74.

Clean Seas (2013). *Clean seas sustainable seafood investor update September 2013.* Port Lincoln, South Australia. http://www.cleanseas.com.au/main/home.html [Website accessed April 2014].

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Elston RA, Hasegawa H, Humphrey KL, Polyak IK and CC Hase (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119-134.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Gavine FM, BA Ingram, P Hardy-Smith and M Doroudi (2007). *Biosecurity control measures for abalone herpes-like virus: a code of practice.* Prepared as part of FRDC Project No. 2006/243. Department of Primary Industries, Victoria. 31 pp.

Goodwin AE, Petersen JE, Meyers TR and DJ Money (2004). Transmission of exotic fish viruses. *Fisheries* 29(5): 19-23.

Handlinger J, Bastianello S, Callinan R, Carson J, Creeper J, Deveney M, Forsyth WM, Freeman K, Hooper C, Jones B, Lancaster M, Landos M, Loh R, Oyay BS, Phillips P, Pyecroft S and F Stephens (2006). *Abalone aquaculture subprogram: a national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs.* FRDC project Report 2002/201, Tasmanian Aquaculture and Fisheries Institute, Hobart. 170 pp.

Heasman M and N Savva (2007). *Manual for intensive hatchery production of abalone. Theory and practice for year round, high density seed production of blacklip abalone (Haliotis rubra).* New South Wales Department of Primary Industries and Australian Government Fisheries Research and Development Corporation. 95 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Huynh C and M Landos (2013). *Yellowtail kingfish (Seriola lalandi) taurine deficiency - a diagnostic case study.* Presented at 2nd FRDC Australasian aquatic animal health scientific conference Cairns, Australia, 8-12 July 2013.

Krogdahl Å, Bakke-McKellep AM and G Baeverfjord (2003). Effects of graded levels of standard soybean meal on intestinal structure, mucosal enzyme activities, and pancreatic response in Atlantic salmon (*Salmo salar* L.). *Aquaculture Nutrition* 9: 361-371.

Lowers JM and JL Bartholomew (2003). Detection of myxozoan parasites in oligochaetes imported as food for ornamental fish. *Journal of Parasitology* 89(1): 84-91.

Meyer FP (1991). Aquaculture disease and health management. *Journal of Animal Science* 69: 4201-4208.

Ogawa K (1996). Marine parasitology with special reference to Japanese fisheries and mariculture. *Veterinary Parasitology* 64(1): 95-105.

OIE (2012). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.1 Epizootic haematopoietic necrosis.* 21 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Penn MH, Bendiksen EÅ, Campbell P and Å Krogdahl (2011). High level of dietary pea protein concentrate induces enteropathy in Atlantic salmon (*Salmo salar* L.). *Aquaculture* 310: 267-273.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinærmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Stewart JE (1998). *Sharing the waters: an evaluation of site fallowing, year separation and distances between sites for fish health purposes on Atlantic salmon farms.* Canadian Technical Reports in Fisheries and Aquatic Sciences 2218. 56 pp.

Warren JW (1983a). *Synthesis of a fish health management program. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp 151-158.

Warren JW (1983b). *Viral hemorrhagic septicaemia. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 175-180.

Whittington RJ, Crockford M, Jordan D and JB Jones (2008). Herpesvirus that caused epizootic mortality in 1995 and 1998 in pilchard *Sardinops sagax neopilchardicus* (Steindachner), in Australia is now endemic. *Journal of Fish Diseases* 31: 97-105.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 16 pp.

Zeldis J, Broekhuizen N, Forsythe A, Morrisey D and J Stenton-Dozey (2010). *Waikato marine finfish farming: production and ecological guidance.* NIWA report prepared for the Aquaculture Unit, Ministry of Fisheries. Report no. CHC2010-147. 112 pp.

5.13 GOOD HUSBANDRY

5.13.1 General

Marine and freshwater fish/shellfish, including aquaculture production species, are susceptible to a range of viral, bacterial, fungal, parasitic, nutritional and other non-infectious diseases. The interaction between three factors influences the occurrence of disease outbreaks in cultured aquatic animals (Snieszko 1973, Warren 1983a; European Food Safety Authority (EFSA) 2008):

- the host;
- the environment; and
- the presence or absence of a disease agent (pathogen).

All three may be present without disease, as many pathogens are ubiquitous in the environment or within the tissues of the cultured organisms themselves (Warren 1983a; EFSA 2008). However, changes to any of these factors, such as sub-optimal husbandry (i.e. the health of the host) or environmental parameters can facilitate the establishment and spread of clinical disease (EFSA 2008). Thus, clinical disease is generally indicative of an underlying husbandry or environmental perturbation (EFSA 2008). However, changes in the virulence of the pathogen can also facilitate the establishment and spread of clinical disease; there is increasing evidence that relatively unimportant bacterial pathogens can become highly virulent with the introduction of phage (Austin *et al.* 2003).

The interaction between host, environment and pathogen can be illustrated as three overlapping circles (Figure 6; Snieszko 1973). Circumstances that will result in the disease occurrence are represented by the common central area. Reductions in the influence of any of the three elements result in a corresponding decrease in the disease threat (Warren 1983a).

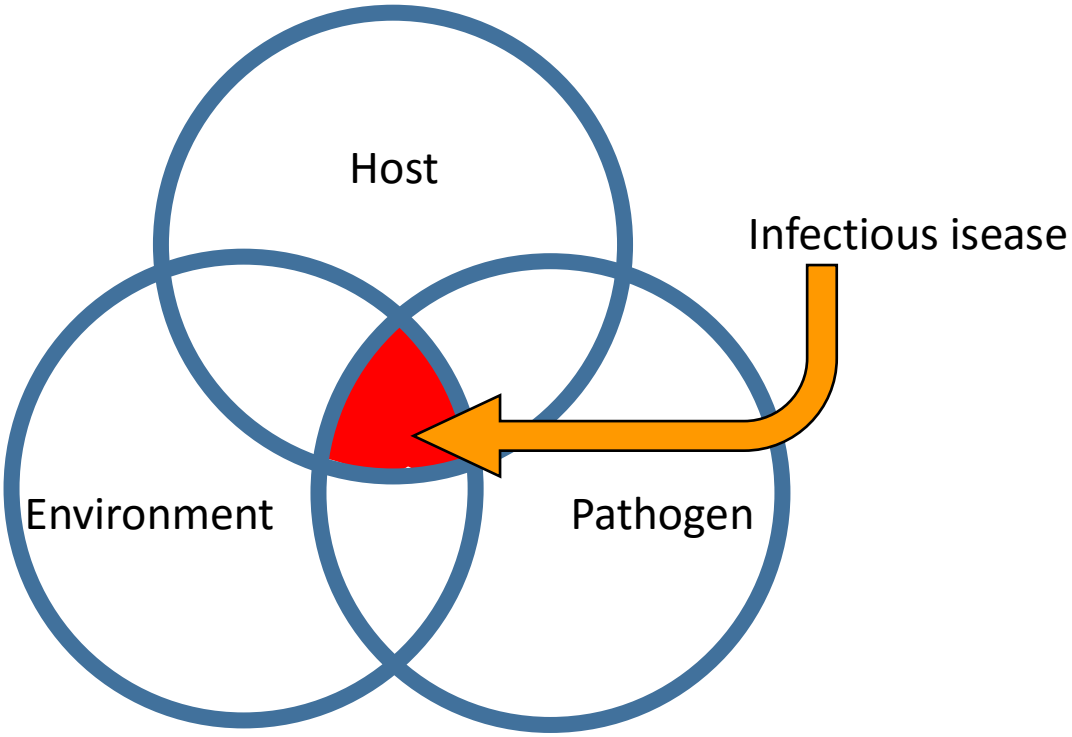

Figure 6: Host-Environment-Pathogen interrelationship with disease (Snieszko 1973).

Disease in cultured aquatic animals is closely linked with the animal husbandry and the environmental conditions experienced. As a consequence, facility managers attempt to minimise the risk of disease through optimising animal husbandry practices and environmental conditions for the species cultured, and to prevent the pathogens of concern (Maine Aquaculture Association 2006). For example, multi-nucleated sphere unknown (MSX) disease in Chesapeake Bay oysters can be preventively managed by producing stock in areas of low salinity (Ewart and Ford 1993).

Environmental conditions imposed on aquaculture production stock are determined by site selection, water supply characteristics, facility design, handling and transport systems, and the efficiency of waste removal (Warren 1983b). Good husbandry practices can be used to reduce the effects of adverse environmental conditions, to overcome deficiencies in facility design, and to reduce the frequency and severity of stress in production stock (Griffiths and Warren 1983).

Non-infectious diseases can have impacts to an aquaculture establishment that can be as devastating as infectious diseases (Subasinghe 2009). Non-infectious diseases are typically caused by factors such as inadequate management, poor water quality, inappropriate nutrition, environmental degradation, or exposure to chronic or acute contamination (Table 15; Subasinghe 2009). With respect to disease, preventive measures are typically the most effective, cost-efficient, and long-lasting (Meyer 1991).

Table 15: Examples of non-infectious diseases or causes of mortality in fish and shellfish (Post 1987; Untergasser 1989; EFSA 2008; Meyers 2010).

Description	Organism	Explanation
Gas bubble disease	Finfish	Air entrapment, drop in barometric pressure, heating of very cold water.
Gill hyperplasia	Finfish	Feed or particulate abrasion, chemicals including ammonia or formalin toxicity
Drop out	Finfish	Too little yolk at swim-up, sequel to white spot or not osmocompetent in seawater situations.
High egg or yolksac fry mortality	Finfish	Mechanical failure of incubator accompanied by ammonia toxicity and *Saprolegna*; overloading, blank eggs or other developmental problem.
Excessive fat in body cavity or fatty liver or both	Finfish	Overfeeding during cold water temperatures, inappropriate dietary fats.
Bloat	Finfish	Excessive feeding in seawater.
Malformation/deformations	Finfish	Inherited, oxygen depletion, pH imbalance, vitamin deficiency.
Gastrointestinal disorders	Finfish	Nutritional imbalance, vitamin deficiency, protein source (soya beans).
Malnutrition	Finfish	Protein, amino acid deficiency, aggressive behaviour of bigger fish and alpha males.
Hyperglycemia, liver hyperglycogenesis and increased liver mass	Finfish	Excess digestible carbohydrates in diet.
Vitamin deficiency	Finfish	Deficiency in essential nutrients in diet.
Skin abrasions	Finfish	Combat with other fish, poor handling, mechanical damage by nets.

Description	Organism	Explanation
Sunburn	Finfish	Exposure to excessive sunlight or UV light sources.
Acidosis/alkalosis	Finfish/shellfish	Extremes in pH.
Temperature stress	Finfish/shellfish	Sudden temperature changes, temperature out of inherent range for particular species.
Neoplastic diseases (Tumour growth)	Finfish/shellfish	Inherited, exposure to carcinogens, hormonal imbalance.
Contaminant exposure	Finfish/shellfish	Exposure to oxygen depleting materials, heavy metals, organic compounds, pesticides, therapeutic compounds, etc.
Mechanical trauma	Shellfish/finfish	Mechanical damage from fish pumps, brailing nets, grading, handling removal from substrate.
Summer mortality	Shellfish	Stress related due to prolonged near-mature condition of gonads.

Detection of a pathogen in association with a clinical disease outbreak does not necessarily mean causality. For example, stressful conditions, i.e. suboptimal environmental conditions resultant from poor management practices, may have provided the opportunity for proliferation of one or more infectious agents (Castinel *et al.* 2013).

Sub-optimal husbandry practices can induce chronic stress in aquatic animals making them more susceptible to diseases (Olafson 2001; Johnston and Jungalwalla no date). Consequences to stock health may range from the exacerbation and emergence of a "new" disease to the increased frequency of established diseases, impaired growth rates or reproductive capacity (Stewart 1998; Johnston and Jungalwalla no date; Castinel *et al.* 2013). This may result in sudden increases in mortalities or decreased productivity (Johnston and Jungalwalla no date). Improvements in stock husbandry and welfare can often improve productivity and hence lead to increased profitability (Johnston and Jungalwalla no date; Mouton and Gummow 2011; OIE 2013). In Scotland, improved husbandry was a key factor leading to a reduction of the number of smolts transferred per tonne of salmon harvested (Stewart 1998).

Many aquatic pathogens are opportunistic, as such disease outbreaks often occur in combination with an underlying stress, (e.g. poor water quality, environmental and physiological stressors, or poor nutrition) (Meyer 1991; Stewart 1998; Anon 2005; Yanong and Erlacher-Reid 2012). For example, furunculosis is fundamentally a finfish disease resulting from high population densities, with outbreaks occurring following further stressful conditions such as rapid temperature change, low water flow, high water temperature, crowding or handling (Raynard *et al.* 2007).

Because a range of husbandry practices can both prevent the occurrence and restrict the spread of aquatic diseases, good husbandry practices should be at the forefront of aquatic animal production operations (Stewart 1998; Anon 2000; Anon 2003; Anon 2005; OIE 2013). Stress of production stock has been linked to a large number of aquatic diseases, for example:

- finfish:
    - *Aeromonas hydrophila* (Cipriano 2001);
    - bacterial cold water disease (*Flavobacterium psychrophilum*) (Madetoja *et al.* 2000; Ryce and Zale 2004; Cipriano and Holt 2005; Johansen *et al.* 2009);
    - bacterial gill disease (*Flavobacterium branchiophila*) (Schachte 1983; Bullock 1990);

- enteric red mouth disease (*Yersina ruckeri*) (Furones *et al.* 1993; Tubbs *et al.* 2007; Johansen *et al.* 2009);
- epizootic haematopoietic necrosis (EHN) (OIE 2012a);
- fungal diseases (Meyer 1991);
- furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*) (Raynard *et al.* 2007);
- infection with *Mycobacterium* sp. (Tubbs *et al.* 2007);
- infectious pancreatic necrosis (IPN)/birnaviruses (Tubbs *et al.* 2007);
- infectious salmon anaemia (ISA) (Gustafsen *et al.* 2007);
- *Lactococcus garvieae* (Tubbs *et al.* 2007);
- parasites (e.g. monogeneans) (Thoney and Hargis Jr 1991);
- *Oncorhynchus masou* virus (OMV) (OIE 2012b);
- *Piscirickettsia salmonis* (Mauel and Miller 2002; Rozas and Enriquez 2014);
- red sea bream iridovirus (OIE 2012c);
- *Streptococcus iniae* (Tubbs *et al.* 2007);
- *Tenacibaculum maritimum* (Tubbs *et al.* 2007);
- viral encephalopathy and retinopathy virus (OIE 2012d); and
- viral haemorrhagic septicaemia (VHS) (Warren 1983c; OIE 2012e);

- shellfish:
  - bonamiosis (*Bonamia exitiosa; B. ostreae*) (Bower *et al.* 1994; OIE 2012f);
  - haplosporidian infection (*Haplosporidium* sp.) (Diggles and Oliver 2005);
  - hinge ligament disease (*Cytophaga*-like bacteria) (Elston 1993);
  - infection with *Boccardia* spp. (Tubbs *et al.* 2007);
  - infection with platyhelminth flatworms (Tubbs *et al.* 2007);
  - infection with *Polydora* spp. (Tubbs *et al.* 2007);
  - *Mycoplasmosis* (*Mycoplasma* sp.) (Tubbs *et al.* 2007);
  - marteiliosis (*Marteilia refringens*) (Bower *et al.* 1994; OIE 2012g);
  - ostreid herpesvirus microvariant 1 (OsHV-1) (Paul-Pont *et al.* 2013);
  - perkinsosis (*Perkinsus olseni; P. marinus*) (Villalba *et al.* 2004; Lester and Hayward 2005; Petty 2011); and
  - vibriosis (*Vibrio sp.*) (Elston 1984; Bolinches *et al.* 1986; Bower *et al.* 1994; Jones 2007).

Recent research investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors (Sim-Smith *et al.* 2014). The interviewees from freshwater salmonid farms reported that disease events experienced, namely enteric red mouth (*Y. ruckeri*), white spot (*Ichthyophthirius multifiliis*), amoebic gill disease (*Neoparamoeba* spp.), whirling disease (*Myxobolus cerebralis*), and fungal infections were typically the result of poor husbandry and could be eliminated with the improvement of farm management (Sim-Smith *et al.* 2014).

Preventive measures in aquaculture typically focus on:

- preventing the introduction of pathogens/pests **(Chapter 5.1 Biosecurity (general))**;
- maintenance of good water quality;
- avoidance or reduction of environmental stressors (low dissolved oxygen, temperature control, density control, and removal of metabolic wastes) **(Chapter 5.6 Biofouling (finfish); Chapter 5.7 Biofouling (shellfish); Chapter 5.12 Feeds and feeding; Chapter 5.27 Site location)**;
- adequate nutrition **(Chapter 5.12 Feeds and feeding)**;
- isolation of cultured animals from feral stocks **(Chapter 5.28 Stock containment)**; and

- vaccination, if available **(Chapter 5.23 Preventive practices (surveillance and vaccination)** (Meyer 1991).

5.13.1.1 Water quality

High standards of water quality are essential to the welfare of both aquaculture production and wild stocks. Aquaculture production creates the potential for water quality deterioration via the addition of nutrients, metabolites and other wastes to the water column. Impacts may include eutrophication leading to algal blooms and oxygen depletion (Hinrichsen 2007).

Although large fluctuations in water quality can cause severe stress or death, more subtle deterioration in water quality can compromise fish health (Georgiadis *et al.* 2001). Poor water quality has been linked with several infectious disease outbreaks within finfish production units, including, EHN, enteric red mouth disease, *Lactococcus garvieae, Mycobacterium* sp., *Streptococcus iniae* and *Tenacibaculum maritimum* (Tubbs *et al.* 2007). Water quality has also been implicated in increased susceptibility of oysters to OsHV-1 (Paul-Pont *et al.* 2013) and perkinsosis (Villalba *et al.* 2004).

Maintenance of water quality parameters within the known acceptable limits for the species concerned of should be a concern to production facilities (New South Wales Department of Primary Industries 2006; Zeldis *et al.* 2010; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012a; Aquaculture Stewardship Council 2012b). Stock at different stages of development may have different water quality requirements, particularly in relation to dissolved oxygen and carbon dioxide, temperature, pH, ammonia and levels of suspended particulate material (Code of Good Practice Management Group 2011).

Oxygen can be a limiting factor in both onshore and offshore aquaculture. In the former case, this is dependent on pond size to biomass ratio, climate, the rate of water displacement and oxygenation. In the case of cage aquaculture, this factor can be overcome provided species specific stocking densities are maintained and cages are well positioned (Hinrichsen 2007).

The sustainable production capacity of the water resource should be determined to prevent nutrient enrichment and eutrophication, which may result in algal blooms (Hinrichsen 2007; **Chapter 5.15 Harmful algal blooms 1: marine; Chapter 5.16 Harmful algal blooms 2: freshwater**). Site rotation (fallowing) of cage culture systems may reduce the localised water quality impacts of such systems (Hinrichsen 2007; **Chapter 5.11 Fallowing**).

The majority of New Zealand salmonid farmers (both freshwater and seawater), who responded to the recent biosecurity in aquaculture questionnaire monitored water temperature, dissolved oxygen concentrations at least weekly (Sim-Smith *et al.* 2014). pH, ammonia, and total nitrogen were generally monitored only occasionally by freshwater farmers and not at all by seawater farmers.

Few water quality parameters were monitored by questionnaire respondents from the mussel and oyster industries (Sim-Smith *et al.* 2014). One-third of respondents from the oyster industry monitored and one quarter of respondents from the mussel industry monitored water temperature on a weekly basis.

Poor water quality in farming regions can lead to food safety concerns. Seven interviewees believe that more is needed to be done to fix poor water quality issues (e.g. pollution from obsolete sewage treatment plants, septic tanks, recreational boats, terrestrial farm live-stock and sedimentation) (Sim-Smith *et al.* 2014). Poor water quality in farming regions

compromises biosecurity as stock reared in sub-optimal conditions is more susceptible to disease. Further it increases the number of stock transfers that occur because farmers must move shellfish to areas of good water quality to be suitable for human consumption.

In Europe, North America, Asia and Australia land-based facilities are used to depurate bivalves of bacterial contaminants and harmful microalgae (Dijkema 1995; McKindsey *et al.* 2007; Lees *et al.* 2010). The use of such facilities in New Zealand would remove the need for harvestable oysters to be transferred to new sites and could be used for the depuration of Kaitaia mussel spat during toxic algal blooms (Sim-Smith *et al.* 2014).

5.13.1.2 Stocking density

Overcrowding of production stock has been linked to outbreaks of disease (Warren 1983c; Raynard *et al.* 2007). Appropriate stocking densities are governed according to the species being farmed and the farm environment including the production system and the ability to maintain a high standard of water quality (Anon 2005; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Sim-Smith and Forsythe 2013). One of the foundations for operational success of an aquaculture establishment is based on the farm location with respect to the animal's physiology and the seawater and seafloor dynamics (Warren 1983b; Blaylock and Whelan 2004).

Stocking density influences the rate of disease transmission on aquaculture facilities. Increasing the stocking density increases the rate of contact between infected and susceptible animals (Anon 2005). Reductions in stocking density may be used to alleviate disease problems (Anon 2005; OIE 2012d; OIE 2012e; OIE 2012f). Reducing the stocking densities of finfish has been recommended to prevent outbreaks of ISA (Gustafsen *et al.* 2007), bacterial cold water disease (*F. psychrophilum*) (Barnes and Brown 2011) and viral encephalopathy and retinopathy virus (OIE 2012d). Reducing stocking densities has been recommended to manage outbreaks of bonamiosis (Bower *et al.* 1994; OIE 2012f), marteiliosis (OIE 2012g) and perkinsosis (*Perkinsus olseni; P. marinus*) in shellfish (Petty 2011).

The sea bed beneath an aquaculture site often acts as a sink for solid organic wastes (for example, faeces, pseudo-faeces, debris and uneaten food) (Anon 2000; Aquaculture New Zealand 2007; Aquaculture Stewardship Council 2012a; Aquaculture Stewardship Council 2012b). Input of solid organic waste is influenced by factors such as farm production scale, duration and intensity, husbandry practices and food utilisation rate and efficiency in addition to factors that control the environmental assimilative capacity (e.g. water depth, sedimentation rate, current and wind speed) (Keeley *et al.* 2009; Aquaculture Stewardship Council 2012b). Typically, faster sediment recovery has been found at high energy sites, while recovery is slower at more heavily impacted sites (Anon 2000). Changes in the sediments due to high waste deposits are thought to have adverse effects on stock health (Wheatley *et al.* 1995). The positioning of farm structures has recently shifted to be perpendicular to current flow to allow maximisation of water flow, oxygen supply and waste removal (Jensen *et al.* 2010).

5.13.1.3 Carrying capacity

Where filter feeding shellfish are cultivated in high densities the potential exists for the production carrying capacity of the water body to be exceeded (Global Aquaculture Alliance 2013). If the rate at which the phytoplankton is removed by the molluscs outstrips the capacity of the ecosystem to replenish the supply, the reduced food availability can negatively

impact the growth and health of molluscs (farmed and wild) as well as other species (Association of Scottish Shellfish Growers 2005; Global Aquaculture Alliance 2013).

5.13.1.4 Stock handling

Handling or transport of aquaculture stock can lead to stress and increased susceptibility to infection (Olafsen 2001; Barnes and Brown 2011). Handling stress has been implicated in the outbreaks of finfish diseases, including, VHS (Warren 1983c), enteric red mouth disease (Furones *et al.* 1993), bacterial cold water disease (Ryce and Zale 2004) and furunculosis (Raynard *et al.* 2007). Handling can result in cutaneous lesions and tissue death providing the ideal point-of-entry for the pathogen (Westers 1983; Meyer 1991; Barnes and Brown 2011). Abrasion of the skin and mucus enhanced invasion of *F. psychrophilum* among rainbow trout (Madetoja *et al.* 2000). Maintenance of a healthy integument has also been identified as a measure for the prevention of EHN (OIE 2012a).

Although some handling stress is unavoidable, the effects can be reduced through proper facility and equipment design and technique (Westers 1983). Handling minimisation and care has been recommended as a preventive measure for ISA, OMV and VHS (Gustafsen *et al.* 2007; OIE 2012b; OIE 2012d). In oysters, avoidance of handling stress has been recommended as a preventive measure for *B. exitiosa* (OIE 2012f). Further, improvements to shell handling techniques eliminated pearl oyster mortalities due to *V. harveyi* infection (Jones 2007).

5.13.2 Conclusions

Inappropriate husbandry is a major cause of both infectious and non-infectious disease in aquaculture, causing losses in stock condition and increasing stock susceptibility to disease. Optimal husbandry practices will reduce the potential for on-farm disease outbreaks and serve to minimise the risk of transferring husbandry related problems (e.g. disease, water quality, carrying capacity) to neighbouring farms and the ecosystem. Improvements in stock husbandry and welfare can often improve productivity and lead to increased profitability.

5.13.3 Options to aid the adoption of good husbandry

5.13.3.1 Objectives

To prevent of disease outbreaks and optimise production by managing stock health and welfare.

5.13.3.2 High level options

Facilities should have a veterinary health plan (VHP) which set out protocols for maintaining optimal stock health and welfare.

Facilities should have a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

5.13.3.3 Detailed options

General husbandry

Facilities should contain only one commercial species.

On a daily basis (weather and unforeseen circumstances permitting), the following should be inspected, monitored, and recorded:

- stock behaviour for signs of stress or other abnormalities;
- integrity of the structures and equipment;
- environmental factors (e.g. water quality);
- feeding behaviour; and
- presence or absence of predators and scavengers.

Remedial action should be taken immediately to rectify any unsatisfactory situation.

Water quality

Monitoring should be carried out to ensure that water quality parameters are maintained within the known acceptable limits for the species and developmental stage. The parameters measured and the monitoring intervals is dependent on the system, species, stage of development and time of year.

The facility should have a written water quality management plan that includes:

- monitoring procedures that includes frequent or continuous monitoring of parameters upon which the stock are critically dependent (e.g. dissolved-oxygen concentration);
- monitoring for other aspects of water quality in the vicinity of the facility, including seasonal occurrences, such as phytoplankton blooms;
- training of staff on monitoring procedures; and
- a list of practical mitigation measures that can be used in the event of water quality problems, as well as available equipment and trained staff to enact remedial action as soon as possible.

Where appropriate, automatic equipment fitted with alarms should be used to monitor water quality.

Aeration, oxygenation and water level monitoring equipment should be fitted with alarms and backup systems that are tested daily.

Automatic and emergency back-up and monitoring equipment should be routinely inspected, calibrated and serviced in accordance with manufacturer's recommendations.

Facility staff should be familiar with water quality parameters for their stock and be able to recognise visual and behavioural indicators of inadequate water quality.

All measurements should be made with calibrated instruments that provide reliable results.

Stocking density (general)

Stock should be held at densities that ensure adequate level of oxygen for their development and permit optimum health status.

Stocking density should be monitored in relation to health, behaviour and water quality to ensure that stock welfare is not compromised.

Offshore stock should be held at densities that prevent a significant accumulation of organic matter under holding facilities (e.g. cages, longlines, racks).

Stocks should be graded and thinned at regular intervals.

All stock movements onto the facility and from cage to cage, tank to tank or raceway to raceway etc, should be recorded for destination, age and date of shift to assist with traceability.

Stocking density (mussels and oyster racks)

Seeding, harvest and yearly growth surveys should be used to determine optimum stocking density.

Stocks should be graded and thinned at regular intervals. Methods should be employed to reduce loss or drop-off of animals during grow-out.

Carrying capacity (filter-feeding shellfish)

Nutrient inputs and outputs should be quantified for each production area.

Food community (e.g. detritus, phytoplankton and zooplankton) health and production issues should be monitored.

Growth and survival of shellfish should indicate that adequate food levels for the entire population during growth seasons.

Food availability should be enhanced by facility orientation and regular maintenance and cleaning.

Facilities should have in place a management plan that describes the corrective or collaborative actions to be taken when production carrying capacity at the facility or ecosystem level is exceeded.

Handling (finfish)

A standard operating procedure for all fish handling activities should be written and maintained.

Live fish should only be removed from water and handled when absolutely necessary.

Handling protocols should minimise abrasion, scale loss or undue fish stress.

If fish are handled, adequate support should be given to the body - live fish should never be held by the gills or tail only. Gloves should be worn at all times.

Although different species have different tolerances to being out of water, the time out of water should never be so long as to produce signs of distress. It is important to keep skin irrigated.

Facility staff should be trained in the handling of fish, as appropriate to each employee's job description. Documentation of this training should be recorded.

In all cases, fish should be kept wet, except where blotting dry is essential to avoid contamination of gametes during stripping.

Where pumps, pipes and grading equipment are used, these should be properly designed and correctly set up so that they do not injure or unnecessarily stress fish.

When hand nets are used they should be:

- of suitable proportions – physical size and mesh size;
- designed and constructed to minimise physical damage to fish; and
- kept clean, disinfected and in good repair.

Documentation of the following fish handling activities should be recorded:

- measurement and weight control;
- grading;
- selection;
- incubation of the eggs;
- counting of eggs and fish;
- splitting fish;
- internal transfers;
- control of photoperiod;
- fasting before harvesting;
- harvesting (only for on-growing centres); and
- disinfection of materials and equipment.

The traceability of each lot of fish throughout its growing cycle should be recorded, including at least origin, feeding, treatment and transfers (up to the processing plant).

Crowding

A written procedure for crowding of fish should be prepared and personnel trained in the appropriate techniques.

The frequency and duration of crowding should be kept to a minimum.

Nets should be checked for tears and damage prior to crowding and any damage detected should be repaired before fish are crowded.

Facility staff should:

- monitor fish behaviour during crowding and take action if fish show signs of stress or damage;
- remove and cull any moribund or damaged fish;
- ensure that enclosure nets and screens are kept clean to avoid water quality problems during crowding; and
- monitor oxygen levels during crowding and take corrective action if levels fall below a critical point for that species (the critical point will vary between species and with environmental factors).

Grading

The avoidance of injury and stress to fish should be a primary consideration when deciding on the method of grading to be employed.

Grading equipment should be designed and maintained so as not to damage, or unduly stress the fish.

Details of planned frequency and procedures for grading should be part of the veterinary health plan and biosecurity plan.

All fish in net pens should be counted during each grading.

Handling (shellfish)

A standard operating procedure for all shellfish handling activities should be written and maintained.

Handling protocols should assure the welfare of the shellfish, for example, by avoiding mechanical damage to the foot of paua.

Facility staff should be trained in the handling of shellfish, as appropriate to each employee's job description. Documentation of this training should be recorded.

Live shellfish should only be removed from water and handled when absolutely necessary.

Different species have different tolerance to being out of water, but the time out of water should never be so long as to produce signs of distress.

Documentation of following shellfish handling activities should be recorded:

- measurement and weight control;
- grading;
- selection;
- incubation of the eggs;
- counting of eggs and stock;
- separating shellfish;
- internal transfers;
- fasting before harvesting (where applicable);
- harvesting (only for on-growing centres); and
- disinfection of materials and equipment.

Where equipment is used, this should be designed to avoid injury or unnecessary stress to shellfish.

The traceability of each lot of shellfish throughout its growing cycle should be recorded, including at least origin, feeding, treatment and transfers (up to the processing plant).

Care should be taken to avoid the crushing of shell-stock during harvest.

Handling (mussels and oysters)

Shellfish should be handled with care, avoiding extremes of temperature, drying out, throwing into trucks, high densities, etc.

Facility staff should be trained to identify stress factors and indicators to watch out for, such as shell gape.

Holding and transport facilities should be kept at cool temperatures and records should be available to document this action.

During the culling and grading process precautions should be taken to prevent any waste shell or other material from escaping into the environment, including traps or filters for containing any solids in wastewater from processing facilities and barges.

5.13.4 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture New Zealand (2007). *Greenshell™ mussel industry environmental code of practice.* New Zealand Mussel Industry Council Limited, 1999 (Revised, June 2007 by Aquaculture New Zealand). 82 pp.

Aquaculture Stewardship Council (2012a). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Aquaculture Stewardship Council (2012b). *ACS bivalve standard. Version 1.0.* January 2012. 57 pp.

Association of Scottish Shellfish Growers (2005). *Code of good practice.* 44 pp.

Austin B, Pride AC and GA Rhodie (2003). Association of a bacteriophage with virulence in *Vibrio harveyi. Journal of Fish Diseases* 26: 55-58.

Barnes ME and ML Brown (2011). A review of *Flavobacterium psychrophilum* biology, clinical signs, and bacterial cold water disease prevention and treatment. *The Open Fish Science Journal* 4: 40-48.

Blaylock RB and DS Whelan (2004). *Fish health management for offshore aquaculture in the Gulf of Mexico. In*: Bridger CJ (Ed.) Efforts to develop a responsible offshore aquaculture industry in the Gulf of Mexico: A compendium of offshore aquaculture consortium research.

Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, United States of America. pp. 129-161.

Bolinches J, Toranzo AE, Silva A and JL Barja (1986). Vibriosis as the main causative factor of heavy mortalities in the oyster culture industry in Northwestern Spain. *Bulletin of the European Association of Fish Pathologists* 6(1): 1-4.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Bullock GL (1990). *Bacterial gill disease of freshwater fishes.* United States Department of the Interior. Fish and Wildlife Service. Fish Disease Leaflet 84. 7 pp.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Cipriano RC and RA Holt (2005). *Flavobacterium psychrophilum, cause of bacterial cold-water disease and rainbow trout fry syndrome.* United States Department of the Interior. Fish and Wildlife Service. Fish Disease Leaflet 86. 44 pp.

Cipriano RC (2001). *Aeromonas hydrophila and motile aeromonad septicaemias of fish.* United States Department of the Interior. Fish and Wildlife Service. Fish Disease Leaflet 68. 25 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Diggles BK and M Oliver (2005). *Diseases of cultured paua (Haliotis iris) in New Zealand. In*: P Walker, R Lester and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 275-287.

Dijkema R (1995). *Large-scale recirculation systems for storage of imported bivalves as a means to counteract introduction of cysts of toxic dinoflagellates in the coastal waters of the Netherlands. In*: Poggi Rand JY Le Gall (Eds.) Second Conference Internationale sur la Purification des Coquillages. Rennes, France, 6-8 April 1992. IFREMER, pp. 355-367.

Elston RA (1993). Infectious diseases of the Pacific oyster, *Crassostrea gigas. Annual Review of Fish Diseases* 3: 259-276.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

European Food Safety Authority (EFSA) (2008). Scientific opinion of the panel on animal health and animal welfare on a request from the European Commission on the animal welfare aspects of husbandry systems for farmed trout. *The EFSA Journal* 796: 1-22.

Ewart JW and SE Ford (1993). *History and impact of MSX and dermo diseases on oyster stocks in the Northwest region.* Northeastern Regional Aquaculture Center Fact Sheet No. 200. University of Massachusetts, Dartmouth. pp 1-8.

Furones MD, Rodgers CJ and CB Munn (1993). *Yersinia ruckeri, the causal agent of enteric redmouth disease (ERM) in fish. Annual Review of Fish Diseases* 3: 105-125.

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Griffiths RH and JW Warren (1983). *The role of improved husbandry practices. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Special Publication 83-2. pp. 15-22.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Jensen Ø, Dempster T, Thorstad EB, Uglem I and A Fredheim (2010). Escape of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions* 1: 71-83.

Johansen R, Kongtorp RT, Bornø G, Skjelstad HR, Olsen AB, Flesjå K, Colquhoun D, Ørpetveir I, Hansen H, Garseth ÅH and B Hjeltnes (2009). *The health situation in farmed salmonids 2008.* National Veterinary Institute, Norway. 18 pp.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Jones JB (2007). *The Australian experience: pearl oyster mortalities and disease problems. In*: MG Bondad-Reantaso, SE McGladdery and FCJ Berthe (Eds.) Pearl oyster health management: a manual. FAO Fisheries Technical Paper. No. 503. Rome, FAO. pp. 87-93.

Keeley N, Forrest B, Hopkins G, Gillespie P, Clement D, Webb S, Knight B and J Gardiner (2009). *Sustainable aquaculture in New Zealand: Review of ecological effects of farming shellfish and other non-finfish species.* Prepared for the Ministry of Fisheries. Cawthron Report No. 1476. 150 pp.

Lees D, Younger A and B Doré (2010). *Depuration and relaying. In*: Rees G, Pond K, Kay D, Bartram J, and J Santo Domingo (Eds.) Safe Management of Shellfish and Harvest Waters. IWA Publishing, London. pp. 145-181.

Lester RJG and CJ Hayward (2005). *Control of Perkinsus disease in abalone.* University of Queensland - Marine Parasitology, Brisbane. Final Report. Project No. 2000/151. 41 pp.

Lumsden JS, Young K, Welsh K, MacInnes J, Russell S and S Hesami (2006). *Management approaches for coldwater disease caused by Flavobacterium psychrophilum. In*: Proceedings of the Canadian Freshwater Aquaculture Symposium - Aquaculture Canada 2004. St. Andrews, New Brunswick; Aquaculture Association of Canada Special Publication No. 11. pp. 111-117.

Madetoja J, Nyman P and T Wiklund (2000). *Flavobacterium psychrophilum*, invasion into and shedding by rainbow trout *Oncorhynchus mykiss. Diseases of Aquatic Organisms* 43: 27-38.

Maine Aquaculture Association (2006). *In*: Howell L and S Belle (Eds.) *Recommended code of practice for aquaculture in Maine.* Maine Aquaculture Association. Hallowell, Maine. 35 pp.

Mauel MJ and DL Miller (2002). Piscirickettsiosis and piscirickettsiosis-like infections in fish: a review. *Veterinary Microbiology* 87: 279-289.

McKindsey CW, Landry T, O'Beirn FX and IM Davies (2007). Bivalve aquaculture and exotic species: a review of ecological considerations and management issues. *Journal of Shellfish Research* 26(2): 281-294.

Meyer FP (1991) Aquaculture disease and health management. *Journal of Animal Science* 69: 4201-4208.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Mouton A and B Gummow (2011). The occurrence of gut associated parasites in the South African abalone, *Haliotis midae*, in Western Cape aquaculture facilities. *Aquaculture* 313: 1-6.

New South Wales Department of Primary Industries (2006). *The NSW oyster industry sustainable aquaculture strategy.* 64 pp.

OIE (2013). *Aquatic animal health code. Chapter 7.1. Introduction to recommendations for the welfare of farmed fish.* 4 pp.

OIE (2012a). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.1 Epizootic haematopoietic necrosis.* 21 pp.

OIE (2012b). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.10 Oncorhynchus masou virus.* 12 pp.

OIE (2012c). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.7 Red sea bream iridoviral disease.* 12 pp.

OIE (2012d). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.11 Viral encephalopathy and retinopathy virus.* 19 pp.

OIE (2012e). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.9 Viral haemorrhagic septicaemia.* 23 pp.

OIE (2012f). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.2 Bonamia exitiosa.* 11 pp.

OIE (2012g). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.4 Marteilia refringens*. 12 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Paul-Pont I, Dhand NK and R Whittington (2013). Influence of husbandry practices on OsHV-1 associated mortality of Pacific oysters *Crassostrea gigas. Aquaculture* 412-413: 202-214.

Petty D (2011). *Perkinsus infections of bivalve molluscs.* University of Florida, IFAS Extension. Document FA178. 7 pp.

Post G (1987). *Textbook of fish health. Revised and expanded edition.* TFH Publications Inc. pp. 225-282.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinærmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Rozas M and R Enriquez (2014). Piscirickettsiosis and *Piscirickettsia salmonis* in fish: a review. *Journal of Fish Diseases* 37(3): 163-188.

Ryce EKN and AV Zale (2004). *Bacterial coldwater disease in westslope cutthroat trout: hatchery epidemiology and control.* Final feport to the Wild Fish Habitat Initiative. Montana Water Center, Montana State University, Bozeman. 13 pp.

Schachte JH (1983). *Bacterial gill disease. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 181-184.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Sim-Smith C and A Forsythe (2013). *Comparison of the international regulations and best management practices for marine fish farming.* Prepared for the Ministry of Primary Industries. NIWA client report no. AKL2013-013. 85 pp.

Snieszko SE (1973). Recent advances in scientific knowledge and developments pertaining to diseases of fishes. *Advances in Veterinary Science and Comparative Medicine* 17: 291-314.

Stewart JE (1998). *Sharing the waters: an evaluation of site fallowing, year separation and distances between sites for fish health purposes on Atlantic salmon farms.* Canadian Technical Reports in Fisheries and Aquatic Sciences 2218. 56 pp.

Subasinghe R (2009). *Disease control in aquaculture and the responsible use of veterinary drugs and vaccines: the issues, prospects and challenges. In*: Rogers C and B Basurco (Eds.). The use of veterinary drugs and vaccines in Mediterranean aquaculture.
Options Méditerranéen nes: Série A. Séminaires Méditerranéens. No. 86. pp. 5-11.

Thoney DA and WJ Hargis Jr (1991). Monogenea (Platyhelminthes) as hazards for fish in confinement. *Annual Review of Fish Diseases* 1: 133-153.

Tobback E, Decostere A, Hermans K, Haesebrouck F and K Chiers (2007). *Yersinia ruckeri* infections in salmonid fish. *Journal of Fish Diseases* 30: 257-268.

Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M and C Sim-Smith (2007). *A review of aquatic diseases of significance to New Zealand.* Final Research Report for MAF Biosecurity New Zealand. NIWA Project No. ZBS 2005-17. 461 pp.

Untergasser D (1989). *Handbook of fish diseases.* HR Axelrod (Ed.) TFH Publications Inc. pp. 112-118.

Villalba A, Reece KS, Ordás MC, Casas SM, and A Figueras (2004). Perkinsosis in molluscs: a review. *Aquatic Living Resources* 17: 411-432.

Warren JW (1983a). *The nature of fish diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 7-14.

Warren JW (1983b). *Synthesis of a fish health management program. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 151-158.

Warren JW (1983c). *Viral hemorrhagic septicaemia. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 175-180.

Werkman M, Green DM, Murray AG and JF Turnbull (2011). The effectiveness of fallowing strategies in disease control in salmon aquaculture assessed with an SIS model. *Preventive Veterinary Medicine* 98: 64-73.

Westers H (1983). *Considerations in hatchery design for the prevention of diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 29-36.

Wheatley SB, McLoughlin MF, Menzies FD and EA Goodall (1995). Site management factors influencing mortality rates in Atlantic salmon (*Salmo salar* L.) during marine production. *Aquaculture* 136: 195-207.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Publication No. 4707 February 2012. 16 pp.

Zeldis J, Broekhuizen N, Forsythe A, Morrisey D and J Stenton-Dozey (2010). *Waikato marine finfish farming: production and ecological guidance.* NIWA Client Report: CHC2010-147 prepared for MFish Aquaculture Unit. 112 pp.

5.14 HACCP PROCEDURES

HACCP (Hazard Analysis Critical Control Point) analysis is a science based risk management approach that has been traditionally used to enhance food safety (Whitehead and Orriss 1995; Jancke and Schwarz 2000; Gunderson and Kinnunen 2002). The HACCP approach was originally developed by The Pillsbury Co. in partnership with United States National Aeronautics and Space Administration (NASA) during the early 1960s for food supply to the the United States of America space programme (Food and Agriculture Association of the United Nations (FAO) 2009).

The HACCP approach is recognised as essential to ensuring the safety and suitability of food for human consumption. For example, the Codex Alimentarius General Principles of Food Hygiene recommends the adopting the HACCP approach wherever possible to enhance food safety (Codex Alimentarius Commission 1995; Whitehead and Orriss 1995).

The HACCP approach is used as a preventive tool to assess hazards and establish control systems rather than reactively relying on end-product testing. In addition to improving product safety, benefits the HACCP approach include:

- more effective resources use;
- cost savings;
- more timely response to issues; and
- enhanced potential for international trade (Whitehead and Orriss 1995; FAO 2009).

HACCP approaches are well advanced in the seafood-processing sector for food safety assurance, however, their application to aquaculture stock production is still in early development (Cato 1998; Joint FAO/NACA/WHO Study Group 1999). In terms of its applicability to biosecurity in aquaculture, the HACCP approach can be thought of as a pathway management tool (Jonathan Thompson pers. comm.). HACCP can illustrate how activities on and around an aquaculture facility can result in pathogen and pest introduction, establishment and spread. The process identifies critical points where such introductions can occur and develops standard procedures for minimising the risk to an acceptable level (Jancke and Schwarz 2000; Gunderson and Kinnunen 2003; Natural Resource Management 2007). Although minimisation is acceptable in some instances, it is unacceptable in others (Gunderson and Kinnunen 2003).

In terms of HACCP application on aquaculture production sites, preliminary experiments to control food-borne trematode infections in humans from cultured freshwater fish using HACCP have been successfully carried out by FAO in Asia (Khamboonruang *et al.* 1997; Lima dos Santos and Howgate 2011). Specific to biosecurity in aquaculture, the HACCP approach has been applied in shrimp hatchery operations (Schwarz 2007). Subcommittee on Aquatic Animal Health (SCAAH; 2016) suggest that biosecurity plans can be integrated with quality control systems such as HACCP.

HACCP plans relating to pest and disease management have been widely adopted by the US Fish and Wildlife Service for their natural resource management activities, including finfish production and re-stocking (http://haccp-nrm.org/plans.asp). Further, the use of HACCP analysis to prevent the spread of invasive species has become an American Society for Testing and Materials (ASTM) International standard (ASTM E2590-09 http://www.astm.org/Standards/E2590.htm) (Britton *et al.* 2011).

The implementation of HACCP methodology and principles has recently been recommended as the foundation of biosecurity for aquaculture facilities and disease-free compartments (Zepeda *et al.* 2008). Diagrams showing the pathways for potential introduction and spread of pathogens to and from the different production stages provide a good way of conceptualising different risk sources (Zepeda *et al.* 2008).

A HACCP-based biosecurity programme would involve the systematic assessment of all stages of an aquaculture operation, and the identification of stages that are critical to on-site biosecurity (Table 16). However, prior to application of HACCP to any part of the production process, pre-requisite programmes such as good aquacultural practices should be in place (Joint FAO/NACA/WHO Study Group 1999).

Table 16: The seven principles of the HACCP system (FAO 2001; Zepeda *et al.* 2008; Code of Good Practice Management Group 2011).

Step	Action
Hazard Analysis	Produce flow diagram of the aquaculture operation - from intake of stock to dispatch of final product; Identify and list potential physical, chemical, and biological hazards; and Specify preventive measures for the identified hazards.
Critical Control Points (CCPs)	Determine the points, procedures and operational steps that can be controlled to eliminate the hazards or minimize their likelihood of occurrence.
Critical Limits	Set limits to be met to ensure that critical control points can be managed.
Monitoring	Establish a system to monitor management of critical control points by observations or scheduled testing to ensure that critical limits are being met.
Corrective Actions	Establish corrective actions when monitoring indicates that critical limits are not being met.
Verification and Review	Establish procedures for verification which include supplementary tests and procedures to confirm that the HACCP system is working effectively. Review the system if the aquaculture operation is altered in any way.
Documentation	Documentation of all operating procedures. Maintenance of records of system monitoring.

As with all on-site biosecurity, successful implementation of the HACCP approach requires the full commitment and ongoing involvement of facility management and staff (Whitehead and Orriss 1995; Joint FAO/NACA/WHO Study Group 1999).

Documentation regarding the development of a HACCP plan can be found:
Ministry for Primary Industries
http://www.foodsafety.govt.nz/industry/general/haccp/
Food and Agriculture Association of the United Nations
http://www.fao.org/docrep/005/y1390e/y1390e0a.htm
US Fish and Wildlife Service
http://haccp-nrm.org/

Examples of a HACCP analysis applied to a typical shellfish hatchery and salmon farm are provided by Zepeda *et al.* (2008).

5.14.1 Conclusions

The establishment of an on-site biosecurity programme would benefit from using a HACCP based approach.

5.14.2 Options to aid the adoption of a HACCP based approach for on-site biosecurity

5.14.2.1 Objective

To identify effective control points to manage the risk of pest and pathogen transfer onto, within and from the facility.

5.14.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Facility biosecurity should be based on HACCP principles and methodologies.

HACCP plans should consider all potential biosecurity hazards, including those that may affect animal husbandry and therefore biosecurity indirectly, such as chemical, microbiological and physical hazards not controlled by existing provisions.

5.14.2.3 Detailed options

HACCP plans should be developed by a multi-disciplinary HACCP team. It should be possible to demonstrate that the team members have specific knowledge of HACCP principles and relevant knowledge of the production process.

HACCP systems should be capable of accommodating change, such as advances in equipment design, processing procedures or technological developments.

5.14.3 References

Britton D, Heimowitz P, Pasko S, Patterson M and J Thompson (Eds.) (2011). *HACCP. Hazard analysis and critical control point planning to prevent the spread of invasive species.* United States Fish and Wildlife Service National Conservation Training Center. 90 pp.

Cato JC (1998). *Economic values associated with seafood safety and implementation of seafood Hazard Analysis Critical Control Point (HACCP) programmes.* FAO Fisheries Technical Paper. No. 381. Rome, FAO. 70 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Codex Alimentarius Commission (1995). *Recommended international code of practice - general principles of food hygiene (CAC/RCP 1-1969, Rev. 2 (1985)).* In Codex Alimentarius, Volume 1B, General requirements (food hygiene). Rome, FAO/WHO. pp. 1-20.

Food and Agriculture Association of the United Nations (FAO) (2001). *Manual on the application of the HACCP system in mycotoxin prevention and control.* FAO/IAEA training and reference centre for food and pesticide control. FAO Food and Nutrition Paper 73. 118 pp. http://www.fao.org/docrep/005/y1390e/y1390e0a.htm
[Website accessed May 2014].

Food and Agriculture Association of the United Nations (FAO) (2009). *Food quality and safety systems. A training manual on food hygiene and the hazard analysis and critical control point (HACCP) system.* FAO Agricultural Policy and Economic Development Series. 243 pp. http://www.fao.org/docrep/W8088E/W8088E00.htm
[Website accessed May 2014].

Gunderson JL and RE Kinnunen (2003). *The HACCP approach to prevent the spread of aquatic invasive species by aquaculture and baitfish operations. In*: RC Summerfield and RD Clayton (Eds.) Aquaculture effluents: overview of EPA guidelines and standards and BMPs for ponds, raceways, and recycle culture systems. Proceedings from the conference, Ames, Iowa, October 9, 2003. Publications Office, North Central Regional Aquaculture Center, Iowa State University. pp. 27-40.

Jahncke ML and MH Schwarz (2000). *Application of hazard analysis and critical control point (HACCP) principles as a risk management approach for re-circulating aquaculture systems (RAS). In*: Proceedings of the third international symposium on recirculating aquaculture systems. 366 pp.

Joint FAO/NACA/WHO study group on food safety issues associated with products from aquaculture (1999). WHO Technical Report Series 883. 56 pp.

Khamboonruang C, Keawvichit R, Wongworapat K, Suwanrangsi S, Sukhawat K, Tonguthai K and CA Lima dos Santos (1997). Application of hazard analysis critical control point (HACCP) as a possible control measure for *Opisthorchis viverrini* infection in cultured carp (*Puntius gonionotus*). *Southeast Asian Journal of Tropical Medicine* 28(Suppl. 1): 65-72.

Lima dos Santos CAM and P Howgate (2011). Fishborne zoonotic parasites and aquaculture: a review. *Aquaculture* 318: 253-261.

Natural Resource Management (2007). *Hazard analysis and critical control point planning for natural resource management.* Available at: http://haccp-nrm.org/ [Website accessed April 2014].

Schwarz M (2007). *HACCP application in shrimp hatchery operations.* JIFSAN good aquacultural practices manual. Section 4. University of Maryland. 4 pp.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Whitehead AJ and G Orriss (1995). *Food safety through HACCP - the FAO approach.* Food, nutrition and agriculture 15 - Food safety and trade.
http://www.fao.org/docrep/v9723t/v9723t0e.htm [Website accessed May 2014].

Zepeda C, Jones JB and FJ Zagmutt (2008). Compartmentalisation in aquaculture production systems. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 229-241.

5.15 HARMFUL ALGAL BLOOMS 1: MARINE

Rapid population increases of particular phytoplankton species can occur in response to favourable environmental conditions. Although not all algal blooms are harmful to aquaculture growing operations (Anderson *et al.* 2001; Keeley *et al.* 2009), concern regarding algal blooms has grown as the number, type of resource affected, economic losses and number of harmful species have increased (Shumway 1990; Anderson 2009).

The defining characteristic of a harmful algal bloom (HAB) is that it causes harm. The harm caused may be the result of a toxin produced, the organisms' physical structure or their accumulated biomass (Blaylock and Whelan 2004; Johnston and Jungalwalla no date; Anderson 2009).

5.15.1 Effects associated with HABs

Mass mortalities and reduced aquaculture production have been attributed both to direct (e.g. toxicity) and indirect (e.g. hypoxia) effects of HABs (Shumway 1990; New Zealand Mussel Industry Ltd. 2002; Anderson *et al.* 2009; **Chapter 5.13 Good Husbandry**).

With respect to toxin-producing HABs, adverse effects can be observed on aquaculture stock only, on both aquaculture stock and human consumers, and on human consumers only (Shumway 1990).

Toxin-producing phytoplankton may be taken up by filter-feeding organisms that can accumulate the toxins to concentrations, which can be lethal to humans and other consumers (Shumway 1990; Anderson 2009). Many of the toxins resulting in human shellfish poisoning are produced by dinoflagellates, however, the amnesic shellfish toxin is produced by diatoms (Anderson 2009). HABs can appear and render shellfish toxic for human consumption virtually overnight (Shumway 1990).

Ciguatera fish poisoning is solely caused by the consumption of seafood contaminated with toxins produced by dinoflagellate microalgae, particularly *Gambierdiscus toxicus*. While there have been reports of potentially ciguatoxic dinoflagellate species in northern New Zealand waters, no cases of ciguatera fish poisoning have been associated with fish from these waters and, at least under New Zealand conditions (Creesey *et al.* 2007).

With respect to finfish, toxins may damage or disrupt gill function leading to blood hypoxia and death (Anderson *et al.* 2001). In terms of food safety, this process is said to occur rapidly with the toxins not being accumulated in the edible portions of the fish, although some exceptions exist (Anderson *et al.* 2001).

Alternatively, algal blooms may cause death by physically clogging gill respiratory surfaces, thus reducing oxygen absorption (Jones and Rhodes 1994). One such incidence was recorded in Wellington in 1993 (Jones and Rhodes 1994).

Phytoplankton blooms of high biomass can lead to widespread hypoxia and death as oxygen is consumed during the blooms' decay. Prolonged blooms of non-toxic species may also result in light attenuation and impact upon the viability of sea grass beds and the ecosystems that they support (Anderson 2009; Government of South Australia 2014).

Macroalgal blooms have a broad range of impacts (e.g. overgrowth of infrastructure including aquaculture stock and associated equipment, light attenuation, entanglement, noxious odour

caused by decay), which typically last longer than those produced by phytoplankton blooms (Anderson 2009; Fitridge *et al.* 2012) **(Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish))**.

The economic impacts to aquaculture operations as a result of HABs are wide-ranging, including: those associated with the conduct of monitoring programmes for food and stock safety, short- and long-term closures (with flow-on effects to processors, middle-men and suppliers), impacts on international trade and loss of market niche, and reductions in local seafood sales (Cato 1998; Anderson 2009).

One ongoing impact, known as the "halo effect", is the avoidance of uncontaminated seafood due to misinformed public perception (Shumway 1990; Cato 1998; Anderson *et al.* 2001; Anderson 2009). Management strategies focussed on increased public awareness, accurate reporting and positive education are required to prevent and mitigate the impacts associated with this effect (Shumway 1990; Anderson *et al.* 2001).

5.15.2 Monitoring programmes (preventive approach)

The primary goal for HAB monitoring and management programmes is to protect public health. Another major goal is ensuring the financial viability of aquaculture producers through protection against economic losses (Anderson *et al.* 2001). The foundation of any HAB monitoring programme is the ability to detect cells or toxins sufficiently early to enable management actions to be undertaken. Monitoring and industry awareness should be of sufficient temporal and spatial coverage to allow for selective closures of discrete sections of coastline (Anderson *et al.* 2001; Figure 7).

HABs are considered an issue for New Zealand aquaculture. For example, there have been recent HAB associated closures of commercial Greenshell™ mussel growing areas: http://www.foodsafety.govt.nz/elibrary/industry/seafood-risks-paralytic-shellfish-blooms.pdf

With respect to finfish, in January 1989 a bloom of the raphidophyte *Heterosigma akashiwo* was associated with the loss of an estimated 600 tonnes of farmed Chinook salmon (*Oncorhynchus tshawytscha*) in Big Glory Bay, Stewart Island. The total cost was estimated to be $17 million (Chang *et al.* 1990). In June 2010, approximately 200 tonnes of Chinook salmon died as a result of exposure to a bloom of the dictyochophyte *Pseudochattonella verruculosa* at Ruakaka Bay, Queen Charlotte Sound (MacKenzie *et al.* 2011).

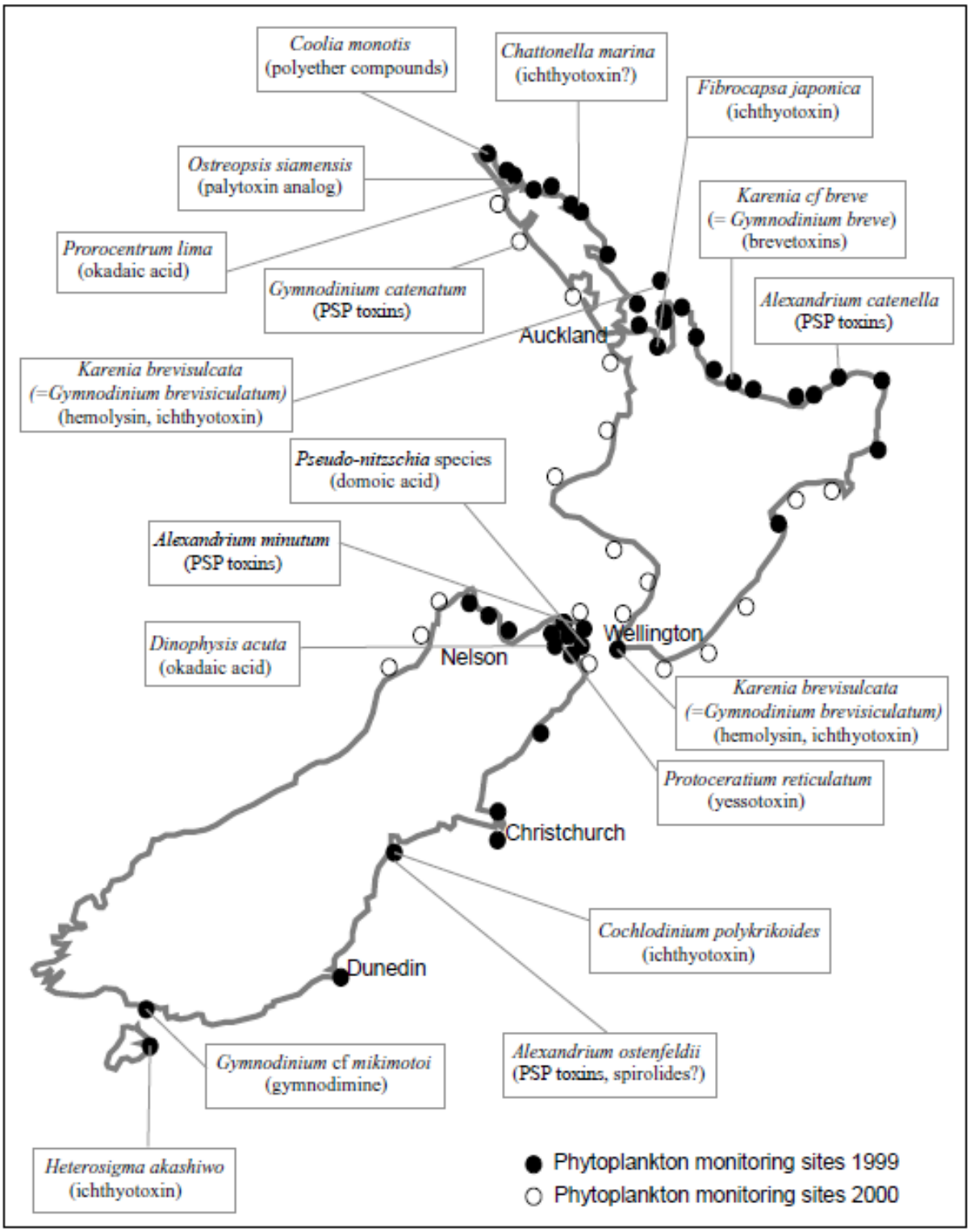

Figure 7: Map showing the many different toxic or potentially harmful phytoplankton species in New Zealand waters (Anderson *et al.* 2001).[5]

[5] Note: many more findings (and wider distribution) of toxic species have been found since the production of this map. For example, *Alexandrium catenella* in Marlborough Sounds, *Dinophysis acuta* Banks Peninsula, *Pseudonitzchia* species throughout New Zealand and *Gymnodinium catenatum* over big area of North Island and parts of Marlborough sounds (Forrest *et al.* 2011; Rhodes *et al.* 2013).

5.15.3 Spread via aquaculture industry and its management

The movement of HAB exposed shellfish can be a source of HAB spread (Shumway 1990; Anderson *et al.* 2001; New Zealand Mussel Industry 2002). In 2000, a bloom of *Gymnodinium catenatum* occurred off New Zealand's northwest coastline resulting in high densities of cysts being detected in shellfish spat. To mitigate the risk of spread, a voluntary ban on spat movements to all aquaculture regions in New Zealand was undertaken (Inglis *et al.* 2013). In response to this HAB bloom, the New Zealand Mussel Industry National Spat Transfer Programme was released in 2002 (New Zealand Mussel Industry Council Ltd. 2002). This programme was to facilitate "the safe transfer of mussel spat around areas of New Zealand in a manner designed to minimise the spread of the *G. catenatum*" (New Zealand Mussel Industry Council Ltd. 2002).

The programme represents a stepwise plan in response to detection of *G. catenatum* and its cysts. Spat treatment plants and transfer restrictions are used when 'trigger' levels are reached (New Zealand Mussel Industry Council Ltd. 2002; Inglis *et al.* 2013).

The New Zealand Mussel Industry National Spat Transfer Programme is currently under review. As at April 2014, the National Spat Transfer Programme has not been updated since 01/10/02 and only covers *G. catenatum* (New Zealand Mussel Industry Council Ltd. 2002). However, at the time of release there was "the intention that other unwanted toxic phytoplankton that may impact our spat growing areas in the future can be easily written into this programme so a comprehensive management tool can be provided" (New Zealand Mussel Industry Council Ltd. 2002). Further, Taylor (2000) recommended that to maximise industry benefit, lot testing of Kaitaia spat should include all potentially toxic dinoflagellate cysts and the review of the proposed lot testing regime at regular intervals.

Recent research investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors (Sim-Smith *et al.* 2014). The entry, establishment or exacerbation of harmful microalgae is a major concern from all the major aquaculture sectors. The main method used to manage the risk of entry, exacerbation or transfer by questionnaire respondents from the mussel industry is not harvesting when there is a harmful algal bloom in the area. Similarly, respondents from the oyster industry also test for harmful algal blooms. However, with respect to mussel spat harvesters there were some discrepancies in the questionnaire answers and on-site interviews regarding the testing for the presence of harmful algae and actions taken prior to transfer (Sim-Smith *et al.* 2014).

In Europe, North America, Asia and Australia land-based facilities are used to depurate bivalves of bacterial contaminants and harmful microalgae (Dijkema 1995; McKindsey *et al.* 2007; Lees *et al.* 2010). Such facilities could be used for the depuration of Kaitaia mussel spat and oysters during toxic algal blooms to prevent transfer to new sites (Sim-Smith *et al.* 2014).

5.15.4 Mitigation

There is much evidence to support the correlation between increased nutrient inputs and the development and persistence of many HABs species (Anderson *et al.* 2001). Although HABs may be influenced by nutrient inputs, there is no evidence to indicate that localised aquaculture generated enrichment or alteration in phytoplankton community structure has resulted in an increase in HAB incidence (Keeley *et al.* 2009; Aquaculture Stewardship Council 2012). It is also acknowledged that there are many areas, including within New Zealand, with little or no anthropogenic nutrient inputs that have ongoing incidences of HABs (Anderson *et al.* 2001; Keeley *et al.* 2009).

General improvement to water quality may help in limiting HAB impacts through reductions in nutrient loading to coastal waters although natural systems are complex, so such policies are not guaranteed to work (Anderson *et al.* 2001). As a result, prevention and management strategies are often employed in conjunction with environmental stewardship to avoid or minimise the effects observed from HABs (Anderson *et al.* 2001).

Mitigation of the effects of HABs to aquaculture production facilities is problematic. Planning and management method selection should typically be tailored to take into account the local hydrographic conditions (e.g. depth, current velocity, mixing properties), the nature of the HAB (e.g. vertical distribution, mode of action) and the needs and behaviour of the species cultured (Anderson *et al.* 2001). Such strategies may include:

- informed selection of site, species and culture method (Shumway 1990; Anderson *et al.* 2001; Anderson 2009);
- advance preparation of a prevention and management plan, detailing possible actions to be taken, including consideration of surveillance and monitoring and the management techniques available (Anderson *et al.* 2001);
- ongoing surveillance and monitoring (Shumway 1990; Anderson *et al.* 2001);
- good husbandry practice (cessation of feeding or handling) to reduce stress and oxygen consumption (Anderson *et al.* 2001);
- implementation of biofouling prevention and management practices (macroalgae) **(Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish))**;
- stock relocation (Anderson *et al.* 2001; Johnston and Jungalwalla no date; IFA Aquaculture 2011; MacKenzie *et al.* 2011);
- displacement of algae within net pens by lifting deep water (Anderson *et al.* 2001);
- use of perimeter skirts, aeration and ammonia stripping (Anderson *et al.* 2001);
- movement restrictions or treatment of spat (New Zealand Mussel Industry Council Ltd. 2002);
- pre-emptive harvesting (Anderson *et al.* 2001); and
- pre-emptive closures at specific times of the year (Shumway 1990).

Many of the above management methods are used by the Norwegian finfish aquaculture industry (Anderson *et al.* 2001).

Many chemicals have been proposed to prevent or manage the impact of HABs. However, the claims associated with their efficacy and environmental impacts (if any) are often not supported by robust scientific analysis (Anderson *et al.* 2001). Clay, as a flocculation agent, has shown promise to manage large scale blooms and is widely used in Korea (Anderson *et al.* 2001). However, a number of issues need to be resolved regarding its widespread use, including cost and potential for negative environmental effects (Anderson *et al.* 2001).

5.15.5 Conclusions

Harmful algal blooms can produce a variety of negative effects to an aquaculture facility including those associated with stock welfare and consumer safety. Preventive actions such as contingency planning supported by ongoing surveillance and monitoring can help producers minimise these impacts.

5.15.6 Options to minimise the risks associated with harmful algal blooms

5.15.6.1 Objective

To manage the risk of harmful algae transfer onto, within and from marine facilities.

5.15.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

In selecting a facility location care should be taken to avoid areas that have historically had frequent harmful algal blooms (HABs).

Facilities should be vigilant for the presence of algal blooms.

Facilities should have documented procedures for emergency response for specific types of HABs.

Consideration should be given to the translocation of algae when transferring stock or equipment between production units or sites.

5.15.6.3 Detailed options

Monitoring

Water quality parameters routinely tested should include the presence of harmful algae.

HAB monitoring and management programmes must be well documented, organised and as simple as possible to be functional and effective.

A HAB monitoring and management manual should be prepared, describing the structure of the monitoring programme in detail, the methods to be used and the management plans in relation to HABs.

Training courses should be implemented in the fields of phytoplankton taxonomy, quantitative analysis of phytoplankton (including HAB species), as well as handling and evaluation of results.

A geographic information system (GIS) database should be considered for storage, handling, evaluation and presentation of monitoring data for management of HABs.

HAB monitoring and management programmes should be reviewed annually and should be flexible to respond to change.

Periodic synthesis and analysis of fish and shellfish toxicity data generated by the monitoring programme should occur to determine long-term toxicity patterns, develop predictive relationships and allow re-evaluation of monitoring programme design, analysis and practices.

Finfish

Finfish facilities should have a strategy in place to prevent and/or manage HABs.

Such strategies may include:

- informed selection of site, species and culture method;
- advance preparation of a prevention and management plan, detailing possible actions to be taken, including consideration of surveillance and monitoring and the management techniques available;
- ongoing surveillance and monitoring;
- good husbandry practice (cessation of feeding or handling) to reduce stress and oxygen consumption;
- implementation of biofouling prevention and management practices (macroalgae);
- stock relocation (where permitted and taking into consideration the removal of fouling from nets and cages);
- displacement of algae within net pens by lifting deep water;
- use of perimeter skirts, aeration and ammonia stripping;
- pre-emptive harvesting.

Shellfish

Collection of broodstock from areas of known HABs should be avoided.

Information from the National and Local Biotoxin Management Plans should be considered prior to site selection, collection of broodstock, stock movements, etc.

Practices within the New Zealand Mussel Industry National Spat Transfer Programme should be reviewed (updated as necessary) and followed.

Lot testing of spat should include all potentially toxic dinoflagellate cysts found in New Zealand. A safe level should established for each species.

Shellfish (including spat and seedstock) should not be moved from an area currently experiencing a HAB.

MPI should be made aware of the status of the New Zealand Mussel Industry National Spat Transfer Programme and of any amendments or reviews that are made.

5.15.7 References

Anderson DM (2009). Approaches to monitoring, control and management of harmful algal blooms (HABs). *Ocean and Coastal Management* 52(7): 342-347.

Anderson DM, Andersen P, Bricelj VM, Cullen JJ and JE Rensel (2001). *Monitoring and management strategies for harmful algal blooms in coastal waters.* APEC #201-MR-01.1, Asia Pacific Economic Program, Singapore, and Intergovernmental Oceanographic Commission Technical Series No. 59, Paris. 269 pp.

Aquaculture Stewardship Council (2012). *ASC salmon standard. Version 1.0*. June 2012. 103 pp.

Blaylock RB and DS Whelan (2004). *Fish health management for offshore aquaculture in the Gulf of Mexico. In*: Bridger, C.J. (Ed.) Efforts to develop a responsible offshore aquaculture industry in the Gulf of Mexico: a compendium of offshore aquaculture consortium research.

Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, United States of America. pp. 129-161.

Cato JC (1998). *Economic values associated with seafood safety and implementation of seafood Hazard Analysis Critical Control Point (HACCP) programmes.* FAO Fisheries Technical Paper. No. 381. Rome, FAO. 70 pp.

Chang FH, Anderson C and NC Boustead (1990). First record of a *Heterosigma* (Raphidophyceae) bloom with associated mortality of cage-reared salmon in Big Glory Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24(4): 461-469.

Cressey P, Gilbert S and R Lake (2007). *Risk profile: ciguatoxins in seafood.* Prepared for New Zealand Food Safety Authority. Institute of Environmental Science and Research Limited Client Report FW0701. 43 pp.

Dijkema R (1995). *Large-scale recirculation systems for storage of imported bivalves as a means to counteract introduction of cysts of toxic dinoflagellates in the coastal waters of the Netherlands. In*: Poggi Rand JY Le Gall (Eds.) Second Conference Internationale sur la Purification des Coquillages. Rennes, France, 6-8 April 1992. IFREMER, pp. 355-367.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Government of South Australia (2014). *Fish kill investigation: Coffin Bay harmful algal (Karenia mikimotoi) bloom February 2014.* PIRSA Fisheries and Aquaculture Division. Aquatic Animals Health Unit. 33 pp.

IFA Aquaculture (2011). *The farmed salmonid handbook. Version 1.0.* 66 pp. http://www.fishhealth.ie/FHU/ [Website accessed May 2014].

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Jones JB and LL Rhodes (1994). Suffocation of pilchards (*Sardinops sagax*) by green microalgal bloom in Wellington Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 28(4): 379-383.

Keeley N, Forrest B, Hopkins G, Gillespie P, Clement D, Webb S, Knight B and J Gardiner (2009). *Sustainable aquaculture in New Zealand: review of ecological effects of farming shellfish and other non-finfish species.* Prepared for the Ministry of Fisheries. Cawthron Report No. 1476. 150 pp.

Lees D, Younger A and B Doré (2010). *Depuration and relaying. In*: Rees G, Pond K, Kay D, Bartram J, and J Santo Domingo (Eds.) Safe Management of Shellfish and Harvest Waters. IWA Publishing, London. pp. 145-181.

MacKenzie L, Smith K, Rhodes L, Brown A, Langi V, Edgar M, Lovell G, Preece M (2011). Mortalities of sea-cage salmon (*Oncorhynchus tshawytscha*) due to a bloom of *Pseudochattonella verruculosa* (Dictyochophyceae) in Queen Charlotte Sound, New Zealand. *Harmful Algae* 11: 45-53.

McKindsey CW, Landry T, O'Beirn FX and IM Davies (2007). Bivalve aquaculture and exotic species: a review of ecological considerations and management issues. *Journal of Shellfish Research* 26(2): 281-294.

New Zealand Mussel Industry Council Limited (2002). *New Zealand Mussel Industry National Spat Transfer Programme.* 64 pp.

Shumway S (1990). A review of the effects of algal blooms on shellfish and aquaculture. *Journal of the World Aquaculture Society* 21(2): 65-104.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Taylor MD (2000). *Sampling programme for lot testing of Gymnodinium catenatum cyst contamination in "Kaitaia spat"*. Report prepared for the New Zealand Mussel Industry Council Ltd. 12 pp.

5.16 HARMFUL ALGAL BLOOMS 2: FRESHWATER

Rapid population increases of particular freshwater phytoplankton species can occur in response to favourable environmental conditions. The factors that stimulate the majority of freshwater harmful algal blooms (HAB) include excessive nutrients (particularly nitrogen and phosphorous), temperature (greater than 20°C), light conditions, and lack of water turbulence and mixing (Rodgers Jr. 2008; Cheung 2013). HABs can be prolonged when conditions suitable for growth persist, such as those found in intensive aquaculture production systems (Smith *et al.* 2008).

Anthropogenic nutrients enter freshwater bodies through a variety of point and non-point sources. Point sources include urban storm-water collection systems, industrial conveyances, and farming operations (Hudnell 2010; Cheung 2013). Non-point sources include runoff from lawns, roads, highways, fields, pastures, forests and sewer overflows (Hudnell 2010; Cheung 2013).

Nutrient runoff from non-point sources enter the freshwater environment during rains and floods (Hudnell 2010).This is exacerbated by the depletion of wetlands following expansion of human populations and agricultural areas (Cheung 2013).

Not all algal blooms are harmful to aquaculture growing operations, however there is increasing concern regarding them in the freshwater environment (Rodgers Jr. 2008; Cheung 2013). Although the factors that stimulate HAB are relatively well known, the factors that stimulate toxin-production or the dominance of toxic versus non-toxic species are less understood (Cheung 2013).

The defining characteristic of a HAB is that it causes harm. The harm caused may be the result of a toxin produced, the organisms' physical structure or their accumulated biomass (Rodgers Jr. 2008; Smith *et al.* 2008; Hudnell 2010; IFA Aquaculture 2011).

In New Zealand the occurrence of freshwater HABs is monitored by regional, city and district councils, and public health agencies, for example:
http://www.gw.govt.nz/toxic-algae-faqs/
http://www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Rivers/Waikato-River/Algal-Blooms-in-the-Waikato-region/
http://ecan.govt.nz/services/online-services/monitoring/swimming-water-quality/Pages/Potentially-Toxic-Cyanobacteria.aspx
http://www.orc.govt.nz/Information-and-Services/Pest-Control/Plant-pests/toxic-algae/
http://www.tasman.govt.nz/environment/water/rivers/river-water-quality/monitoring-toxic-algae/
This monitoring is directed towards human health rather than for aquaculture purposes.

5.16.1 Effects associated with HABs

Mass mortalities and reduced aquaculture production have been attributed both to direct (e.g. toxicity) and indirect (e.g. hypoxia) effects of HABs (Rodgers Jr. 2008). Reduced production may be a result of decreased nutritional intake or energy re-allocated towards detoxification or repair processes (Smith *et al.* 2008). Compromised stock immunity may increase disease susceptibility (Johnston and Jungalwalla no date; Smith *et al.* 2008).

Cyanobacteria occur in freshwater (lakes, ponds, rivers and reservoirs) throughout the world including New Zealand (Carmichael 2001; Wood *et al.* 2006). Cyanotoxins can be hazardous

to humans through recreational activities or via consumption of contaminated drinking water or food (Wood *et al.* 2006).

Occurrence of "off-flavour" due to HAB toxins represents a significant barrier to growth of the freshwater aquaculture industry (Rodgers Jr. 2008; Smith *et al.* 2008). Costs associated with off-flavour include:

- stock holding and feeding during depuration;
- delays in restocking while depurating previous cohort; and
- stock mortalities during these delays (Smith *et al.* 2008).

Off-flavours have been reported to impact a number of commercially important species, including river caught Atlantic salmon and farmed rainbow trout (Farmer *et al.* 1995; Province of Manitoba 2003; Robertson *et al.* 2006; Salie *et al.* 2008).

5.16.2 Didymosphenia geminata

Didymosphenia geminata (didymo) is a freshwater diatom that was found in the lower Waiau and Mararoa rivers in Southland in October 2004. It has since spread to more than 150 rivers in the South Island. The Ministry of Agriculture and Forestry Biosecurity New Zealand (now Ministry for Primary Industries) declared the entire South Island a Controlled Area for didymo. This made it a legal requirement to clean all gear used in the water before going from one waterway to another. A check, clean, dry campaign is in place to help to limit didymo spread (http://www.mpi.govt.nz/funding-and-programmes/other-programmes/campaigns/check-clean-dry/). Didymo has yet to be detected in the North Island.

Didymo blooms are unusual because they typically occur in rivers with low nutrient concentrations, i.e. low supplies of soluble reactive phosphorus (Bothwell *et al.* 2014).

In a recent survey, New Zealand freshwater salmonid producers have expressed concern about preventing or managing didymo (Sim-Smith *et al.* 2014) and that didymo remains a risk to the producers and the aqutic environment. There have been impacts on freshwater salmon farming through implementation of voluntary decontamination requirements (Deloitte Touche Tohmatsu Ltd. 2011; http://www.biosecurity.govt.nz/pests/didymo/cleaning-specific). Sim-Smith *et al.* (2014) reported that all salmonid eggs from didymo-positive areas are treated before transfer to didymo-negative areas.

A build-up of didymo may restrict the flow of water through water intake screens (Deloitte Touche Tohmatsu Ltd. 2011) and nets. However, significant impacts of didymo on freshwater salmonid aquaculture have yet to be reported in New Zealand (Deloitte Touche Tohmatsu Ltd. 2011).

5.16.3 Management

Similar to marine aquaculture, mitigation of the effects of HABs to freshwater aquaculture production facilities is problematic (**Chapter 5.15 Harmful algal blooms 1: marine**). Planning and management method selection should typically be tailored to take into account the local hydrographic conditions (e.g. depth, current velocity, mixing properties), the nature of the HAB (e.g. vertical distribution, mode of action) and the needs and behaviour of the species cultured (Anderson *et al.* 2001). Such strategies may include:

- informed selection of site, species and culture method (Shumway 1990; Anderson *et al.* 2001; Anderson 2009);

- advance preparation of a prevention and management plan, detailing possible actions to be taken, including consideration of surveillance and monitoring and the management techniques available (Anderson *et al.* 2001);
- ongoing surveillance and monitoring (Shumway 1990; Anderson *et al.* 2001);
- good husbandry practice (cessation of feeding or handling) to reduce stress and oxygen consumption (Anderson *et al.* 2001; IFA Aquaculture 2011);
- implementation of biofouling prevention and management practices (macroalgae) **(Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish))**;
- stock relocation (Anderson *et al.* 2001; Johnston and Jungalwalla no date; IFA Aquaculture 2011; MacKenzie *et al.* 2011);
- displacement of algae from nets (Salie *et al.* 2008);
- use of aeration and ammonia stripping (Anderson *et al.* 2001; Rodgers Jr 2008; Smith *et al.* 2008);
- movement restrictions (Sim-Smith *et al.* 2014); and
- pre-emptive harvesting (Anderson *et al.* 2001).

Internationally, freshwater HABs are typically treated by chemical or non-chemical means. Chemical treatments include:

- potassium permanganate;
- diuron;
- aluminium sulphate;
- copper sulphate; and
- ammonium sulphate (Province of Manitoba 2003; Rodgers Jr. 2008; Salie *et al.* 2008; Smith *et al.* 2008; Hudnell 2010).

If such chemicals were to be used by the New Zealand industry, the application of chemical treatments would be subject to approval under the Hazardous Substances and New Organisms (HSNO) Act 1996. Chemical treatments may result in unwanted impacts on stock and the environment or result in resistant species (Rodgers Jr. 2008; Smith *et al.* 2008; Hudnell 2010).

For non-chemical management of HABs, nutrient inputs and water flow are the typical intervention points. Non-chemical measures include:

- vertical destratification via mechanical mixing and aeration;
- decreasing water retention time by increases to flow rate or flushing;
- biological control; and
- decreasing or altering nutrient input and composition (Province of Manitoba 2003; Rodgers Jr. 2008; Salie *et al.* 2008; Hudnell 2010).

These options may not be viable at all sites and in all situations (Rodgers Jr. 2008).

Improvement to water quality may help in limiting HAB impacts through reductions in nutrient loading (Paerl *et al.* 2001). However, as natural systems are complex such policies are not guaranteed to work (Anderson *et al.* 2001). As a result, prevention and management strategies (e.g. decreases in water retention, mixing and aeration) are often employed in conjunction with environmental stewardship to avoid or minimise the effects observed from HABs (Anderson *et al.* 2001; Hudnell 2010). Post-harvest chemical treatment of fish to remove off-flavour metabolites has had limited success (Smith *et al.* 2008).

5.16.4 Conclusion

Harmful algal blooms can produce a variety of negative effects to an aquaculture facility. Preventive actions such as contingency planning supported by ongoing surveillance and monitoring can help producers minimise these impacts.

5.16.5 Options to minimise the risks associated with harmful algal blooms

5.16.5.1 Objectives

To manage the risk of harmful algae transfer onto, within and from freshwater facilities.

5.16.5.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

In selecting a facility location care should be taken to avoid areas that have historically had frequent harmful algal blooms (HABs).

Facilities should be vigilant for the presence of algal blooms.

Facilities should have documented procedures to prevent the occurrence of HABs. For example, facilities should limit the amount of nutrients entering the environment by optimising feeding.

Facilities should consider mixing water in tanks, ponds, production units by mechanical methods or aeration.

Facilities should have documented procedures for emergency response for specific types of HABs.

Consideration should be given to the translocation of algae when transferring stock or equipment between production units or sites.

5.16.5.3 Detailed options

General

Tanks, ponds, production units should remain free of excess sediment, faeces and algae.

Nets should remain free of excess algae.

Regular testing should be conducted before harvesting to ensure fish are free of “off-flavour.”

Monitoring

Water quality parameters routinely tested should include the presence of harmful algae.

HAB monitoring and management programmes should be well documented, organised and as simple as possible to be functional and effective.

A HAB monitoring and management manual should be prepared, describing the structure of the monitoring programme in detail, the methods to be used and the management plans in relation to HABs.

Training courses should be implemented in the fields of phytoplankton taxonomy, quantitative analysis of phytoplankton (including HAB species), as well as handling and evaluation of results.

A geographic information system (GIS) database should be considered for storage, handling, evaluation and presentation of monitoring data for management of HABs.

HAB monitoring and management programmes should be reviewed annually and should be flexible to respond to change.

Periodic synthesis and analysis of fish toxicity data generated by the monitoring programme should occur to determine long-term toxicity patterns, develop predictive relationships and allow re-evaluation of monitoring programme design, analysis and practices.

Finfish

Finfish facilities should have a strategy in place to prevent and manage HABs.
Such strategies may include:

- informed selection of site, species and culture method;
- advance preparation of a prevention and management plan, detailing possible actions to be taken, including consideration of surveillance and monitoring and the management techniques available;
- ongoing surveillance and monitoring;
- good husbandry practice (cessation of feeding or handling) to reduce stress and oxygen consumption;
- implementation of biofouling prevention and management practices (macroalgae);
- stock relocation (where permitted and taking into consideration the removal of fouling from nets and cages);
- displacement of algae within net pens by lifting deep water;
- use of perimeter skirts, aeration and ammonia stripping;
- pre-emptive harvesting.

5.16.6 References

Anderson DM (2009). Approaches to monitoring, control and management of harmful algal blooms (HABs). *Ocean and Coastal Management* 52(7): 342-347.

Anderson DM, Andersen P, Bricelj VM, Cullen JJ and JE Rensel (2001). *Monitoring and management strategies for harmful algal blooms in coastal waters.* APEC #201-MR-01.1, Asia Pacific Economic Program, Singapore, and Intergovernmental Oceanographic Commission Technical Series No. 59, Paris. 269 pp.

Bothwell ML, Taylor BW and C Kilroy (2014). The didymo story: the role of low dissolved phosphorus in the formation of *Didymosphenia geminata* blooms. *Diatom Research 29*(3): 229-236.

Carmichael WW (2001). Health effects of toxin-producing cyanobacteria: "the CyanoHABs". *Human and Ecological Risk Assessment: An International Journal* 7(5): 1393-1407.

Cheung MY, Liang S and J Lee (2013). Toxin producing cyanobacteria in freshwater: a review of the problems, impact on drinking water safety, and efforts for protecting public health. *Journal of Microbiology* 51(1): 1-10.

Deloitte Touche Tohmatsu Ltd. (2011). MAF – didymo and other freshwater pests: economic impact assessment. Report prepared for Ministry of Agriculture and Forestry. 37 pp.

Farmer LJ, McConnell JM, Hagan TDJ and DB Harper (1995). Flavour and off-flavour in wild and farmed Atlantic salmon from locations around Northern Ireland. *Water Science and Technology* 31(11): 259-264.

Hudnell HK (2010). The state of U.S. freshwater harmful algal blooms assessments, policy and legislation. *Toxicon* 55: 1024-1034.

IFA Aquaculture (2011). *The farmed salmonid handbook. Version 1.0.* 66 pp. http://www.fishhealth.ie/FHU/ [Website accessed May 2014].

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: Guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australian-aquacultureportal.com/action_agenda/disease.html [Website accessed May 2014].

MacKenzie L, Smith K, Rhodes L, Brown A, Langi V, Edgar M, Lovell G, Preece M (2011). Mortalities of sea-cage salmon (*Oncorhynchus tshawytscha*) due to a bloom of *Pseudochattonella verruculosa* (Dictyochophyceae) in Queen Charlotte Sound, New Zealand. *Harmful Algae* 11: 45-53.

Paerl HW, Fulton III RS, Moisander PH and J Dyble (2001). Harmful freshwater algal blooms with an emphasis on cyanobacteria. *The Scientific World* 1: 76-113.

Province of Manitoba (2003). *Trout farming in Manitoba.* Manitoba, Canada. 25 pp. http://www.gov.mb.ca/waterstewardship/fisheries/commercial/tfarm.pdf

Robertson RF, Hammond A, Jauncey K, Beveridge MCM and LA Lawton (2006). An investigation into the occurrence of geosmin responsible for earthy–musty taints in UK farmed rainbow trout, *Onchorhynchus mykiss*. *Aquaculture 259*(1): 153-163.

Rodgers Jr. JH (2008). Algal toxins in pond aquaculture. Southern Regional Aquaculture Center Publication No. 4605. 8 pp.

Salie K, Resoort D, du Plessis D and M Maleri (2008). Training manual for small-scale rainbow trout farmers in net cages on irrigation dams: water quality, production and fish health. Report to the Water Research Commission. WRC Report NO TT 369/08. 25 pp.

Shumway S (1990). A review of the effects of algal blooms on shellfish and aquaculture. *Journal of the World Aquaculture Society* 21(2): 65-104.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Smith JL, Boyer GL and PV Zimba (2008). A review of cyanobacterial odorous and bioactive metabolites: impacts and management alternatives in aquaculture. *Aquaculture* 280: 5-20.

Wood SA, Briggs LR, Sprosen J, Ruck JG, Wear RG, Holland PT and M Bloxham (2006). Changes in concentrations of microcystins in rainbow trout, freshwater mussels, and cyanobacteria in Lakes Rotoiti and Rotoehu. *Environmental Toxicology* 21: 205-222.

5.17 HARVEST (FINFISH)

Dead fish, fish blood, body fluids and viscera are known sources of infectious material, therefore harvesting of farmed fish may spread disease. Risks are also associated with the transport of fish (alive or dead) and movement of contaminated equipment and personnel between sites (Anon 2000; Anon 2003; Anon 2005; Raynard *et al.* 2007; Code of Good Practice Management Group 2011; **Chapter 5.26 Removal and disposal of dead and moribund stock; Chapter 5.12 Feeds and feeding; Chapter 5.8 Cleaning and disinfection**).

Harvest and processing sites can have contacts with many farms and thus can act as hubs for widespread infection, highlighting the need for biosecurity procedures (Anon 2005). The spread of finfish diseases, especially viruses, through harvesting and associated activities has been repeatedly demonstrated. Outbreaks of infectious salmon anaemia (ISA) in Norway decreased dramatically in the years following the introduction of stricter hygiene regulations in processing plants and vessels that service them (i.e. well-boats) in 1990/91 (Jarp 1999). In Scotland, a strong association was observed between the movement of well-boats (i.e. a type of transport vessel), through shipment of live fish and visits for harvesting, and the spread of ISA virus at the regional and larger (ranging from 10 to several hundred kilometres) scale (Murray *et al.* 2002). This study was further supported by McClure *et al.* (2005) who found that sites had higher odds of contracting ISA if processing boats travelled within 1 km of them. Saksida (2006) also reported an instance where the smolts transported to two farms contracted infectious haematopoietic necrosis virus (IHNV) from water pumped into the fish holds as they travelled past a salmon processing facility (Saksida 2006).

5.17.1 On-site harvest

Although on-site harvesting has the advantage of not requiring the movement of live stock, it is associated with risks associated with containment of blood water and wastes and the between site movement of equipment and personnel (Anon 2000; Anon 2003; Munro *et al.* 2003; Anon 2005; Raynard *et al.* 2007). On-site harvesting poses a particular risk to neighbouring farms (Anon 2005). Following harvest, there are risks associated with spillage, loss of harvest bins at sea or cross-contamination from the re-use of dirty or contaminated harvest bins (Anon 2000; Anon 2003).

Inclement weather can exacerbate the risks associated with the on-site harvest of fish, therefore contingencies need to be adapted for heavy rainfall (e.g. containment of blood water) and rough seas (e.g. appropriate and secure moorings) to mitigate the contamination and containment risks (Anon 2000; Anon 2003).

5.17.2 Harvesting station at sea

At sea harvesting stations typically have holding cages into which live fish from production sites are transferred. By creating an independent harvest population, this type of harvest facility allows for greater harvest control and flexibility (e.g. allows for short-term planning). Further, the risks associated with between site movements of harvest equipment or personnel as well as weather dependency are greatly reduced (Anon 2000).

The principal risks associated with this method of harvest are in the uplifting and movement of live fish (e.g. containment) and the potential for transmission of infection, via transport vessel, back to the original farm sites as harvesting stations may act as disease hubs. Where

transport cages are used instead of transport vessels, there is the risk of equipment failure leading to escape and potential disease transmission (Anon 2000).

5.17.3 Shore-based harvesting stations

By allowing the transfer of fish directly from a transport vessel to an onshore harvesting facility, the discharge of fish into a sea-based holding facility should be eliminated from shore-based operations. Compared to harvesting at sea, shore-based harvesting has the advantage of being able to implement a higher level of containment (Anon 2000). However, Jarp and Karlsen (1997) demonstrated that close proximity to a shore-based processing plant was a risk factor for the occurrence of ISA on production sites.

The uplifting and movement of live fish and the disinfection of a large quantity of water from transport vessels are the principal risks associated with onshore harvesting. This method may also be associated with increased pre-harvest stress for fish resulting loss of product quality (Anon 2000).

5.17.4 Conclusions

Disease spread has been shown to be associated with the harvesting of farmed fish. It is important to both the individual farm and the industry as a whole that these risks are managed through good biosecurity practices as vectors associated with harvesting have been shown to transport diseases over large distances.

5.17.5 Options to minimise the risks associated with harvesting finfish

5.17.5.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility via harvesting.

5.17.5.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Facilities should maintain and comply with documented best practice procedures for harvesting.

Facilities should have procedures and contingency plans in place to ensure there are no fish escapes or effluent discharges.

5.17.5.3 Detailed options

Harvesting (general)

Crowding fish prior to harvesting should be for the minimum time possible, especially where more than one crowding session is necessary to complete the harvest.

Nets should be examined before crowding the fish and at intervals during harvesting operations to ensure the absence of defects likely to give rise to escapes and any defects repaired.

The harvest procedure should include a harvesting record that contains:

- length of time fasting before harvesting;
- method of disinfection of materials and implements;
- anaesthesia system and harvesting method;
- handling and disposal of blood water; and
- disposal of slaughtering wastes.

Mortalities should be collected, identified, and disposed of in an approved manner.

Facilities should have documented procedures to minimise the likelihood of damage from boats, rafts and equipment moored alongside pens.

Bleeding of fish should take place at a facility where the blood water is contained.

Blood water, effluent and waste should be treated and disposed of by an approved method.

At the end of each period of harvesting, all equipment (including harvest bins) should be thoroughly cleaned and disinfected.

Rafts and equipment should be made from materials which can be readily disinfected.

All activities involving movement of fish and the cleaning and disinfection of equipment should be recorded and the records retained.

Harvesting (Offshore)

On-site harvesting

The methods used to crowd fish, remove them from pens and harvest them should be assessed for the risk of escapes and contingency arrangements put in place to minimise the risk.

Killing tables should be equipped with sides high enough to prevent escapes or have a net positioned to capture any escaped fish. A suitable container or tarpaulin should be placed under the killing table to contain blood spillage and splashing.

Containment measures should be in place to prevent the leakage of blood water from harvest rafts, bins, etc. Leakage from harvest bins can be prevented by using harvest bins that:

- are leak proof;
- are in good condition;
- are double skinned; and
- have rubber seals and bindings.

Measures should be in place to prevent the loss of harvest bins and their lids at sea. Loss of harvest bins at sea can be prevented by:

- maintaining rafts in good repair;
- having contingency arrangements for poor weather conditions;
- ensuring harvest bins are properly loaded and secured; and

- using harvest bins that are buoyant and therefore recoverable.

Harvest bins and transport containers should not be overfilled, and enough 'freeboard' should be left at the top of the container to prevent spillage in any reasonably foreseeable conditions.

Harvest bins should be checked for damage, thoroughly cleaned and disinfected according to standard procedures between operations.

Harvest bins should have close fitting lids secured by ties.

All harvest bins should be labelled for identification purposes.

Equipment used for on-site harvesting should be dedicated to individual sites or, if moved between sites, should be thoroughly cleaned and disinfected prior to being moved.

Contingency plans for deteriorating weather should be in place before commencing harvest, including:

- rigorous procedures to minimise the likelihood of damage from harvest rafts, and equipment moored alongside cages;
- covering of blood water containment equipment to prevent rain water from entering; and
- delaying harvest until weather conditions become suitable.

Vehicles used to transport harvest bins should be fitted with a drainage pipe and sump to collect any spillage.

In the event of spillage the bed and sump should be cleaned and disinfected.

Vehicles should carry cleaning and disinfecting material. Staff should be trained in the use of the equipment and chemicals to be applied on leaving a site and in the event of spillage during transit.

Contingency plans should be in place to manage the risk of a major spillage or loss of a harvest bin in transit.

Pick-ups of harvested fish from more than one facility on route to a processing plant should be avoided.

Dedicated offshore harvest station (in addition to the above)

Production facilities (farms) should not be sited within the same management area as an offshore harvest site without approved effluent disinfection facilities.

The use of transport pens for moving fish from facilities to offshore harvest station should be limited to the transport of fish within a single management area.

Fish should not be transported from a harvest station to a production site.

Offsite harvesting (transport)

Live fish should not be moved into holding pens situated adjacent to a processing plant. It is acceptable to hold fish in tanks where the effluent from the tanks is disinfected.

The method used to crowd fish, remove them from pens for transport should be assessed for the risk of escapes and contingency arrangements put in place to minimise the risk.

Fish should not be transported from a processing facility to a production site.

Facilities should not be sited within the same management area as a processing plant without approved effluent disinfection facilities.

Provision should be made either for the disinfection of water used to transport live fish destined for harvesting, or the safe disposal of the water at sea (i.e. either at the site where it was extracted or at a minimum safe distance from any other site stocked with fish).

If a transport vessel is used to transport fish, any valves should remain closed within 5 km or at an appropriate distance (whichever is greater) of any fish production facility. Fish should be transferred directly from the vessel and not held in cages at the processing plant prior to harvest. Vessel associated water should either pass through the processing plant effluent treatment system prior to discharge or be discharged out at an appropriate distance or 5 km of any fish production facility (whichever is greater).

5.17.6 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Jarp J (1999). Epidemiological aspects of viral diseases in the Norwegian farmed Atlantic salmon (*Salmo salar* L.). *Bulletin of the European Association of Fish Pathologists* 19: 240-244.

Jarp J and E Karlsen (1997). Infectious salmon anaemia (ISA) risk factors in sea-cultured Atlantic salmon *Salmo salar*. *Disease of Aquatic Organisms* 28: 79-86.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anaemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Munro PD, Murray AG, Fraser DI and EJ Peeler (2003). An evaluation of the relative risks of infectious salmon anaemia transmission associated with different salmon harvesting methods in Scotland. *Ocean and Coastal Management* 46(1-2): 157-174.

Murray AG, Smith RJ and RM Stagg (2002). Shipping and the spread of infectious salmon anaemia in Scottish Aquaculture. *Emerging Infectious Diseases* 8(1): 1-5.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Saksida SM (2006). Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms* 72: 213-223.

5.18 HARVEST (SHELLFISH)

A variety of culture and harvesting methods are used by the New Zealand shellfish aquaculture industry. Harvesting is dependent on the tides, weather and the production method used (BC Shellfish Growers Association 2013). However, despite a moderate to high level of concern regarding pests and diseases, biosecurity practices to prevent the transmission of pests and diseases on mussel and oyster farms and mussel spat harvesting facilities are typically minimal (Sim-Smith *et al.* 2014).

5.18.1 Biofouling (Chapter 5.7 Biofouling management (shellfish))

Physical removal is the preferred industry practice to remove biofouling from both live-stock and equipment (Inglis *et al.* 2013). Methods of fouling removal and their frequency are dictated by the fouling composition and/or intensity (Fitridge *et al.* 2012).

The majority of New Zealand mussel farmers recently surveyed were found to only remove biofouling from their farms at harvest (Sim-Smith *et al.* 2014). During harvest or reseeding, mussels are mechanically stripped from the ropes and passed through tumblers which remove any soft fouling. Hard fouling, such as blue mussels and barnacles, are typically not removed by this equipment. Biofouling is typically cleaned on-site and disposed of in the sea. However, in some instances it is disposed of in a landfill.

In general, manual removal methods for biofouling do not remove all organisms. Organism fragments (e.g. *Didemnum vexillum*) or microscopic resistant stages (e.g. *Undaria pinnatifida* spores) may require additional treatment methods (e.g. desiccation, chemical disinfection) (National System for the Prevention and Management of Marine Pest Incursions (NSPMMPI) 2013).

Practices that return viable fouling organisms removed from the structures into the water may contribute to subsequent fouling problems in the surrounding environment (Aquaculture New Zealand 2007a; Inglis *et al.* 2013).

During mussel harvesting, biofouling organisms are removed from both floats and backbone ropes and returned to the sea in the consented farm area (Woods *et al.* 2012; Inglis *et al.* 2013). The cleaned floats are turned over to expose the biofouling to the air and the sun for at least 3 days. Backbone lines are also exposed at this time. Infrastructure and equipment that is not required is typically are taken onshore, washed down with freshwater, and dried for at least 3 days prior movement to different areas (Inglis *et al.* 2013).

The New Zealand oyster industry code of practice (Aquaculture New Zealand 2007b) gives guidance regarding the removal of biofouling from posts and rails during harvesting or re-stocking. Farmers are required to dispose of farm waste to an approved land-based site. Washing-down of crops (with seawater) may be used to prevent crop siltation and mudworm infestation (Aquaculture New Zealand 2007b; Inglis *et al.* 2013).

The main impacts of biofouling on shellfish aquaculture are:

- physical damage of stock;
- mechanical interference of stock;
- competition between fouling species and stock;
- increased disease risk; and

- deformation and maintenance of infrastructure (Fitridge *et al.* 2012; Johnston 2014; **Chapter 5.7 Biofouling management (shellfish)**).

Disposal of waste material should occur to an approved site on land, as per the oyster industry (Aquaculture New Zealand 2007b) however, the practicalities of this need to be explored (Inglis *et al.* 2013).

5.18.2 Disease

Dead and moribund shellfish may be sources of infectious material, therefore a high risk of spread of disease is often associated with harvesting. Further risk activities associated with shellfish harvesting include stock transport and movement of contaminated equipment and personnel between sites (**Chapter 5.7 Biofouling management (shellfish); Chapter 5.8 Cleaning and disinfection; Chapter 5.26 Removal and disposal of dead and moribund stock**).

It is widely recognised that dead and moribund shellfish are known pathogen sources, for example:

- abalone herpesvirus (Corbeil *et al.* 2012);
- ostreid herpesvirus microvariant 1 (OsHV-1) (Sauvage *et al.* 2009);
- *Perkinsus olseni* (Raynard *et al.* 2007); and
- *Perkinsus marinus* (Bobo *et al.* 1997).

The prompt removal and the appropriate storage (i.e. separated from rest of the site in secure, leak proof containers) and disposal of moribund and dead animals will help to reduce the probability of infection spread (Raynard *et al.* 2007; OIE 2013; **Chapter 5.26 Removal and disposal of dead and moribund stock).**

Handling of aquaculture stock can lead to stress and increased susceptibility to infection (Olafsen 2001; Maryland Aquaculture Co-ordinating Council 2007). In oysters, avoidance of handling stress has been recommended as a preventive measure for *Bonamia exitiosa* (OIE 2012). Further, improvements to shell handling techniques eliminated pearl oyster mortalities due to *Vibrio harveyi* infection (Jones 2007; **Chapter 5.13 Good husbandry**).

Once a disease is present within a shellfish harvesting area it is difficult to control and there is little possibility of eradication. Therefore, prevention is seen as the only effective measure (Centre for Environment, Fisheries and Aquaculture Science (CEFAS) 2009). Molluscan shellfish are susceptible to contamination during harvest (Maryland Aquaculture Co-ordinating Council 2007). The implementation of biosecurity and human hygiene procedures at harvest and processing sites is paramount because these sites can have contact with many farms and act as hubs for widespread infection (Anon 2005; Maryland Aquaculture Co-ordinating Council 2007).

New Zealand mussel spat harvesters generally do not use any methods to manage the risk of disease entry, exacerbation or transfer (Sim-Smith *et al.* 2014; **Chapter 5.30 Stock transfers**).

5.18.3 Conclusions

Biofouling of live-stock, infrastructure and vessels can potentially have wide-ranging impacts to shellfish aquaculture.

Once a disease is present within a shellfish harvesting area there is little possibility of eradication. Therefore, it is important to both the individual farm and the industry as a whole that these risks are preventively managed through good biosecurity practices.

Management actions are required to minimise the risks associated with shellfish harvest to the aquaculture industry and the environment.

5.18.4 Options to minimise the risks associated with harvesting shellfish

5.18.4.1 Objectives

To manage the risk of pest and pathogen transfer onto, within and from the facility via harvesting.

5.18.4.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Facilities should maintain and comply with documented best practice procedures for harvesting.

5.18.4.3 Detailed options

Ensure harvesting equipment is well maintained and regularly inspected.

The harvest procedure should include a harvesting record that contains the following:

- disinfection of materials and implements;
- harvesting method; and
- handling and disposal of wastes (e.g. unacceptable stock, biofouling).

Harvesting and grading should be carried out in such a manner as to minimise trauma to the live-stock.

Shellfish should be handled with care, avoiding extremes of temperature, drying out, high densities, etc.

Mortalities should be collected, identified, reported and disposed of in an approved manner.

At the end of each period of harvesting, all equipment (including harvest bins) should be thoroughly cleaned and disinfected according to standard procedures.

Documented procedures to minimise the likelihood of damage from boats, rafts and equipment moored alongside culture equipment should be established to prevent stock damage, stress or stock entering the environment.

Rafts and equipment should be made from material which is readily disinfected.

Records of all stock movements to and from cultivation sites (including delivery of spat and juveniles and dispatch of stock for relaying or to the market) should be maintained,

identifying, at the minimum, movement date, source, destination, volume or number or weight.

All activities involving movement of stock and the cleaning and disinfection of equipment should be recorded and the records retained.

Equipment used for on-site harvesting should be dedicated to individual sites or, if moved between sites, should be thoroughly cleaned and disinfected according to standard procedures prior to being moved.

Contingency plans for deteriorating weather should be in place before commencing harvest, including rigorous procedures to minimise the likelihood of damage from harvest rafts, and equipment moored alongside lines, racks, etc, to prevent stock damage, stress or stock entering the environment.

Harvest and transport containers should not be overfilled, and enough 'freeboard' should be left at the top of the container to prevent spillage in any reasonably foreseeable conditions.

Vehicles used to transport harvested stock should be fitted with a drainage pipe and sump to collect any spillage.

In the event of spillage the bed and sump should be cleaned and disinfected according to standard procedures.

Vehicles should carry cleaning and disinfecting material. Staff should be trained in the use of the equipment and chemicals to be applied on leaving a site and in the event of spillage during transit.

Contingency plans should be in place to manage the risk of a major spillage or loss of a harvested stock in transit.

Pick-ups of harvested stock from more than one facility location on route to a processing plant should be avoided.

5.18.5 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Aquaculture New Zealand (2007a). *Greenshell™ mussel industry environmental code of practice.* New Zealand Mussel Industry Council Limited, 1999 (Revised, June 2007 by Aquaculture New Zealand). 82 pp.

Aquaculture New Zealand (2007b). *New Zealand oyster industry code of practice.* 51 pp.

Association of Scottish Shellfish Growers (2005). *Code of good practice.* 44 pp.

BC Shellfish Growers Association (2013). *Environmental management code of practice.* 75 pp.

Bobo MY, Richardson DL, Coen LD and VG Burrell (1997). *A report on the protozoan pathogens Perkinsus marinus (Dermo) and Haplosporidium nelson (MSX) in South Carolina shellfish populations.* South Carolina Marine Resources Division Technical Report No. 86. 50 pp.

Centre for Environment, Fisheries and Aquaculture Science (CEFAS) (2009). *Shellfish biosecurity measures plan. Guidance and templates for shellfish farmers and traders.* Fish Health Inspectorate, Centre for Environment, Fisheries and Aquaculture Science. 28 pp.

Corbeil S, Williams LM, Bergfield J and M StJ Crane (2012). Abalone herpes virus stability in sea water and susceptibility to chemical disinfectants. *Aquaculture* 326-329: 20-26.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Johnston CJ (2014). *Statement of evidence on behalf of fisheries submitters before the Environmental Protection Authority.* 4 April 2014. 14 pp.

Jones JB (2007). *The Australian experience: pearl oyster mortalities and disease problems. In*: MG Bondad-Reantaso, SE McGladdery and FCJ Berthe (Eds.) Pearl oyster health management: a manual. FAO Fisheries Technical Paper. No. 503. Rome, FAO. pp. 87-93.

Maryland Aquaculture Co-ordinating Council (2007). *Best management practices a manual for Maryland aquaculture.* 44 pp.

National System for the Prevention and Management of Marine Pest Incursions (NSPMMPI) (2013). *National biofouling management guidelines for the aquaculture industry.* National System for the Prevention and Management of Marine Pest Incursions, Commonwealth of Australia, Canberra. 26 pp.

OIE (2013). *Aquatic animal health code. Chapter 4.6. Handling, disposal and treatment of aquatic animal waste.* 6 pp.

OIE (2012). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.2 Bonamia exitiosa.* 11 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Sauvage C, Pepin JF, Lapegue S, Boudry P and T Renault (2009). Ostreid herpes virus 1 infection in families of the Pacific oyster, *Crassostrea gigas*, during a summer mortality outbreak: differences in viral DNA detection and quantification using real-time PCR. *Virus Research* 142 (1-2): 181-187.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Woods CMC, Floerl O and BJ Hayden (2012). Biofouling of Greenshell™ mussel (*Perna canaliculus*) farms: a preliminary assessment and potential implications for sustainable aquaculture practices. *Aquaculture International* 20: 537-557.

5.19 JELLYFISH

Jellyfish associated impacts on aquaculture facilities are often caused by swarms of oceanic species whose migration is controlled by wind and currents (Delannoy *et al.* 2011; Gibbons and Richardson 2013).

Jellyfish can pass through the cage mesh either as whole or nematocyst-containing pieces (Purcell *et al.* 2007; Baxter *et al.* 2011; Delannoy *et al.* 2011; Mitchell *et al.* 2011). Jellyfish swarms can cause heavy stock losses (Purcell *et al.* 2007; Royal Society for the Prevention of Cruelty to Animals (RSPCA) 2012). Other impacts of jellyfish swarms on finfish aquaculture include:

- stinging of the fish (RSPCA 2012; Farm Animal Welfare Committee 2014);
- irritation and damage of the gills (Purcell *et al.* 2007; Baxter *et al.* 2011; Delannoy *et al.* 2011; Mitchell *et al.* 2011);
- accumulation within the gills (Farm Animal Welfare Committee 2014);
- reduction of water flow into cages (Bornø and Sviland 2011; Farm Animal Welfare Committee 2014);
- de-oxygenation of water (Hay 2006; Baxter *et al.* 2011; RSPCA 2012);
- stress (Johnston and Jungalwalla No date; Code of Good Practice Management Group 2011; RSPCA 2012); and
- secondary bacterial infections (Delannoy *et al.* 2011).

Some jellyfish species may harbour finfish pathogens, which may result in an opportunistic infection following gill damage (Delannoy *et al.* 2011). Delannoy *et al.* (2011) demonstrated the presence of the pathogenic bacteria, *Tenacibaculum maritimum* (formerly *Flexibacter maritimus*), on the mouth of a jellyfish (*Pelagia noctiluca*) that had no previous contact with farmed fish. Tenacibaculosis is an important disease of finfish aquaculture in both northern and southern hemispheres (Handlinger *et al.* 1997). Jellyfish may act as a vector of this disease within aquaculture populations (Delannoy *et al.* 2011).

Jellyfish have been recorded to clog the water intake screens of power stations (Purcell *et al.* 2007), and the potential exists for them to clog the intake screens of land-based facilities. Further, swarms may interrupt other activities integral to the running of the aquaculture facility. For example, feeding of salmon had to be stopped as one such swarm blocked the water pumping systems on the feeding boat (Mitchell *et al.* 2011).

Aquaculture and other marine structures may provide favourable habitat for the benthic stages of jellyfish (Purcell *et al.* 2007; Lo *et al.* 2008; **Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish)**). Jellyfish were identified as a common pest species by the New Zealand saltwater salmonid farmers interviewed by Sim-Smith *et al.* (2014).

Jellyfish and harmful algal blooms (HABs) have the following similarities:

- they can cause severe human health effects and even death;
- they are problematic to aquaculture;
- they form large yet ephemeral blooms; and
- they have complex lifecycles that provide management challenges (Hay 2006; Gibbons and Richardson 2013; **Chapter 5.15 Harmful algal blooms 1: marine**).

Similar to the management of HABs, in regions where jellyfish swarms are likely, early warning via on-site and area monitoring, area management agreements (**Chapter 5.4 Area-based management**), and pre-emptive contingency planning (**Chapter 5.9 Contingency plans**) are integral to their long-term management (Johnston and Jungalwalla No date; Code of Good Practice Management Group 2011; RSPCA 2012).

In addition, RSPCA (2012) and Gibbons and Richardson (2013) identified the following existing strategies for managing the impacts of jellyfish swarms:

- predicting blooms using hydrodynamic models;
- use of aeration systems/skirts;
- modified management for aquaculture farms (e.g. stopping feeding; stress avoidance); and
- the shutting down of coastal water intakes.

5.19.1 Conclusions

Jellyfish swarms can produce a variety of negative effects to an aquaculture facility. Preventive actions such as contingency planning supported by ongoing surveillance and monitoring can help producers minimise these impacts.

5.19.2 Options to minimise the risks associated with jellyfish

5.19.2.1 Objectives

To manage the risks associated with jellyfish.

5.19.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

In selecting a facility location, care should be taken to avoid areas that have historically had frequent jellyfish swarms.

Facilities should have documented procedures for emergency response for jellyfish swarms.

5.19.2.3 Detailed options

Monitoring

Facilities should be vigilant for the presence of jellyfish and jellyfish swarms and conditions favourable to these.

Jellyfish monitoring and management programmes should be well documented, organised and as simple as possible to be functional and effective.

A jellyfish monitoring and management manual should be prepared, describing the structure of the monitoring programme in detail, the methods to be used and the management plans/actions in relation to jellyfish.

A geographic information system (GIS) database should be considered for storage, handling, evaluation and presentation of monitoring data for management of jellyfish.

Periodic synthesis and analysis of data generated by the monitoring programme should occur to determine long-term patterns, develop predictive relationships and allow re-evaluation of monitoring programme design, analysis and practices.

5.19.3 References

Baxter EJ, Sturt MM, Ruane NM, Doyle TK, McAllen R, Harman L and HD Rodger (2011). Gill damage to Atlantic salmon (*Salmo salar*) caused by the common jellyfish (*Aurelia aurita*) under experimental challenge. *PLoS ONE* 6(4): e18529. doi:10.1371/journal.pone.0018529.

Bornø G and C Sviland (Eds.) (2011). *The health situation in Norwegian aquaculture 2010.* Norwegian Veterinary Institute. pp. 36.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Delannoy CMJ, Houghton JDR, Fleming NEC and HW Ferguson (2011). Mauve stingers (*Pelagia noctiluca*) as carriers of the bacterial fish pathogen *Tenacibaculum maritimum*. *Aquaculture* 311: 255-257.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Gibbons MJ and AJ Richardson (2013). Beyond the jellyfish joyride and global oscillations: advancing jellyfish research. *Journal of Plankton Research* 35(5): 929-938.

Handlinger J, Soltani M and S Percival (1997). The pathology of *Flexibacter maritimus* in aquaculture species in Tasmania, Australia. *Journal of Fish Diseases* 20: 159-168.

Hay S (2006). Marine ecology: gelatinous bells may ring change in marine ecosystems. *Current Biology* 16(17), R679-R682.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Lo W-T, Purcell JE, Hung J-J, Su H-M, and P-K Hsu (2008). Enhancement of jellyfish (*Aurelia aurita*) populations by extensive aquaculture rafts in a coastal lagoon in Taiwan. *ICES Journal of Marine Science* 65 (3): 453-461.

Mitchell SO, Baxter EJ and HD Rodger (2011). Gill pathology in farmed salmon associated with the jellyfish *Aurelia aurita*. *Veterinary Record* doi: 10.1136/vr.100045

Purcell JE, Uye S and W-T Lo (2007). Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. *Marine Ecology Progress Series* 350: 153-174.

Royal Society for the Prevention of Cruelty to Animals (RSPCA) (2012). *RSPCA welfare standard for farmed Atlantic salmon.* 84 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

5.20 NEW OR UNFAMILIAR AQUACULTURE SPECIES

The intensive production of new or unfamiliar aquaculture species without considerable planning (including detailed background knowledge of biology, disease or pest susceptibility and behaviour) may result in animal welfare and biosecurity issues (Zeldis *et al.* 2010; Farm Animal Welfare Committee 2014; **Chapter 5.12 Feeds and feeding; Chapter 5.13 Good husbandry**). As such, an extensive amount of pilot studies is required to ensure good husbandry and welfare before transfer to commercial production (Farm Animal Welfare Committee 2014; **Chapter 5.13 Good husbandry**). For native species the potential genetic impact should be also be investigated (Hinrichsen 2007; **Chapter 5.29 Stock origin, production of gametes**).

In terms of potential pathogens and pests, it is critical to identify local species and determine the potential for harm. This includes using qualitative risk analyses to determine the likelihood and consequence of transfer of pathogens from wild to farmed stock (Hutson *et al.* 2007; Raynard *et al.* 2007; **Chapter 5.28 Stock containment**). However, there is limited ability to identify pathogens related to the culture of a new species. For example, some disease outbreaks may only occur under aquaculture conditions or other pathogens may result in disease in the new species without any effect in their natural host (Anon 2005). That is, significant diseases in aquaculture have been associated with pathogens/parasites that were considered benign, or for which pathology is unknown or unrecorded in wild host populations (Bouloux *et al.* 1998).

New species often lack the immunity that endemic fish species have developed over time (Mauel and Miller 2002). Stress induced by aquaculture practices resulting in reduced immune response (**Chapter 5.13 Good husbandry**) or lack of a primed immune response may result in disease susceptibility. For example, in Chile outbreaks of piscirickettsiosis resulted in a shift in production from the more commercially desirable Coho salmon to the less desirable but more resistant Atlantic salmon (Mauel and Miller 2002).

In some areas of the world the global distribution of aquaculture species has lead to economic or environmental damage either through the escape and naturalisation of the species themselves or the outbreak of associated pest and diseases (Egidius 1987; Critchley *et al.* 1990; Blanchard 1997; Hinrichsen 2007; Raynard *et al.* 2007; Asche *et al.* 2009; Inglis *et al.* 2013). The importation of live fish/shellfish, eggs or sperm into New Zealand for food production purposes is not currently permitted. The exception to this rule is the importation of juvenile yellowtail kingfish (*Seriola lalandi*) from Australia under the conditions imposed by the relevant import health standard (IHS) (Ministry of Agriculture and Forestry Biosecurity New Zealand 2010; **Chapter 5.29 Stock origin, production of gametes**).

The import of new organisms[6] into New Zealand is regulated under the Hazardous Substances and New Organisms (HSNO) Act 1996 by the Environmental Protection Authority (EPA): http://www.epa.govt.nz/new-organisms/Pages/default.aspx

In New Zealand, a new organism is defined as:

- an organism that arrived in New Zealand after 29 July 1998;
- an organism that became extinct before July 29 1998;

[6] An organism includes microorganisms (including bacteria and viruses), cell lines, human cells (but not human beings), sperm, oocytes (cells from which an egg or ovum develops), embryos, seeds, plants, fish and animals.

- an organism with approval to be in containment;
- an organism with approval to be released with controls;
- a genetically modified organism;
- an organism that was deliberately eradicated from New Zealand (as the result a specified eradication programme with a stated goal or purpose of eliminating the organism from New Zealand);
- an organism that was present in New Zealand before 29 July 1998 in contravention of the Animals Act 1967 or the Plants Act 1970 (except for the rabbit haemorrhagic disease virus (rabbit calicivirus)); and
- a risk species.

If an organism fits the above definition, a HSNO approval from the EPA is required to import, develop, field test or release it in New Zealand.

5.20.1 Conclusions

All stock for aquaculture should be of New Zealand origin unless the appropriate regulatory procedures are met. For example, import must meet the requirements of an import health standard based on a documented risk analysis in association with the appropriate regulatory authority; http://mpi.govt.nz/importing/overview/import-health-standards/; http://www.epa.govt.nz/new-organisms/Pages/default.aspx.

The genetic diversity of native organisms cultured in open water systems or produced for re-seeding purposes should be taken into account with respect to the ability to affect wild stocks.

The inclusion of new or unfamiliar species to aquaculture requires a detailed knowledge of biology, disease and pest susceptibility and behaviour before farming should take place.

5.20.2 Options to minimise the risks associated with the culture of new or unfamiliar species

5.20.2.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility from the production of new species.

5.20.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All facility inputs, throughputs and outputs (e.g. stock, equipment, water) should be assessed for potential biosecurity risks.

Facilities should demonstrate a knowledge of biology, pest and disease susceptibility and behaviour prior to production of new species. Transfer to commercial practice should not take place until these have been assured.

5.20.2.3 Detailed options

For importation of stock, use of wild stock or consideration of stock genetics, see:
Chapter 5.29 Stock origin, production of gametes.

5.20.3 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Asche F, Hansen H, Tveteras R and S Tveterås (2009). The salmon disease crisis in Chile. *Marine Resource Economics* 24: 405-411.

Blanchard M (1997). Spread of the slipper limpet *Crepidula fornicata* (L. 1758) in Europe. Current state and consequences. *Scientia Marina* 61 (Suppl. 2): 109-118.

Bouloux C, Langlais M and P Silan (1998). A marine host-parasite model with direct biological cycle and age structure. *Ecological Modelling* 107: 73-86.

Critchley AT, Farnham WF, Yoshida T and TA Norton (1990). A bibliography of the invasive alga *Sargassum muticum* (Yendo) Fensholt (Fucales: Sargassaceae). *Botanica Marina* 33(6): 551-562.

Egidius E (1987). *Import of furunculosis to Norway with Atlantic salmon smolts from Scotland.* Mariculture Committee Report no. C.M. 1987/F:8, International Council for the Exploration of the Sea (ICES). 8 pp.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Hutson KS, Ernst I and ID Whittington (2007). Risk assessment for metazoan parasites of yellowtail kingfish *Seriola lalandi* (Perciformes: Carangidae) in South Australian sea-cage aquaculture. *Aquaculture* 271: 85-99.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Mauel MJ and DL Miller (2002). Piscirickettsiosis and piscirickettsiosis-like infections in fish: a review. *Veterinary Microbiology* 87: 279-289.

Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) (2010). *Import health standard for juvenile yellowtail kingfish (Seriola lalandi) from Australia.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 9 pp. http://www.biosecurity.govt.nz/files/ihs/kngfisic.aus.pdf [Website accessed May 2014].

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinærmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Zeldis J, Broekhuizen N, Forsythe A, Morrisey D and J Stenton-Dozey (2010). *Waikato marine finfish farming: production and ecological guidance.* NIWA Client Report: CHC2010-147 prepared for MFish Aquaculture Unit. 112 pp.

5.21 ON-SITE MANAGEMENT OF STAFF AND VISITORS

The main goals of biosecurity are to protect the facility and the surrounding environment from the introduction and exacerbation of pathogens, parasites and pests (Subasinghe and Bondad-Reantaso 2006; Friedman and Renault 2007; Aquaculture Stewardship Council 2012; Subcommittee on Aquatic Animal Health (SCAAH) 2016). Poor biosecurity increases the likelihood of spread of diseases or pests within and between farms and from farmed to wild populations (Anon 2005; Raynard *et al.* 2007). To be effective, biosecurity must be applied consistently by all personnel present at a facility (Racicot *et al.* 2011). Creation and maintenance of biosecurity awareness within a work environment ensures economic viability and profitability (Hardy-Smith 2006). Creation and maintenance of such an environment takes time and effort, but these can be quickly negated through expediency, lack of support, lack of training and discipline, and improper procedures (Westers 1983; Hardy-Smith 2006).

For example, a visitor's log-book allows for the rapid and effective traceability of visitors in the event of disease or pest outbreaks. However, Racicot *et al.* (2011) observed almost 70% of visits not recorded on a poultry farm site, despite the log-book being clearly visible and accessible. Similarly, Sim-Smith *et al.* (2014) identified comprehensive biosecurity SOPs embedded in many of New Zealand's larger aquaculture companies however, adherence to these SOPs could be improved.

The research of Sim-Smith *et al.* (2014) investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors and showed that the majority of farmers were at least moderately concerned about preventing and managing pests and diseases. However, the authors found large variations in biosecurity practices occur within the industry and the high level of industry concern regarding pests and diseases is not always reflected in their biosecurity practices. Therefore, engagement with the aquaculture industry was identified as critical to ensuring effective uptake of biosecurity best practice. To this end, the authors recommend better education of farm staff to encourage engagement and adherence to biosecurity measures.

In New Zealand, many owners and managers are proactive in training their staff regarding biosecurity practices through meetings, training courses, and encouraging formal qualifications in biosecurity and animal health (Sim-Smith *et al.* 2014). The beliefs of farm owners/managers regarding biosecurity often influenced staff opinions. However, some owners/managers did not see the value in training their staff with respect to biosecurity.

Direct evidence of pathogen transfer on or between aquaculture facilities via site staff or visiting personnel is scarce in the scientific literature (Anon 2000). However, personnel who come into contact with infected stock have been repeatedly identified as risk factors of pathogen transfer (Jarp *et al.* 1993; Vågsholm *et al.* 1994; Anon 2000; Anon 2003; Hendrikson 2004).

For example, the study of infectious salmon anaemia (ISA) outbreaks in Norway, Canada and Scotland indicates that the risk of virus transfer is associated with the use of shared, unsterilised equipment, including the use of the same personnel on several sites (Anon 2000). In 2008, it was established that a communal container used to store diving masks was the likely vector for the spread of an infectious disease, in this case conjunctivitis among divers (Olsson *et al.* 2008). Cleaning with detergent and disinfection with bleach were used to control the outbreak (Olsson *et al.* 2008). More recent results indicate that some bacteria found in communal rinsing tanks was of human origin (Washburn *et al.* 2010).

With respect to pathogen transmission associated with staff and staff clothing, the risk may be reduced, where:

- a site is not in receipt of equipment from outside its own waterbody;
- a defined disinfection routine and auditing procedure exists;
- general site hygiene is good; and
- the transfer of any biologically active material is prohibited (Anon 2000; Anon 2003).

Control of site access and the creation of barriers between and within farm compartments are measures used by the agriculture and aquaculture industries to prevent pathogen transfer. Hand-washing stations and footbaths represent common tools to help achieve this task (Yoshimizu 2009). However, in a survey of poultry farms, not changing boots and not washing hands were the second and third most common biosecurity errors committed by personnel (Racicot *et al.* 2011).

A recent disease outbreak at a paua farm has consequently led to the improvement of biosecurity measures on-site to include:

- the use of separate on-site and off-site footwear;
- the deployment and use of footbaths and hand sanitisers around the site;
- regular staff meetings where biosecurity is discussed;
- restriction of staff to certain zones on-site; and
- the adoption of a company biosecurity protocol, which has been reviewed by MPI (Sim-Smith *et al.* 2014).

The effectiveness of footbaths and hand-washing stations for staff and visitor disinfection has recently been questioned by Hardy-Smith (2006)[7] and Hick *et al.* (2011), respectively. The justification of footbath use due to their presence in maintaining on-site "biosecurity awareness" has also been questioned (Hardy-Smith 2006). However, Curry *et al.* (2005) identified an effective procedure for boot cleaning to reduce the risk of pathogen translocation to Antarctica. Similarly, Department of Agriculture, Fisheries and Forestry (DAFF) (2008) stated that footbaths are valuable in restricting the transport of pathogens on footwear and offer continual emphasis to personnel regarding the maintenance of on-site biosecurity. Although it is acknowledged that the value of footbaths is dependent on their correct use, which includes suitable contact times for disinfectant efficacy and the replenishing of disinfectant as required (DAFF 2008).

The spread of human, animal and plant pathogens has been repeatedly demonstrated to be associated with footwear (e.g. Ajello and Getz 1954; Newell and Fearnley 2003; Curry *et al.* 2005; Davidson *et al.* 2005). In the human health setting, "hand washing is considered the single most important intervention for prevention of hospital-acquired infections in patients and health care workers" (Katz 2004). However, even in this environment there is poor uptake of protocols for hand hygiene (Katz 2004). Further, the value of hand-washing in terms of prevention of disease cross-contamination has recently been highlighted following outbreaks of *Vibrio parahaemolyticus* infections among restaurant patrons (Haendiges *et al.* 2014).

Gavine *et al.* (2007), DAFF (2008), Code of Good Practice Management Group (2011) and OIE (2012) recommend the use hand-washing stations and footbaths for staff and visitor disinfection prior to entry and exit of production areas. However, the deployment of such "barriers" serves little purpose where there is little opportunity to control the movement of potential pathogens within sites and between sites and the environment (Hardy-Smith 2006).

[7] Hardy-Smith co-authored a code of practice recommending the appropriate use of footbaths (Gavine et al. 2007).

5.21.1 Conclusions

Good staff and visitor hygiene practices may reduce the risk of pathogen transmission at individual farm level and also may help to minimise the risk of pathogen transfer between neighbouring sites and other management areas.

5.21.2 Options to minimise the risks associated with on-site staff and visitors

5.21.2.1 Objective

To manage the risk of staff and visitors transferring pests and pathogens onto, within and off the facility.

5.21.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All facility inputs, throughputs and outputs (e.g. staff, visitors and associated equipment and procedures) should be assessed for potential biosecurity risks.

Ensure all facility staff and visitors understand their responsibilities to maintain facility biosecurity.

Production units should be managed separately to reduce the risk of pest and pathogen spread within the farm. Staff should be assigned to production units based on risk.

5.21.2.3 Detailed options

Facilities should have clearly identified physical barriers and entrances to prevent the unauthorised entry of people, vehicles or animals. Domestic animals should not circulate freely within the facility.

Contractors and visitors should enter a facility through the main gate or a single dedicated entrance.

Access to facilities should be controlled and full biosecurity briefings given to all people entering a site. A written statement of restrictions should also be presented to the visitor prior to the visit.

A register of incoming visitors must be kept including the person's name (and company) and the name and date of recent (past fortnight) visits to:

- hatcheries and on-growing facilities;
- harvesting and processing facilities; or
- wild habitats.

Visitors should be required to sign in, decontaminate their footwear in the footbaths provided or be provided with alternative footwear (e.g. clean gumboots, overshoes) and appropriate clothing.

Visitors, contractors and staff should clearly understand the areas that they have access to and the areas that are off-limits.

Signs should be placed at the entry to each building to remind staff, contactors and visitors of on-site biosecurity protocols.

Sanitary barriers (e.g. footbaths, hand-washing stations) should be installed to disinfect people and their gear and equipment when entering and leaving the facility. These barriers should be clearly labelled and the quality and quantity of the disinfectant maintained according to manufacturer's specifications.

Separate production units should have facilities for disinfection of staff and visitors and their gear and equipment.

Sanitary barriers should be positioned at strategic locations throughout the site (e.g. anterooms or in doorways at the entry and exit of buildings).

Footbath stations should incorporate a method of cleaning footwear before it is immersed in the disinfecting solution. This may include a separate bath of detergent next to the footbath, stiff brushes to remove mud, or specially designed boot scrubbers.

To be effective, footbaths should:

- be of sufficient size;
- utilise appropriate contact times;
- use a disinfectant solution that is resistant to organic matter;
- incorporate a cleaning procedure to remove accumulations of mud, soil, or organic matter;
- be regularly emptied and refreshed;
- be protected from the weather (so that rain does not dilute the disinfectant and the sun does not degrade the disinfectant); and
- be placed on a hard surface (so that mud does not form around the footbath and get stuck to footwear).

Clear instructions, outlining procedures and minimum contact times, should be posted at each footbath station. A log should be kept of changes of the disinfection solution.

Where possible, personnel should be assigned specific work areas based on the age of stock, the species, and the disease status.

If staff must work in multiple production units, higher health animals should be visited first and lower health or diseased animals last, with appropriate cleaning and disinfection protocols followed between visits.

Access to sensitive areas (e.g. broodstock) should be restricted.

Fit for purpose reusable or disposable protective clothing (including footwear) should be provided for each personnel.

Reusable protective clothing should be retained on the premises and laundered at a temperature of at least 60°C.

Rubber overalls should be cleaned and then disinfected according to the manufacturer's instructions.

Disposable protective clothing should be disposed of in an appropriate manner.

5.21.3 References

Ajello L and ME Getz (1954). The recovery of dermatophytes from shoes and shower stalls. *The Journal of Investigative Dermatology* 22: 17-24.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012). *ASC salmon standard. Version 1.0.* June 2012. 103 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Curry CH, McCarthy JS, Darragh HM, Wake RA, Churchill Se, Robins AM and RJ Lowen (2005). Identification of an agent suitable for disinfecting boots of visitors to the Antarctic. *Polar Record* 41(1): 39-45.

Department of Agriculture, Fisheries and Forestry (DAFF) (2008). *Operational procedures manual - decontamination (Version 1.0). In*: Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT. 122 pp.

Davidson JM, Wickland AC, Patterson HA, Falk KR and DM Rizzo (2005). Transmission of *Phytophthora ramorum* in mixed-evergreen forest in California. *Ecology and Epidemiology* 95(5): 587-596.

Friedman C and T Renault (2007). *Report on Australian herpes-like viral outbreak and field notes.* Report prepared for Western Abalone Divers Association of Victoria, Australia. 17 pp.

Gavine FM, Ingram BA, Hardy-Smith P and M Doroudi (2007). *Biosecurity control measures for abalone viral ganglioneuritis: a code of practice.* Prepared as part of FRDC Project No. 2006/243. 31 pp.

Haendiges J, Rock M, Myers RA, Brown EW, Evans P and N Gonzalez-Escalona (2014). Pandemic *Vibrio parahaemolyticus*, Maryland, USA, 2012 [letter]. *Emerging Infectious Diseases* 20(4) http://dx.doi.org/10.3201/eid2004.130818 [Website accessed April 2014].

Hardy-Smith P (2006). *Biosecurity at the farm level - how to create a state of mind. In* Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 149-154.

Hendriksen NH (2004). RTFS: experiences from Denmark. *Trout News* 37: 16-17.

Hick P, Schipp G, Bosmans J, Humphrey J and R Whittington (2011). Recurrent outbreaks of viral nervous necrosis in intensively cultured barramundi (*Lates calcarifer*) due to horizontal transmission of betanodavirus and recommendations for disease control. *Aquaculture* 319: 41-52.

Jarp J, Tangen K, Willumsen FV, Djupvik HO and AM Tveit (1993). Risk factors for infection with *Aeromonas salmonicida* in Norwegian freshwater hatcheries. *Diseases of Aquatic Organisms* 17: 81 - 86.

Katz JD (2004). Hand washing and hand disinfection: more than your mother taught you. *Anesthesiology Clinics of North America* 22: 457-471.

Newell DG and C Fearnley (2003). Sources of *Campylobacter* colonization in broiler chickens. *Applied Science and Environmental Microbiology* 69(8): 4343-4351.

OIE (2012). *Manual of diagnostic tests for aquatic animals. Chapter 1.1.3. Methods for disinfection of aquaculture establishments.* 12 pp.

Olsson DJ, Grant WD and JM Glick (2008). Conjunctivitis outbreak among divers. *Undersea and Hyperbaric Medicine* 35(3): 169-174.

Racicot M, Venne D, Durivage A and J-P Vaillancourt (2011). Description of 44 biosecurity errors while entering and exiting poultry barns based on video surveillance in Quebec, Canada. *Preventive Veterinary Medicine* 100: 193-199.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Subasinghe RP and MG Bondad-Reantaso (2006). *Biosecurity in aquaculture: international agreements and instruments, their compliance, prospects, and challenges for developing countries. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. pp. 149-154.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Vågsholm I, Djupvik HO, Willumsen FV, Tveit AM and K Tangen (1994). Infectious salmon anaemia (ISA) epidemiology in Norway. *Preventive Veterinary Medicine* 19: 277-290.

Washburn BK, Levin AE, Hennessy K and MR Miller (2010). Identification of bacteria in SCUBA divers' rinse tanks. *Undersea and Hyperbaric Medicine* 37(4): 233-240.

Westers H (1983). *Considerations in hatchery design for the prevention of diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 29-36.

Yoshimizu M (2009). Control strategy for viral diseases of salmonid fish, flounders and shrimp at hatchery and seed production facility in Japan. *Fish Pathology* 44(1): 9-13.

5.22 POPULATION SEPARATION WITHIN LAND-BASED FACILITIES

Once a pathogen is established, horizontal transmission of infection throughout the site is likely if biosecurity procedures are not established and strictly implemented (Poynter 1983; Warren 1983). Biosecurity procedures can be used to separate a farm, or group of farms, from the environment or can be used to separate onsite stocks within a farm.

The separation of on-site stocks into epidemiologically distinct populations by strict biosecurity conditions can prevent the introduction or spread of diseases (Poynter 1983; Anon 2000; Anon 2003; Subcommittee on Aquatic Animal Health (SCAAH) 2016). In the event that an outbreak of infectious disease occurs in one stock population, the pathogen is more likely to be confined and less likely to threaten the entire facility (Warren 1983).

The effectiveness of on-site population separation was shown when the agent for bacterial kidney disease (*Renibacterium salmoninarum*) was eliminated from a Scottish trout hatchery on a tank-by-tank basis (Murray *et al.* 2012). The effectiveness of this approach was attributed to the maintenance of good internal biosecurity.

Similarly, the 1980 infectious haematopoietic necrosis outbreak in Alaskan sockeye salmon resulted in the production of guidelines/criteria for disease control. These criteria included:

- ensuring supplies of virus-free water;
- rigorous disinfection procedures;
- separation of eggs and fry during incubation and rearing; and
- immediate destruction of infected stock followed by disinfection to contain within hatchery virus spread and to prevent environmental exposure (Meyers 2010).

The greatest benefits of biosecurity are achieved through preventive rather than reactive action (Hnath 1983; Warren 1983; Elston 1984; Elston 1993; Jarp *et al.* 1993; Bower *et al.* 1994; Danner and Merrill 2006; Robertsen 2011). On-site population separation represents a cost-effective insurance policy with respect to the prevention of stock losses following pathogen outbreaks. Following the outbreak of abalone herpes virus in several farms in Victoria, Australia, the implementation of on-site population separation may have been the single most effective step in improving the ability of Australia to respond to outbreaks of novel pathogens (Handlinger 2007).

Because boundaries are never perfectly sealed, the risk that infection can enter a pathogen-free population remains (Murray 2013). Creation and maintaining biosecurity awareness within a work environment takes time and effort, but these can be quickly negated through expediency, lack of support, lack of training and discipline, and improper procedures (Westers 1983; Hardy-Smith 2006).

For population separation to be effective, all the potential pathways for the introduction and transfer of infection need to be identified. The critical points for the most significant pathways must be addressed via implementation of preventive measures that are documented in a biosecurity plan (Zepeda *et al.* 2008).

Recent research showed that the majority of New Zealand aquaculture farmers were at least moderately concerned about preventing and managing pests and diseases. However, large variations in biosecurity practices occur within the industry and the high level of industry concern regarding pests and diseases is not always reflected in their biosecurity practices (Sim-Smith *et al.* 2014). For example, although used by some members of the freshwater

salmonid industry, division of facilities into discrete units to manage the risk of pest or disease entry, exacerbation or transfer was considered by other members as impractical, not necessary or not possible.

5.22.1 Conclusions

Population separation within land-based facilities represent an effective preventive strategy whereby the risk of pathogen transfer throughout the site is minimised.

5.22.2 Options to aid the adoption of population separation on land-based facilities

5.22.2.1 Objective

To manage the risk of pest and pathogen transfer within land-based facilities.

5.22.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Facilities should be made up of multiple epidemiologically separate culture units with separate water supplies, feeding arrangements, waste management, equipment and staff.

Stock from different year classes should be grown and maintained in separate culture systems or sites throughout their production cycle. Stocking a given facility location or section with a single cohort is preferred ("all-in, all-out culture").

5.22.2.3 Detailed options

Biosecurity procedures (e.g. staffing, hand washing, footbaths, cleaning and disinfection) should be maintained for each sub-population.

Separate equipment should be assigned for use in production units of different health status. Where equipment must be used in multiple production units it should be cleaned and disinfected prior to movement between units.

Tanks within culture units should be separated (or have lids or barriers) to reduce aerosol contamination. Tank outflows should be piped into drains to reduce aerosol contamination.

5.22.3 References

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Danner GR and P Merrill (2006). *Disinfectants, disinfection and biosecurity in aquaculture. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.). Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 91-128.

Elston RA (1993). Infectious diseases of the Pacific oyster, *Crassostrea gigas*. *Annual Review of Fish Diseases* 3: 259-276.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

Handlinger J (2007). *Report to Western Abalone Divers Association of Victoria on the ganglioneuritis outbreak.* Report from Judith Handlinger Senior Veterinary Pathologist, Aquatic Animal Health, DPIW, Tasmania. Prepared for WADA, Victoria, Australia. 48 pp.

Hardy-Smith P (2006). *Biosecurity at the farm level - how to create a state of mind. In*: Scarfe AD, Lee C-S and PJ O'Bryen (Eds.). Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 149-154.

Hnath JG (1983). *Hatchery disinfection and disposal of infected stocks. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 121-134.

Jarp J, Tangen K, Willumsen FV, Djupvik HO and AM Tveit (1993). Risk factors for infection with *Aeromonas salmonicida* in Norwegian freshwater hatcheries. *Diseases of Aquatic Organisms* 17: 81-86.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01, Juneau, Alaska. 57 pp.

Murray AG (2013). Implications of leaky boundaries for compartmentalised control of pathogens: a modelling case study for bacterial kidney disease in Scottish salmon aquaculture. *Ecological Modelling* 250: 177-182.

Murray AG, Munro LA, Wallace IS, Allan CET, Peeler EJ and MA Thrush (2012). Epidemiology of *Renibacterium salmoninarum* in Scotland and the potential for compartmentalised management of salmon and trout farming areas. *Aquaculture* 324-325: 1-13.

Poynter R (1983). *Stock and year class separation. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 59-62.

Robertsen B (2011). Can we get the upper hand on viral diseases in aquaculture of Atlantic salmon? *Aquaculture Research* 42: 125-131.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Warren JW (1983). *Synthesis of a fish health management program. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 151-158.

Westers H (1983). *Considerations in hatchery design for the prevention of diseases. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 29-36.

Zepeda C, Jones JB and FJ Zagmutt (2008). Compartmentalisation in aquaculture production systems. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 229-241.

5.23 PREVENTIVE PRACTICES (SURVEILLANCE AND VACCINATION)

Problems with diseases and aquatic pest species have been long associated with the aquaculture industry (Snieszko 1973; Brown and Russo 1979; Olafsen 2001; Fitridge *et al.* 2012). The implementation of rigorous preventive biosecurity practices is seen as critical for a successful production environment (**Chapter 5.1 Biosecurity (general)**). The value of on-farm planning and biosecurity best management practices is increasingly recognised in the aquaculture industry (Hinrichsen 2007; Mohan *et al.* 2008; Farm Animal Welfare Committee 2014).

One of the pillars of the preventive approach to disease and pest management is the use of surveillance techniques, such as routine monitoring and recording of stock, facility structures and equipment by personnel trained in the recognition of disease signs and the presence of pest species, respectively (Hinrichsen 2007; Massachusetts Shellfish Farmers 2009; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; IFA Aquaculture 2011; Aquaculture Stewardship Council 2012b; Global Aquaculture Alliance 2013; Farm Animal Welfare Committee 2014; **Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish)**).

The importance of regular surveillance via stock sampling, as part of disease management, cannot be overemphasised (Meyers 2010). This type of monitoring involves external and internal examination of healthy, moribund and dead stock, where present. Surveillance can result in the production of healthier stock by allowing staff to fine tune their feeding and other environmental parameters. Such production improvements create a less stressful environment and thus help to prevent disease occurrence (Meyers 2010; **Chapter 5.13 Good husbandry**).

In 1983, it was suggested that a thorough monitoring programme was essential to a successful programme of prevention and control of bacterial kidney disease in finfish (Warren 1983). This approach has been validated by the Norwegian surveillance programme, which has resulted in a dramatic reduction in the number of registered disease cases in salmon broodstock (Johansen *et al.* 2009).

More recently in Europe and Australia, the implementation of active surveillance for ostreid herpesvirus microvariant 1 (OsHV-1) has allowed for the rapid implementation of quarantine measures (e.g. movement controls) in affected areas to prevent or slow disease spread in Pacific oysters (Castinel *et al.* 2013; Paul-Pont *et al.* 2013).

The Norwegian Food Health Authority's control plan for pancreas disease includes, in co-operation with the industry, disease surveillance and vaccination (Johansen *et al.* 2009).

5.23.1 Government inspection

Many countries require regular inspection through government agencies or independent third parties that report to government. According to European Commission Directive 2006/88/EC "Routine inspections should be carried out in the Member States to ensure that aquaculture production business operators are familiar with, and apply, the general rules on disease control and biosecurity" (European Commission 2006).

The controls consist of "regular inspections, visits, audits, and where appropriate, sampling, for each aquaculture production business, taking account of the risk the aquaculture

production business and authorised processing establishment poses in relation to the contracting and spreading of diseases" (European Commission 2006). Part B of Annex III of the Directive contains recommendations for the frequencies of such controls, depending on the health status of the concerned zone or compartment (European Commission 2006).

The objectives of inspections by qualified aquatic animal professionals is to:

- monitor the health status of the animals;
- advise the facility operator on aquatic animal health issues; and
- undertake the necessary veterinary measures, as required (European Commission 2006).

An example of how such regulations are applied by a Member State of the European Union, is provided by IFA Aquaculture (2011):

Site inspections in Ireland are carried out under Directive 2006/88/EC and European Regulation SI 2008 No. 261, by the Fish Health Unit of the Marine Institute.Inspection frequency is determined in accordance with the risk categorisation of the site:

- high surveillance:
    - 1 visit per year from private services (active surveillance) and
    - 1 visit per year by Marine Institute (active surveillance and compliance).
- medium surveillance:
    - 1 visit per year alternating between the private services (active surveillance) and the Marine Institute (active surveillance and compliance).
- low surveillance:
    - 1 visit every 2 years alternating between the private services (Active Surveillance) and the Marine Institute (active surveillance and compliance).

According to Directive 2006/88/EC, passive surveillance shall include mandatory immediate notification of the occurrence or suspicion of specified diseases or of any increased mortalities.

Active surveillance shall include:

- routine inspection by the competent authority or by other qualified health services on behalf of the competent authorities;
- examination of the aquaculture animal population on the farm or in the mollusc farming area for clinical disease;
- diagnostic samples to be collected on suspicion of a listed disease or observed increased mortality during inspection; and
- mandatory immediate notification of occurrence or suspicion of specified diseases or of any increased mortalities.

Targeted surveillance shall include:

- routine inspection by the competent authority or by other qualified health services on behalf of the competent authorities;
- prescribed samples of aquaculture animals to be taken and tested for specific pathogen(s) by specified methods; and
- mandatory immediate notification of occurrence or suspicion of specified diseases or of any increased mortalities.

Under the system employed in Ireland, the risk category for each farm is determined according to the following criteria:

- high surveillance level:
    - sites importing live fish and ova (including "open" ornamental facilities);
    - broodstock sites producing for themselves and others;
    - sites producing stock for on-growing elsewhere within the country or abroad.
    - marine sites (except those with protected water);
    - aquaculture facilities with on-site processing units which process fish from other sites; or
    - quarantine facilities.
- medium surveillance level:
    - broodstock sites producing only for themselves;
    - freshwater sites producing fish for human consumption, including those processing solely their own fish; or
    - sites producing fish for ranching purposes (i.e. those releasing fish back into the system from which the broodstock came).
- low surveillance level:
    - put and take fisheries;
    - ornamental commercial aquaria;
    - sites holding non-susceptible species; or
    - recirculation systems (IFA Aquaculture 2011).

In Alaska, annual or biannual hatchery inspections are conducted by a veterinarian or qualified aquatic health professional evaluate facility design and practices for the prevention and control of disease (Meyers 2010).

Further work is required to determine whether the surveillance system in New Zealand requires strengthening and how this could be achieved.

Recent research investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors (Sim-Smith *et al.* 2014). The authors observed that disease testing is currently conducted on an *ad hoc* basis (7/12 freshwater salmonid farms, 2/2 saltwater salmonid farms, 8/20 oyster farms, 3/5 research facilities, 1/19 mussel farms and 0/2 paua farms). To assist in early detection and thus improve the likelihood of minimising any potential consequences, the authors recommended the establishment of a national disease testing and surveillance system that facilitates the routine disease testing of stock. This service should be inexpensive (e.g. subsidised by the government) to encourage widespread participation. Further work is required to determine the feasibility of such a system.

5.23.2 Vaccination (finfish)

Vaccination is one of the main techniques used for disease prevention in finfish (Roche 1999; Anon 2005; Yanong 2011). However, rather than being used in place of biosecurity plans and procedures, vaccination is complementary to best management practices (Anon 2005).

Atlantic salmon farming in Norway is said to be impossible without vaccination against vibriosis, coldwater vibriosis and furunculosis (Johansen *et al.* 2009; Robertsen 2011). Similarly, the most commonly used vaccine in Alaska is the immersion type for vibriosis, which is used to reduce Atlantic salmon losses following transfer to seawater net pens (Meyers 2010). In addition to the bacterial diseases mentioned above, nearly all Norwegian salmon are vaccinated against infectious pancreatic necrosis (Midtlyng *et al.* 2011).

The effect of vaccination in relation to other preventive measures is often debated (Johansen *et al.* 2009). However, the widespread use of preventive vaccination in Norway has positively contributed to a reduced need in the reactive use of antibacterial drugs from about 48 tonnes to approximately 1 tonne annually (Midtlyng *et al.* 2011).

More recently, vaccination against pancreas disease had a positive effect in reducing the number of outbreaks, and decreasing cumulative mortality and the number of fish discarded at slaughter (Bang Jensen *et al.* 2012). The probability for pancreas disease outbreak was reduced by a factor of 3 if the location reared vaccinated fish (Bang Jensen *et al.* 2012).

To ensure the efficacy of vaccination, many factors need to be taken into account, including:

- the pathogen (including strain);
- the fish species and age;
- production type;
- route of administration;
- potential side effects; and
- economics (Johansen *et al.* 2009; Yanong 2011).

A number of vaccines have been developed for bacterial and viral pathogens:
Vaccines available (bacterial pathogens)

- *Aeromonas salmonicida* subsp. *salmonicida* (Anon 2005; Meyers 2010);
- *Edwardsiella ictaluri* (Yanong 2011);
- *Flavobacterium columnare* (Yanong 2011);
- *F. psychrophilum* (Barnes and Brown 2011);
- *Lactococcus garvieae* (Yanong 2011);
- *Listonella angullarum* (Yanong 2011);
- *Moritella viscosa* (Anon 2005; Yanong 2011);
- *Photobacterium damsela* subsp. *piscicida* (Yanong 2011);
- *Piscirickettsia salmonis* (Anon 2005);
- *Renibacterium salmonarium* (Yanong 2011);
- *Streptococcus iniae* (Yanong 2011);
- *Vibrio salmonicida* (Anon 2005);
- *V. anguillarum* (Anon 2005);
- *V. alginolyticus* (Yanong 2011);
- *V. harveyi* (Yanong 2011);
- *V. ordalii* (Yanong 2011);
- *V. parahaemolyticus* (Yanong 2011);
- *V. vulnificus* (Yanong 2011); and
- *Yersinia ruckeri* (Anon 2005; Meyers 2010; Yanong 2011).

Vaccines available (viral pathogens)

- grass carp aquareovirus (Yanong 2011);
- koi herpes virus (CyHV-3) (Yanong 2011);
- infectious haematopoietic necrosis virus (Anon 2005; Meyers 2010; Yanong 2011);
- infectious pancreatic necrosis virus (Anon 2005; Midtlyng *et al.* 2011);
- infectious salmon anaemia virus (Anon 2005; Yanong 2011);
- iridovirus in *Seriola spp.* (Yanong 2011);
- pancreas disease virus (Anon 2005; Yanong 2011); and
- viral haemorrhagic septicaemia virus (GT 1a and GT 1b) (Anon 2005; Yanong 2011).

There are no vaccines or other veterinary medicines currently registered in New Zealand to prevent diseases in the aquaculture industry (Sim-Smith *et al.* 2014). However, there are regulatory channels whereby a registered veterinarian can provide treatment using a range of active ingredients for preventive purposes (as outlined below). In Norway, implementation of mass vaccinations in addition to biosecurity plans and routine monitoring have limited the use of other veterinary medicines (e.g. antibiotics). Therefore, these medicines have become less profitable in terms of offsetting the costs of registration (which includes research and development). The availability of medicinal products for the reactive treatment of stock is still seen as important even when disease outbreaks are infrequent, for example, for:

- animal welfare;
- contingency planning; and
- mitigation of losses to single producers (Midtlyng *et al.* 2011).

5.23.3 Vaccination (shellfish)

Vaccination is ineffective for invertebrates as they lack adaptive immunity (Roche 1999; Aquaculture Stewardship Council 2012a). Therefore, the most effective way of preventing on-farm disease is through the use of best management practices for biosecurity and animal husbandry (Elston 1984; Bower *et al.* 1994; Elston *et al.* 2008; Massachusetts Shellfish Farmers 2009; Aquaculture Stewardship Council 2012a).

5.23.4 Registration of agricultural compounds and veterinary medicines in New Zealand

The primary legislation for authorisation of veterinary medicines is the Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM Act) and the associated Agricultural Compounds and Veterinary Medicines (Exemptions and Prohibited Substances) Regulations 2011 (ACVM Regulations).

The purpose of the ACVM Act is to manage risks associated with trade in primary produce, animal welfare, agricultural security, and those aspects of public health not managed by other legislation, along with ensuring residues in food producing species are compliant with domestic residue standards. Products requiring registration are assessed to determine the risk associated with these areas on balance with the benefits of product registration. Products exempt from registration under the ACVM Regulations are subject to specific risk management requirements and conditions under these Regulations.

Under the Act, animal means any living stage of any member of the animal kingdom except human beings.

If a product meets the definition of an agricultural compound under the ACVM Act 1997, authorisation is required to import, manufacture, sell or use the product. The ACVM Group of MPI is responsible for authorisation of ACVM products in New Zealand.

Under the ACVM Act, all substances that are agricultural compounds must be registered unless exempted. The ACVM Regulations lists a number of exempt categories. Under Schedule 2, the ACVM Regulations allows organisations to conduct research, testing, teaching or training with agricultural compounds under an ‘operating plan’, provided a number of conditions are met. See http://www.foodsafety.govt.nz/elibrary/industry/rtt-op-guideline.pdf

Depending on the risk profile of the product, it may be either exempt from registration under the ACVM Regulations, or require registration to manage associated risks under the ACVM

Act. If a product requires registration, it is further classified as to whether it is registered as a restricted veterinary medicines (i.e. can only be authorised by a veterinarian) or an unrestricted veterinary medicine (i.e. can be sold "over the counter").

Under the Hazardous Substances and New Organisms (HSNO) Act, an agricultural compound trade name product that is a hazardous substance or contains new organisms, including genetically modified organisms (GMOs), cannot be imported into, or manufactured in, New Zealand unless it has prior substance approval from the Environmental Protection Authority (http://www.epa.govt.nz/hazardous-substances/importing-manufacturing/Pages/Veterinary-medicines-old.aspx).

Product registrants and users have legal obligations under other Acts (http://www.foodsafety.govt.nz/elibrary/industry/Regulatory_Control-Chemicals_Medicines.pdf). Other relevant legislation includes:

- Biosecurity Act 1993;
- Fair Trading Act 1986 and the Consumer Guarantees Act 1993;
- Health and Safety in Employment Act 1992;
- Animal Products Act 1999;
- Animal Welfare Act 1999 and codes of welfare under the Act;
- Medicines Act 1981 and its Regulations 1984;
- Food Act 1981 and its Regulations 1984;
- Medicines Act 1981;
- Misuse of Drugs Act 1975; and
- Veterinarians Act 2005.

The registration process under the ACVM Act for veterinary medicines typically requires data on product chemistry, efficacy, residue dynamics, GMP approval and consumer safety. Once registered, the veterinary medicine should be used to treat the species as per the advice on the label label (Fielder and Heasman 2011).

The New Zealand ACVM data requirements for veterinary medicines (agricultural compounds) may be found here:
http://www.foodsafety.govt.nz/industry/acvm/agricultural-chemicals/authorisation/Registration.htm

The New Zealand EPA data requirements veterinary medicines may be found here:
http://www.epa.govt.nz/hazardous-substances/importing-manufacturing/Pages/Data-requirements-vet-meds.aspx

5.23.5 Conditions of off-label use for a product or unregistered use in aquaculture

Off label use of an unrestricted product by an end user is permitted provided they seek expert advice on the safety and efficacy of the product prior to administration. If the product is a Restricted Veterinary Medicine (that is, a product that can only be sold or used under the authorisation of a veterinarian), off-label use must be directed by a veterinarian, and all associated risks managed by that veterinarian. This includes a legal requirement to advise of an appropriate post-treatment withholding period for food producing animals where necessary under section 55 (3) of the ACVM Act. Veterinarians or their clients may be charged with an offence (under provisions of the Animal Products Act 1999, Food Act 1981 or both) for supplying primary produce that contravenes this legislation.

The offence under section 55(3) of the ACVM Act is specific to veterinarians and relates to whether or not they provided the client with information about not supplying the non-compliant primary produce. Whether or not the veterinarian will be accountable depends on the information provided to the client.

Veterinarians must comply with the conditions of registration on all veterinary medicines they choose to use, sell or authorise, and are subject to authorising and use restrictions under the Veterinary Council of New Zealand's Code of Professional Conduct and the Veterinarians Act 2005.

For an unrestricted veterinary medicine product such as an anthelmintic, if a veterinarian determines it can be used in an off-label manner and advises an alternative withholding period, then a client may use the product legally in accordance with that advice. If as a result of the professional advice, non-compliances with the Animal Products Act 1999 thresholds are reported, then the veterinarian may be legally liable for actual losses by the client that are directly attributable to the professional advice.

The controls imposed on the substance as a consequence of the HSNO approval must be adhered to. The EPA does not explicitly prohibit off-label use. However, off-label use that contravenes any of the HSNO controls would not be compliant, and may be subject to enforcement action.

There are a range of reporting requirements under the various Acts, primarily around adverse reactions and workplace accidents and incidents.

Failure to comply with the legislation may (and does) result in prosecution.

5.23.6 Conclusions

The importance of regular monitoring via surveillance and stock sampling regimes and the analysis of these data are of paramount to the management of pests and diseases. This may be achieved through on-farm implementation with a complementary Government Inspection programme.

Vaccination is a complementary technique to biosecurity plans and procedures for disease prevention in finfish. Although not current practice in the New Zealand, use of vaccines may, in the event of a disease threat or outbreak, be required in the future, noting any vaccine must be first authorised under the ACVM Act (and where appropriate other legislation) prior to its use.

5.23.7 Options to aid the adoption of preventive practices (surveillance and vaccination)

5.23.7.1 Objective

To manage pest and pathogen establishment and impacts on the facility.

5.23.7.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

A preventive approach should be taken that incorporates routine diagnostic health status checks of stock rather than subjective observations.

Facility staff should be trained in the recognition of stock health problems. There should be a trained staff member on-site during normal working hours.

All stock should be routinely monitored for early signs of stress, behavioural changes, abnormalities, pests and disease.

Where appropriate, VHPs and biosecurity plans should include a vaccination regime to protect fish from diseases that may present a risk to their health.

Vaccination should only be carried out by trained, named, competent persons under veterinary authorisation.

5.23.7.3 Detailed options

Surveillance

Observation of all stock and recording of abnormalities and mortalities should occur at regular (daily) intervals.

Key pests and diseases of concern for the stock should be identified and it should be ensured that there are measures incorporated for their detection.

Mortalities should be subject to post mortem health examinations and archiving.

Mortality rates should be monitored carefully so that long term 'normal averages' can be determined and slightly raised levels detected.

An active surveillance programme should be adopted to facilitate movement of stock between regions. Active surveillance programmes should consider MPI guidelines.

Suspected health problems, including unusual or unexplained stock appearance or behaviour, should be investigated promptly. If the cause is not readily apparent (e.g. mechanical injury, low dissolved oxygen, known disease), then assistance from a veterinarian or an appropriately qualified aquatic health professional should be sought.

Facilities should have procedures to ensure that staff notify the manager responsible immediately on suspicion of abnormalities, pests or diseases (**Chapter 5.9 Contingency plans**).

Each facility should have access to a veterinarian or aquatic health professional with equivalent qualifications experienced in stock health to advise on health matters and who is available to provide advice at short notice in case of disease.

Veterinary examinations to determine the cause of epizootics should be made where there are abnormal, unexplained mortalities.

Facilities should undergo a twice yearly assessment for the disease status or otherwise determined by their veterinarian or aquatic health professional following an assessment of their biosecurity risk profile. The hatchery disease status assessment should cover current

(e.g. broodstock) and future (e.g. smolt or stock prior to transfer) populations. The agent should be a certified veterinarian or aquatic health professional and the assays should be conducted using approved and accepted procedures at an MPI approved facility. One of these assessments should be taken during a period of high stress (e.g. high seawater temperature at sites with stressfully warm summers, or immediately after spawning at cool water sites) as identified by past experience, and the second sample approximately six months later.

Vaccines and vaccinations (finfish)

Contingency plans should be put into place regarding the MPI and EPA approval process to register and approve the use of veterinary medicines (e.g. vaccines), respectively.

Records should be kept of all vaccination procedures conducted on site and should include the following information:

- date of vaccination;
- identification of the batch(es) of fish vaccinated;
- vaccine used (including batch numbers and method of application);
- details of dosage; and
- the names of the personnel involved.

Vaccines should be used and stored in accordance with the manufacturer's data sheet or veterinary advice.

Vaccines should be stored in an appropriate container and should not be used after the expiry date.

Vaccination equipment should be maintained in a hygienic manner.

Where vaccination equipment is brought on site from elsewhere:

- the supplier should provide proof that the equipment has been appropriately disinfected;
- the equipment should be disinfected before and after use; and
- disinfection records should be maintained.

Booster vaccinations, if required, should be administered in accordance with manufacturers' directions and veterinary advice.

Facility staff should record any suspected adverse reactions to a medicine, either in fish being treated or in persons involved in the application of a treatment.

5.23.8 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Aquaculture Stewardship Council (2012a). *ACS bivalve standard. Version 1.0*. January 2012. 57 pp.

Aquaculture Stewardship Council (2012b). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Bang Jensen B, Kristoffersen AB, Myr C and E Brun (2012). Cohort study of effect of vaccination on pancreas disease in Norwegian salmon aquaculture. *Diseases of Aquatic Organisms* 102: 23-31.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Barnes ME and ML Brown (2011). A review of *Flavobacterium psychrophilum* biology, clinical signs and bacterial cold water disease prevention and treatment. *The Open Fish Science Journal* 4: 40-48.

Brown C and DJ Russo (1979). Ultraviolet light disinfection of shellfish hatchery sea water. I. Elimination of five pathogenic bacteria. *Aquaculture* 17: 17-23.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Elston RA, Hasegawa H, Humphrey KL, Polyak IK and CC Hase (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119-134.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

European Commission (2006). Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals. *Official Journal of the European Union* L328: 14-56. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006L0088&from=EN [Website accessed August 2014].

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Fielder D and M Heasman (2011). *Hatchery manual for the production of Australian bass, mulloway and yellowtail kingfish.* Industry and Investment NSW Government. 170 pp.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

IFA Aquaculture (2011). *The farmed salmonid handbook.* Version 1.0. 66 pp. http://www.fishhealth.ie/FHU/ [Website accessed May 2014].

Johansen R, Kongtorp RT, Bornø G, Skjelstad HR, Olsen AB, Flesjå K, Colquhoun D, Ørpetveir I, Hansen H, Garseth ÅH and B Hjeltnes (2009). *The health situation in farmed salmonids 2008*. National Veterinary Institute, Norway. 18 pp.

Massachusetts Shellfish Growers (2009). *In*: DF Leavitt (Ed.) Best management practices for the shellfish culture industry in Southeastern Massachusetts. Version 09-04a. 100 pp.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Mohan CV, Phillips MJ, Bhat BV, Umesh NR and PA Padiyar (2008). Farm level plans and husbandry measures for aquatic animal disease emergencies. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 161-173.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Paul-Pont I, Dhand NK and R Whittington (2013). Influence of husbandry practices on OsHV-1 associated mortality of Pacific oysters *Crassostrea gigas. Aquaculture* 412-413: 202-214.

Robertsen B (2011). Can we get the upper hand on viral diseases in aquaculture of Atlantic salmon? *Aquaculture Research* 42: 125-131.

Roche P (1999). Defense mechanisms and disease prevention in farmed marine invertebrates. *Aquaculture* 172: 125-145.

S.I. 261 of 2008. *European Communities (Health of Aquaculture Animals and Products) Regulations*. 37 pp. http://www.irishstatutebook.ie/2008/en/si/0261.html [Website accessed August 2014].

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Snieszko SE (1973). Recent advances in scientific knowledge and developments pertaining to diseases of fishes. *Advances in Veterinary Science and Comparative Medicine* 17: 291-314.

Warren JW (1983). *Bacterial kidney disease. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 185-192.

Yanong RPE (2011). *Use of vaccines in finfish aquaculture.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 8 pp.

5.24 REACTIVE MEASURES FOR DISEASE MANAGEMENT (VETERINARY MEDICINES)

The risk of disease or pest occurrence should be reduced by the implementation of preventive methods such as biosecurity plans and good animal husbandry (Hinrichsen 2007; Code of Good Practice Management Group 2011; Farm Animal Welfare Committee 2014; **Chapter 5.1 Biosecurity (general); Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish); Chapter 5.13 Good husbandry**).

The early detection of pests and diseases is facilitated by an active health surveillance programme which enables the mounting of rapid responses (if required) (Hinrichsen 2007; Massachusetts Shellfish Farmers 2009; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; IFA Aquaculture 2011; Aquaculture Stewardship Council 2012b; Global Aquaculture Alliance 2013; Farm Animal Welfare Committee 2014).

The use of veterinary medicines in response to a disease outbreak should be viewed as a last resort rather than a substitute for poor management (Hinrichsen 2007; Farm Animal Welfare Committee 2014). In Norway, implementation of mass vaccinations, in addition to biosecurity plans and routine monitoring, have limited the use of other veterinary medicines (e.g. antibiotics). Therefore, these medicines have become less profitable in terms of offsetting the costs of registration (including research and development). The availability of medicinal products for the reactive treatment of stock is still seen as important even when disease outbreaks are infrequent, for example, for:

- animal welfare;
- contingency planning; and
- mitigation of losses to single producers (Midtlyng *et al.* 2011).

However, for some bacterial pathogens and parasites there are no effective vaccines. In this case, the disease outbreaks may be treated with veterinary medicines (e.g. antibiotics or ectoparasiticides) (Anon 2005; Aquaculture Stewardship Council 2012b).

5.24.1 Finfish

In finfish culture, veterinary medicines are often administered at the population level via feed or water "bathing". Treatment at this level can reduce the risk of a wider disease outbreak of by reducing the level of pathogenic organisms in the environment (Farm Animal Welfare Committee 2014).

5.24.2 Shellfish

In terms of therapeutic treatment of shellfish, some veterinary medicines (e.g. antibiotics) can be applied to the water in a hatchery/land-based situation (Roche 1999). However, stock size and number and the open nature of shellfish farming often precludes the application of veterinary medicines to offshore facilities (Roche 1999).

The most effective way of preventing on-farm disease is through the use of best management practices for biosecurity and animal husbandry (Elston 1984; Bower *et al.* 1994; Elston *et al.* 2008; Massachusetts Shellfish Farmers 2009; Aquaculture Stewardship Council 2012a).

5.24.3 Vaccination

(See Chapter 5.23 Preventive practice (surveillance and vaccination))

5.24.4 Registration of agricultural compounds/veterinary medicines

(See Chapter 5.23 Preventive practice (surveillance and vaccination))

5.24.5 Conclusions

The importance of preventive management of pests and diseases cannot be over emphasised. The mounting of rapid responses is facilitated by an active on-farm pest and disease surveillance programme.

The use of veterinary medicines should be complementary to biosecurity plans and preventive management and should be viewed as a last resort rather than used as a substitute for poor management

The key drivers for the use of veterinary medicines are animal welfare and biosecurity and site profitability (i.e. can the stock still be sold after an appropriate withholding period or should the stock be culled?). Although this is not current practice in New Zealand, the use of veterinary medicines may, in the event of a disease threat or outbreak, be required in the future, noting any medicine use must be appropriate under the ACVM Act (and where appropriate other legislation) prior to its use.

5.24.6 Options to aid the adoption of reactive measures for disease management (veterinary medicines)

5.24.6.1 Objective

To manage the impacts of pathogens on the facility.

5.24.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Use of chemical treatments and other compounds at facilities should be undertaken only where there is no effective alternative to protect health and welfare, and should use appropriate therapeutants, used in effective amounts. Preventive techniques of disease management using best practice alternatives (e.g. good husbandry, biosecurity) without reactive treatments should be used wherever practicable.

Treatment of pathogens and parasites should be undertaken by recognised methods and under the guidance of a veterinarian or appropriately qualified aquatic animal health professional.

If a disease breakout occurs, production systems should be isolated from each other and the surrounding environment. Further management inputs and treatments should be under the guidance of a veterinarian or appropriately qualified aquatic animal health professional.

Contingency plans should be put into place regarding the MPI and EPA approval process to licence the use of veterinary medicines and therapeutic agents, noting that many treatments

may only be administered under the direction of a registered veterinarian, or where an Approved Operating Plan exists.

5.24.7 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Aquaculture Stewardship Council (2012a). *ACS bivalve standard. Version 1.0.* January 2012. 57 pp.

Aquaculture Stewardship Council (2012b). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Bower SM, McGladdery SE and IM Price (1994). Synopsis of infectious disease and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Elston RA, Hasegawa H, Humphrey KL, Polyak IK and CC Hase (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119-134.

Elston RA (1984). Prevention and management of infectious diseases in intensive mollusc husbandry. *Journal of the World Mariculture Society* 15: 284-300.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

IFA Aquaculture (2011). *The farmed salmonid handbook. Version 1.0.* 66 pp. http://www.fishhealth.ie/FHU/ [Website accessed May 2014].

Massachusetts Shellfish Growers (2009). In: Leavitt DF (Ed.) Best management practices for the shellfish culture industry in Southeastern Massachusetts. Version 09-04a. 100 pp.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Roche P (1999). Defense mechanisms and disease prevention in farmed marine invertebrates. *Aquaculture* 172: 125-145.

5.25 RECORD KEEPING AND TRACEABILITY

The importance of accurate record keeping and document management to the aquaculture industry has long been recognised (Pettijohn 1983; Zanin *et al.* 1983) and is still widely acknowledged today (Hinrichsen 2007; Zepeda *et al.* 2008; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Global Aquaculture Alliance 2013; OIE 2013; Farm Animal Welfare Committee 2014). Monitoring and the availability of good records provides data that can be used to proactively evaluate and optimise on-farm procedures (Pettijohn 1983). Such production improvements create a less stressful environment and thus help to prevent disease occurrence and therefore improve facility profitability (HDR Engineering, Inc. 2010; Meyers 2010; **Chapter 5.13 Good husbandry**). Further, documentation and standard operating procedures can help provide certainty that employees fulfil assigned tasks to a prescribed level and aid in the timely maintenance of facilities and equipment (Yanong 2012; **Chapter 5.5 Auditing**). Comprehensive documentation can also enable a biosecurity audit to ensure that adequate precautions have been taken (Yanong 2012). Alternatively, the analysis of stock production records, such as, broodstock fecundity, mortality/morbidity, etc, can also be used to evaluate the effectiveness of biosecurity practices (Yanong 2012).

Records of stock history can assist in the identification of potential risk factors following a disease or pest outbreak, thus allowing action to be taken to minimise those risks (HDR Engineering, Inc. 2010).

In New Zealand, farmers are legally required to keep purchase and sales invoices under the Fisheries Act 1996.

Recently, Sim-Smith *et al.* (2014) investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors. The authors found that the all of the respondents maintained accurate records regarding stock transfers except for those respondents within the mussel and oyster industries.

5.25.1 Recording keeping and diseases

Accurate records supporting product traceability are crucial to disease prevention and management as they allow trace back to the source and inputs of origin (Global Aquaculture Alliance 2011*).* For example, McClure *et al.* (2005) identified that feed delivered by the feed company (as opposed to factory pick-up) increased the likelihood of a site becoming positive with infectious salmon anaemia. Murray *et al.* (2012) identified that the movement of farmed fish was critical for the spread of *Renibacterium salmoninarum* in Scotland through contact tracing and analysis of the number of movements onto the farms.

Accurate records can facilitate a more rapid response in the diagnosis of a stock health problem as the focus of an investigation may be narrowed by the records provided (Meyers 2010). Where diseases do occur, records can be used to demonstrate that best practice in biosecurity was being followed, that affected groups were isolated, and that cross-contamination was negligible (Yanong 2012). Such records could facilitate the removal of any restrictions imposed and thus a more rapid recovery to trade.

The availability of accurate records can provide a valuable reference source for future investigations concerning the health status, disease history and well being of stocks (Pettijohn 1983; Furones *et al.* 1993).

Biosecurity measures can be significantly improved when co-ordinated by neighbouring farms in an area management approach (Anon 2000; Gustafsen *et al.* 2007; Midtlyng *et al.* 2011). Documentation and records management are elements essential to the effective set-up and maintenance of an area-based management agreement (Anon 2000; Aquaculture Stewardship Council 2012; **Chapter 5.4 Area-based management**).

5.25.2 Record keeping for environmental monitoring and animal husbandry

Environmental and husbandry conditions, such as, water quality, stocking density, handling, feed type and levels, etc, can alter the predisposition of aquaculture stock to infectious and non-infectious disease (Olsen *et al.* 1997; Lumsden *et al.* 2006; Tobback *et al.* 2007; Johansen 2013; Salama and Rabe 2013; **Chapter 5.13 Good husbandry; Chapter 5.12 Feeds and feeding**).

The monitoring of environmental conditions and animal husbandry practices may provide insights as to those conditions that lead to sub-optimal stock production or disease. This prolfiling may enable the forecast of stressful situations and either the prevention of problems before they arise, or the implementation of rapid remedial actions (Cipriano 2001; Johansen 2013; Farm Animal Welfare Committee 2014).

5.25.3 Record keeping for biofouling and pests

The same principles of data collection and analysis can be used to further the understanding and management of aquaculture pest species. For example, accurate records can support the implementation of preventive practices, such as:

- not seeding mussel lines when late-stage blue mussel or barnacle larvae are at their most abundant;
- submerging oyster farms or mussel long-lines to a specific depth for a period of time to avoid unwanted mussel settlement; and
- raising green mussel long-lines to a specific depth for a period of time to avoid barnacle settlement (Sim-Smith *et al.* 2014; **Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling Management (Shellfish)**).

Further, accurate records can be used to establish a biofouling profile (e.g. voyage history and antifouling maintenance schedule) of aquaculture service vessels to ascertain if they pose a risk of pest transfer.

5.25.4 Industry-wide record keeping

Collection and collation of data from across the industry can provide a strong indication of performance (Stewart 1998) and the potential for improvement. For example, the annual production survey of finfish farms in Scotland is carried out by Marine Scotland Science to investigate industry trends (Munro and Wallace 2013). This comprehensive multi-year dataset includes, but is not limited to, the following information on rainbow trout, salmon (hatchery, smolt and adult production sites) and “other” finfish species:

- total production (tonnes);
- numbers of companies, sites, staff and main methods of production;
- number (000s), proportions (%) and sources of ova types laid down to hatch;
- number (000s) of fry and fingerlings traded;
- number (000s) of smolts produced and stocking densities by production system;

- source and number (000s) of ova, parr and smolts imported;
- destination and number (000s) of ova, parr and smolts exported;
- number of sites using vaccines and number (millions) of fish vaccinated;
- survival and production of year classes;
- number (000s) and origin of smolts put to sea;
- number of seawater sites employing a fallow period;
- number of sites holding broodstock; and
- number of confirmed escape incidents notified to the Scottish Government (Munro and Wallace 2013).

Improving the understanding of diseases and their risk factors would contribute to better disease prevention and management (Castinel *et al.* 2013). Industry-wide disease reporting and data collection can assist in surveillance and monitoring to support the understanding of disease epidemiology, development of management strategies and the identification of emerging disease issues (Johansen 2013).

The Norwegian Veterinary Institute produces an annual report that discusses the disease trends of cultured finfish (Johansen 2013). The report is based on diagnostic data from the Norwegian Veterinary Institute laboratories as well as information gathered from fish health services, other research institutions and the Norwegian Food Safety Authority (Johansen 2013).

Based on the data collected the document is able to assess the status of various diseases and their management. For example, in 2012:

- the spread of pancreas disease was managed by the destruction of affected stocks. Departure from this strategy led to rapid spread of the disease. However, an increasing trend towards lower losses was noted. Other measures to manage this disease included:
    - implementation of observation, eradication and control zones;
    - improvement in smolt quality and the timing of transfer;
    - screening for the presence of the virus; and
    - improvements to animal husbandry (e.g. careful handling) (Johansen 2013).

- losses due to infectious pancreatic necrosis appeared to decrease in hatchery and post-smolt stages. Management measures that contributed to this decline included:
    - the use of genetically improved broodstock;
    - improved hygiene during the hatchery phase;
    - implementation of stress-reducing routines; and
    - improvement in smolt quality and the timing of transfer (Johansen 2013).

- the number of outbreaks of heart and skeletal muscle inflammation (HSMI) appears to have stagnated. Factors identified to avoid mass losses include maintaining low levels of stress and optimal feeds. Large scale losses during an outbreak may be precipitated by stress events, such as, lice-treatments, storms and grading (Johansen 2013).

- there was an increase in the incidences of cardiomyopathy syndrome with nearly twice the number of cases reported compared with 2010. Increased incidence was particularly apparent in the north, while the greatest losses are reported from mid-Norway (Johansen 2013).

5.25.5 Conclusions

The keeping of accurate records is an integral biosecurity practice to an individual aquaculture facility, facilities within an area-based management agreement. Further, data collection and analysis at an industry-wide level may provide greater insights regarding the epidemiology and subsequent management of aquatic pests and diseases.

5.25.6 Options to aid the adoption of recording keeping for traceability

5.25.6.1 Objectives

To record all information necessary to support good biosecurity practice in accordance with the facility biosecurity plan.

5.25.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

The biosecurity plan should be implemented at all times and actions taken be verifiable by record keeping (e.g. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/278578/Finfish_biosecurity_logbook.pdf).

Facilities should establish a stringent monitoring and recording programme to build-up a history of events associated with each holding facility or batch of stock. This programme should interconnect links within the production chain and allow tracing of each processed lot back to the culture unit and inputs of origin.

Health monitoring records should be kept for different stock populations within the facility and should include details of any sickness, mortality, treatments and relevant environmental information.

Records should be maintained for all stock moved onto the facility or between zones of different biosecurity status within the facility.

Data across the industry should be collected, collated and analysed to provide an indication of performance, identify trends in production and practices and the potential for improvement.

5.25.6.3 Detailed options

For specific options regarding record keeping, please see each relevant chapter.

Stock history and traceability

The following data should be recorded for each culture unit and each production cycle:

- facility and company reporting structures and responsibilities, including contact details, relevant to on-site biosecurity;
- culture unit identification number;
- unit area or volume;
- common and scientific names of stock;

- source of stock (e.g. hatchery name or wild geographic source and supplier);
- stocking date;
- quantity of stock;
- stocking density;
- production figures and stock records;
- sources of supplies and feed;
- manufacturer and lot number for each feed used (as applicable);
- feeding schedules;
- stock performance;
- health monitoring and surveillance results, behavioural and feeding observations;
- unusual events that could affect stock health;
- environmental and water quality parameters monitoring (e.g. air and water temperature, rainfall, dissolved oxygen levels);
- veterinary visits (including observations and agreed actions), veterinary and pathology reports;
- all treatments and vaccinations undertaken;
- herbicide and other pesticide use;
- stock movements;
- fallowing periods;
- breaches of containment (i.e. escapes) (as applicable);
- amount and type of fouling present;
- morbidity and mortality;
- chemical store log book;
- cleaning and disinfection dates;
- inspection and maintenance of equipment and structures;
- visitor logbook;
- harvest date;
- harvest method;
- harvest quantity;
- transport method; and
- processing plant or purchaser.

A copy of previous history should accompany the movement of stock or products. The receiver should add their processing history to that provided by the producer. Aquaculture product buyers will then have access to the information for chain-of-custody traceability.

Within industry disease data collection should be conducted, reported to and made available to the MPI where appropriate, to:

- assist in surveillance and monitoring;
- support the understanding of pest spread and disease epidemiology;
- develop management strategies; and
- aid the identification of emerging pest and disease issues.

Pest and disease trends of each type of production stock should be reported annually.

5.25.7 References

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Cipriano RC (2001). *Aeromonas hydrophila and motile aeromonad septicaemias of fish.* United States Department of the Interior. Fish and Wildlife Service. Fish Disease Leaflet 68. 25 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Furones MD, Rodgers CJ and CB Munn (1993). *Yersinia ruckeri, the causal agent of enteric redmouth disease (ERM) in fish. Annual Review of Fish Diseases* 3: 105-125.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

HDR Engineering, Inc. (2010). *Illinois aquaculture biosecurity manual.* Prepared for Southern Illinois University Carbondale Fisheries and Illinois Aquaculture Center. 177 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Johansen R (Ed.) (2013). The health situation in Norwegian aquaculture 2012. *Norwegian Veterinary Institute, Norway*. 38 pp.

Lumsden JS, Young K, Welsh K, MacInnes J, Russell S and S Hesami (2006). *Management approaches for coldwater disease caused by Flavobacterium psychrophilum. In*: Proceedings of the Canadian Freshwater Aquaculture Symposium - Aquaculture Canada 2004. St. Andrews, New Brunswick; Aquaculture Association of Canada Special Publication No. 11. pp. 111-117.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Munro LA and IS Wallace (2013). *Scottish fish farm production survey 2012.* Marine Scotland Science. The Scottish Government. 49 pp.

Murray AG, Munro LA, Wallace IS, Allan CET, Peeler EJ and MA Thrush (2012). Epidemiology of *Renibacterium salmoninarum* in Scotland and the potential for compartmentalised management of salmon and trout farming areas. *Aquaculture* 324-325: 1-13.

OIE (2013). *Aquatic animal health code.* http://www.oie.int/international-standard-setting/aquatic-code/access-online/ [Website accessed June 2014].

Olsen AB, Melby HP, Speilberg L, Evensen Ø and T Håstein (1997). *Piscirickettsia salmonis* infection in Atlantic salmon *Salmo salar* in Norway - epidemiological pathological and microbiological findings. *Diseases of Aquatic Organisms* 31: 35-48.

Pettijohn LL (1983). *Routine fish disease monitoring. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 89-98.

Salama NKG and B Rabe (2013). Developing models for investigating the environmental transmission of disease causing agents within open-cage salmon aquaculture. *Aquaculture Environment Interactions* 4: 91-115.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Stewart JE (1998). *Sharing the waters: an evaluation of site fallowing, year separation and distances between sites for fish health purposes on Atlantic salmon farms.* Canadian Technical Reports in Fisheries and Aquatic Sciences 2218. 56 pp.

Tobback E, Decostere A, Hermans K, Haesebrouck F and K Chiers (2007). *Yersinia ruckeri* infections in salmonid fish. *Journal of Fish Diseases* 30: 257-268.

Yanong RPE (2012). *Biosecurity in aquaculture, part 2: recirculating aquaculture systems.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 9 pp.

Zanin E, Allegretti M, Giorgetti, G and G Ceshia (1983). Initiation and appraisal of an official prophylactic policy against VHS in farmed trout in the Province of Trento, Italy. *Bulletin of the European Association of Fish Pathologists* 3: 5-6.

Zepeda C, Jones JB and FJ Zagmutt (2008). Compartmentalisation in aquaculture production systems. *Revue Scientifique et Technique de L'office International des Epizooties* 27(1): 229-241.

5.26 REMOVAL AND DISPOSAL OF DEAD AND MORIBUND STOCK

Some level of stock mortality will occur during an aquaculture production cycle. Reasons for these events may include age, predator damage, congenital defects, infections, mismanagement, suboptimal water quality, runting or natural attrition (Environmental Protection Authority South Australia (EPA SA) 2007; New Zealand King Salmon Ltd. 2011). Mortality extent can range from losses of a few organisms from day to day, to large scale events resulting from disease or environmental conditions (e.g. algal blooms) (EPA SA 2007).

The prompt collection of mortalities:

- ensures early detection of problems, and if necessary, implementation of management measures;
- minimises the spread of any disease from mortalities to the living;
- minimises the attraction of predators to the sea pen;
- minimises waste and additional weight in the sea pen from the mortalities; and
- assists records management (trend analysis and problem identification) (New Zealand King Salmon Ltd. 2011).

It is recognised that dead and moribund aquaculture stock are known pathogen sources;

- in finfish:
    - infectious pancreatic necrosis virus (IPNV) (Anon 2003);
    - infectious salmon anaemia virus (ISAV) (Jarp and Karlsson 1997);
    - viral haemorrhagic septicaemia virus (Kocan *et al.* 1997);
    - *Aeromonas salmonicida* subsp. *salmonicida* (Pérez *et al.* 1996);
    - *Flavobacterium branchiophila* (Schachte 1983);
    - *F. columnare* (Johansen *et al.* 2011); and
    - *F. psychrophilum* (Cipriano and Holt 2005; Lumsden *et al.* 2006).

- in shellfish:
    - abalone herpes virus (Corbeil *et al.* 2012);
    - ostreid herpesvirus microvariant 1 (OsHV-1) (Sauvage *et al.* 2009);
    - *Perkinsus olseni* (Raynard *et al.* 2007); and
    - *Perkinsus marinus* (Bobo *et al.* 1997).

The prompt removal and appropriate storage (i.e. separated from rest of the site in secure, leak proof containers) and disposal of moribund and dead animals will help to reduce the probability of infection spread (Schachte 1983; Anon 2005; Cipriano and Holt 2005; Lumsden *et al.* 2006; Raynard *et al.* 2007; Johansen *et al.* 2011; OIE 2013). In Norway the risk of ISAV outbreaks was tripled on farms that did not remove dead fish daily during the summer. Although it was noted that the frequency of removal during winter did not seem to be related to the risk of ISA infection (Jarp and Karlsson 1997).

In New Zealand, respondents surveyed from commercial and non-commercial salmonid farms (freshwater and marine) regularly remove mortalities from their production facilities (Sim-Smith *et al.* 2014). Finfish mortalities are immediately disposed of in compost pits located on or off-site; or stored in sealed, water-tight containers, rubbish bags or bins or open containers prior to disposal. Mortalities from paua farms are removed daily or immediately when observed. These are frozen or stored in lidded rubbish bins before disposal in a landfill or in a mortality pit on-site. Mortalities from mussel or oyster farms are typically not removed from

farms or only removed at the point of harvest. Disposal varies from on-land (oysters) to sea (mussels).

Disposal options for dead or moribund aquaculture animals are dependent on the organism type, cause of death and quantity to be disposed of. Further, these options require consideration of the potential for contamination of surface and groundwater (EPA SA 2007; Department of Agriculture, Fisheries and Forestry (DAFF) 2009; OIE 2013). Suitable methods identified for the disposal of aquaculture mortalities include:

- composting;
- reusing or recycling;
- biogas production;
- rendering;
- ensiling;
- sterilisation;
- pasteurisation;
- on-site burial;
- waste depot (landfill);
- incineration; and
- pyre or pit burning (Table 17; EPA SA 2007; DAFF 2009; OIE 2013).

Table 17: Advantages and disadvantages of mortality disposal options[1] (EPA SA 2007; DAFF 2009; OIE 2013).

Option	Advantages	Disadvantages
Composting	Environmentally sustainable. Most suited to low risk waste. Although has been demonstrated that correct composting can kill all the major known fish pathogens except IPN virus. End products may be on-sold (e.g. compost products and fertilisers).	Does not inactivate all pathogenic agents. High risk waste should be heated (85°C for 25 minutes or an equivalent temperature/time combination) prior to composting. Shells of molluscs may need to be crushed prior to composting to facilitate their breakdown. Needs to be conducted in a secure area, free from scavenging animals and birds. Timing: When held in windrows, the entire material needs an exposure time of at least two weeks at 55°C, while in closed vessels exposure to 65°C for one week is required. Location: Can only be conducted in locations where conditions are deemed suitable (e.g. where the potential for ground and surface water contamination is negligible).
Reuse/recycling	Environmentally sustainable. End products may be on-sold (e.g. fishmeal products and fertilisers).	May not inactivate all pathogenic agents. May not be appropriate if the fish kill was the result of a disease.
Ensiling	Environmentally sustainable. Does not require prior inactivation step in the case of low risk waste.	Does not inactivate all pathogenic agents (e.g. IPNV). High risk waste should be heated (85°C for 25 minutes or an equivalent

Option	Advantages	Disadvantages
	Heat-treated silage can be used commercially (e.g. as a fertiliser or feed additive for terrestrial animals or as biogas feedstock). Fish oils can be separated and used (e.g. biodiesel).	temperature/time combination) prior to ensiling. Stock needs to be thoroughly macerated before loading into the ensiling plant. Not considered appropriate for mollusc disposal as shells tend to resist chemical breakdown.
Biogas production	Environmentally sustainable. Produces methane which can be on-sold (e.g. heating). Does not require prior inactivation step in the case of low risk waste.	Does not inactivate all pathogenic agents. High risk waste should be treated to ensure inactivation prior to production. End material often pasteurised by heating to 70°C for 1 hour.
Rendering	Environmentally sustainable. Will inactivate all known aquatic animal pathogenic agents. Leads to the creation of stable, sterilised products, such as animal fat and dried animal protein.	Carcasses may need to be processed soon after mortality. End product quality dependent on quality of inputs.
Sterilisation	Will inactivate all known aquatic animal pathogenic agents. The minimum requirement for sterilisation is a core temperature of at least 90°C for at least 60 minutes.	Cost.
Pasteurisation	Uses heat treatment at temperatures below 100°C.	Does not inactivate all pathogenic agents. Should only be used on low risk waste. Heat-resistant spores of mesophilic or thermophilic spore-formers require extremely long exposure times, or multiple heating steps with cooling steps in between. Specific pathogens that require higher temperature or duration will need to be processed appropriately to ensure inactivation of the pathogen. The requirements for thermal inactivation of pathogens will depend on the size of the carcasses being treated.
Freezing	Secure method for temporary storage of dead and diseased animals. Deactivates some protozoa and most metazoan parasites.	Generally does not affect viability of bacteria and viruses.
On-site burial	Logistical simple. Quick. Cheap. Easily achievable. No associated transportation risks.	Does not inactivate all pathogenic agents. Aquatic animal waste should be subjected to a treatment that ensures inactivation of pathogenic agents prior to burial. Generally discouraged due to risks associated with site re-infection and attraction of predators, scavengers and vermin.

Option	Advantages	Disadvantages
		Can only be conducted in locations where conditions are deemed suitable (e.g. where the potential for ground and surface water contamination is negligible). Residues may persist for long periods. Large burial sites may result in public opposition. Not environmentally sustainable.
Landfill	Easily achievable. Infrastructure often already in place. Enables large quantities of stock to be disposed of.	Does not inactivate all pathogenic agents. Aquatic animal waste should be subjected to a treatment that ensures inactivation of pathogenic agents prior to burial. Can only be conducted in locations where conditions are deemed suitable (e.g. where the potential for ground and surface water contamination is negligible). Residues may persist for long periods. Additional on-site biosecurity measures may be warranted. Landfill employees may require additional training to prevent disease spread. Disposal at site may result in public opposition. Not environmentally sustainable.
Incineration (air curtain)	Effectively inactivates all known aquatic pathogens. Process can be carried out on-site with mobile air curtain incinerators. Improved combustion efficiency reduces emissions (more environmentally friendly than pyres/pit burning). Removes risks associated with carcass transportation. Quick (a single unit can burn 34 tonnes of carcasses per day).	Requires considerable amounts of fuel. Properly trained personnel required. Will not reduce the amount of shellfish material to be disposed of. Need to take into account fire restrictions in place. Not environmentally sustainable. Ashes still require burial. Must be attended at all times.
Pyre/pit burning	Effectively inactivates all known aquatic pathogens. May be appropriate for small quantities of mortalities. Relatively quick (~48 hours)	Considered final option for waste disposal. Expensive. May not be suitable for large amounts of aquatic animal waste. Requires considerable amounts of fuel. Health authority and public opposition to smoke, carbon dioxide and toxic emission

Option	Advantages	Disadvantages
		from fuels used. Can only occur at specific locations under specific weather conditions. Creates highly visible air pollution. Creates odours. Will not reduce the amount of shellfish material to be disposed of. Need to take into account fire restrictions in place. Not environmentally sustainable. Ashes still require burial. Fire must be attended at all times.

[1]High risk waste means aquatic animal waste that constitutes, or is suspected of constituting, a serious health risk to aquatic animals or humans. Low risk waste means aquatic animal waste that is not high risk waste (less readily transmitted diseases, non-zoonotic diseases and other sources of mortality e.g. algal blooms, equipment failure, jellyfish strike)) (EPA SA 2007; OIE 2013).

5.26.1 Conclusions

The prompt removal and disposal of dead and moribund stock represents a disease risk reduction measure for both the individual site and the industry overall.

5.26.2 Options to minimise the risks associated with dead and moribund stock

5.26.2.1 Objective

To manage the risk of dead or moribund animals transferring pathogens onto, within and from the facility.

5.26.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Where problems are identified during an inspection, prompt remedial action must be taken in accordance with the VHP and biosecurity plan to determine the cause and deal with the problem, including where appropriate consultation with a veterinarian or appropriately qualified aquatic health professional.

Facility design should allow the regular removal of moribund or dead animals (preferably daily).

Injured, moribund, or severely deformed stock should be culled from the population and humanely destroyed whenever possible and disposed of appropriately.

If stock populations become sick, precautions should be taken to avoid contact with other facility populations until the cause is known and the situation resolved.

5.26.2.3 Detailed options

General

Records should be kept of each inspection, including the number of dead animals removed and the likely cause of death, as determined by a competent person.

Mortalities and moribund stock should be subject to post mortem health examinations and archiving.

Mortality rates should be monitored carefully so that long term 'normal averages' can be determined and slightly raised levels detected.

When impaired animals and unwanted species are removed, their number, total weight and condition should be recorded.

Storage

Dead animals or parts of should be removed from the site as soon as practicable. Dead animals or parts of stored on site for more than 24 hours should be stored within a dedicated, prepared storage area.

The storage area should be separated from aquaculture sites and bodies of water. For example, it should have appropriate bunding to prevent stormwater runoff entering nearby surface or ground water.

Waste storage containers should be leak-proof and secured.

Mortalities kept on site for any period of time should be kept refrigerated or frozen.

Containers used for transport of aquatic animal waste should be leak-proof and labelled regarding content.

Mortality events

Facility staff should notify their appropriate health professionals and/or call MPI's pest and diseases hotline (0800 80 99 66) when unusual or unexplained mortalities are experienced.

The facility should develop a stepwise contingency plan that considers both non-infectious and infectious causes. The plan should be developed under the guidance of a veterinarian or aquatic health professional.

If a mortality event occurs, or abnormal animal behaviour is observed, the event must be investigated and a satisfactory explanation for the mortality event provided and logged. Relevant details to be recorded in the log are date, stock behaviour, grow-out unit number, cause of event, action taken and conclusion.

Destruction of stock

In consultation with stakeholders, MPI may issue an order under the Biosecurity Act 1993 or Freshwater Fish Farming Regulations 1983 for the destruction of infected stock if it is considered that such action is appropriate for pest or disease control. Such action would be on a case by case basis and take in to account many factors before reaching a decision.

Destruction is likely to be carried out on site, and precautions should be taken to avoid spread of the disease through the spilling of body fluids or release on fomites.

Special attention should be given to preventing birds from contacting carcasses during destruction. Netting of sites before destruction of stock is the most effective control method for birds and other scavengers (e.g. rodents, cats, dogs).

Rapid disposal of infectious carcass material, such that it cannot be accessed by scavengers (e.g. rodents, cats, dogs), will reduce the need for extensive scavenger control programmes.

Disposal of mortalities

Suitable methods of storage and disposal for mortalities and stock waste should be identified and implemented prior to waste being generated. This should include identifying waste depots, composters, etc, that are licensed to receive such waste.

Mortalities should be disposed of in a way that should not cause hazard to other stocks.

A contingency plan should be developed that deals with unexpected large volumes of carcasses and waste material mortalities that may result in the event of large-scale mortality. This contingency plan needs to be regularly reviewed and updated. Large-scale mortality events may require resource consent prior to dumping.

Blood water, effluent and other liquid waste should be treated before discharge, e.g. addition of sodium hypochlorite to a final concentration of 1 g/L (wt./vol.). Before discharge, the hypochlorite should be neutralised by the addition of sodium thiosulfate.

Facilities should dispose of mortalities according to their licence conditions and legislation.

Permission must be requested from MPI prior to the disposal of any dead stock from sites that are subject to controls for listed diseases.

Disposal should be accompanied by appropriate documentation to allow tracing, if required.

Transportation

Precautions should be taken during transport of the carcasses to avoid pathogen spread.

Transport containers should not be overfilled, and enough (at least half a metre) ‘freeboard’ should be left at the top of the container to prevent spillage in any reasonably foreseeable conditions.

Care must be taken to eliminate the potential for leakage of carcasses or body fluids during their transfer to the disposal site.

Vessels carrying infected stock should avoid other aquaculture facilities. Where possible, boats should not approach within 5 km or an appropriate distance from such facilities (whichever is greater).

Where practicable, infected stock should be landed at a different dock or harbour from that usually used by the aquaculture industry in the area.

Infected stock should be transported downstream or down-current rather than upstream or up-current.

Transport should be accompanied by documentation detailing origin, content and destination to allow tracing, if required.

5.26.3 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Bobo MY, Richardson DL, Coen LD and VG Burrell (1997). *A report on the protozoan pathogens Perkinsus marinus (Dermo) and Haplosporidium nelson (MSX) in South Carolina shellfish populations.* South Carolina Marine Resources Division Technical Report No. 86. 50 pp.

Cipriano RC and RA Holt (2005). *Flavobacterium psychrophilum, cause of bacterial cold-water disease and rainbow trout fry syndrome.* United States Fish and Wildlife Service Fish Disease Leaflet 86. 44 pp.

Corbeil S, McColl KA, Williams LM, Mohammad I, Hyatt AD, Crameri SG, Fegan M and M St.J. Crane (2012). Abalone viral ganglioneuritis: establishment and use of an experimental immersion challenge system for the study of abalone herpes virus infections in Australian abalone. *Virus Research* 165: 207-213.

Department of Agriculture, Fisheries and Forestry (DAFF) (2009). *Operational procedures manual: disposal (Version 2.0)*. Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT. 65 pp.

Environmental Protection Authority South Australia (EPA SA) (2007). *Managing aquaculture stock mortalities.* Environmental Protection Authority South Australia. 7 pp.

Jarp J and E Karlsen (1997). Infectious salmon anaemia (ISA) risk factors in sea-cultured Atlantic salmon *Salmo salar*. *Diseases of Aquatic Organisms* 28: 79-86.

Johansen L-H, Jensen I, Mikkelsen H, Bjorn P-A, Jansen PA and Ø Bergh (2011). Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. *Aquaculture* 315: 167-186.

Kocan R, Bradley M, Elder N, Meyers T, Batts W and J Winton (1997). North American strain of viral haemorrhagic septicaemia virus is highly pathogenic for laboratory-reared Pacific herring. *Journal of Aquatic Animal Health* 9: 279-290.

Lumsden JS, Young K, Welsh K, MacInnes J, Russell S and S Hesami (2006). *Management approaches for coldwater disease caused by Flavobacterium psychrophilum*. *In*: Proceedings of the Canadian Freshwater Aquaculture Symposium-Aquaculture Canada 2004. St. Andrews, New Brunswick; Aquaculture Association of Canada Special Publication No. 11. pp. 111-117.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

OIE (2013). *Aquatic animal health code. Chapter 4.6. Handling, disposal and treatment of aquatic animal waste.* 6 pp.

Pérez MJ, Fernández AIG, Rodríguez LA and TP Nieto (1996). Differential susceptibility to furunculosis of turbot and rainbow trout and release of furunculosis agent from furunculosis-affected fish. *Diseases of Aquatic Organisms* 26: 133-137.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Sauvage C, Pepin JF, Lapegue S, Boudry P and T Renault (2009). Ostreid herpes virus 1 infection in families of the Pacific oyster, *Crassostrea gigas*, during a summer mortality outbreak: differences in viral DNA detection and quantification using real-time PCR. *Virus Research* 142 (1-2): 181-187.

Schachte JH (1983). *Coldwater disease. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 193-198.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

5.27 SITE LOCATION

The foundation of a successful aquaculture site is based on its ability to provide conditions appropriate for the growth and welfare (including biosecurity) of the species to be farmed (Goldthwaite and Carey 1983; Blaylock and Whelan 2004; Anon 2005; Hinrichsen 2007; Massachusetts Shellfish Growers 2009; Global Aquaculture Alliance 2013; Farm Animal Welfare Committee 2014; **Chapter 5.13 Good husbandry**).

Many factors are important for the selection of an appropriate aquaculture site, including: water supply (primary and contingency), hydrography, depth, temperature, oxygen profile, disease history, presence of (intermediate)-hosts, predators and tidal flow (Munro and Waddell 1984; Jarp *et al.* 1993; Anon 2003; Blaylock and Whelan 2004; Hinrichsen 2007; Hutson *et al.* 2007; Zeldis *et al.* 2010). Further, the site should provide reasonable shelter from adverse weather and sea conditions to maintain its integrity (Anon 2005; Hinrichsen 2007; **Chapter 5.28 Stock containment**).

The primary resource upon which aquaculture depends is water, as it:

- supplies the medium, oxygen and temperature necessary for stock survival and production performance;
- supplies nutrients and food to stock (e.g. filter-feeding organisms); and
- removes accumulated and excess nutrients and metabolites from the production site (Hinrichsen 2007).

Considering its central importance to aquaculture, the following questions should be considered regarding access to water resources at a prospective site:

- is water of a sufficient volume and quality accessible? (**Chapter 5.13 Good husbandry)**;
- what mitigation measures are required to ensure that the water quality and volume are maintained? (**Chapter 5.13 Good Husbandry; Chapter 5.9 Contingency plans**);
- how will effluent or excess water be treated after use? (**Chapter 5.32 Water treatment**); and
- has the assimilative or carrying capacity of the environment been determined? (**Chapter 5.13 Good Husbandry;** Hinrichsen 2007).

Other factors to consider for biosecurity purposes include, physical accessibility and infrastructure, i.e. the site needs to be accessible for:

- electricity (primary and contingency);
- supply of feeds and services;
- dispatch of products;
- waste removal and disposal (including wastewater treatment); and
- access by personnel (Hinrichsen 2007).

Site selection should involve input from a qualified aquatic health professional (Farm Animal Welfare Committee 2014).

5.27.1 Distance between sites (Chapter 5.4 Area-based management)

Since many aquatic animal pathogens can survive outside their host, they can be transported to neighbouring farms that are connected by water currents without the presence of an infected host (Peeler 2005; Salama and Murray 2013).

Farm proximity has been identified as a risk factor in the spread of aquatic animal pathogens including: infectious salmon anaemia (ISA) (McClure *et al.* 2005; Gustafson *et al.* 2007; Aldrin *et al.* 2010), pancreas disease (Kristoffersen *et al.* 2009; Aldrin *et al.* 2010) and parasites, such as sea lice and monogeneans (Anon 2000; Chambers and Ernst 2005). Midtlyng *et al.* (2011) maintained that the "re-location to increase the distance between sites; and zoning and co-ordination between farmers within a zone" were among the most important measures to prevent horizontal transmission of both ISA and furunculosis in Norway. Implementation of these measures, among others, also contributed to the reduction in the amount of antibiotics used in Norwegian finfish production (Midtlyng *et al.* 2011).

The rationale behind the management of separated and discrete units within a wider area is to create an epidemiological 'firebreak', reducing the probability of infection spread from infected to susceptible sites (Green 2010). As such, the further positioning of both farms and management areas need to consider whether or not they may bridge these 'firebreaks' (Anon 2000; Midtlyng *et al.* 2011). In the case of ISA, distances > 5 km between sites (farms and processing facilities) appears to be effective in reducing the probability of disease transmission (Jarp and Karlson 1997; Håstein *et al.* 1999; Anon 2000; McClure *et al.* 2005). Ideally, farms should be situated at least 5 km or one tidal excursion, whichever is greater, from any broodstock farm, harvesting station or processing plant (Anon 2000). Anon (2005) recommended that those farms within one tidal excursion of the discharge from a processing plant processing infected fish should be subject to increased frequency of health inspections.

To prevent the spread of disease, the locational guidelines of the Scottish Executive specify a minimum distance of 8 km between finfish farms, 3 km between finfish and shellfish farms and 1.5 km between shellfish farms (Anon 2005).

To mitigate the risk of spread of pancreas disease, the Norwegian coastline has been divided into two administrative units north and south of a 10 NM section of coastline with no fish farms. This section of coast is assumed to act as an efficient barrier between an endemic south region and a disease-free north region (Bang Jensen *et al.* 2012). In terms of parasites, Chambers and Ernst (2005) recommended that a distance > 8 km was required to separate down-current farms from the monogenean *Benedenia seriolae*.

The Norwegian Food Safety Authority currently enforces a 5 km restricted zone and a 10 km observation zone around ISA-infected farms (Aldrin *et al.* 2011). Hydrographically defined farm management areas in Scotland have their origins in strategies for controlling furunculosis and sea lice (Anon 2000). The "control zone" of notifiable diseases is defined as a circle of radius equal to one tidal excursion centred on the farm that has been diagnosed as infected. In inland areas a "control zone" may comprise all or part of a water catchment area (Code of Good Practice Management Committee 2011). A "surveillance zone" is defined as an area surrounding the control zone of overlapping tidal excursion zones. In inland areas a "surveillance zone" comprises an extended area outside the established control zone (Code of Good Practice Management Committee 2011).

Epidemiological analysis and marine hydrography should be taken into account when determining between site distances (Blaylock and Whelan 2004). Such analysis should also include established sites farming other species (Anon 2000). However, farm and area management boundaries are never perfectly sealed and there is always a risk that infection can enter a pathogen-free population (Murray 2013).

The same principles of spacing with respect to site location can also be used to minimise the spread of pest species.

Literature regarding advisable distances between freshwater facilities is scarce. In contrast to offshore facilities, most land-based facilities have the ability to treat both influent and effluent (**Chapter 5.32 Water treatment**).

5.27.2 Conclusions

The success of an aquaculture operation is dependent on the selection of a suitable site. Stock health considerations, such as animal welfare and biosecurity risks (pests and diseases), are key to appropriate site selection. Epidemiological and hydrographical modelling should be considered when determining the distances between sites. However, emphasis should be placed on the management of areas rather than individual sites.

5.27.3 Options to minimise the risks associated with site location

5.27.3.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility.

5.27.3.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Facilities should be situated in areas that provide the appropriate biological and physical factors for the target species and type of culture.

Facilities should be located in a place that meets regulatory requirements and minimises the potential for biosecurity risk issues.

Epidemiological analysis and hydrography should be taken into account when determining between site distances. Such analysis should also include established facilities producing other species. New offshore, marine-linked or freshwater land-based sites should be located an appropriate distance from any production facilities. If, through a risk assessment (which gives due consideration to relevant hydrodynamic information), it can be shown that the risk of spread of pests and pathogens is satisfactorily low, and all companies within the management area agree, the establishment of such a site within the management area may be acceptable.

New offshore or marine or freshwater-linked land-based broodstock sites should be located an appropriate distance from any production facilities. If, through a risk assessment (which gives due consideration to relevant hydrodynamic information), it can be shown that the risk of spread of pests and pathogens is satisfactorily low, and all companies within the management area agree, the establishment of such a site within the management area may be acceptable.

All new facilities should be located at an appropriate distance from existing broodstock sites.

Approved best management practices for biosecurity should be applied to each new development, activity, or change in products or services.

5.27.3.3 Detailed options

General

The development of facilities should comply with the relevant laws and requirements in place at that time.

Prior to expansion of any facility or addition of new structures, a biosecurity assessment of the proposed change should be undertaken.

The location (or expansion) of facilities (including hatcheries) should be selected on the basis that there is an adequate supply of water of suitable quality at all times.

Whenever practical, select sites with good water exchange that are not depositional environments.

Where appropriate (e.g. hatcheries, land-based facilities), there should be emergency back-up systems to maintain a high standard of water quality.

New tank and pond sites should be located in areas that are unlikely to be affected by flooding.

Contingency plans are to be developed covering actions to be taken in the event of a serious incident, such as storm damage or water quality problems.

Where possible, the position, design and construction of facility should consider the interaction with wildlife and the exclusion of predators at the planning stage.

A thorough investigation of all other land uses in the vicinity should be conducted to identify potential areas of conflict or possible future water quality problems.

The distance between the hatchery and wild or on-growing populations should be maximised to reduce the risk of infection through dilution.

Sites should be chosen away from navigational channels.

Finfish

In determining sites for finfish aquaculture the following factors should be considered:

- water chemistry;
- water temperature;
- water flow and exchange;
- sediment type;
- proximity to predator populations;
- presence of harmful algae or history of toxic blooms;
- presence of jellyfish or history of swarms;
- water depth;
- protection from severe weather;
- potential for impacts from surrounding land-based activities; and
- site security.

Mussels

In determining sites for mussel aquaculture the following factors should be considered:

- water chemistry;
- water temperature;
- water flow and exchange;
- phytoplankton availability and carrying capacity;
- sediment type;
- proximity to predator populations;
- presence of harmful algae and history of toxic blooms;
- water depth;
- protection from severe weather;
- potential for impacts from surrounding land-based activities; and
- site security.

Growth rates should be recorded at least annually to indirectly monitor any potential variation in carrying capacity.

Oysters

In determining sites for oyster aquaculture the following factors should be considered:

- water chemistry;
- water temperature;
- water flow;
- phytoplankton availability and carrying capacity;
- sediment type;
- presence of harmful algae and history of toxic blooms;
- proximity to predator populations;
- water depth (correct tidal height and distance above seabed of structures);
- shelter from excess wave action and swells;
- protection from severe weather;
- potential for impacts from surrounding land-based activities; and
- site security.

The building of facilities in shallow waters should be avoided (to prevent siltation). Suitable inter-tidal growing areas typically have waters at least 0.7 m deep at the level of extreme low water neap tides.

Growth rates should be recorded at least annually to indirectly monitor any potential variation in carrying capacity.

Oysters should not be stocked at a rate such that the accumulation of faecal matter (biodeposits) exceeds the capability of the site to disperse this material.

Paua

In determining appropriate sites for land-based paua aquaculture the following factors should be considered:

- water chemistry;
- water temperature;
- water flow and exchange;
- proximity to predator populations;

- presence of harmful algae and history of toxic blooms;
- protection from severe weather;
- potential for impacts from surrounding land-based activities; and
- site security.

5.27.4 References

Aldrin M, Lyngstad TM, Kristoffersen AB, Storvik B, Borgan Ø and PA Jansen (2011). Modelling the spread of infectious salmon anaemia among salmon farms based on seaway distances between farms and genetic relationships between infectious salmon anaemia virus isolates. *Journal of the Royal Society Interface* 8(62): 1346-1356.

Aldrin M, Storvik B, Frigessi A, Viljugrein H and PA Jansen (2010). A stochastic model for the assessment of the transmission pathways of heart and skeleton muscle inflammation, pancreas disease and infectious salmon anaemia in marine fish farms in Norway. *Preventive Veterinary Medicine* 93: 51-61.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Bang Jensen B, Kristoffersen AB, Myr C and E Brun (2012). Cohort study of effect of vaccination on pancreas disease in Norwegian salmon aquaculture. *Diseases of Aquatic Organisms* 102: 23-31.

BC Pacific Salmon Forum (2007). *British Columbia finfish aquaculture regulation: an information review and progress report 1/22/07*. 17 pp.

Blaylock RB and DS Whelan (2004). *Fish health management for offshore aquaculture in the Gulf of Mexico. In*: CJ Bridger (Ed.) Efforts to develop a responsible offshore aquaculture industry in the Gulf of Mexico: A compendium of offshore aquaculture consortium research. Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, United States of America. pp. 129-161.

Chambers CB and I Ernst (2005). Dispersal of the skin fluke *Benedenia seriolae* (Monogenia: Capsalidae) by tidal currents and implications for sea-cage farming of *Seriola* spp. *Aquaculture* 250: 60-69.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Goldthwaite DB and TG Carey (1983). *Planning a fish health program for hatchery management. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Special Publication 83-2. pp. 23-26.

Green DM (2010). A strategic model for epidemic control in aquaculture. *Preventive Veterinary Medicine* 94: 119-127.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Håstein T, Hill BJ and JR Winton (1999). Successful aquatic animal disease emergency programmes. *Revue Scientifique et Technique de L'office International des Epizooties* 18: 214-227.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1*. Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Hutson KS, Ernst I and ID Whittington (2007). Risk assessment for metazoan parasites of yellowtail kingfish *Seriola lalandi* (Perciformes: Carangidae) in South Australian sea-cage aquaculture. *Aquaculture* 271: 85-99.

Jarp J and E Karlsen (1997). Infectious salmon anaemia (ISA) risk factors in seacultured Atlantic salmon *Salmo salar*. *Diseases of Aquatic Organisms* 28: 79-86.

Jarp J, Tangen K, Willumsen FV, Djupvik HO and AM Tveit (1993). Risk factors for infection with *Aeromonas salmonicida* in Norwegian freshwater hatcheries. *Diseases of Aquatic Organisms* 17: 81-86.

Kristoffersen AB, Viljugrein H, Kongtorp RT, Brun E and PA Jansen (2009). Risk factors for pancreas disease (PD) outbreaks in farmed Atlantic salmon and rainbow trout in Norway during 2003-2007. *Preventive Veterinary Medicine* 90: 127-136.

Massachusetts Shellfish Growers (2009). *In*: Leavitt DF (Ed.) Best management practices for the shellfish culture industry in Southeastern Massachusetts. Version 09-04a. 100 pp.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

Murray AG (2013). Implications of leaky boundaries for compartmentalised control of pathogens: a modelling case study for bacterial kidney disease in Scottish salmon aquaculture. *Ecological Modelling* 250: 177-182.

Peeler E (2005). *The role of risk analysis and epidemiology in the development of biosecurity for aquaculture. In*: P Walker, R Lester and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 35-45.

Salama NKG and AG Murray (2013). A comparison of modelling approaches to assess the transmission of pathogens between Scottish fish farms: the role of hydrodynamics and site biomass. *Preventive Veterinary Medicine* 108: 285-293.

Zeldis J, Broekhuizen N, Forsythe A, Morrisey D and J Stenton-Dozey (2010). *Waikato marine finfish farming: production and ecological guidance.* NIWA Client Report: CHC2010-147 prepared for MFish Aquaculture Unit. 112 pp.

5.28 STOCK CONTAINMENT

Stocks are typically the most valuable assets on an aquaculture farm, therefore considerable efforts are made to limit their escape (Anon 2000). In Norway, escape events are largely caused by technical and operational failures of farming equipment (Jensen *et al.* 2010). Similarly, the investigation of the 2006 Te Pangu salmon farm escape event in New Zealand found that the mooring failure was predominantly due to uneven tensioning on the moorings occurring over time (New Zealand King Salmon Ltd. 2011). Stock escapes occur within the New Zealand aquaculture industry: http://www.stuff.co.nz/national/9717218/Fishermen-out-for-escaped-salmon. Effective containment of farmed stock is dependent on the selection of appropriate installations and holding facilities and their maintenance (Code of Good Practice Management Group 2011). Correct facility construction has financial benefits with respect to cost savings associated with less maintenance and lower incidences of unexpected construction failures (vom Berg 2008).

Stock escape from aquaculture establishments is a perceived threat to other farmed and wild populations (Anon 2000; Jensen *et al.* 2010) as they may:

- compete with wild fish for resources (Gillanders and Joyce 2005; Naylor *et al.* 2005; Jensen *et al.* 2010);
- change ecosystems (Kochmann *et al.* 2008; Markert *et al.* 2013);
- replace native species, for example, *Crassostrea gigas* has displaced the native New Zealand oyster (*C. glomerata*) from a broad distribution in the intertidal to a rare occurrence in the high intertidal (Bell *et al.* 2011);
- prey upon wild organisms (Gillanders and Joyce 2005; Naylor *et al.* 2005);
- alter the genetic structure of wild fish populations (Doupe and Lymbery 1999; Gillanders and Joyce 2005; Naylor *et al.* 2005; Jensen *et al.* 2010); and
- act as a reservoir for the spread of infection (Anon 2003; Gillanders and Joyce 2005; Naylor *et al.* 2005; Gavine *et al.* 2007; Raynard *et al.* 2007; Jensen *et al.* 2010; Murray 2013).

In terms of land-based aquaculture facilities, uncontrolled stock presents the following risks:

- stock in pipe-work (shellfish) and in settlement tanks (shellfish and finfish) can:
    - block pipe-work or reduce flow rates;
    - attract predators (birds, rats);
    - re-enter the farm and spread infection to healthy stock; and
- stock in settlement tanks or ponds can escape to the wild and interact with wild stock. They can represent a reservoir of disease that can re-infect farm stock or spread it to the marine environment (Gavine *et al.* 2007). This may result in significant legal issues as observed in Australia following the outbreak of abalone viral ganglioneuritis (http://www.smh.com.au/business/farm-settles-in-abalone-virus-case-20130917-2tx6p.html).

The survival and behaviour of farmed salmon in the wild are determining factors in the risk posed to wild and farmed populations, respectively. These factors are influenced by the size and age at escape, geographical location of the escape, season, physiological status and the extent of domestication (Anon 2000). Anecdotal information from Scotland suggests the dispersion of fish following escape is very rapid. By contrast, Norwegian studies have observed that escaped fish have been found to spend up to three weeks in the vicinity of the escape location (Anon 2000). Similarly, escaped yellowtail kingfish often remain close to farms for several days enabling their prompt recapture (vom Berg 2008).

Background knowledge of diseases that exist in a species or an area prior to aquaculture is often lacking, and as a result determining whether aquaculture is the source for introducing or transferring a disease to wild populations is difficult. Despite interactions between escaped and wild populations, there is little direct evidence of pathogen transfer from escaped aquaculture stock to wild stock (Raynard *et al.* 2007; vom Berg 2008; Jensen *et al.* 2010). The difficulty in obtaining this evidence stems from the determination of pathogen origin in wild-stock and establishing the link with disease in farmed stock (vom Berg 2008). However, there are several incidences where "good" evidence of pathogen transfer exists (Raynard *et al.* 2007):

- the transfer of viral haemorrhagic anaemia virus between rainbow trout farms has been attributed to escaped rainbow trout (Raynard *et al.* 2007);
- the rapid spread of *Aeromonas salmonicida* subsp. *salmonicida* between farmed and wild salmon populations in Norway has been associated with escaped fish (Naylor *et al.* 2005);
- clinical infectious salmon anaemia was detected in wild and escaped farmed Atlantic salmon that had entered the same Canadian river (Naylor *et al.* 2005);
- wild adult predatory fish may have become infected with infectious pancreatic necrosis by feeding on escaped rainbow trout (Anon 2003);
- escaped salmon have been identified as reservoirs of sea lice in Norwegian coastal waters (Heuch and Mo 2001); and
- worldwide spread of the Asian fish tapeworm *Bothriocephalus acheilognathi* from cultured to wild freshwater fish populations (Salgado-Maldonado and Pineda-Lopez 2003).

More recently, Murray (2013) speculated that escaped fish may act as a reservoir source for salmon alpha virus (pancreas disease) in Scotland.

Non-containment of stock also has the potential to negatively influence on-farm biosecurity measures. For example, the presence of wild and escaped reservoirs may constitute a risk of re-infection following the restocking a fallowed farm (Wallace *et al.* 2011).

Norway has established a number of measures to address the issue of stock escapes, these include:

- mandatory reporting of all escape incidents (introduced in 1980's);
- establishment, in 2006, of the Norwegian Escapes Commission to learn from past escape events and disseminate knowledge to both farmers and aquaculture equipment suppliers;
- introduction of enforceable technical regulations for the design, dimensions, installation and operation of sea-cage farms (Norwegian Technical Standard NS 9415 2009);
- ongoing investment in research and development to improve the design and material properties of sea-cage equipment; and
- training of fish farm operators in the different aspects escape prevention (Jensen *et al.* 2010).

5.28.1 Conclusions

The prevention of stock escape is beneficial to both the individual farmer and the aquaculture industry as a whole. Containment represents the protection of farmer investment from direct

stock losses and indirect losses to through potential disease transfer. Further, stock containment protects the environment from a number of potential consequences.

5.28.2 Options to minimise the risks associated with stock containment

5.28.2.1 Objective

To manage the risk of pest and pathogen transfer onto, within and from the facility.

5.28.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

A documented facility containment protocol should be developed. This should be based on a risk assessment for escapes which should consider extreme weather events, predator fencing, theft, equipment failure and fouling. The assessment should also identify the risks from escape, for example, whether the stock will survive in the wild and whether gametes will escape and survive.

All production units should have appropriate features to prevent escape of stock.

If an escape is known or suspected to have occurred, the cause should be investigated immediately, and steps should be taken to correct it. These actions should be documented in facility records. A further report should be made to MPI once the number of stock concerned has been confirmed.

A record of stock escapes should be developed to identify critical control points for effective escape risk monitoring and escape risk reduction.

5.28.2.3 Detailed options

Containment (general)

Any incidence or occurrence that did, or could have, led to an escape should be recorded.

Evidence and records of best management practices to minimise escapes should be easily accessible for audit purposes.

Procedures such as grading, transfers and harvesting, which can increase the risk of escape, should be:

- planned;
- conducted by trained personnel;
- supervised; and
- follow best management practice.

Facilities should record and report annual stock losses due to non-containment to MPI.

A decision to attempt to recapture stock and the method to be employed should be agreed and permission granted from MPI.

Gametes, fertilised eggs or stock should not be intentionally released into the aquatic environment, except as part of special re-stocking programmes by written request from the proper authority and authorised by MPI.

If the deployment of gill nets is sanctioned for recovery of fish, these must be of the appropriate mesh size.

Contingency plans should be documented to cover events where there is catastrophic damage to structures.

Structures (general)

Structures and equipment should be designed, constructed, installed and maintained so they:

- are capable of the function they were designed for;
- are capable of dealing with the weather and other environmental conditions likely to be experienced on the site (e.g. flooding in the case of tank, raceway and pond systems); and
- ensure the containment of facility stocks.

Facilities should be aware of, and consider the implementation of, technological advances in aquaculture structures and equipment that may improve biosecurity.

Offshore facilities

Specifications and other design records for critical structures and equipment, including moorings, anchors, cages and nets should be documented and recorded.

Routine inspection and maintenance programmes should be implemented and documented to ensure that the structures and equipment are maintained in a manner that assures operational, facility stock and environmental integrity. Maintenance records should be maintained. Specific checks required include:

- regular inspections of moorings, anchors, cages and nets; and
- visual post-storm inspections of the above.

The facility should be adequately marked to warn navigators of the potential obstruction and reduce the risk of collision.

The design should facilitate the control of predators (e.g. seals).

Moorings

Facilities should have documented procedures to be followed in the selection and installation of moorings.

Facilities should hold on record the design specifications of mooring systems, along with evidence that they are suitable for the purpose and are correctly installed.

Enclosure and mooring components should be inspected in accordance with a documented standard operating procedure and a documented inspection plan which is based on risk assessment.

Nets

The design, quality and standard of manufacture of nets should take account of the conditions likely to be experienced on the site and include an adequate safety margin.

An inventory should be kept of all nets, which includes information on supplier, date of manufacture, date of purchase, location, history of testing and history of antifoulant application.

Nets should be treated with UV inhibitor and stored away from direct sunlight when not in use, to minimise deterioration in strength.

Nets should be of a mesh size, quality and strength suitable for their purpose.

The minimum net strength should meet or exceed industry standards.

The net mesh size must be such that it is capable of containing all fish when new stock is introduced to fresh or saltwater pen sites.

Facilities should demonstrate an awareness of the minimum fish size supplied at smolt input and at other relevant times.

Net depth should be sufficient to ensure that the net base does not come into contact with the sea bed.

Nets should be tested at a predetermined frequency and in accordance with a test procedure which is based on manufacturer's advice.

Systems used to attach nets to pens (including net weighting where this is used) should be inspected as frequently as possible.

Nets should be regularly inspected for damage, holes or excessive biofouling, and inspection records maintained. Action should be taken immediately to rectify any problems.

Where damage to nets and any associated fittings has occurred (or the potential for damage to occur is apparent), remedial action should be taken.

Boat operations

The operation of facility support vessels may present a risk to the integrity of pens and nets. Work boat operations should be planned and conducted in a manner which avoids damage to nets and pens.

Boatmen should be trained, competent and possess the qualifications required by the certification for the operations in which they are involved.

Training records for designated boatmen should be maintained and be readily accessible.

Land-based facilities

Production systems should be designed to contain stock effectively, including provision for containment during periods of flooding.

Procedures for the selection and installation of culture or production units and systems should be documented and maintained.

Design specifications of culture units, along with evidence that they are suitable for the purpose and are correctly installed should be recorded and maintained on-site.

Culture or production systems should be inspected and approved by suitably qualified and experienced person(s).

Production systems and holding units, including inlets and outlets, should be designed to minimise escapes.

Air-gaps should be used to prevent stock moving up-stream through the plumbing, however care should be taken to prevent the creation of aerosols.

Grates should be placed at the water discharge outlets to prevent escape into drains, other tanks, settlement tanks and the wild.

The grate size should be capable of containing stock appropriate to the particular culture system. Stock gamete size should be taken into consideration when designing these grates.

Grates for outlet pipes, tanks and ponds should be inspected regularly for holes or fouling. Remedial action should be taken immediately to rectify any unsatisfactory situation.

Pipes, outlet channels and settlement tanks and ponds should be regularly cleaned to ensure that no organism populations are establish in these areas.

Settlement tanks and ponds should be regularly treated to kill escaped stock.

Within facility escaped stock should be health tested.

Transportation

Transfer procedures should be carefully planned and supervised to minimise any risk of stock release or escape from pens or tanks.

Standard operating procedures should be written and adhered to for transporting stock. These procedures should include provisions for preventing mortalities or stress or escape.

Vehicles and equipment used for transport, whether on land or water, should be designed and maintained to safely load, hold, and transport stock, and to ensure containment of transport water and stock.

Contingency planning

Each facility should have documented procedures for emergency response **(Chapter 5.9 Contingency plans)**.

5.28.3 References

Anon (2003). *Final report of the aquaculture health joint working group subgroup*

on infectious pancreatic necrosis in Scotland. Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Bell A, Phillips S, Denny C, Georgiades E and D Kluza (2011). *Risk Analysis: Vessel Biofouling.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 145 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf [Website accessed May 2014].

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Doupé RG and AJ Lymbery (1999). Escape of cultured barramundi (*Lates calcarifer* Bloch) into impoundments of the Ord River system, Western Australia. *Journal of the Royal Society of Western Australia* 82 (4): 131-136.

Gavine FM, Ingram BA, Hardy-Smith P and M Doroudi (2007). *Biosecurity control measures for abalone viral ganglioneuritis: a code of practice.* Prepared as part of FRDC Project No. 2006/243. 31 pp.

Gillanders BM and TC Joyce (2005). Distinguishing aquaculture and wild yellowtail kingfish via natural elemental signatures in otoliths. *Marine and Freshwater Research* 56: 693-704.

Heuch PA and TA Mo (2001). A model of salmon louse production in Norway: effects of increasing salmon production and public management measures. *Diseases of Aquatic Organisms* 45: 145-152.

Jensen Ø, Dempster T, Thorstad EB, Uglem I and A Fredheim (2010). Escape of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions* 1: 71-83.

Kochmann J, Buschbaum C, Volkenborn N and K Reise (2008). Shift from native mussels to alien oysters: differential effects of ecosystem engineers. *Journal of Experimental Marine Biology and Ecology* 364: 1-10.

Markert A, Esser W, Frank D, Wehrmann A and K-M Exo (2013). Habitat change by the formation of alien *Crassostrea*-reefs in the Wadden Sea and its role as feeding sites for waterbirds. *Estuarine, Coastal and Shelf Science* 131: 41-61.

Murray AG (2013). Epidemiology of the spread of viral diseases under aquaculture. *Current Opinion in Virology* 3: 74-78.

Naylor R, Hindar K, Fleming IA, Goldberg R, Williams S, Volpe J, Whoriskey F, Eagle J, Kelso D and M Mangel (2005). Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *BioScience* 55(5): 427-437.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Salgado-Maldonado G and RF Pineda-Lopez (2003). The Asian fish tapeworm *Bothriocephalus acheilognathi*: a potential threat to native freshwater fish species in Mexico. *Biological Invasions* 5: 261-268.

vom Berg F (2008). *Finfish aquaculture in Western Australia: final ESD risk assessment report for sea-cage and land-based finfish aquaculture.* Government of Western Australia Department of Fisheries. Fisheries Management Paper No. 229. 158 pp.

Wallace IS, Munro LA, Kilbrun R, Hall M, Black J, Raynard RS and AG Murray (2011). *A report on the effectiveness of cage and farm-level fallowing for the control of bacterial kidney disease and sleeping disease on large cage-based trout farms in Scotland.* Scottish Marine and Freshwater Science Report. Volume 02, Number 10. 40 pp.

5.29 STOCK ORIGIN AND GAMETE PRODUCTION

5.29.1 Stock origin

In some areas of the world the global distribution of aquaculture species has lead to economic or environmental damage either through the escape and naturalisation of the species themselves or the outbreak of associated pest and diseases (Egidius 1987; Critchley *et al.* 1990; Blanchard 1997; Hinrichsen 2007; Raynard *et al.* 2007; Asche *et al.* 2009; Inglis *et al.* 2013). Importation of live fish or shellfish, and eggs or sperm into New Zealand for food production purposes is currently not permitted. The exception to this rule is the importation of juvenile yellowtail kingfish (*Seriola lalandi*) from Australia under the conditions imposed by the relevant import health standard (IHS) (Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) 2010a).

The Ministry for Primary Industries (MPI formerly MAFBNZ) has the lead role in preventing unwanted pests and diseases being imported, and for controlling, managing or eradicating them should they arrive (http://www.mpi.govt.nz/). IHSs are put in place to manage the biosecurity risks associated with goods imported into New Zealand. These standards include the requirements that must be undertaken in the exporting country, during transit and during importation, before biosecurity clearance can be given. The standards exist to effectively manage the risks associated with bringing goods into New Zealand: http://mpi.govt.nz/importing/overview/import-health-standards/

The first stage in the development of an IHS is a risk analysis. This document sets out scientific justification for the requirements (if any) to be met for the import and biosecurity clearance of risk goods. Risk analysis involves the identification of pests and diseases that might be associated with the goods, the likelihood of entry and establishment in New Zealand, and the potential impacts on the environment, human health and economy: http://mpi.govt.nz/importing/overview/import-health-standards/risk-analysis/

Information regarding requests for development of an IHS may be found here: http://mpi.govt.nz/importing/overview/import-health-standards/requesting-a-new-ihs/

With the exception of yellowtail kingfish, aquaculture stock and broodstock are currently sourced from New Zealand to minimise any potential environmental and economic impacts in terms of pathogen or pest introduction or spread.

5.29.2 Stock genetics

Due to concerns regarding their impact on the integrity of wild populations, the use of transgenic organisms in aquaculture is not currently recommended by any international code of practice (Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012a; Aquaculture Stewardship Council 2012b; Aquaculture Stewardship Council 2012c). Genetic enhancement of fish is considered acceptable due to the benefits associated with feed conversion. The cultivation of triploid or all female fish is also allowed, so long as they are not transgenic (Aquaculture Stewardship Council 2012c).

However, an application for the sale of transgenic salmon and eggs for human consumption has been lodged by AquaBounty Technologies with the US Food and Drug Administration (FDA) for approval (Ledford 2013). To sell these fish in the US, each farm would require

separate FDA approval, but because the food safety of the fish has already been vetted, the approval process would be based on an environmental effects evaluation (Ledford 2013). The company hopes to sell its salmon eggs to farmers and expand to markets in Argentina, Canada, Chile and China (Ledford 2013).

The maintenance of genetic diversity, particularly with respect to native species cultured in open water systems or produced for re-seeding, is a less recognised environmental effect of aquaculture (Keeley *et al.* 2009). Although selective breeding can facilitate the expression of favourable growth characteristics, increasing the dependence on hatchery-supplied rather than wild-caught animals has the potential to adversely affect the genetic fitness of wild stocks (Li *et al.* 2004; Keeley *et al.* 2009). To overcome this problem in abalone, Heasman and Savva (2007) recommended that a minimum number of parents (at least 30 to 40 of each sex) need to be used. Where selective breeding is practised over a number of successive generations, the authors recommend that each generation be derived from a large number of mating pairs to avoid inbreeding. They also strongly recommend that specialist advice be sought when planning selective breeding programmes (Heasman and Savva 2007). Lemay and Boulding (2009) pointed out the difficulties faced when attempting to manage genetic diversity in hatchery populations of abalone (and other broad-cast spawning species).

To preserve local gene pools of brown trout, the policy of the United Kingdom Environment Agency is to use triploid animals from farmed-based restocking (or the progeny of local broodstock). Similarly, the use of triploid salmon has been proposed to prevent escapees interbreeding with native wild stocks (Farm Animal Welfare Committee 2014).

5.29.3 Hatcheries

Biosecurity within the hatchery environment is paramount as hatcheries often act as hubs of infection, not only at the individual farm level but also in a national and international context (Georgiadis *et al.* 2001; Anon 2005).

In addition to good husbandry practice (**Chapter 5.13 Good husbandry**), prevention of the hatchery diseases primarily involves the application of best management practices for:

- broodstock selection and maturation, including:
    - the use of certified specific pathogen-free broodstock;
    - the testing and elimination of broodstock carriers of specific pathogens; and,
    - chemical treatment of the broodstock to control a specific pathogen.
- gamete production, collection, storage and incubation, including:
    - chemical treatment of the gametes, the embryos or the early life stages; and,
    - mechanical rinsing with pathogen-free water of the eggs or the early larval stages.
- water quality, including:
    - the use of pathogen-free culture water; or,
    - chemical or physical disinfection of the culture water (Brock and Bullis 2001).

Despite the existence of best management practices, human error is an important factor in the translocation of infectious diseases of aquaculture species (Brock and Bullis 2001). Therefore, it is important to stress that facility economic viability and profitability is based on maintaining biosecurity awareness within the work environment (Hardy-Smith 2006).

Recently Sim-Smith *et al.* (2014) investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors. This research showed that few hatcheries or land-based facilities surveyed treated their in-coming water. The authors

recommend certification of hatcheries to ensure hatchery stock are pest and disease-free. Recent disease findings in a New Zealand land-based facility also highlights the importance of testing of incoming stock, quarantine procedures, and influent and effluent treatment for protection of hatchery stock, the industry and the environment:
http://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=15953
http://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=17208

5.29.4 Broodstock

As broodstock are typically held for longer periods than production stock, they have a greater potential to be exposed to pathogens or be subclinical carriers of disease (IFA Aquaculture 2011). These stock may become more susceptible to disease as a consequence of the stress associated with reproductive maturation (Carey 1983; IFA Aquaculture 2011).

Disease prevention in gametes and embryos begins with the broodstock. Pathogens may spread from broodstock to the progeny by either vertical or horizontal transmission (Warren 1983).

Horizontal transmission is the transmission of an infectious agent to a susceptible host via contact (the agent is either shed in the environment by an infected animal, or ingested) (Castinel *et al.* 2013). This includes *extra-ovum* transmission, where the pathogen is only attached to the egg surface and the offspring is infected during hatch (Muroga 2001; Anon 2003).

Vertical transmission is the transmission of a pathogen within the contents of the gametes, i.e. from parents to offspring (Anon 2000). Further, transmission from broodstock to progeny may occur from infected water, personnel, clothing and equipment associated with stripping broodfish and fertilising ova (Anon 2003).

Proving vertical transmission is significant as effective disinfection of eggs cannot be achieved in this case (Muroga 2001). However, determination of vertical transmission can be difficult. For example, Ryce and Zale (2004) claim that *Flavobacterium psychrophilum* is vertically transmitted and to have observed the bacteria within the egg. However, the more recent articles claim that *F. psychrophilum* has been observed on the exterior of the egg, in milt, and in ovarian fluid, but not yet within the egg itself (Madsen and Dalsgaard 2008; Barnes and Brown 2011).

Known vertically transmitted diseases include:

- finfish:
    - infectious pancreatic necrosis and other birnaviruses [aquatic birnaviruses];
    - nodavirus [betanodavirus];
    - *Oncorhynchus masou* virus;
    - *Renibacterium salmoninarum;* and
    - retroviral infection of salmon [retrovirus]

(Brock and Bullis 2001; Anon 2003; Raynard *et al.* 2007; Tubbs *et al.* 2007; DAFF 2012; OIE 2013a).

Suspected vertically transmitted diseases include:

- finfish:
    - *F. psychrophilum*;

    - infectious haematopoietic necrosis;
    - infectious salmon anaemia;
    - *Photobacterium damselae* subsp. *piscicida;*
    - *Piscirickettsia salmonis;*
    - salmonid alphavirus; and
    - *Yersinia ruckeri.*
- shellfish:
    - ostreid herpesvirus microvariant 1 (OsHV-1);
    - abalone viral ganglioneuritis (AVG); and,
    - *Steinhausia mytilovum* and *Steinhausia* sp. (Microsporidia)

(Raynard *et al.* 2007; Nylund et al, 2007; Tobback *et al.* 2007; Tubbs *et al.* 2007; Vike *et al.* 2009; Bower 2010; Barnes and Brown 2011; OIE 2012a; OIE 2013b; Marshall *et al.* 2014).

Because of the potential of pathogens to devastate stocks, many jurisdictions have instituted measures to screen broodstock. For example, salmon broodstock from infectious pancreatic necrosis virus infected seawater sites in Scotland have been tested since 1993 and eggs from positive parents destroyed (Bruno 2004). Also, the number of cases of *R. salmoninarum* in Norway has dramatically declined over the last 15 years following a yearly monitoring programme that includes all salmon broodstock farms (Johansen *et al.* 2011). Further, the repopulation of hatcheries with certified virus-free broodstock, among other measures, has lead to the successful control of viral haemorrhagic septicaemia in several areas of Europe (Meyers and Winton 1995).

Even with the above screening procedures in place, there is a high risk of transferring pathogens from mature fish to susceptible young fry. Staff and equipment should be separated between the broodstock facilities and hatchery units (IFA Aquaculture 2011).

5.29.5 Wildcaught broodstock

The health status of incoming stock can be categorised as follows:

- unknown health status, e.g. caught from the wild, no testing conducted;
- specific disease-free, e.g. free of disease "X" but may carry diseases "Y" and "Z";
- health certified, e.g. reduced chance of carrying disease "X" based on the sensitivity and specificity of the test methods employed[8] (Meyers 2010); and
- free of disease, e.g. an F1 generation reared in a biosecure environment sourced from adults which were destructively tested after spawning and known to be free of vertically transmissible diseases (Thorne and Brayford 2000).

Sim-Smith *et al.* (2014) found that non-commercial salmonid farms in New Zealand regularly bring wild broodstock on-site, often without disease testing, quarantine or treatment. The introduction of wild caught broodstock, or animals of unknown health status, represents an important route of infection to farm stock (International Council for the Exploration of the Sea (ICES) 2005; Gavine *et al.* 2007; Raynard *et al.* 2007; Meyers 2010; Yanong and Erlacher-Reid 2012). Quarantine procedures, monitoring and sampling are critical at the time of introduction of stock of unknown health status (Code of Good Practice Management Group 2011; Yanong and Erlacher-Reid 2012; Castinel *et al.* 2013).

Quarantine facilities are an important investment for controlling pathogen introduction and spread (Meyers 2010). The purpose of these facilities is to:

[8] $n = 150$ is internationally accepted as a standard sample size. This sample size gives a probability of 95% of finding a pathogen in the sample if 2% or more of the sampled population are infected (Thorne 2002; Meyers 2010).

- prevent pathogens and pests entering the farm;
- prevent the spread of pathogens and pests on the farm; and
- prevent pathogens and pests leaving the farm (ICES 2005; Gavine *et al.* 2007; Meyers 2010; Yanong and Erlacher-Reid 2012).

Quarantine also provides the newly received stock time to acclimatise to water, feeds and management and to recover from the stress associated with handling and transport (Yanong and Erlacher-Reid 2012). Animal stress has been shown to increase disease susceptibility (Johnston and Jungalwalla No date; **Chapter 5.13 Good husbandry**).

All aspects of quarantine systems, including staff, equipment and water, should be separate from that on the main farm, and effluent should be handled appropriately to prevent pathogen spread into the environment (Code of Good Practice Management Group 2011; Yanong and Erlacher-Reid 2012). Staff who use the quarantine area should make it their last port-of-call for the day.

Quarantine systems typically target only the containment of disease agents and parasites, however, non-pathogenic epi-/endobionts may also require the quarantine of target organisms (ICES 2005). Therefore, it is necessary that the quarantine period is long enough to detect all non-target species, even if no pathogens or disease signs are observed (ICES 2005).

The required duration of quarantine may vary depending on;
- the aquatic taxon;
- seasonality of pathogens of concern;
- rearing conditions; and
- reason for quarantine (ICES 2005).

For example, with respect to protecting farm stock and the environment from AVG a quarantine period of 42 days (seven weeks) was recommended for wild caught abalone broodstock brought onto a land-based aquaculture facility (Gavine *et al.* 2007). More recently, ASC (2012a) recommended a period of eight weeks minimum quarantine with cohabitation and disease surveillance for wild to farm translocations for abalone. By contrast, Heasman and Savva (2007) recommended a quarantine period of at least two weeks, however, AVG is not present in the waters of New South Wales, Australia. These authors also recommended cleaning the shell of biofouling and treating for mud-worms during the quarantine period. The rationale for, and the efficacy of, a two week quarantine period is not-known, however, the MPI IHS for marine ornamental fish and invertebrates is “not less than three weeks” (MAFBNZ 2011a). The length of this period is “in line with recommendations by authorities in other countries, which have determined from previous records that if mortalities are to occur in quarantine, they will mostly occur within the first three weeks” (Hine and Diggles 2005). “High risk” species must meet additional pre-quarantine or quarantine measures before clearance (MAFBNZ 2011a).

The quarantine period for marine species imported into New Zealand takes into account the time between their capture in their country of origin and entry into New Zealand which was estimated to be approximately seven-19 days. Added to the three week quarantine period gives between 28-40 days between capture and release from quarantine (Hine and Diggles 2005). Exported fish are likely to have been stressed by capture, handling, crowding, transport and the poor water quality experienced over this time making them more susceptible to pathogens and more likely to reveal sub-clinical infections (Hine and Diggles 2005).

Hine and Diggles (2005) concluded that many diseases would run their courses well before the end of a six week quarantine period. Reductions of this quarantine period would require that consignments are accompanied by an international aquatic animal health certificate for live fish. The certificate would need to be signed by the exporting country's competent authority, stating that the fish are free from specified disease agents or are sourced from populations or zones free from specified disease agents. Further, the risk analysis suggested that the cut-off cumulative mortality rate for the taking of samples should be reduced to 10% (Hine and Diggles 2005). According to the standard for transitional facilities for ornamental fish and marine invertebrates, disease investigations and testing are under the discretion of the veterinarian appointed to inspect the transitional facility and audit the operation of quarantine (MAFBNZ 2011b). This approach allows the targeting of diagnostic effort, rather than the compulsory enforcement of a broad range of diagnostic tests in the event of set percentage mortality (MAFBNZ 2010b).

High value ornamental species, especially marine specimens, are considered to be much less likely to be released into the environment leading to potential environmental exposure to novel pathogens (MAFBNZ 2009). This is in contrast to the risks associated with the transfer of hatchery reared aquaculture stock for on-growing, or release in the marine or freshwater environment, or the volumes of untreated effluent released directly into the aquatic environment from land-based facilities.

It is also noted that "direct entry of aquatic organisms into, and lifelong holding in, suitably approved and inspected containment facilities should negate the requirement for either standard import requirements or specified risk management options for high risk species" (MAFBNZ 2009).

With respect to finfish, where disease-free status cannot be established prior to receipt Fielder and Heasman (2011) recommended that incoming broodstock be quarantined and monitored for four to 12 weeks with prophylactic disease disinfection applied as necessary.

For broodstock from the wild, the Code of Good Practice Management Group (2011) recommends that the quarantine period be decided by the competent authority. However, the Code of Good Practice Management Group (2011) recommends that all imported marine finfish should be held in quarantine in a land-based site with appropriate effluent disinfection where their health should be monitored for a period not less than 3 months. Alternatively, the Western Australian Government encourage the lifetime quarantine of broodstock (Thorne and Brayford 2000; Jones pers. comm.).

The importance of testing and quarantine of broodstock and their progeny with respect to environmental protection cannot be overstated. For example, Liggins and Upston (2010) could not exclude the possibility that *Perkinsus* sp. infections were spread through efforts to reseed abalone for fisheries enhancement: "Hatchery broodstock was obtained from locations at which *Perkinsus* sp. infections in abalone were known to occur and there was no testing of samples of broodstock or hatchery reared juveniles prior to 2002" (Liggins and Upston 2010). As a general rule, the restocking of open waters should be with products of a health status higher than or equal to, that of the receiving area (Hill 2004).

5.29.5.1 Hatchery production (Molluscs)

Typical of bivalve aquaculture globally, wild sourced broodstock, spat or juvenile bivalves are transported throughout New Zealand and transplanted into open water farms (Aquaculture New Zealand 2007a,b; Raynard *et al.* 2007). Health management strategies may be

compromised by these movements (Raynard *et al.* 2007; Castinel *et al.* 2013). Preventive strategies are essential for bivalve aquaculture as vaccination is not possible and eradication programmes have proven extremely difficult in shellfish stocks (Raynard *et al.* 2007; Castinel *et al.* 2013).

While quarantine of incoming stock into hatcheries is achievable, the feasibility of this approach for open-water shellfish on-growing may be difficult given the large volumes of spat and seed-stock transported around New Zealand (Castinel *et al.* 2013).

5.29.6 Gamete production

Poor egg quality and resulting mass mortalities are serious problems for larval production systems (Olafsen 2001). Gamete health is associated with the methods used during gamete production, collection, storage and fertilisation and the circumstances associated with pre- to post-hatch embryo incubation (Brock and Bullis 2001).

In aquaculture, gamete quality and incubation conditions can result in mortality or overgrowth by bacteria and fungi (Meyer 1991; Brock and Bullis 2001; Olafsen 2001). Saprophytic bacteria (*Aeromonas* sp.) other gram-negatives and fungi (*Saprolegnia* sp.) are the principal microorganism of concern for embryos prior to hatch (Brock and Bullis 2001).
Fungal growths (saprolegniasis) on the surface of eggs and larvae of fish and shellfish can cause extensive direct mortalities. Saprolegniasis in trout hatcheries results in an average annual production losses of approximately 20%, with losses peaking to greater than 40% (Forneris *et al.* 2003). The observation of fungal and bacterial infection is primarily a signal of compromised sanitary conditions (Meyer 1991; Brock and Bullis 2001).

Formalin is often used to control fungal growths on eggs (1-2 mg/L for 15 minutes) (Meyers 2010). Hydrogen peroxide may also be used (500-1000 mg/L for 15 minutes) to treat *Saprolegnia* sp. contamination (Yanong 2011).

Heasman and Savva (2007) highlight that integument/muscle detachment syndrome observed in abalone larvae is likely the result of either poor seawater quality or inadequate hygiene. To prevent its occurrence, the authors recommend that floors and walls of spawning facility, including tanks and seawater lines are cleaned and disinfected before the day of spawning. Further, filtered (1 µm) and UV disinfected seawater is recommended for the spawning and rearing process (Heasman and Savva 2007). The authors state that antibiotics are unnecessary in abalone gamete production or larval rearing.

5.29.7 Disinfection

Egg disinfection is necessary to prevent the transmission of pathogens carried on the surface of eggs to the progeny and their subsequent spread (Warren 1983; Meyers 2010; Code of Good Management Practice Working Group 2011). Eggs that have not been disinfected should not be placed into water at the receiving station unless that water can be treated prior to release (Meyers 2010). To improve biosecurity best practice in New Zealand, Sim-Smith *et al.* (2014) recommended routine egg disinfection for all finfish.

The use of disinfectants should not be relied upon to prevent true vertical transmission of pathogens (OIE 2012b). A brief summary of the primary egg disinfection methods is provided below, however, reference should be made to current OIE guidelines (OIE 2012b: http://www.oie.int/fileadmin/Home/eng/Health_standards/aahm/current/1.1.03_DISINFECTION.pdf) and product manufacturer's instructions as appropriate.

5.29.7.1 Iodophor

Disinfection of eggs with iodine can be carried out for the various fish species, but it is most commonly used for eggs of fish of the Salmonidae family (salmon, trout and char) (OIE 2012b).

There are a number of protocols regularly used to disinfect eyed eggs. In general, the pH of the solutions of the iodophor product must be between 6 and 8. The contact time for a 100 mg/L iodophor solution should not be less than 10 minutes and the solution should be used only once (Alderman *et al.* 1984; Meyers 2010; Code of Good Practice Management Group 2011; OIE 2012b). Thorough rinsing of disinfected, fertilised eggs should be carried out using clean isotonic saline followed by freshwater (Code of Good Practice Management Group 2011).

For disinfecting newly fertilised salmonid eggs via a water-hardening process with iodophors, the active iodine concentration should be 100 mg/L (OIE 2012b). Provided the manufacturer's instructions are followed, significant losses to viable embryos are unexpected (Alderman *et al.* 1984). However, it is important that eggs are not fertilised in the presence of the iodophor solution as this will kill sperm cells (OIE 2012b).

For other species, preliminary tests should be conducted to determine at what egg stage and iodophor concentration, disinfection can be carried out safely (OIE 2012b).

5.29.7.2 Glutaraldehyde

Disinfection of eggs of marine species, such as plaice, cod and Atlantic halibut, for which some adverse effects of iodophors have been documented, may be achieved with 400-600 mg/L glutaraldehyde and a contact time of 5-10 minutes (OIE 2012b).

The use of glutaraldehyde for egg disinfection has become standard procedure in several Norwegian hatcheries. At SINTEF (*Stiftelsen for industriell og teknisk forskning)*, the procedure is 400 mg/L glutaraldehyde for 10 minutes (Skjermo and Vadstein 1999).

Glutaraldehyde is not effective against nodaviruses for which the use of ozone at 1 mg O_3/l for 30 seconds is recommended (OIE 2012b).

5.29.7.3 Ozone

The strength of ozone is measured using a contact time [CT] value (the concentration of ozone [mg O_3/l] multiplied by the contact time [minutes]) (Ballagh *et al.* 2011). An ozone concentration of 0.1-0.2 mg O_3/l for 3 minutes [CT = 0.3-0.6] has been found to be effective in inactivation of bacterial pathogens in a range of aquatic cultivated species (Ballagh *et al.* 2011; OIE 2012b).

A common side effect of ozone treatment is a reduction in hatchability (Ballagh *et al.* 2011), therefore, the tolerance of eggs to ozonated seawater should be carefully evaluated for each species (Grotmol *et al.* 2003). For example, 2 mg O_3/l for 2 minutes [CT = 4] and lower exposures are sufficient to ensure efficient inactivation of fish pathogens while avoiding negative effects on the hatchability of halibut, cod and turbot eggs (Grotmol *et al.* 2003). However, CT = 1 was the highest concentration of ozone used to treat mulloway eggs without negatively impacting on hatching success (Ballagh *et al.* 2011).

5.29.8 Mollusc eggs and larvae

Disinfection of eggs and larval stages is not considered practical for most molluscan culture systems, as a result OIE (2012b) recommend three stages of disinfection for molluscan hatcheries:

- pre-treatment of influent water, e.g. filters (1.0 and 0.22 μm) or chemical disinfection for protection of mollusc stocks;
- treatment within the facilities (particularly recycling systems) for protection of mollusc stocks; and
- treatment of effluent water for protection of the environment (OIE 2012b).

5.29.9 Conclusions

All stock for aquaculture should be of New Zealand origin unless the appropriate regulatory procedures are met (e.g. import meets the requirements of an import health standard based on a documented risk analysis in association with the appropriate regulatory authority).

The production of transgenic organisms is not recommended until the concerns regarding their potential impacts to human health and the environment are adequately addressed with the appropriate regulatory authority.

The genetic diversity of native organisms cultured in open water systems or produced for re-seeding purposes should be taken into account with respect to the ability to affect wild stocks.

Aquaculture establishments, particularly those cultivating early life stages of aquatic animals, should employ a number of methods for disease prevention and control, including broodstock quarantine, monitoring and treatment (as appropriate), the sanitary production of gametes and disinfection of fertilised eggs. These measures should form part of the facility's routine biosecurity programme.

5.29.10 Options to minimise the risks associated with stock origin and gamete production

5.29.10.1 Objective

To manage the risk of transferring pests and pathogens onto, within and from the facility via introduction of stock and gamete production.

5.29.10.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All facility inputs, throughputs and outputs (e.g. stock, gametes, staff, equipment, procedures and water) should be assessed for potential biosecurity risks.

Stock should only be introduced to the facility if they are of known health status and that status is of equal or better status than animals on the facility.

Quarantine procedures and facilities should be required for all new stock of unknown health status (particularly wild or uncertified stock).

If disease-free status cannot be established prior to receipt, incoming stock should be quarantined for 12 weeks of observation and subjected to prophylactic disease disinfection. Quarantine is also recommended for health-certified broodstock brought in to the hatchery but a reduced period of four weeks is satisfactory. Alternatively broodstock should be subject to lifetime quarantine with release of the F1 generation following appropriate testing.

While held in quarantine, all dead stock and stock that show signs of morbidity should be tested for listed, notifiable and other pathogens. The cause of mortalities should be determined in a timely manner by a veterinary practitioner or MPI approved laboratory.

Where feasible, treatment of quarantined animals may be considered to mitigate disease risks (e.g. for external parasites). Treatments must be conducted in accordance with regulatory requirements.

Stock movements between different farm populations should only occur following consideration of the pest and pathogen risks and with a view to maintaining high health status.

5.29.10.3 Detailed options

Stock origin

Proposals to import live fish, gametes and fertilised eggs must be subject to an import health standard underpinned by a documented risk analysis in association with the appropriate regulatory authority (Ministry for Primary Industries: http://mpi.govt.nz/importing/overview/import-health-standards/; **Chapter 5.20 New or unfamiliar aquaculture species**).

Stock genetics

Facilities should not produce transgenic stock, which are defined as stock that has been genetically modified by artificial transfer of genetic material from a different species.

Sex-reversal and triploidy should be carried out in strict accordance under best management practices.

Genetic diversity and management of inbreeding should occur to maintain genetically healthy and viable stocks.

Stock genetics (native stock)

Facilities should be aware of possible negative impacts from repeatedly using the same broodstock or limited numbers of spawners.

Effort to address genetic concerns specific to species and geographic region where the stock will be deployed should be documented.

Wild-caught broodstock

Broodstock collection should comply with MPI requirements. Wild finfish or shellfish can only be collected using commercial fishing permits or special permits.

Avoid collection of broodstock from known infected areas, including areas of active harmful algal blooms.

Broodstock should be chosen on the basis of appearance, health and vigour.

Sanitation procedures should be employed within the quarantine area.

Quarantine facilities should be separated from other organisms in a system to:

- ensure containment of pests and disease agents (including through effluent);
- prevent entry by birds and other animals;
- prevent entry by unauthorised personnel; and
- prevent pests, pathogens and contaminants from entering the quarantine unit.

Water used in the quarantine facility should not mix with the water of other culture systems within the facility.

There should be zero discharge of untreated liquid effluent from the quarantine facility to the aquatic environment.

Liquid wastes, including water used to transport stock, and solid waste outputs, including all filtered residues and filters, should be disinfected prior to release.

Access to a quarantine facility should be restricted to trained, authorised personnel. Footwear, hands, and any material used within the facility need to be cleaned and disinfected before exit from the facility.

Equipment used in the quarantine facility should not be used in other areas of the facility. Where this is not possible, all equipment and supplies used within a quarantine facility should be cleaned and disinfected in a manner that will effectively destroy pests and pathogens before removal from quarantine.

Upon receipt, all life-stages, tanks, water, shipping containers, and equipment in contact with the incoming stock, including the transport vehicles, should be handled to ensure that there is no escape of the individuals or associated pests and pathogens from the facility. All shipping and packing material should be cleaned and disinfected or disposed of appropriately.

No mortalities, body parts or shells should be discarded without approved treatment to ensure complete disinfection. Heat treatment, such as autoclaving, or chemical sterilisation can be employed.

Broodstock should be inspected daily by suitably qualified and experienced persons, with health checks being appropriate to species and potential health issues.

Sentinel organisms of facility origin, should be placed and monitored in the quarantine facility for the duration of the quarantine period to help detect any pests or pathogens present. Health examinations should be performed on the sentinel organisms prior to release of quarantined stock into other culture systems.

Testing of broodstock and progeny for vertically transmitted diseases should occur prior to mixing of the progeny with other stock.

All quarantine and isolation facilities and sites should maintain accurate records of:

- entry and exit times of personnel, all of whom should have authorisation for access;
- numbers of mortalities and method of storage or disposal;
- effluent and influent treatments and monitoring of residuals;
- sample submissions to a laboratory to test for diseases and parasites of the imported organisms as well as for non-pathogenic epi or endobionts;
- any abnormal conditions affecting quarantine or isolation operations (e.g. power outages, building damage, serious weather conditions); and
- maintenance records of tanks and pipe-work, pumps and equipment (including when on and offline), pigging and cleaning rosters.

Accurate records should be maintained for all stock movements (translocation) onto and off the facility including translocation approvals, the location and contact details of the supplier or receiver, date of supply, the numbers of species of stock translocated and wastewater treatment.

Broodstock should not leave these facilities for on-growing elsewhere. Where it is proposed to move broodstock, this should be based on a satisfactory outcome from a documented risk assessment.

Facility staff should notify their appropriate health professionals and/or call MPI's pest and diseases hotline (0800 80 99 66) when unusual or unexplained mortalities are experienced.

Facility staff should notify MPI (0800 80 99 66) to report suspect exotic aquatic pest species.

Production of gametes (general)

To maintain biosecurity and prevent the spread of pests and pathogens, broodstock populations should be physically separated from the rest of the stock.

Breeding programmes should employ established and scientifically sound procedures.

Breeding and rearing programmes should be managed by documented systems. The sperm and eggs should be traceable to individual parents.

Procedures should only be carried out by properly trained and competent personnel.

Strict protocols and high standards of hygiene, with respect to facility staff, clothing, personal protective equipment and other equipment, should be applied at each stage of the spawning and fertilisation process.

Handling of broodstock should be kept to a minimum for the task being undertaken.

Repeat-spawners that are regularly removed from the broodstock tank should be appropriately marked (e.g. pit tagging) by trained personnel so that individual organisms can easily be located without stressing other organisms in the population.

When broodstock are being stripped:

- contamination of eggs and milt with urine, faeces and blood should be avoided; and
- eggs should be disinfected using an appropriate disinfectant applied in accordance with the manufacturer's instructions.

Where health testing of broodstock is feasible (i.e. where non-destructive testing methods are available), staff should identify vertically transmissible pathogens and:

- test all of the stock, either individually or in pools; and
- hold the gametes under biosecure conditions while tests are conducted.

If test results are positive, destroy the gametes and cull progeny from infected stock.

Where testing of broodstock is not feasible (i.e. where non-destructive test methods are not available) staff should identify serious vertically transmissible pathogens, and:

- test at least 150 of the progeny derived from each batch of eggs; and
- maintain batches of stock under biosecure conditions while tests are conducted.

If test results are positive, cull the infected batches of stock.

To maintain biosecurity and prevent the spread of pests and pathogens, broodstock and juveniles should be physically separated.

The use of any chemicals for spawning, breeding or hatchery programmes should be carried out in strict accordance with veterinary or aquatic health professional instructions and facility standard operating procedures by trained personnel.

All chemical and antibiotic treatments on eggs and larvae, including the reason for their use and the quantity used should be disclosed to the recipient prior to any transfers.

Production of gametes (finfish)

Live fish that are to be stripped of eggs or milt should be properly anaesthetised and handled carefully at all times (**Chapter 5.13 Good Husbandry**).

The use of anaesthetics should be addressed in the VHP and biosecurity plan.

The broodstock fish should be starved for an appropriate time prior to stripping to assist in avoiding contamination of eggs and milt with faeces.

If broodstock are to be culled, this should be done prior to stripping.

Broodstock which have been reared in seawater should be stripped on the seawater site and only disinfected fertilised trout eggs transferred to freshwater.

5.29.11 References

Alderman DJ (1984). The toxicity of iodophors to salmonid eggs. *Aquaculture* 40: 7-16.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup*

on infectious pancreatic necrosis in Scotland. Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture New Zealand (2007a). *Greenshell™ mussel industry environmental code of practice.* New Zealand Mussel Industry Council Limited, 1999 (Revised, June 2007 by Aquaculture New Zealand). 82 pp.

Aquaculture New Zealand (2007b). *New Zealand oyster industry code of practice.* 51 pp.

Aquaculture Stewardship Council (2012a). *ACS abalone standard. Version 1.0.* January 2012. 42 pp.

Aquaculture Stewardship Council (2012b). *ACS bivalve standard. Version 1.0.* January 2012. 57 pp.

Aquaculture Stewardship Council (2012c). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Asche F, Hansen H, Tveteras R and S Tveterås (2009). The salmon disease crisis in Chile. *Marine Resource Economics* 24: 405-411.

Ballagh DA, Pankhurst PM and DS Fielder (2011). Embryonic development of mulloway, *Argyrosomus japonicus*, and egg surface disinfection using ozone. *Aquaculture* 318: 475-478.

Barnes ME and ML Brown (2011). A review of *Flavobacterium psychrophilum* biology, clinical signs and bacterial cold water disease prevention and treatment. *The Open Fish Science Journal* 4: 40-48.

Blanchard M (1997). Spread of the slipper limpet *Crepidula fornicata* (L. 1758) in Europe. Current state and consequences. *Scientia Marina* 61 (Suppl. 2): 109-118.

Bower SM (2010). *Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish*. http://www.pac.dfo-mpo.gc.ca/science/species-especes/shellfish-coquillages/diseases-maladies/index-eng.htm [Website accessed May 2014].

Brock JA and R Bullis (2001). Disease prevention and control for gametes and embryos of fish and marine shrimp. *Aquaculture* 197: 137-159.

Bruno DW (2004). Changes in prevalence of clinical infectious pancreatic necrosis among farmed Scottish Atlantic salmon, *Salmo salar* L. between 1990 and 2002. *Aquaculture* 235: 13-26.

Carey TG (1983). *Regional control of communicable diseases in fish. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 137-148.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Critchley AT, Farnham WF, Yoshida T and TA Norton (1990). A bibliography of the invasive alga *Sargassum muticum* (Yendo) Fensholt (Fucales: Sargassaceae). *Botanica marina* 33(6): 551-562.

Department of Agriculture, Fisheries and Forestry (DAFF) (2012). *Aquatic animal diseases significant to Australia: identification field guide, 4th edition.* Australian Government, Canberra. http://www.daff.gov.au/animal-plant-health/pests-diseases-weeds/aquatic-animal-diseases-significant-to-australia-identification-field-guide-4th-edition. [Website accessed August 2014].

Egidius E (1987). *Import of furunculosis to Norway with Atlantic salmon smolts from Scotland.* Mariculture Committee Report no. C.M. 1987/F:8, International Council for the Exploration of the Sea (ICES). 8 pp.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Fielder DS and MP Heasman (2011). Hatchery manual for the production of Australian bass, mulloway and yellowtail kingfish. Industry and Investment NSW Government. 170 pp.

Forneris G, Bellardi S, Palmegiano GB, Saroglia M, Sicuro B, Gasco L and I Zoccarato (2003). The use of ozone in trout hatchery to reduce saprolegniasis incidence. *Aquaculture* 221: 157-166.

Gavine FM, Ingram BA, Hardy-Smith P and M Doroudi (2007). *Biosecurity control measures for abalone viral ganglioneuritis: a code of practice.* Prepared as part of FRDC Project No. 2006/243. 31 pp.

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Grotmol S, Erik D, Geir T (2003). Hatchability of eggs from Atlantic cod, turbot and Atlantic halibut after disinfection with ozonated seawater. *Aquaculture* 221: 245–254

Hardy-Smith P (2006). *Biosecurity at the farm level - how to create a state of mind. In* Scarfe AD, Lee C-S and PJ O'Bryen (Eds.) Aquaculture biosecurity: prevention, control, and eradication of aquatic animal disease. Blackwell Publishing, Iowa. pp. 149-154.

Heasman M and N Savva (2007). *Manual for intensive hatchery production of abalone. Theory and practice for year round, high density seed production of blacklip abalone (Haliotis rubra).* New South Wales Department of Primary Industries and Australian Government Fisheries Research and Development Corporation. 95 pp.

Hill BJ (2004). *Aquatic animal disease zoning. In*: Arthur JR and MG Bondad-Reantaso (Eds.) Capacity and awareness building on import risk analysis for aquatic animals. Proceedings of the workshops held 1-6 April 2002 in Bangkok, Thailand and 12-17 August 2002 in Mazatlan, Mexico. APEC FWG 01/2002, NACA, Bangkok. pp. 43-50.

Hine PM and DK Diggles (2005). *Import risk analysis: ornamental fish.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 270 pp. http://www.biosecurity.govt.nz/files/regs/imports/risk/ornamental-fish-ira.pdf [Website access July 2014].

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

International Council for the Exploration of the Sea (ICES) (2005). *ICES code of practice on the introductions and transfers of marine organisms 2005.* 30 pp.

IFA Aquaculture (2011). *The farmed salmonid handbook. Version 1.0.* 66 pp. http://www.fishhealth.ie/FHU/ [Website accessed May 2014].

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Johansen L-H, Jensen I, Mikkelsen H, Bjorn P-A, Jansen PA and Ø Bergh (2011). Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. *Aquaculture* 315: 167-186.

Johnston C and P Jungalwalla (No date). *Aquatic animal welfare guidelines: guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.* National Aquaculture Council Inc. Australia. 38 pp. http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/AA%20welfare%20guidelines.pdf [Website accessed February 2015].

Keeley N, Forrest B, Hopkins G, Gillespie P, Clement D, Webb S, Knight B and J Gardiner (2009). *Sustainable aquaculture in New Zealand: review of ecological effects of farming shellfish and other non-finfish species.* Prepared for the Ministry of Fisheries. Cawthron Report No. 1476. 150 pp.

Ledford H (2013). Transgenic salmon nears approval. *Nature* 497: 17-18.

Lemay MA and EG Boulding (2009). Microsatellite pedigree analysis reveals high variance in reproductive success and reduced genetic diversity in hatchery-spawned northern abalone. *Aquaculture* 295: 22-29.

Li Q, Park C, Endo T and A Kijima (2004). Loss of genetic variation at microsatellite loci in hatchery strains of the Pacific abalone (*Haliotis discus hannai*). *Aquaculture* 235: 207-222.

Liggins GW and J Upston (2010). *Investigating and managing the Perkinsus-related mortality of blacklip abalone in NSW.* Final report to the Fisheries Research and Development Corporation for Project No. 2004/084. New South Wales Government Industry and Investment. 182 pp.

Madsen L and I Dalsgaard (2008). Water recirculation and good management: potential methods to avoid disease outbreaks with *Flavobacterium psychrophilum*. *Journal of Fish Diseases* 31: 799-810.

Marshall SH, Ramirez R, Labra A, Carmona M and C Munoz (2014). Bona fide evidence for natural vertical transmission of infectious salmon anaemia virus in freshwater brood stocks of farmed Atlantic salmon (*Salmo salar*) in Southern Chile. *Journal of Virology* 88(11): 6012-6018.

Meyer FP (1991). Aquaculture disease and health management. *Journal of Animal Science* 69: 4201-4208.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Meyers TR and JR Winton (1995). Viral hemorrhagic septicaemia virus in North America. *Annual Review of Fish Diseases* 5: 3-24.

Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) (2011a). *Import health standard for ornamental fish and marine invertebrates from all countries.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 72 pp. http://www.biosecurity.govt.nz/files/ihs/fisornic.all.pdf [Website accessed May 2014].

Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) (2011b). *Standard for transitional facilities for ornamental fish and marine invertebrates.* 154.02.06. Ministry of Agriculture and Forestry Biosecurity New Zealand. 24 pp. http://www.biosecurity.govt.nz/files/regs/stds/154-02-06.pdf [Website accessed July 2014].

Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) (2010a). *Import health standard for juvenile yellowtail kingfish (Seriola lalandi) from Australia.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 9 pp. http://www.biosecurity.govt.nz/files/ihs/kngfisic.aus.pdf [Website accessed May 2014].

Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) (2010b). *Import risk analysis: tropical, subtropical and temperate freshwater and marine ornamental fish and marine molluscs and crustaceans. Review of submissions on supplementary risk analysis.* Ministry of Agriculture and Forestry Biosecurity New Zealand. 108 pp. http://www.biosecurity.govt.nz/files/biosec/consult/ira-ornamental-fish-ros-on-supplementary-ra-jun2010.pdf [Website access July 2014].

Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) (2009). *Import risk analysis: tropical, subtropical and temperate freshwater and marine ornamental fish and*

marine molluscs and crustaceans. Review of submissions on supplementary risk analysis. Ministry of Agriculture and Forestry Biosecurity New Zealand. 163 pp. http://www.biosecurity.govt.nz/files/biosec/consult/ira-ornamental-fish-supplementary-ra-ros.pdf [Website access July 2014].

Muroga K (2001). Viral and bacterial diseases of marine fish and shellfish in Japanese hatcheries. *Aquaculture* 202: 23-44.

Nylund A, Plarre H, Karlsen M, Fridell F, Ottem KF, Bratland A and PA Saether (2007). Transmission of infectious salmon anaemia virus (ISAV) in farmed populations of Atlantic salmon (*Salmo salar*). *Archives of Virology* 152: 151-179.

OIE (2013a). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.11. Viral encephalopathy and retinopathy.* 19 pp.

OIE (2013b). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.9. Infection with ostreid herpesvirus 1 microvariant.* 14 pp.

OIE (2012a). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.4. Infectious haematopoietic necrosis.* 14 pp.

OIE (2012b). *Manual of diagnostic tests for aquatic animals. Chapter 1.1.3. Methods for disinfection of aquaculture establishments.* 12 pp.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Ryce EKN and AV Zale (2004). *Bacterial coldwater disease in westslope cutthroat trout: hatchery epidemiology and control.* Final report to the Wild Fish Habitat Initiative. Montana Water Center, Montana State University, Bozeman. 13 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Skjermo J and O Vadstein (1999). Techniques for microbial control in the intensive rearing of marine larvae. *Aquaculture* 177: 333-343.

Thorne T (2002). *The translocation of barramundi (Lates calcarifer) for aquaculture and recreational fishery enhancement in Western Australia.* Department of Fisheries. Fisheries Management Paper No. 159. 32 pp.

Thorne T and H Brayford (2000). *The aquaculture of non-endemic species in Western Australia. Silver perch (Bibyanus bidyanus).* Fisheries Western Australia. Fisheries Management Paper No. 145. 17 pp.

Tobback E, Decostere A, Hermans K, Haesebrouck F and K Chiers (2007). *Yersinia ruckeri* infections in salmonid fish. *Journal of Fish Diseases* 30: 257-268.

Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M and C Sim-Smith (2007). *A review of aquatic diseases of significance to New Zealand.* Final Research Report for MAF Biosecurity New Zealand. NIWA Project No. ZBS 2005-17. 461 pp.

Vike S, Nylund S and A Nylund (2009). ISA virus in Chile: evidence of vertical transmission. *Archives of Virology* 154: 1-8.

Warren JW (1983). *Synthesis of a fish health management program. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 151-158.

Yanong RPE (2011).*Use of hydrogen peroxide in finfish aquaculture.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 8 pp.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 16 pp.

5.30 STOCK TRANSFERS

5.30.1 Stock transfers

Stock movements are an essential part of aquaculture production cycles. However, the movement of aquaculture stock between production facilities is recognised as an important risk factor in the spread of pests and disease which would not occur under natural conditions (Carey 1983; Warren 1983; Critchley *et al.* 1990; Blanchard 1997; Anon 2000; Anon 2003; Anon 2005; Raynard *et al.* 2007; Johansen *et al.* 2011; Morrisey *et al.* 2011; Munro and Wallace 2012; Inglis *et al.* 2013). Transport and the associated handling of aquaculture stock can lead to stress and increased susceptibility to infection (Olafsen 2001; Barnes and Brown 2011; **Chapter 5.13 Good husbandry**). Therefore, the best management strategy is to minimise stock transfers (Anon 2000; Anon 2003).

The Aquaculture Readiness Data project showed linkages between marine farms within a region and across New Zealand (Morrisey *et al.* 2011). These linkages have the potential to undermine the biosecurity protection afforded by the geographical isolation of facilities and growing regions (Morrisey *et al.* 2011).

Recent research investigating current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors showed that the majority of farmers were at least moderately concerned about preventing and managing pests and diseases (Sim-Smith *et al.* 2014). However, the authors found that large variations in biosecurity practices occur within the industry and that the high level of industry concern regarding pests and diseases is not always reflected in their biosecurity practices.

Each of the New Zealand aquaculture sectors surveyed by Sim-Smith *et al.* (2014) move stock around the country, with the mussel, oyster and salmonid industries particularly reliant on stock movement. Further, trout, salmon and paua production facilities regularly release stock into the wild for fisheries enhancement purposes. Although, stock transfers are generally believed to be one of the most likely transmission vectors for pests and diseases (behind natural water movement; shipping vessels; recreational vessels), in New Zealand stock are rarely treated or tested for pests and diseases prior to transfer.

Prohibition of stock movement would have major economic consequences to New Zealand aquaculture (Sim-Smith *et al.* 2014). This is particularly true for the mussel and oyster industries where the availability of spat, either locally-caught or hatchery-reared, is insufficient for current demands. Further, poor water quality can require farmers to relay oysters to manage stock in the event of harvest closures.

Given their heavy reliance on stock transfers, the risk of pests and disease transmission via this pathway is a controversial topic for the mussel and oyster industries (Sim-Smith *et al.* 2014). Unsurprisingly, there are differences in opinion in both of these industries regarding the pest and disease transmission risk associated with stock transfers. Some farmers believe that stock transfer is a potential disease transfer vector and may hasten the spread of pests and diseases. By contrast, others believe that pests and diseases will be transferred around the country eventually by other transmission vectors.

Some oyster farmers believe that there are benefits to spreading disease via stock transfers as it would allow wild spat to develop resistance. Other oyster farmers are either unconcerned or unaware of the disease transmission risk associated with stock movement. For example, rather

than restricting movements following incidences of infection during the 2010 ostreid herpesvirus outbreak, industry continued to transfer their stock to areas where no mortalities were observed (Castinel *et al.* 2013; Sim-Smith *et al.* 2014).

The code of practice (COP) for mussel seed transfer between the North and South Island involves declumping, washing and visual inspection of mussel seed for pest species prior to transfer. However, this COP does not appear to be widely followed (Sim-Smith *et al.* 2014).

In a recent survey, New Zealand freshwater salmonid producers were concerned about preventing or managing didymo (Sim-Smith *et al.* 2014). There have been impacts on freshwater salmon farming through the implementation of voluntary decontamination requirements (Deloitte Touche Tohmatsu Ltd. 2011; http://www.biosecurity.govt.nz/pests/didymo/cleaning-specific). Sim-Smith *et al.* (2014) reported that all salmonid eggs from didymo-positive areas are treated before transfer to didymo-negative areas.

The import of furunculosis to Norway further illustrates the need for precaution with respect to stock importation and transfers (Egidius 1987). In 1985, ~250 000 Atlantic salmon smolts were imported from Scotland. Following an outbreak of furunculosis in these smolts immediately after their arrival, no measures were taken and the disease soon spread (Egidius 1987). In 1992, 74 water systems and 550 aquaculture sites were infected (Johnsen and Jensen 1994).

Pests and pathogens may be transferred with stock via the following processes:

- importation of eggs, juveniles or broodstock from geographical isolated water sources to support hatchery production;
- movement of spat from geographical isolated water sources to support on-growing;
- transfer of stock between hatchery facilities within or between regions;
- release of hatchery-reared stock into the environment to create fisheries or to enhance natural production of wild stocks; and
- relaying stock to avoid contaminated water (Carey 1983; Culloty and Mulcahy 2007; Raynard *et al.* 2007; Inglis *et al.* 2013; Sim-Smith *et al.* 2014).

The basic premise of most stock movement controls is the application of biosecurity principles to permit the transfer of only those stocks that are considered free of specific pests and pathogens (Carey 1983; Inglis *et al.* 2013). However, low disease prevalence or sub-clinical infections might go undetected as disease carriers may not exhibit overt disease signs (Carey 1983; Johansen *et al.* 2011). Bacterial kidney disease might be detected in very low incidence in the carrier state at a hatchery, yet the facility may never experience an epizootic (Carey 1983). Similarly, as all fragments of pests may not be effectively removed during cleaning, there is potential for some organisms to be spread via stock transfers (Forrest *et al.* 2011). Transfers of mussel seed-stock within New Zealand have been suggested to have facilitated the spread of both *Undaria pinnatifida* (Forrest and Blakemore 2002) and *Didemnum vexillum* (Forrest *et al.* 2011).

Recently, the Marine Institute (Ireland) commissioned a report to increase awareness of the importance of pro–active shellfish health management with respect to *Bonamia ostreae.* With respect to disease–free areas, Culloty and Mulcahy (2007) recommended:

> *The remaining flat oyster beds in areas which are bonamiosis–free, should be safeguarded, and maintained as single species areas. Cultivation and movements of other mollusc species into these areas should be avoided, thus minimising the danger of transfers of B. ostreae or other pathogens. Currently, this is important while the*

issue of the possible role of vectors in the transfer of B. ostreae is being resolved. Appropriate biosecurity plans should be developed in these areas. Boats and equipment should be used in one area only, and not be moved between areas, because pathogens including B. ostreae could potential be carried and passively transferred by them between areas.

The precautionary approach is advisable until such time as the full life cycle and transmission of B. ostreae are understood, and until, validation of all current diagnostics for bonamiosis have been carried out, and the limitations of all currently available techniques have been determined.

With respect to Irish native oyster growing regions, the authors recommended:

Movements of other shellfish species in and out should be minimised or, better still avoided.

The following recommendations were made by Sim-Smith *et al.* (2014) to improve biosecurity best practice in New Zealand:

- continued research on disease-resistant oysters;
- the development of remote setting technology for oysters;
- the installation of holding and purging facilities for shellfish;
- use of freshwater, hot water or air exposure to reduce shellfish pests;
- biosecurity certification of hatcheries;
- routine disease testing prior to stock transfers;
- quarantining and routine disease testing for wild broodstock;
- routine egg disinfection; and
- preventing stock transfers from pest and disease positive sites to negative sites.

Sim-Smith *et al.* (2014) also identified area-based management as a mechanism for isolating farming areas because the transfer of stock, equipment or vessels between such areas is typically prohibited without certification of appropriate risk management measures.

The above recommendations were considered along with best practice literature as part of the development of this document and development of the below options.

Feed should be withheld prior to transport to reduce metabolic rate and the excretion of waste products to maximise water quality while minimising organism stress and the risk of microbiological contamination (Farm Animal Welfare Committee 2014; **Chapter 5.12 Feeds and feeding; Chapter 5.13 Good husbandry)**.

Some land-based abalone farms depend on the collection of wild seaweeds to supplement the pelleted diets of their stock (Aquaculture Stewardship Council 2012a). However, wild seaweed may act as a vector for parasites, pests, diseases and associated organisms (Aquaculture Stewardship Council 2012a). For example, in Tasmania and South Africa the presence of sessile single celled coccidia-like parasites attached to gut epithelial cells were associated with stock fed wild seaweed (Handlinger *et al.* 2006).

5.30.2 Gamete transfers

Biosecurity within the land-based facilities is paramount as these facilities, particularly hatcheries, often act as hubs of infection not only at the individual farm level but also in a national and international context (Georgiadis *et al.* 2001; Anon 2005). Risks to stock health

associated with the movement of gametes and fertilised eggs are considerably lower than risks associated with the movement of juvenile/adult stock (Code of Good Practice Management Group 2011). However, the transfer of vertically and horizontally transmitted diseases via gamete/egg movements is still an important pathway. This can be avoided by broodstock certification and eggs disinfection, respectively (Meyers and Winton 1995; Bruno 2004; Meyers 2010; Johansen *et al.* 2011; **Chapter 5.29 Stock origin and gamete production**). For example, the import of Norwegian salmon eggs into Chile is speculated to be the source of the outbreaks of infectious salmon anaemia (ISA), as phylogenetic analyses of ISA virus from Chile suggests a Norwegian origin (Vike *et al.* 2009).

5.30.3 Smoltification (salmonids)

To avoid animal stress and associated biosecurity issues, including post-smolt mortalities, stock should be in good physical condition and physiologically competent to thrive in sea water prior to transfer (Anon 2000; McClure *et al.* 2005; **Chapter 5.13 Good husbandry**). For example, poor physical condition during smolting has resulted in increased susceptibility of Atlantic salmon to pathogens, including *Aeromonas* spp., *Vibrio* spp., infectious pancreatic necrosis virus and ISA virus (Anon 2000). The optimal transfer window can be determined by a smolting status assessment (Code of Good Management Practice 2011).

Prior to transfer, smolts should be certified as clinically healthy and free of diseases and parasites (Munro 1988; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012b). The meeting of these criteria is the joint responsibility of supplier and purchaser (Anon 2000; Code of Good Management Practice 2011). Munro and Waddell (1984) noted that outbreaks of furunculosis in Scotland often occurred shortly after smolt transfer. Such outbreaks could be traced to smolt rearing units with a history of overt disease (Munro and Waddell 1984). To further reduce the risk of pathogen exposure, Anon (2000) also recommended that the number of hatcheries used to stock a site is minimised.

5.30.4 Transfer (transport vessels)

Transport vessels are essential to the efficient running of finfish aquaculture production facilities and are used for a variety of tasks, such as:

- transfer smolts to sea water sites;
- to grade stock;
- to transfer stock between sea water sites;
- to assist in changing nets;
- to transport stock for harvest at the end of the production cycle;
- to carry out bath treatments; and
- delivery of equipment or feed (Anon 2000; Code of Good Practice Management Group 2011).

The use of vessels for delivery and collection of stock from multiple sites can present a risk of pathogen transfer (Murray *et al.* 2002; Code of Good Practice Management Group 2011). The level of risk posed by a transport vessel is dependent upon:

- the disease status of the operating area;
- the activity being conducted; and,
- the ability to effectively clean and disinfect the vessel (Anon 2000).

For example, compared with movements between different areas, the risks are often lower where stock movements occur within an area implementing an area-based management

agreement (Code of Good Practice Management Group 2011; **Chapter 5.4 Area-based management**). The risk of pathogen transfer is also reduced when stock is delivered to sites that are unstocked or have been fallowed (Code of Good Practice Management Group 2011; **Chapter 5.11 Fallowing; Chapter 5.34 Year class separation**).

Factors that may increase the risk of pathogen exposure include:

- undertaking bus stop deliveries (Anon 2000; Anon 2003);
- proximity of passage to known infected areas or processing plants (Anon 2000 [e.g. ISA]; Saksida 2006 [e.g. infectious haematopoietic necrosis virus]); and
- poor standards of hygiene in the wells, superstructure, bilges, ballast tanks and transport vessel's/well boat's pumping equipment (Anon 2000; Gustafsen *et al.* 2007; Murray *et al.* 2012).

However, Anon (2000) note that the biggest risk associated with transport vessels is contamination from the stock themselves rather than the vessel itself. Therefore, stock transporters should be kept informed of the health status of stock in their care and be aware of cleaning and disinfection procedures (Anon 2003; **Chapter 5.8 Cleaning and disinfection**).

5.30.5 Conclusions

The movement of aquaculture stock between production facilities is one of the most important risk factors in the spread of aquatic pests and diseases. Although stock transfers are an essential part of aquaculture production, the implementation of a preventive approach to biosecurity can reduce the risks associated with these processes to individual farms, industry as a whole and the environment.

5.30.6 Options to minimise the risks associated with stock transfers

5.30.6.1 Objective

To manage the risk of stock transferring pests and pathogens onto, within and off the facility.

5.30.6.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

All facility inputs, throughputs and outputs (e.g. stock, gametes, staff, visitors, equipment and water) should be assessed for potential biosecurity risks.

All stock transfers (including gamete and eggs) must have the appropriate authorisations and meet the necessary requirements. The originating hatchery should have appropriate health verification accrediting the condition of the eggs, the screening of broodstock and the results of the disease screening.

All stock, at all stages in the life cycle should only be sourced from a supply that is of equal or better health status than the receiving stock.

All stock that is moved off site, at all stages in the life cycle, should only be moved to a location of equal or lesser health status.

The health status of the stock should be verified (within 30 days of transfer) before accepting new stock onto the facility.

All incoming stock should be received by quarantine facilities before they enter production areas.

Any equipment, vehicles or vessels brought onto the facility should be assessed for biosecurity risk. Procedures and infrastructure should be in place to clean and disinfect equipment, vehicles or vessels.

The facility should have designated delivery and loading areas.

5.30.6.3Detailed options

Health status

For land-based facilities, MPI authorisation for stock and egg transfer is required under regulations 18 and 22 of the Freshwater Fish Farming Regulations 1983. For freshwater species, approval from the Department of Conservation under Section 26ZM of the Conservation Act 1987 is also required. Approvals are not required for transfers to and from at sea (marine) facilities.

Diagnostic tests that are capable of detecting all diseases, parasites and pests of concern should be used in the health verification process. Mortality rates for each batch should also be recorded. Attestation of health status can be in the form of batch health certification or by facilities being part of a formal health monitoring and surveillance programme. Broodstock and progeny sampling should be incorporated into the health verification programme.

Accurate records of all stock movements (translocation) within, on and off the facility should be maintained including:

- translocation approvals;
- the location and contact details of the supplier or receiver;
- species;
- date of supply;
- the numbers of stock transferred;
- stocking density during transport;
- health status before and after unloading; and
- wastewater treatment.

Stock should not be transferred between sites with multiple year classes.

The number of different sources of stock transported to a site for on-growing should be kept to a minimum.

Stock should not be transported from a processing facility to a production site.

Transportation

Standard operating procedures should be written and adhered to for transporting stock. These procedures should include:

- environmental standards for transport conditions;

- equipment requirements;
- water preparation and quality;
- provisions for preventing stock mortalities, stress or escape; and
- discharge of transport water and other organic waste.

Prior to transfer, the facility should:

- check stock on the day of transport to ensure all stock are healthy and to minimise the risk of spread of pests and pathogens, stress and mortality;
- assess stock, equipment and water quality prior to and during transport;
- initiate remedial action to immediately rectify any unsatisfactory situation; and
- maintain written records of these checks.

The facility should be able to provide evidence to demonstrate that transport companies used to transport their stock are aware of the biosecurity issues surrounding transport and are actively involved in the maintenance of high standards of biosecurity.

Crowding of stock before collection for transport should be kept to a minimum.

Stock exhibiting clinical signs of disease, injured stock and dead stock should not be loaded for transport.

Only a single species and year class should be transported in tanks or containers.

Vehicles and equipment used for transport, whether on land or water, should be designed and maintained to safely load, hold, and transport stock, and ensure containment of transport water and stock. They should be equipped with suitable monitoring equipment to maintain water quality and biosecurity standards during transport.

Where a transport vessel is used to transport stock, any valves should remain closed within 5 km or a minimum safe distance (whichever is greater) of any aquaculture establishment, aquatic organism processing facility or wild fishery.

Excessive or rapid changes in water temperature or pH in transport tanks should be avoided.

Any stock dead or injured during transportation should be removed as soon as possible after arrival and the cause of death determined by a competent person. Mortalities should be disposed of appropriately.

There should be post-transfer monitoring of stock condition to determine transport effects, and these checks should be recorded.

Transporters should have suitable emergency response equipment on hand for containing stock. All vehicles transporting live-stock should have on board facility contact phone numbers for reporting unusual or emergency events.

Documented reporting protocols should be established to cover any accident or spillage of stock (and water) in transit which require:

- the driver to immediately report any such incident to his own company;
- the driver's company to immediately notify the aquaculture facility whose stock are being transported; and
- the driver's company to immediately notify MPI.

Where stock is being transferred into pens by helicopter, the receiving pen(s) should be properly prepared with the nets secured, and the pens marked with buoys clearly visible from the air. Facility staff responsible for receiving the stock should maintain radio contact with the helicopter crew. Where this is not possible, the enclosure(s) being stocked should be manned to ensure correct delivery of the stock.

Data from transport monitoring should be used to make improvements or changes in procedures.

For land-based facilities, transport water and other waste should not be discharged into natural water courses outside of the facility or hatchery boundaries.

For freshwater facilities within known didymo range, freshwater water supplies and stock should be tested according to MPI guidelines for the absence of didymo prior to that water being used for transporting stock.

Procedures which could increase the risk of stock escaping from pens or tanks should be carefully planned and supervised to minimise any risk.

Restocking

All statutory measures which apply to restocking activities should be observed.

Facility operators, fishery permit owners, and others involved in the movement of stock between sites should be able to demonstrate an understanding of the risks posed by such activities.

All decisions to place stock into water bodies upstream or downstream of a hatchery or facility should be based on a satisfactory outcome from a documented risk assessment carried out by the party receiving the stock.

The preparation of such a documented risk assessment should involve the party supplying the stock and operators of hatcheries or facilities that might be affected by stocking activities.

Vehicle, vessel and equipment disinfection

Following delivery, vehicles, vessels, hauling tanks, pumps, nets, buckets, waders, or anything that may come in contact with the delivery site water should be inspected, cleaned and disinfected prior to return to the facility.

The vehicles, vessels, etc, for transporting stock, eggs and gametes, by land, air or water, should be washed and disinfected by trained personnel or by accredited services before and after each transport.

All fixtures and fittings (e.g. aeration equipment, pipe-work) should be dismantled and disinfected.

Vehicles and vessels should be designed and constructed so as not to cause contamination of stock contained within them.

Surfaces coming into contact with the stock should be made of non-porous, corrosion-resistant material that is smooth and easy to clean and disinfect.

Reusable equipment should be disinfected after use.

Documented evidence of disinfection should be obtained from the transport company.

5.30.7 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012a). *ACS abalone standard. Version 1.0.* January 2012. 42 pp.

Aquaculture Stewardship Council (2012b). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Barnes ME and ML Brown (2011). A review of *Flavobacterium psychrophilum* biology, clinical signs, and bacterial cold water disease prevention and treatment. *The Open Fish Science Journal* 4: 40-48.

Blanchard M (1997). Spread of the slipper limpet *Crepidula fornicata* (L. 1758) in Europe. Current state and consequences. *Scientia Marina* 61 (Suppl. 2): 109-118.

Bruno DW (2004). Changes in prevalence of clinical infectious pancreatic necrosis among farmed Scottish Atlantic salmon, *Salmo salar* L. between 1990 and 2002. *Aquaculture* 235: 13-26.

Carey TG (1983). *Regional control of communicable diseases in fish. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 137-148.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Critchley AT, Farnham WF, Yoshida T and TA Norton (1990). A bibliography of the invasive alga *Sargassum muticum* (Yendo) Fensholt (Fucales: Sargassaceae). *Botanica Marina* 33(6): 551-562.

Culloty SC and MF Mulcahy (2007). *Bonamia ostreae* in the native oyster *Ostrea edulis*. A review. *Marine Environmental Health Series* No. 29. 36 pp.

Deloitte Touche Tohmatsu Ltd. (2011). MAF – didymo and other freshwater pests: economic impact assessment. Report prepared for Ministry of Agriculture and Forestry. 37 pp.

Egidius E (1987). *Import of furunculosis to Norway with Atlantic salmon smolts from Scotland.* Mariculture Committee Report no. C.M. 1987/F:8, International Council for the Exploration of the Sea (ICES). 8 pp.

Farm Animal Welfare Committee (2014). *Opinion on the welfare of farmed fish.* Department for the Environment Food and Rural Affairs (United Kingdom). 40 pp.

Forrest B, Hopkins G, Webb S and L Tremblay (2011). *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region.* Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 pp.

Forrest B and KA Blakemore (2002). *Inter-regional marine farming pathways for the Asian kelp Undaria pinnatifida*. Cawthron Report No. 726. Cawthron Institute, Nelson. 27 pp.

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Handlinger J, Bastianello S, Callinan R, Carson J, Creeper J, Deveney M, Forsyth WM, Freeman K, Hooper C, Jones B, Lancaster M, Landos M, Loh R, Oyay BS, Phillips P, Pyecroft S and F Stephens (2006). *Abalone aquaculture subprogram: a national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs.* FRDC project Report 2002/201, Tasmanian Aquaculture and Fisheries Institute, Hobart. 170 pp.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Johansen L-H, Jensen I, Mikkelsen H, Bjorn P-A, Jansen PA and Ø Bergh (2011). Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. *Aquaculture* 315: 167-186.

Johnsen BO and AJ Jensen (1994). The spread of furunculosis in salmonids in Norwegian rivers. *Journal of Fish Biology* 45(1): 47-55.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Meyers TR and JR Winton (1995). Viral hemorrhagic septicaemia virus in North America. *Annual Review of Fish Diseases* 5: 3-24.

Morrisey D, Plew D and K Seaward (2011). *Aquaculture readiness data phase II.* Report prepared for the Ministry of Agriculture and Forestry, New Zealand. Technical Paper No.: 2011/68. 64 pp.

Munro LA and IS Wallace (2012). Analysis of farmed fish movements between catchments identifies a simple compartmentalised management strategy for bacterial kidney disease in Scottish aquaculture. *Aquaculture* 338-341: 300-303.

Munro ALS (1988). *Furunculosis in farmed Atlantic salmon in Scotland.* Aquaculture Information Series No. 1. Department of Agriculture and Fisheries for Scotland Marine Laboratory. 8 pp.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

Murray AG, Munro LA, Wallace IS, Allan CET, Peeler EJ and MA Thrush (2012). Epidemiology of *Renibacterium salmoninarum* in Scotland and the potential for compartmentalised management of salmon and trout farming areas. *Aquaculture* 324-325: 1-13.

Murray AG, Smith RJ and RM Stagg (2002). Shipping and the spread of infectious salmon anaemia in Scottish Aquaculture. *Emerging Infectious Diseases* 8(1): 1-5.

Olafsen JA (2001). Interactions between fish larvae and bacteria in marine aquaculture. *Aquaculture* 200: 223-247.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Saksida SM (2006). Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms* 72: 213-223.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Vike S, Nylund S and A Nylund (2009). ISA virus in Chile: evidence of vertical transmission. *Archives of Virology* 154: 1-8.

Warren JW (1983). *Viral hemorrhagic septicaemia. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 175-180.

5.31 WASTE MANAGEMENT (SOLID)

Aquaculture facilities rely on many materials and equipment for successful production, and as such, solid wastes are often generated during typical operations (Association of Scottish Shellfish Growers 2005; New South Wales Department of Primary Industries 2006; Aquaculture New Zealand 2007; Code of Good Practice Management Group 2011*)*. A fundamental requirement for the aquaculture industry is the maintenance of good water quality, therefore effective waste management is critical to ongoing production (Association of Scottish Shellfish Growers 2005; Hinrichsen 2007; Code of Good Practice Management Group 2011; **Chapter 5.13 Good husbandry**).

Waste management includes all processes and resources for secure handling and treatment of waste materials, from the collection, transportation, and disposal of rubbish and sewage to the removal of infrastructure that is no longer serviceable and the management of biofouling (New South Wales Department of Primary Industries 2006; Hinrichsen 2007; BC Shellfish Growers Association 2013). This includes the entry of waste, facility structures and equipment, into the environment via storm damage (BC Shellfish Growers Association 2013; **Chapter 5.9 Contingency plans; Chapter 5.10 Facility design and structures; Chapter 5.27 Site location**).

Aquaculture facilities can also affect environmental quality due to both the input of feed and excretion of metabolic wastes (Global Aquaculture Alliance 2011; Global Aquaculture Alliance 2013; **Chapter 5.12 Feeds and feeding; Chapter 5.13 Good husbandry; Chapter 5.27 Site location**). The magnitude of effects depends on production specific factors such as, scale, duration and intensity, husbandry practices, and feeding efficiency, and abiotic factors such as, water depth, sedimentation rate, current and wind speed (Aquaculture Stewardship Council 2012a).

Aquatic diseases may be spread through the transport of infected stock, equipment or waste, harvesting procedures and scavenging birds (Anon 2005; Maryland Aquaculture Co-ordinating Council 2007; **Chapter 5.26 Removal and disposal of dead and moribund stock; Chapter 5.17 Harvest (finfish); Chapter 5.33 Wildlife management**)). For example, Norwegian epidemiology studies showed that infectious salmon anaemia was most often spread by transport of infected live salmon, stock waste, or effluents (Lyngstad *et al.* 2007). As a result, the use of stock waste material as bait (for example, in lobster pots) has been illegal in Scotland for more than 10 years (Anon 2000; **Chapter 5.26 Removal and disposal of dead and moribund stock**).

According to MPI commissioned research, biofouling is typically cleaned on-site and disposed of in the sea. However, there are instances where it is disposed of in a landfill (Sim-Smith *et al.* 2014). Practices that return viable fouling organisms removed from the structures into the environment may contribute to subsequent fouling problems (Inglis *et al.* 2013; **Chapter 5.6 Biofouling management (finfish); Chapter 5.7 Biofouling management (shellfish)**).

Depending on the disposal and recycling options available, proper handling and treatment of wastes may vary across farms (Aquaculture Stewardship Council 2012b).

5.31.1 Conclusions

Environmental quality is fundamental to ongoing aquaculture production, therefore implementation of effective waste management plans is a critical process. In terms of biosecurity, effective waste management can prevent the outbreak and spread of pests and diseases.

5.31.2 Options to minimise the risks associated with waste management

5.31.2.1 Objective

To manage the risk of waste materials transferring pests and pathogens onto, within and from the facility.

5.31.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Waste management plans should clearly identify all wastes generated on a site and classify them with respect to any risks associated with their collection and appropriate disposal.

A waste management and disposal procedure governed by best practice should be implemented and maintained. This procedure should minimise inorganic and organic waste generated by the facility. Waste materials should be collected and disposed of according to regulatory requirements.

Containment, handling and disposal of waste should minimise pest and disease transfer risks.

Facility staff should be trained in the application of waste collection and disposal procedures, as appropriate to each employee's job description.

Where applicable, the facility should obtain all resource consents for any wastes under the Resource Management Act (RMA).

5.31.2.3 Detailed options

General

A waste management plan should be documented that maps waste flow of the facility including treatment, transfer, storage and final waste utilisation options.

General waste should be collected into suitable water, wind and animal proof waste containers so that it can be removed to a disposal site on a regular basis.

Infrastructure should be developed for the storage, collection and disposal of wastes.

Facilities should operate and be maintained in a clean and sanitary manner at all times.

The facility should support management practices and initiatives that will minimise organic waste input into the aquatic environment including:

- feed management strategies, including improved feed quality;

- appropriate husbandry techniques;
- appropriate site selection; and
- water treatment for facility discharges.

All material waste, such as polypropylene rope, netting, etc, should be removed from the water, and appropriately dispose of.

Emptying out of waste containers should be regular to prevent overfilling.

Excess feed should be disposed of via a formalised waste disposal system.

Filter waste should not disposed of via postproduction water resources.

Offshore facilities should dispose of mortalities onshore.

Biofouling on the structures should be collected and returned to shore for processing or disposal.

Marine facilities should keep the foreshore and sea bed within the consent area free of production debris and stock.

Freshwater facilities should keep the foreshore, banks and river or lake bed within the consent area free of production debris and stock.

Culled product or its residual waste should not enter the aquatic environment.

Waste material should not be used as bait (e.g. in lobster or blue-cod pots).

Facilities should have sufficient contingency plans in place and staff should have the training necessary to properly dispose of resultant waste. For example, large scale mortality events may require resource consent prior to dumping. Facilities will dispose of mortalities according to their licence or registration conditions. All attempts should be made to dispose of the mortalities so as to avoid adverse environmental effects.

Shellfish

Facilities should minimise discharge (including drop-off) of mature shell and fragments of gear and equipment.

All facility waste, including stock, shells, materials, equipment, should not be disposed of into the consent area or into coastal waters. Disposal should occur at an approved disposal site on land.

Broken stock and shell should be kept well separated from marketable stock to prevent contamination. Waste should be stored in covered, leak proof and scavenger proof containers.

5.31.3 References

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture New Zealand (2007). *New Zealand oyster industry code of practice.* 51 pp.

Aquaculture Stewardship Council (2012a). *ACS bivalve standard. Version 1.0.* January 2012. 57 pp.

Aquaculture Stewardship Council (2012b). *ACS abalone standard. Version 1.0.* January 2012. 42 pp.

Association of Scottish Shellfish Growers (2005). *Code of good practice.* 44 pp.

BC Shellfish Growers Association (2013). *Environmental management code of practice.* 75 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Global Aquaculture Alliance (2013). *Mussel farms.* Best aquaculture practices standards, guidelines. 16 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Lyngstad TM, Jansen PA, Brun E, Sindre H and CM Jonassen (2007). *Epidemiological investigation of infectious salmon anaemia outbreaks in Norway 2003-2005*. Veterinaerinstituttets rapportserie 6-2007. Oslo: National Veterinary Institute. 24 pp.

Maryland Aquaculture Co-ordinating Council (2007). B*est management practices. A manual for Maryland aquaculture.* 44 pp.

New South Wales Department of Primary Industries (2006). *The NSW oyster industry sustainable aquaculture strategy.* 64 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

5.32 WATER TREATMENT

Biosecurity within land-based facilities is paramount as these facilities, particularly hatcheries, often act as hubs of infection not only at the individual farm level but also in a national and international context (Georgiadis *et al.* 2001; Anon 2005).

The importance of preventing the spread of pests and diseases associated with aquaculture through responsible practices is gaining attention (Matson *et al.* 2006; Inglis *et al.* 2013). As effective vaccines or reactive measures do not exist for many of the aquatic diseases and pests, avoidance of exposure is often the best biosecurity measure (Håstein *et al.* 1999; Brock and Bullis 2001; Raynard *et al.* 2007; Fitridge *et al.* 2012; Castinel *et al.* 2013).

Water supply is a major source of pathogens to intensive aquaculture facilities. A number of important aquatic diseases, including several of the OIE listed diseases, can be introduced into farms with source water, both freshwater and seawater (OIE 2012a). Examples include;

- finfish:
    - *Aphanomyces invadans* (OIE 2012b);
    - infectious haematopoietic necrosis virus (IHNV) (Meyers 2010; OIE 2012c);
    - infectious pancreatic necrosis virus (IPNV) (Hnath 1983);
    - infectious salmon anaemia virus (Anon 2000);
    - viral encephalopathy and retinopathy virus (OIE 2012d);
    - viral haemorrhagic septicaemia virus (Meyers and Winton 1995);
    - *Aeromonas salmonicida* subsp. *salmonicida* (Raynard *et al.* 2007; Midtlyng *et al.* 2011);
    - *Flavobacterium psychrophilum* (Cipriano and Holt 2005); and
    - *Renibacterium salmoninarum* (Warren 1983).
- shellfish:
    - ostreid herpesvirus microvariant 1 (OIE 2013);
    - *Haplosporidium sp.*; *H. costale*; *H. nelsoni* (Ford *et al.* 2001; Diggles and Oliver 2005; Matson *et al.* 2006);
    - *Marteilia refringens* (OIE 2012e);
    - *Perkinsus olseni* (OIE 2012f);
    - *Perkinsus marinus* (Ford *et al.* 2001; International Council for the Exploration of the Sea (ICES) 2011); and
    - *Vibrio tubiashii* (Elston *et al.* 2008).

Pathogen avoidance is best achieved through the use of pathogen-free water supplies (Sippel 1983; Håstein *et al.* 1999; Meyers 2010; Corbeil *et al.* 2012) and stock (**Chapter 5.29 Stock origin and gamete production**). For example, freshwater Atlantic salmon farms that do not treat incoming seawater are more likely to become infected with infectious salmon anaemia (Anon 2000). The treatment of incoming seawater can ensure the prevention of disease for land-based molluscan hatcheries (Elston 1993; Matson *et al.* 2006; OIE 2012a). For example, particle filtration and ultraviolet (UV) irradiation of influent and effluent water from hatcheries or nurseries can eliminate infective stages of *Perkinsus marinus* (ICES 2011). Similarly, Anon (2003) recommended that, where practicable, water influent to and effluents from land-based farms should be disinfected.

The biosecurity risks associated with a water source will depend on the presence of susceptible aquatic animal populations in that water source and their health status (Subcommittee on Aquatic Animal Health (SCAAH) 2016). As aquaculture pathogens most likely originate from wild populations (Raynard *et al.* 2007), depending on the presence of

these populations, the biosecurity of different water sources may vary (Yanong and Erlacher-Reid 2012). In general, there is a lower likelihood of saline or freshwater groundwater, artificial seawater and municipal water sources carrying significant pathogen levels than surface water and shallow wells (Yanong and Erlacher-Reid 2012; SCAAH 2016). Further, the risk of pathogen transfer from wild to farmed stock is minimal in facilities fed with spring or bore water when effective barriers are in place against upriver fish migrations (Anon 2003; Raynard *et al.* 2007). By contrast, the likelihood of exposure to pathogens is much higher for stock reared in facilities fed with untreated river water (Raynard *et al.* 2007).

A small amount of untreated water can contaminate the entire water supply (Yanong and Erlacher-Reid 2012). For example, an outbreak of furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*) occurred in a facility following the use of untreated river water when its normal loch supply free of migratory fish was inadequate (Munro and Waddell 1984). Similarly, water used for transferring stock should not enter the system (Yanong and Erlacher-Reid 2012; **Chapter 5.30 Stock transfers**).

If water must be derived from an open source, then treatment to eliminate potential pathogens should be considered. For example, it has long been known that source water can be treated with UV, ozone, or chlorine (Brown and Russo 1979; Sippel 1983; Yanong and Erlacher-Reid 2012). It is also known that pre-filtration reduces the particulate organic material present in the water being treated thus improving the efficiency and effectiveness of water treatment with UV, ozone, or chlorine (Sippel 1983).

Each of the above treatments has specific disadvantages such as high cost, need for sophisticated equipment, or production of toxic residues (Jorquera *et al.* 2002). However, these reasons need to be balanced against the potential cost of a pathogen outbreak to the aquaculture industry (Asche *et al.* 2009; Kibenge *et al.* 2012), as well as fisheries and the environment. Ultimately, biosecurity plans, including water treatment, should be viewed as insurance, and as such, require both financial and intellectual investment as well as commitment (SCAAH 2016).

Sippel (1983) recommended that any treatment method used should meet the following criteria:

- efficacy in eliminating the pathogens of concern;
- not be harmful to stock or can be easily rendered safe;
- not alter the physical-chemical properties of the water;
- the treatment should not damage any biofilters (e.g. re-circulating systems); and
- the system should be as fail-safe as possible.

Elimination of pathogens from the incoming water does not guarantee the absence of outbreaks in a land-based facility if care is not taken to prevent other routes of infection (Ford *et al.* 2001; Yanong 2012). Further, water treatment should exclude the entry of trash fish and fouling organisms onto a site as these organisms may facilitate the entry of pathogens (Howard 1994; Raynard *et al.* 2007; Fisheries Research and Development Co-operation 2011; Johnston 2014) in addition to fouling infrastructure and blocking pipe-work (Fitridge *et al.* 2012; **Chapter 5.28 Stock containment**). Again, the entry of pest species via routes other than incoming water (e.g. stock introductions) needs to be managed (Heasman and Savva 2007).

Disinfection of effluent water has been identified as an important measure for environmental protection (OIE 2012a) and for the protection of downstream facilities, because:

- the aquaculture environment may facilitate the pathogen proliferation; and

- some pathogens can survive for a considerable time outside the host (Sippel 1983).

The biosecurity risk associated with untreated effluent is dependent on pathogen concentration, dilution factors and survival time of pathogen outside host and presence of a local host population. Some aquatic pathogens are capable of surviving for long periods of time outside the host, for example:

- *A. invadans* (weeks, OIE 2012b);
- *M. refringens* (weeks; OIE 2012e);
- *P. olseni* (months; OIE 2012f);
- IHNV (months; OIE 2012c); and
- betanodaviruses (months; Frerichs *et al.* 2000).

Recent discoveries of *Bonamia ostreae* (flat oysters), http://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=17208
P. olseni (paua), http://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=14615
ostreid herpesvirus microvariant 1 (oysters; OIE 2013) and *Flavobacterium psychrophilum* (salmon; Anon 2013) infections in New Zealand aquaculture species show the vulnerability of both wild and land-based aquaculture stock to pathogen exposure.

Recent research showed that the majority of New Zealand aquaculture farmers were at least moderately concerned about preventing and managing pests and diseases (Sim-Smith *et al.* 2014). However, the authors noted a lack of treatment of intake and effluent water in land-based facilities because of the capital cost required and the perceived lack of need (because of the proximity to spring heads or the lack of disease history). Although as a consequence of a recent disease outbreak at a paua farm, the company has improved the biosecurity measures on-site to include the treatment of all incoming water and is in the process of installing a system to treat their effluent water.

Contingency plans should be put into place to ensure that all water entering and leaving a facility is treated in the event of system failure (e.g. power outage, pump break down, flood) (Huguenin and Colt 2002; **Chapter 5.9 Contingency plans**). For example, a reservoir can provide a reserve of water at critical times (Rowland *et al.* 2007).

A reservoir receives and stores water from the major source enabling control of water supply and its efficient delivery as well as ensuring quality as unwanted aquatic organisms can be excluded (Rowland *et al.* 2007).

5.32.1 Common influent and effluent treatments

The aim of the following treatments is to reduce potential pathogens to a concentration whereby the risk of acquiring an infectious dose is acceptable.

5.32.1.1 Chlorine

The typical order of resistance to chlorine used for water treatment is protozoan cysts > viruses > vegetative bacteria (Henze *et al.* 2008). The effective concentration of available chlorine required to treat water will depend on the water source, organic loading, and pathogens targeted (Yanong and Erlacher-Reid 2012). For complete microbial sterilisation,

OIE (2012a) recommends a concentration of 50 mg/L available chlorine, however under certain conditions higher concentrations may be required.

For the treatment of drinking water, 1 mg/L available chlorine with a contact time of 30 minutes is generally sufficient to reduce bacterial numbers to an acceptable level. However, in wastewater treatment the efficacy of chlorination is reduced by the presence of interfering substances (e.g. suspended solids, organic material, ammonia, etc), and as a result higher concentrations of chlorine (20-40 mg/L) are required (Henze *et al.* 2008). It is further noted that for some human pathogens are extremely resistant to chlorination, for example, to achieve 90% inactivation of *Cryptosporidium* a concentration of 80 mg/L free chlorine is required with a 90 minute contact time (Henze *et al.* 2008).

However, influent water has been successfully treated for viruses and bacteria at 1.2-1.6 mg/L available chlorine with a minimum contact time of at least 1 minute (Meyers 2010). Effluent water can be treated at 2 mg/L available chlorine with a minimum contact time of 5 minutes (Meyers 2010). For treatment of effluent from fish processing facilities, the Code of Good Practice Management Group (2011) recommend an available chlorine concentration of at least 5 mg/L with a contact time of more than 30 minutes. For these examples it is assumed that the water has undergone filtration prior to treatment.

Treated water should be dechlorinated using sodium thiosulfate or compressed sulphur dioxide and tested for residual chlorine (Meyers 2010; Yanong and Erlacher-Reid 2012). Contaminated sodium thiosulfate, used for de-chlorination, was shown introduce pathogenic *Vibrio* species into a facility (Elston *et al.* 2008).

5.32.1.2 Ultra-violet (UV) light

UV light at wavelengths of ~254 nm can be an effective water treatment option (Sippel 1983). The typical order of resistance of microorganisms to UV treatment is double stranded DNA viruses > bacterial spores > double stranded RNA viruses > single stranded RNA viruses > gram-positive bacteria > gram-negative bacteria (Henze *et al.* 2008; Yanong and Erlacher-Reid 2012). However, clumping bacteria (e.g. *Mycobacteria* sp.) can be difficult to treat (Yanong and Erlacher-Reid 2012). The efficacy of UV treatment depends on several factors including: lamp intensity (wattage), contact time, water clarity (e.g. cell clumping and shadowing, suspended solids, turbidity), and the target organisms (i.e. size and biological characteristics) (Henze *et al.* 2008; Yanong and Erlacher-Reid 2012). As a result, a pre-filtration step is usually necessary for effective UV treatment.

Many aquatic pathogens can be inactivated by UV treatments of 30 mW s/cm^2, the exceptions, which require extremely high UV exposure to inactivate, are Saprolegnia, white spot syndrome baculovirus, and IPN virus (Summerfelt 2003). Department of Agriculture, Fisheries and Forestry (DAFF) (2008) recommend doses of > 25 mJ/cm^2 (where 1 mJ/cm^2 = 1 mWs/cm^2) for the treatment of viruses, bacteria and fungi in facility wastewater and > 35 mJ/cm^2 for the treatment of spores of Myxosporidean species. Such recommended doses require pre-treatment with chemical precipitation or filtration (DAFF 2008). In a worst case scenario of high flows and excess particulates, Meyers (2010) recommends that UV units have a minimum rating of 175 mW s/cm^2 after 7,500 hours of lamp operation to achieve a 99.9% reduction of particular fish pathogens. The monitoring of lamp hours is an important to ensure system efficacy.

Where UV is used for the treatment of fish processing effluent the Code of Good Practice Management Group (2011) recommends that the dose exceed 120 mJ/cm^2 (where 1 mJ/cm^2 =

1 mWs/cm^2). Although in this instance UV treatment is not typically employed on its own, rather it has proved to be an effective secondary treatment in combination with ozone (Code of Good Practice Management Group 2011).

Jorquera *et al.* (2002) notes that relative to other methods, UV treatment systems are less efficient in treating large volumes of water and may involve higher maintenance costs. However, the use of UV treatment of human wastewater is increasing as no known toxic by-products are produced and there is no requirement for storage or handling of toxic chemicals. Further, advances in technology have resulted in more efficient and reliable lamps as well as lowering cost (Henze *et al.* 2008).

5.32.1.3 Ozone

The treatment of seawater with ozone forms residual oxidant compounds that, at levels of 0.08 to 1.0 mg/L, can significantly reduce viable microorganism concentrations (OIE 2012a; Yanong and Erlacher-Reid 2012). DAFF (2008) recommend treatment at mg/L for > 1 minute for all pathgoens. However, due to potential toxicity to stock, any residual oxidants must be removed before the treated water enters the growing facility (Jorquera *et al.* 2002; OIE 2012a; Yanong and Erlacher-Reid 2012). Ozone has also been successful in the treatment of effluent water from quarantine facilities (OIE 2012a).

For the treatment of fish processing effluent the Code of Good Practice Management Group (2011) recommends that ozone should be added to give a minimum of 8 mg/L/min for 3 minutes.

For complete sterilisation, UV treatment of seawater post-ozonation may be required, e.g. for quarantine purposes (Code of Good Practice Management Group 2011; OIE 2012a).

5.32.1.4 Settlement basins and tanks

Land-based aquaculture facilities often have a settlement basin or tank to remove particulate and solid debris from the effluent flow prior to discharge. This is based on the principle that particulate wastes < 100 μm will settle under gravitational forces as low flow rates and a long residence time facilitate gravitational settlement (Castine *et al.* 2013).

There are a large number of factors affecting the duration of wastewater retention in settlement basins (e.g. seasonality associated with facility flow-rates, stock size, temperature, sunlight, pH, ammonia, algal activity, adsorption to or entrapment by settled solids and settling of larger organisms, and basin cleanliness,), thus their design should consider these in the context of volume of water to be treated, water velocity and nature of particles (Gavine *et al.* 2005). Due to this complexity, their effectiveness as a treatment option has been questioned. In Australia, settlement basins from marine and brackish water land based facilities have been shown to remove up to 60% of total suspended solids with variable efficiency (Castine *et al.* 2013).

Importantly, the efficacy of settlement basins in removing suspended sediments decreases markedly over time if not maintained by removing settled solids which build up within the basin, forming a thick nutrient-rich sludge layer (Castine *et al.* 2013) further these nutrients may be leached into the overlying water (Gavine *et al.* 2005).

In the aquaculture context, little data exists on the efficacy of sedimentation basins for effective pest and pathogen treatment or removal. However, Hawkins and Jones (2002) noted

the escape of shellfish larvae from settlement basins. In the treatment of human wastewater, pathogen removal by primary sedimentation appears to be highly variable and dependent on optimal operation of processes (Henze *et al.* 2008). For example, Cripps and Bergheim (2000) report difficulties in removal of solids smaller than ~50 µm from human wastewater citing slow sedimentation rates and low flow capacities of micro-screens with such small pore sizes. Thus, removal of viruses and bacteria by sedimentation is often minimal, but highly variable (Cripps and Bergheim 2000; Henze *et al.* 2008). Removal of helminth eggs is more effective ranging from 60 to 90%, while protozoan removal ranges from 4 to 93% (Henze *et al.* 2008). Cripps and Bergheim (2000) note that for re-circulation systems, solids management needs to be combined with other processes for pathogen removal.

In contrast to sedimentation ponds, oxidation ponds may significantly reduce the concentrations of enteric pathogens if retention times are sufficient (Henze *et al.* 2008). However, thermal gradients can result in short-circuiting thus reducing the retention process, even in multi-pond systems designed for long retention times (i.e. 90 days) (Henze *et al.* 2008).

Alternatively, constructed wetlands are likely to have better sedimentation efficiencies than primary sedimentation ponds even though they typically have shorter retention times (i.e. five days compared to 20 to 30 days, respectively) (Henze *et al.* 2008). This is due to the presence of plants and a lower likelihood of re-suspension (Henze *et al.* 2008).

In terms of discharge from sedimentation ponds, the potential environmental effects of "stored water" should also be considered (Jones 2006).

5.32.2 Conclusions

Land-based facilities, particularly hatcheries, often act as hubs of infection not only at the individual farm level but also in a national and international context.

Avoidance of exposure to aquatic diseases and pests is often the best biosecurity measure however, a number of aquatic diseases and pests can be introduced into farms with source water. Thus treatment of source water to exclude pests and to eliminate potential pathogens should be considered. However, it is recognised that treatment of source water alone does not guarantee the absence of outbreaks if care is not taken to prevent other routes of infection.

Disinfection of effluent water has been identified as an important measure for environmental and fisheries protection in addition to the protection of downstream aquaculture facilities.

5.32.3 Options to aid the adoption of water treatment

5.32.3.1 Objective

To manage the risk of water transferring pests and pathogens onto, within and from the facility.

5.32.3.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

The biosecurity risk of a facility's water source should be considered and appropriate actions taken to manage any identified risks (i.e. pathogens and pests).

Intake and effluent water should be treated (e.g. filtration, UV treatment, ozonation) to exclude or render identified risks (i.e. pathogens and pests) non-viable to an acceptable level.

Infrastructure for decontamination of water should be adequately monitored and maintained to ensure it remains effective.

For land-based facilities, water intake and outflows should be located to avoid cross-contamination.

For sea-based farms, lease sites should be located to maintain epidemiological separation of populations with different health status (e.g. different year classes).

5.32.3.3 Detailed options

Influent

Intake water should be treated (e.g. filtration, UV treatment, ozonation) to exclude or render identified pathogens and pests non-viable to an acceptable level.

All water treatment systems should be designed and installed by a suitably qualified professional.

Regular monitoring should be in place to ensure treatment efficacy is maintained.

Water influent and effluent pipes should be separated as far as possible.

Water influent and effluent discharge locations should be separated to allow for dilution. In particular, avoid placing the intake line downstream from the discharge. There should also be a sufficient separation between the two lines so that the influent line is not siphoning in water that was just discharged and thereby creating a recycling loop between the two pipes.

The inflow into land-based facilities should be double screened to prevent the entry of fish and invertebrates.

Screens should be inspected as often as possible and remedial action taken as required.

Facility staff should be trained in the safe use of water treatment systems and their monitoring and maintenance.

A logging system to monitor the treatment and a back-up method should be in place in the event of failure of the disinfection system.

Pre and post treated water should be regularly monitored to ensure system efficacy.

Records of monitoring and inspections and any remedial action required should be maintained.

Contingency plans should be put into place to ensure that all water entering and leaving a facility is treated in the event of system failure.

Reserviors

Reservoirs should be located and constructed to enable gravity flow. This should ensure water is available during a power failure.

Reservoirs should have capacity should exceed twice volume of largest on-growing pond, tank, raceway.

Reservoirs should be aerated to maintain good water quality and prevent or reduce stratification.

Reservoirs should have separate and double screened inlets and outlets.

The reservoir should have the capacity to be drained and dried to:

- remove all unwanted organisms;
- desiccate pathogens;
- enable disinfection;
- enable silt to be removed; and
- enable repairs and general maintenance.

The reservoir should be maintained free of pests and pathogens and the organisms known to carry them.

Pipe-work

Inlet and outlet piping should be designed so that they can be cleaned (pigged) from the outside into the facility rather than the effluent being discharged into the environment.

All land-based pipes and wastewater channels should be cleaned regularly and disinfected to limit the formation of biofilms and the accumulation of organic matter. During cleaning, the pipe-work should be drained and external fouling removed.

Pipes, outlet channels and settlement basins should be regularly cleaned to ensure that no organisms are established in these areas.

Release of wastewater from cleaning processes should be comply with the relevant regional authorities.

Production and holding units, including inlets and outlets, should be designed in such a way as to minimise escapes.

Air-gaps should be used to prevent stock moving up-stream through the plumbing (this care should be taken to prevent the creation of aerosols).

Grates should be placed at the water inlets to prevent the passage of stock into the culture system.

Grates should be placed at the water discharge outlets to prevent escape into drains, other tanks, settlement tanks and the wild.

The grate size should be such that it is capable of containing stock appropriate to the particular culture system.

Grates for inlet and outlet in pipes, tanks and ponds should be inspected regularly for holes or fouling. Remedial action should be taken immediately to rectify any unsatisfactory situation.

Pipes, outlet channels and settlement tanks and ponds should be regularly cleaned to ensure that no fish and invertebrate populations are established in these areas.

Settlement tanks and ponds should be regularly treated to kill escaped stock.

Within facility escaped stock should be health tested.

Effluent

All water discharged from the facility should be treated (e.g. filtration, UV treatment, ozonation) to exclude or render identified pathogens and pests non-viable to an acceptable level.

All water treatment systems should be designed and installed by a suitably qualified professional.

Regular monitoring should be in place to ensure treatment efficacy is maintained.

To ensure continuous operation and complete containment, effluent treatment systems should be equipped with fail-safe backup mechanisms. This is particularly important for quarantine systems.

The discharges from land-based facilities should be double screened to prevent the entry of unwanted organisms and the loss of stock from the facility.

Screens should be inspected as often as possible and remedial action taken as required.

Facility staff should be trained in the safe use of water treatment systems and their monitoring and maintenance.

A logging system to monitor the treatment and a back-up method should be in place in the event of failure of the disinfection system.

Pre and post treated water should be regularly monitored to ensure system efficacy.

Records of monitoring and inspections and any remedial action required should be maintained.

Contingency plans should be put into place to ensure that all water entering and leaving a facility is treated in the event of system failure.

Settlement basins

A site specific analysis of settling within existing and planned settling basins for each facility should be conducted. Such an analysis should consider pathogens of concern and their appropriate retention time and contingency plans regarding system failure (e.g. short-circuiting).

Settling basin inlet and outlet design should minimise turbulence and short-circuiting.

Settlement basins should be of adequate size to hold necessary volumes of wastewater and ensure adequate retention of pathogens, nutrients and sediments.

Settlement basins should be able to be drained and dried to:

- remove all unwanted macro-organisms;
- desiccate pathogens;
- enable silt to be removed or the substrate to be tilled, scraped or limed;
- prevent excessive growths of aquatic plants; and
- enable repairs and general maintenance.

The outflow from tank and basin systems and discharges from the facility should be double screened to prevent the entry of unwanted species into and loss of stock from the facility.

Settlement basins should be cleaned regularly to maintain efficient removal of solids and unwanted macro-organisms.

Disposal of settled effluent or unwanted macro-organisms should be disposed in an appropriate manner.

Pre and post treated water should be regularly monitored to ensure system efficacy.

5.32.4 References

Anon (2013). Animal health laboratory. *Surveillance* 40(3): 9-13.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture species.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Asche F, Hansen H, Tveteras R and S Tveterås (2009). The salmon disease crisis in Chile. *Marine Resource Economics* 24: 405-411.

Brock JA and R Bullis (2001). Disease prevention and control for gametes and embryos of fish and marine shrimp. *Aquaculture* 197: 137-159.

Brown C and DJ Russo (1979). Ultraviolet light disinfection of shellfish hatchery sea water. I. Elimination of five pathogenic bacteria. *Aquaculture* 17: 17-23.

Castine SA, McKinnon AD, Paul NA, Trott LA and R De Nys (2013). Wastewater treatment for land-based aquaculture: improvements and value-adding alternatives in model systems from Australia. *Aquaculture Environment Interactions* 4: 285-300.

Castinel A, Forrest B and G Hopkins (2013). *Review of disease risks for New Zealand shellfish aquaculture: perspectives for management.* Prepared for Ministry for Business, Innovation and Employment. Cawthron Report No. 2297. 31 pp.

Cipriano RC and RA Holt (2005). *Flavobacterium psychrophilum, cause of bacterial cold-water disease and rainbow trout fry syndrome.* United States Department of the Interior. Fish and Wildlife Service. Fish Disease Leaflet 86. 44 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Corbeil S, Williams LM, Bergfield J and M StJ Crane (2012). Abalone herpes virus stability in sea water and susceptibility to chemical disinfectants. *Aquaculture* 326-329: 20-26.

Cripps SJ and A Bergheim (2000). Solids management and removal for intensive land-based aquaculture production systems. *Aquacultural Engineering* 22: 33-56.

Department of Agriculture, Fisheries and Forestry (2008). *Operational procedures manual - decontamination (Version 1.0). In*: Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT. 122 pp.

Diggles BK and M Oliver (2005). *Diseases of cultured paua (Haliotis iris) in New Zealand. In*: P Walker, R Lester and MG Bondad-Reantaso (Eds.) Diseases in Asian aquaculture V, Fish Health Section, Asian Fisheries Society, Manila. pp. 275-287.

Elston RA, Hasegawa H, Humphrey KL, Polyak IK and CC Hase (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119-134.

Elston RA (1993). Infectious diseases of the Pacific oyster, *Crassostrea gigas*. *Annual Review of Fish Diseases* 3: 259-276.

Fisheries Research and Development Co-operation (2011). *Final Report, OsHV-1 µ-var International Workshop Cairns Queensland 9-10 July 2011.* FRDC Report. 53 pp.

Fitridge I, Dempster T, Guenther J and R de Nys (2012). The impact and control of biofouling in marine aquaculture: a review. *Biofouling: The Journal of Bioadhesion and Biofilm Research* 28(7): 649-669.

Ford SE, Xu Z and G Debrosse (2001). Use of particle filtration and UV irradiation to prevent infection by *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo) in hatchery-reared larval and juvenile oysters. *Aquaculture* 194: 37-49.

Frerichs GN, Tweedie A, Starkey WG and RH Richards (2000). Temperature, pH, and electrolyte sensitivity, and heat, UV and disinfectant inactivation of sea bass (*Dicentrarchus labrax*) neuropathy nodavirus. *Aquaculture*, 185: 13-24.

Gavine F, Larkin B, Ingram B and M Edwards (2005). *Best practice environmental management guidelines for the salmonid aquaculture industry.* Fisheries Victoria Management Report Series No. 25. http://www.depi.vic.gov.au/fishing-and-hunting/aquaculture/aquaculture-management/best-practice-salmonid-aquaculture-industry [Website accessed September 2014].

Georgiadis MP, Gardner IA and RP Hedrick (2001). The role of epidemiology in the prevention, diagnosis, and control of infectious diseases of fish. *Preventive Veterinary Medicine* 48: 287-302.

Håstein T, Hill BJ and JR Winton (1999). Successful aquatic animal disease emergency programmes. *Revue Scientifique et Technique de L'office International des Epizooties* 18: 214-227.

Hawkins CD and JB Jones (2002). Larval escape through abalone culture effluent systems an analysis of the risk. *Journal of Shellfish Research* 21: 805-809.

Heasman M and N Savva (2007). *Manual for intensive hatchery production of abalone. Theory and practice for year round, high density seed production of blacklip abalone (Haliotis rubra).* New South Wales Department of Primary Industries and Australian Government Fisheries Research and Development Corporation. 95 pp.

Henze M., van Loosdrecht M.C.M., Ekama G.A. and Brdjanovic D. (Eds.) (2008). *Biological wastewater treatment - principles, modelling and design.* IWA Publishing, London, United Kingdom. 511 pp.

Hnath JG (1983). *Infectious pancreatic necrosis. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 169-174.

Howard AE (1994). The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. *Bulletin of the European Association of Fish Pathologists* 14(6): 211-212.

Huguenin JE and J Colt (2002). *Design and operating guide for aquaculture seawater systems. Second Edition.* Elsevier, Amsterdam. pp 183-192.

International Council for the Exploration of the Sea (ICES) (2011). *Dermo disease of oysters caused by Perkinsus marinus.* Revised and updated by SE Ford. ICES Identification leaflets for diseases and parasites of fish and shellfish. Leaflet No. 30. 5 pp.

Inglis G, Morrisey D, Woods C, Sinner J and M Newton (2013). *Managing the domestic spread of harmful marine organisms. Part A - Operational tools for management.* Prepared for Preparedness and Partnerships Directorate, Ministry for Primary Industries, New Zealand. NIWA Client Report No: CHC2013-150. 166 pp.

Johnston CJ (2014). *Statement of evidence on behalf of fisheries submitters before the Environmental Protection Authority.* 4 April 2014. 14 pp.

Jones JB (2006). Why won't they grow - inhibitory substances and mollusc hatcheries. *Aquaculture International* 14: 395-403.

Jorquera MA, Valencia G, Eguchi M, Katayose M and C Riquelme (2002). Disinfection of seawater for hatchery aquaculture systems using electrolytic water treatment. *Aquaculture* 207: 213-224.

Kibenge FSB, Godoy MG, Fast M, Workenhe S and MJT Kibenge (2012). Countermeasures against viral diseases of farmed fish. *Antiviral Research* 95: 257-281.

Matson SE, Langdon CJ and S Evans (2006). Specific pathogen free culture of the Pacific oyster (*Crassostrea gigas*) in a breeding research program: effect of water treatment on growth and survival. *Aquaculture* 253: 475-484.

Meyers T (2010). *Regulation changes, policies and guidelines for Alaska fish and shellfish health and disease control.* Alaska Department of Fish and Game, Regional Information Report 5J10-01. Juneau, Alaska. 57 pp.

Meyers TR and JR Winton (1995). Viral hemorrhagic septicaemia virus in North America. *Annual Review of Fish Diseases* 5: 3-24.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

OIE (2013). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.9 Infection with ostreid herpesvirus 1 microvariant.* 14 pp.

OIE (2012a). *Manual of diagnostic tests for aquatic animals. Chapter 1.1.3. Methods for disinfection of aquaculture establishments.* 13 pp.

OIE (2012b). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.2 Epizootic ulcerative syndrome.* 13 pp.

OIE (2012c). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.4. Infectious haematopoietic necrosis.* 14 pp.

OIE (2012d). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.11 Viral encephalopathy and retinopathy virus.* 19 pp.

OIE (2012e). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.4 Infection with Marteilia refringens.* 12 pp.

OIE (2012f). *Manual of diagnostic tests for aquatic animals. Chapter 2.4.6 Infection with Perkinsus olseni*. 12 pp.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Rowland S, Landos M, Callinan R, Allan G, Read P, Mifsud C, Nixon M, Boyd P and P Tully (2007). *Development of a health strategy for the silver perch aquaculture industry.* Final report on the Fisheries Research and Development Corporation, Project No. 2000/267 and 2004/089. NSW Department of Primary Industries - Fisheries Final Report Series No. 93. NSW, Australia. 219 pp.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Sippel AJ (1983). *Water supply sanitation. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 49-58.

Subcommittee on Aquatic Animal Health (SCAAH) 2016. Aquaculture Farm Biosecurity Plan: Generic Guidelines and Template. Department of Agriculture and Water Resources, Canberra. CC BY 3.0.

Summerfelt ST (2003). Ozonation and UV radiation - an introduction and examples of current applications. *Aquacultural Engineering* 28: 21-36.

Warren JW (1983). *Bacterial kidney disease. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 185-192.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 16 pp.

Yanong RPE (2012). *Biosecurity in aquaculture, part 2: recirculating aquaculture systems.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 9 pp.

5.33 WILDLIFE MANAGEMENT

Due to the reliance of aquaculture facilities on good water quality, they are often located in sites remote from large scale human habitation. Coincidentally, wildlife is often abundant in these sites. Wildlife may be attracted to aquaculture facilities as they may provide habitat, food or both (Massachusetts Shellfish Growers 2009; Global Aquaculture Alliance 2011; BC Shellfish Growers Association 2013; Global Aquaculture Alliance 2013).

Wildlife exposure can result in stock mortality, injury (e.g. predation), stress, disease, equipment damage and stock escape. Such interactions result in considerable losses to the production facilities in addition to compromises to stock welfare and on-site biosecurity (Massachusetts Shellfish Growers 2009; Code of Good Practice Management Group 2011; Aquaculture Stewardship Council 2012a; **Chapter 5.13 Good husbandry; Chapter 5.28 Stock containment**).

Wildlife that interact with offshore finfish farms include fish, sharks, predatory and scavenging birds and charismatic megafauna (e.g. seals) (Global Aquaculture Alliance 2011). Shellfish cultivation sites tend to attract diving birds, invertebrates (e.g. seastars, crabs, whelks), fish species that aggregate around cultivation structures and their predators (Massachusetts Shellfish Growers 2009; Aquaculture Stewardship Council 2012a; BC Shellfish Growers Association 2013; Global Aquaculture Alliance 2013). Further, human food scraps, out-of-date feed and other organic waste can attract scavengers (e.g. birds and vermin) (Global Aquaculture Alliance 2011).

Recently Sim-Smith *et al.* (2014) investigated current biosecurity practices, perceptions, needs and awareness in New Zealand's major aquaculture sectors. This research showed that the majority of farmers were concerned about wild animals being a source of pests and diseases. Centre for Environment, Fisheries and Aquaculture Science (CEFAS) (2009) recommended that the presence of scavengers, vermin, birds and other predators (e.g. cats) capable of introducing or spreading disease should be covered under an on-site biosecurity plan.

5.33.1 Fish

Wild fish populations are often observed near open net pens of finfish aquaculture facilities (Aquaculture Stewardship Council 2012b). Many diseases observed in finfish aquaculture are caused by pathogens that have wild origins in the same or similar species (Raynard *et al.* 2007). Thus wild fish species may act as vectors for, and carriers of, pathogens (Code of Good Practice Management Group 2011). For example, introduction of viral haemorrhagic septicaemia from wild to farmed fish has occurred on multiple occasions (Raynard *et al.* 2007). The onset of infectious haematopoietic necrosis epidemics in British Columbia coincided with the annual wild Pacific salmon migration, suggesting that wild salmon may have been the source of the infection (Saksida 2006). Further, sea trout have been shown to be a potential source of infectious salmon anaemia, and actively excrete this virus (Nylund and Jakobsen 1995; Anon 2005). Wild fish in the water supply of onshore facilities has also been highlighted as a potential source of disease outbreaks (Anon 2003). For example, an outbreak of furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*) occurred in a facility following the use of untreated river water when its normal loch supply free of migratory fish was inadequate (Munro and Waddell 1984). Disease transmission has been shown to be bidirectional between farmed and wild fish (Aquaculture Stewardship Council 2012b; **Chapter 5.28 Stock containment**).

5.33.2 Marine mammals

Seals are often reported in the proximity of offshore aquaculture facilities (Anon 2000; New Zealand King Salmon Ltd. 2011). Seals can take advantage of compromised predator defence systems (New Zealand King Salmon Ltd. 2011).

Seal interactions with aquaculture stock can result in:

- stock mortality and injury (e.g. predation);
- stress (New Zealand King Salmon Ltd. 2011; **Chapter 5.13 Good husbandry**);
- disease (Anon 2003);
- equipment damage; and
- stock escape (Code of Good Practice Management Group 2011*;* **Chapter 5.28 Stock containment**).

Seals may have an indirect impact of disease transmission by damaging nets allowing both the influx of wild species and stock escape. Escaped fish may spread diseases between sites or to wild stocks (Anon 2005; **Chapter 5.28 Stock containment**). Thus, seal deterrent measures have a role in lowering disease transmission risk (Anon 2000).

In New Zealand seals are protected under the Marine Mammal Protection Act 1978, administered by the Department of Conservation (DOC). New Zealand King Salmon Ltd. has been granted a permit from DOC which allows seals entering the sea pens to be caught and released. The permit also allows farm staff to deter seals from entering the sea pens. The killing of any seal is not permitted (New Zealand King Salmon Ltd. 2011).

Measures such as the prompt removal dead fish, reducing stocking densities, net tensioning, acoustics, predator mesh and use of seal blinds are important in reducing predation by seals (Anon 2000; Aquaculture Stewardship Council 2012b).

New Zealand King Salmon Ltd. (2011) state that predator nets are the most effective method for excluding seals and predators from aquaculture facilities. By distancing the fish from the predators, they also reduce stock stress (New Zealand King Salmon Ltd. 2011).

5.33.3 Birds

Aquaculture facilities provide attractive structures to birds for drying, roosting and as a platform from which to dive for fish (New Zealand King Salmon Ltd. 2011).

Bird interactions with aquaculture stock can result in:

- stock mortality and injury (e.g. predation) (Association of Scottish Shellfish Growers 2005; BC Shellfish Growers Association 2013);
- stress (New Zealand King Salmon Ltd. 2011; **Chapter 5.13 Good husbandry)**;
- disease (Anon 2003); and,
- equipment damage (Code of Good Practice Management Group 2011).

Birds may act as significant vectors of aquaculture associated diseases as they actively seek out farms as food sources and have the potential to carry pathogens over relatively long distances (Anon 2003; Anon 2005; Murray 2013). For example, gulls and sea birds have been identified as potential factors in the spread of shrimp viruses (e.g. infectious myonecrosis, Taura syndrome, white spot syndrome) between and within regions (Lightner *et al.* 1997; OIE

2012a; OIE 2012b). Access of birds to waste was also identified as a potential factor resulting in virus spread (Lightner *et al.* 1997). Some birds (e.g. sea gulls) may move between fresh and saltwater sites or forage at waste dumps (Anon 2005).

Birds have been identified as potential vectors for the following finfish parasites and diseases:

- epizootic haematopoietic necrosis (OIE 2012c);
- viral haemorrhagic septicaemia (Olesen and Vestergård Jorgensen 1982; OIE 2012e);
- infectious pancreatic necrosis (IPN; Anon 2003);
- koi herpesvirus, (OIE 2012d);
- *Oncorhynchus masou* virus (OMV; OIE 2012f);
- betanodaviruses (OIE 2012g);
- *Aeromonas salmonicida* subsp. *salmonicida* (Department of Agriculture, Fisheries and Forestry (DAFF) 2012);
- *Eustrongylides* sp. (Faragher 1989); and
- *Myxobolus cerebralis* (DAFF 2012).

Secure storage of fish food, mortalities and wastes are recognised as measures that may reduce the risk of stock health associated with birds (Anon 2000; Anon 2005; New Zealand King Salmon Ltd. 2011; Anon 2013). Such actions are particularly important during the emergency harvest of an infected site (Anon 2000).

New Zealand King Salmon Ltd. use predator and overhead bird nets to exclude birds from sea pen structures (New Zealand King Salmon Ltd. 2011). Black-backed gulls, not protected by under the Wildlife Act 1953, may be shot by appropriately licensed and registered staff, and collected and disposed of appropriately.

5.33.4 Invertebrates

Predators of shellfish, such as seastars, snails and crabs, are typically managed by a combination of barriers and trapping (Aquaculture Stewardship Council 2012a; BC Shellfish Growers Association 2013). As the distribution of predators is not uniform in terms of location or season control methods vary in space and time (Massachusetts Shellfish Growers 2009). Advice for predators removal is typically in line with that of biofouling (**Chapter 5.7 Biofouling (shellfish)**).

The presence or abundance of carrier shellfish may influence the risk of pathogen (infectious pancreatic necrosis virus) transfer to susceptible fish species (Anon 2003). Therefore, fouling should be regularly removed as a precautionary measure (Anon 2003).

5.33.5 Scavengers and vermin

Scavengers and vermin are deemed as unwanted animals that may come into a facility (Wyban 2013). They (domestic animals, rats and mice) are frequently attracted to aquaculture facilities due to the potential for food and shelter. Scavengers and vermin that frequent aquaculture facilities have the potential to act as vectors of infection (Anon 2003). The potential for mammalian vectors to be involved in transmission aquatic diseases (e.g. IPN, koi herpesvirus and OMV) has been highlighted by Anon (2003), OIE (2012d), and OIE (2012f). In terms of human health, Wolf (1998) stated that the link between leptospirosis and aquaculture staff appears to involve the contamination of waterways or fish feeds by rodents, seagulls, or other terrestrial vectors. As a result, good site hygiene measures to ensure that sites do not attract scavengers and vermin, such as secure storage of feeds and waste, are

ubiquitous to aquaculture best practice manuals (e.g. Wolf 1998; Hinrichsen 2007; Ingerson *et al.* 2007; HDR Engineering, Inc. 2010; Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Wyban 2013).

Improper feed storage also leads to contamination by invertebrate pests, such as cockroaches (Yanong and Erlacher-Reid 2012).

5.33.6 Conclusions

Wildlife interactions with aquaculture facilities can result in a variety of impacts to stock production including a compromise to site biosecurity. The implementation of preventive management practices can reduce the likelihood of these interactions occurring and their consequences.

5.33.7 Options to minimise the risks associated with wildlife

5.33.7.1 Objective

To manage the risk of wildlife, scavengers and vermin transferring pests and disease onto, within or from the facility.

5.33.7.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Facilities should have and maintain a written wildlife and scavenger interaction plan.

Wildlife and scavenger populations should be controlled or excluded from production facilities.

All production units should have appropriate features to prevent stock escapes.

Safeguarding facilities and stock against predation should be taken into account in any risk assessment prepared when planning and positioning an aquaculture facility. Therefore, the position, design and construction of facility should consider the interaction with wildlife, and the exclusion of predators and scavengers.

The facility should comply with existing legislation regarding wildlife and species or habitats of conservation importance. All measures to exclude wildlife should be approved by the Department of Conservation (DOC).

5.33.7.3 Detailed options

General

Risk assessment should be undertaken on a site-specific basis and at predetermined frequency to ascertain the risks of predator attacks, with records being maintained.

Facilities should have standard operating procedures to prevent and manage predation and wildlife problems. For example, transmission of infectious agents via wildlife can be minimised through:

- measures designed to exclude birds and mammals from areas where stock are held;

- hygienic procedures for handling dead stock; and
- secure feed delivery, storage and feeding practices that minimise wastage.

Deterrents should be appropriate to the predator(s) targeted for exclusion. For example, net material, mesh size and design should minimise injury to wildlife and remain tightly secured.

Deterrents should be maintained and in good repair, for example, cover netting should be UV and weather resistant to prevent tearing. Records should be kept regarding any maintenance and repairs undertaken.

Deterrents may include, but are not limited to:

- predator netting;
- specialised weighting;
- coated and treated nets, using treatments that do not have a toxic environmental impact;
- bird netting;
- proper husbandry;
- electric fences; and
- authorised live trapping and relocation.

Records should be maintained regarding predator presence on and around the site, non-lethal methods of deterrent employed, and the success or failure of those methods (these records should be open to inspection).

The facility should ensure that operational planning takes into account seasonal variations in the use of nearby critical habitat, such as, bird breeding or nesting areas.

Where practically possible and environmentally acceptable, the elimination of perches for birds around aquaculture facilities can reduce the occurrence of bird predators.

The facility should minimise the impact of site substrate modifications on wildlife or marine habitat.

Staff should record any accidental ensnarement of wildlife (e.g. marine mammals) and report such incidences to DOC without delay.

Land-based facilities

Measures should always be taken at water intakes to minimise the risk of ingress of wild fish and invertebrates. Twin sets of screens should be used so that wild fish and invertebrates cannot enter when the screens are being cleaned.

5.33.8 References

Anon (2013). *Environmental code of practice for the sustainable management of Western Australia's abalone aquaculture industry.* Published by Aquaculture Council of Western Australia and Government of Western Australia, Department of Fisheries. 42 pp.

Anon (2005). *Final report of the aquaculture health joint working group sub-group on disease risks and interactions between farmed salmonids and emerging marine aquaculture*

species. Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 54 pp.

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Anon (2000). *Final report of the joint government/industry working group on infectious salmon anaemia (ISA) in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 136 pp.

Aquaculture Stewardship Council (2012a). *ACS bivalve standard. Version 1.0.* January 2012. 57 pp.

Aquaculture Stewardship Council (2012b). *ACS salmon standard. Version 1.0.* June 2012. 103 pp.

Association of Scottish Shellfish Growers (2005). *Code of good practice.* 44 pp.

BC Shellfish Growers Association (2013). *Environmental management code of practice.* 75 pp.

Centre for Environment, Fisheries and Aquaculture Science (CEFAS) (2009). *Finfish biosecurity measures plan. Guidance and templates for finfish farmers and traders.* Fish Health Inspectorate, Center for Environment, Fisheries and Aquaculture Science. 32 pp.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Department of Agriculture, Fisheries and Forestry (DAFF) (2012). *Aquatic animal diseases significant to Australia: identification field guide, 4th edition.* Australian Government, Canberra. http://www.daff.gov.au/animal-plant-health/pests-diseases-weeds/aquatic-animal-diseases-significant-to-australia-identification-field-guide-4th-edition. [Website accessed August 2014].

Faragher RA (1989). *'Red worm' of trout. Advisory note.* Agdex 486/663. No. 3/89. Department of Agriculture, New South Wales. 2 pp.

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

HDR Engineering, Inc. (2010). *Illinois aquaculture biosecurity manual.* Prepared for Southern Illinois University Carbondale Fisheries and Illinois Aquaculture Center. 177 pp.

Hinrichsen E (2007). *Generic environmental best practice guideline for aquaculture development and operation in the Western Cape: edition 1.* Division of Aquaculture, Stellenbosch University Report. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town. 57 pp.

Ingerson T, Flowers T and J Todd (2007). *Code of practice for the environmental management of the South Australian abalone aquaculture industry.* Environmental Protection Authority, South Australia. 39 pp.

Lightner DV, Redman RM, Poulos BT, Nunan LM, Mari JL and KW Hasson (1997). Risk of spread of penaeid shrimp viruses in the Americas by the international movement of live and frozen shrimp. *Revue Scientifique et Technique de L'office International des Epizooties* 16(1): 146-160.

Massachusetts Shellfish Growers (2009). *In*: Leavitt DF (Ed.) Best management practices for the shellfish culture industry in Southeastern Massachusetts. Version 09-04a. 100 pp.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

Murray AG (2013). Epidemiology of the spread of viral diseases under aquaculture. *Current Opinion in Virology* 3: 74-78.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

Nylund A and P Jakobsen (1995). Sea trout as a carrier of infectious salmon anaemia virus. *Journal of Fish Biology* 45:174-176.

OIE (2012a). *Manual of diagnostic tests for aquatic animals. Chapter 2.2.3 Infectious myonecrosis.* 10 pp.

OIE (2012b). *Manual of diagnostic tests for aquatic animals. Chapter 2.2.5 Taura syndrome.* 17 pp.

OIE (2012c). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.1 Epizootic haematopoietic necrosis.* 21 pp.

OIE (2012d). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.6 Koi herpesvirus disease.* 17 pp.

OIE (2012e). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.9 Viral haemorrhagic septicaemia.* 23 pp.

OIE (2012f). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.10 Oncorhynchus masou virus.* 12 pp.

OIE (2012g). *Manual of diagnostic tests for aquatic animals. Chapter 2.3.11 Viral encephalopathy and retinopathy virus.* 19 pp.

Olesen NJ and PE Vestergård Jorgensen (1982). Can and do herons serve as vectors for Egtved virus? *Bulletin of the European Association of Fish Pathology* 3: 48.

Raynard R, Wahli T, Vatsos I and S Mortensen (Eds.) (2007). *Review of disease interactions and pathogen exchange between farmed and wild finfish and shellfish in Europe.* Work package 1, deliverable 1.5. Disease interactions and pathogen exchange between farmed and

wild aquatic animal populations - a European network. Issued by Veterinæmedisinsk Oppdragssenter AS. Project number: 1655. 459 pp.

Saksida SM (2006). Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms* 72: 213-223.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Wolf JC (1998). *Potential zoonotic infections in cultured foodfish. In*: Libey GS and MB Timmons (Eds.) Proceedings of the second international conference on recirculating aquaculture. pp. 162-170.

Wyban J (2013). *Biosecurity measures in specific pathogen free (SPF) shrimp hatcheries. In:* Allan G and G Burnell (Eds.) Advances in aquaculture hatchery technology. Woodhead Publishing. pp 329-338.

Yanong RPE and C Erlacher-Reid (2012). *Biosecurity in aquaculture, part 1: an overview.* Program in fisheries and aquatic sciences, SFRC, Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 16 pp.

5.34 YEAR CLASS SEPARATION

Once a pathogen is established at a site, horizontal transmission of infection between younger and older fish is a predictable occurrence unless there is a gap in stocking (Munro 1988).

The practice of separating year classes has long been used to prevent horizontal pathogen transmission on fish production sites by minimising the contact between younger and older fish (Poynter 1983; Munro and Waddell 1984; Anon 2003).

For the purposes of this document, a single year class is defined as "any group of fish stocked into a site over any six-month period. For marine species, a year class is defined by the calendar year of production of the juvenile fish" (Code of Good Practice Management Group 2011).

A multiple year class site is therefore defined as "a site which contains more than one year class of fish" (Code of Good Practice Management Group 2011).

According to Aquaculture Stewardship Council (2012) "gaps of up to six months between inputs of smolts derived from the same stripping are acceptable as long as there remains a period of time when the site is fully fallow after harvest."

Ideally, an "all in-all out" model is implemented in which all the stock is removed from the site, followed by disinfection and fallowing, prior to introduction of the new or naïve stock (Blaylock and Whelan 2004). For example, a secondary outbreak of infectious haematopoietic necrosis (IHN) in British Columbia, Canada was associated with farms that did not practice year class separation with fallowing prior to re-stocking. As a result, new smolts were exposed to salmon that had survived the outbreak that may have acted as carriers of the virus (St-Hilaire *et al.* 2000; Saksida 2006).

Year class separation has been used to manage a variety of fish pathogens (viral, bacterial, parasites). Munro and Waddell (1984) provide multiple examples of how year class separation was used (in combination with other management measures) to manage and prevent outbreaks of furunculosis (*A. salmonicida* subsp. *salmonicida*) in Scotland.

In New Brunswick Canada, McClure *et al.* (2005) found that having only one year class of fish on the site reduced the likelihood of a site becoming infected with infectious salmon anaemia. Year class separation is also used to help manage the spread of ISA in Maine, USA (Gustafsen *et al.* 2007). Similarly, year class separation has also been used as a measure to aid in the reduction of losses from pancreas disease in Norwegian salmon (Johansen *et al.* 2009).

More recently, Midtlyng *et al.* (2011) maintained that the "year class separation and fallowing" were among the most important measures to prevent horizontal transmission of both ISA and furunculosis in Norway. Implementation of this measure, among others, also contributes to the reduction in the amount of antibiotics used in Norwegian finfish production (Midtlyng *et al.* 2011).

In terms of reducing parasite loads, Grant and Treasurer (1993) maintain that incoming smolts are more likely to become rapidly infested on mixed year class sites. As such, year class separation and fallowing are recognised as important strategies for managing salmon parasites.

In terms of general fish health, Wheatley *et al.* (1995) found that sites that stocked a single generation had a significantly lower total mortality than years where multiple generations were reared.

Year class separation of stock is included in various best practice production standards for finfish aquaculture (Code of Good Practice Management Group 2011; Global Aquaculture Alliance 2011; Aquaculture Stewardship Council 2012).

Although some broodstock sites may hold multiple year classes of fish (Code of Good Practice Management Group 2011) it is acknowledged that a distinction between such sites and production facilities and that alternative biosecurity measures, such as compartmentalisation, should be applied as necessary.

Year class separation is acknowledged by New Zealand salmon industry as a good preventive strategy in salmon farming areas where disease is an issue. This practice is not yet implemented by the New Zealand salmon industry, due to disease free status, low likelihood of disease outbreaks in New Zealand Chinook salmon, production constraints, and difficulties obtaining consents for new growing areas (New Zealand King Salmon Ltd. 2011; Sim-Smith and Forsythe 2013; Sim-Smith *et al.* 2014).

Sim-Smith *et al.* (2014) recommended the implementation of year class separation for New Zealand finfish farms to minimise pest or disease transmission as part of an area-based management agreement. However, the authors identified a lack of farm space as a barrier to the incorporation of this practice without reducing current production.

5.34.1 Conclusions

Year class separation is recognised as an important disease prevention measure, particularly when used in combination with other management measures (e.g. site disinfection and fallowing, area management).

5.34.2 Options to aid the adoption of year class separation

5.34.2.1 Objectives

To manage the risk of pest and pathogen transfer between different production populations (e.g. year classes).

5.34.2.2 High level options

Facilities should have a veterinary health plan (VHP), which includes a biosecurity plan that sets out biosecurity protocols, preventive measures, treatments and contingencies. The VHP should be updated regularly.

Lease sites should be located to maintain epidemiological separation of populations with different health status (e.g. different year classes).

Stock from different year classes should be grown and maintained in separate set of culture systems or sites throughout their production cycle. Stocking a given facility site or section from a single cohort is preferred.

There is an increased level of risk in areas where more than one company operates or more than one year class is present or different species are being produced. In such cases, all

movements within the area should be subject to a satisfactory outcome from a documented risk assessment and the written agreement of all the companies operating within that area.

Where more than one company occupies an area and a single year class is stocked within it, movements within the area should be subject to written agreement between the companies occupying the area.

Facilities within a defined area should be fallowed synchronously on a single year class basis.

5.34.2.3 Detailed options

Area-based management

An exception to the above options may be possible. Where this is the case, the undernoted conditions should be met:

- a documented risk assessment, which considers the risks to the company's own operations and to the operations of other companies within the area and in any adjacent area, should be undertaken and management systems adopted that maintain risks at a satisfactorily low level;
- this risk assessment should include detailed information on strategies to be followed for pathogen and parasite control in the absence of fallowing; and
- the plan should have the written agreement of all other companies within the management area.

New species

Multiple year class production may be required in the case of new marine finfish species.

In all cases, multiple year class production should only be undertaken following a satisfactory outcome from a documented risk assessment.

If more than one year class of marine species is to be cultured on a facility, this should not occur for more than 6 years. Thereafter:

- facilities should adhere to the provisions of a written fallowing plan;
- a minimum fallow period of 4 weeks should be applied at the end of each cycle;
- pens, nets, equipment, etc, should be cleaned and disinfected before the site is restocked with fish; and

disinfection should be conducted to a satisfactory level to inactivate pathogens posing significant risk.

5.34.3 References

Anon (2003). *Final report of the aquaculture health joint working group subgroup on infectious pancreatic necrosis in Scotland.* Published by the Scottish Executive, Fisheries Research Services Marine Laboratory, Aberdeen. 90 pp.

Aquaculture Stewardship Council (2012). *ASC salmon standard. Version 1.0.* June 2012. 103 pp.

Blaylock RB and DS Whelan (2004). *Fish health management for offshore aquaculture in the Gulf of Mexico. In*: Bridger CJ (Ed.) Efforts to develop a responsible offshore aquaculture industry in the Gulf of Mexico: A compendium of offshore aquaculture consortium research.

Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, United States of America. pp. 129-161.

Code of Good Practice Management Group (2011). *The code of good practice for Scottish finfish aquaculture.* Scottish Salmon Producer's Organisation, Perth, Scotland. http://www.thecodeofgoodpractice.co.uk/ [Website accessed May 2014].

Global Aquaculture Alliance (2011). *Aquaculture facility certification. Salmon farms.* Best aquaculture practices. Certification standards, guidelines. 22 pp. http://www.bestaquaculturepractices.org [Website accessed May 2014].

Grant AN and J Treasurer (1993). *The effects of fallowing on caligid infestations in farmed Atlantic salmon (Salmo salar L.) in Scotland. In*: Boxshall GA and D Defaye (Eds.) Pathogens of wild and farmed fish: sea lice. Ellis Horwood, London. pp. 255-260.

Gustafson L, Ellis S, Robinson T, Marenghi F, Merrill P, Hawkins L, Giray C and B Wagner (2007). Spatial and non-spatial risk factors associated with cage-level distribution of infectious salmon anaemia at three Atlantic salmon, *Salmo salar* L., farms in Maine, USA. *Journal of Fish Diseases* 30: 101-109.

Johansen R, Kongtorp RT, BornØ G, Skjelstad HR, Olsen AB, Flesjå K, Colquhoun D, Ørpetveir I, Hansen H, Garseth ÅH and B Hjeltnes (2009). *The health situation in farmed salmonids 2008.* National Veterinary Institute, Norway. 18 pp.

McClure CA, Hammel KL and IR Dohoo (2005). Risk factors for outbreaks of infectious salmon anemia in farmed Atlantic salmon, *Salmo salar*. *Preventive Veterinary Medicine* 72: 263-280.

Midtlyng PJ, K Grave and TE Horsberg (2011). What has been done to minimise the use of antibacterial and antiparasitic drugs in Norwegian aquaculture. *Aquaculture Research* 42: 28-34.

Munro ALS (1988). *Furunculosis in farmed Atlantic salmon in Scotland.* Aquaculture Information Series No. 1. Department of Agriculture and Fisheries for Scotland Marine Laboratory. 8 pp.

Munro ALS and IF Waddell (1984). Furunculosis; experience of its control in the sea water cage culture of Atlantic salmon in Scotland. *International Council for the Exploration of the Sea Co-operative Research Report* 32: 1-9.

New Zealand King Salmon Ltd. (2011). *NZ King Salmon Report.* 165 pp.

Poynter R (1983). *Stock and year class separation. In*: Meyer FP, Warren JW and TG Carey (Eds.) A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Michigan. Special Publication 83-2. pp. 59-62.

Saksida SM (2006). Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms* 72: 213-223.

Sim-Smith C, Faire S and A Lees (2014). *Managing biosecurity risk for business benefit.* Aquaculture biosecurity practices research report prepared by Coast and Catchment Ltd. for the Ministry for Primary Industries. 209 pp.

Sim-Smith C and A Forsythe (2013). *Comparison of the international regulations and best management practices for marine fish farming.* Prepared for the Ministry of Primary Industries. NIWA client report no. AKL2013-013. 85 pp.

St-Hilaire S (2000). *Epidemiology of infectious hematopoietic necrosis disease in net-pen reared Atlantic salmon in British Columbia, Canada.* PhD thesis, University of Guelph. 225 pp.

Wheatley SB, McLoughlin MF, Menzies FD and EA Goodall (1995). Site management factors influencing mortality rates in Atlantic salmon (*Salmo salar* L.) during marine production. *Aquaculture* 136: 195-207.

6 Appendices

6.1 RELEVANT LEGISLATION

Agricultural Compounds and Veterinary Medicines Act 1997
http://www.legislation.govt.nz/act/public/1997/0087/latest/whole.html

For further information see Ministry for Primary Industries website:
http://www.foodsafety.govt.nz/industry/acvm/

Animal Products Act 1999
http://www.legislation.govt.nz/act/public/1999/0093/latest/DLM33502.html

For further information see Ministry for Primary Industries website:
http://www.foodsafety.govt.nz/policy-law/food-regulation/nz-food-legislation/APA-1999/

Animal Welfare Act 1999
http://www.legislation.govt.nz/act/public/1999/0142/latest/DLM49664.html

For further information see the Ministry for Primary Industries website:
http://www.biosecurity.govt.nz/regs/animal-welfare

Aquaculture Reform (Repeals and Transitional Provisions) Act of 2004
http://www.legislation.govt.nz/act/public/2004/0109/latest/DLM324738.html

For further information see the Ministry for Primary Industries website:
http://www.fish.govt.nz/en-nz/Aquaculture+Reform/default.htm

Biosecurity Act 1993
http://www.legislation.govt.nz/act/public/1993/0095/latest/DLM314623.html

For further information see the Ministry for Primary Industries website:
http://www.biosecurity.govt.nz/biosec/pol/bio-act

Building Act 2004
http://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html

For further information see the Department of Building and Housing website:
http://www.dbh.govt.nz/blc-building-act

Conservation Act 1997
http://www.legislation.govt.nz/act/public/1987/0065/latest/DLM103610.html?src=qs

For further information see the Department of Conservation website and contact your local DOC office:
http://www.doc.govt.nz/get-involved/apply-for-permits/interacting-with-freshwater-species/

Consumer Guarantees Act 1993
http://www.legislation.govt.nz/act/public/1993/0091/latest/DLM311053.html

Fair Trading Act 1986
http://www.legislation.govt.nz/act/public/1986/0121/latest/DLM96439.html

Fisheries Act 1996
http://www.legislation.govt.nz/act/public/1996/0088/latest/DLM394192.html

For further information see the Ministry for Primary Industries website:
http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/Marine-based+Aquaculture/Planning+and+Consenting.htm

Food Act 1981
http://www.legislation.govt.nz/act/public/1981/0045/latest/DLM48687.html

For further information see Ministry for Primary Industries website:
http://www.foodsafety.govt.nz/policy-law/food-regulation/nz-food-legislation/
http://www.foodsafety.govt.nz/policy-law/food-regulation/nz-food-legislation/food-act-1981.htm
http://www.foodsafety.govt.nz/industry/sectors/seafood/

Freshwater Fish Farming Regulations
http://www.legislation.govt.nz/regulation/public/1983/0278/latest/DLM93756.html

The Regulations apply to all fish farming above the mean high-water mark and include cage farming in freshwater canals and aquaria inside buildings. Farming on land using seawater or brackish water (either pumped in from the sea or circulated around the farm), are also subject to the Regulations. The Regulations do not cover marine farms such as mussel and oyster farms, and finfish sea cages below Mean High Water Springs (see marine-based aquaculture for more information).

For further information see Ministry for Primary Industries website:
http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/Land-based+Aquaculture/default.htm

Hazardous Substances and New Organisms Act 1996
http://www.legislation.govt.nz/act/public/1996/0030/latest/DLM381222.html

For further information see Environmental Protection Authority website:
http://www.epa.govt.nz/about-us/what/Pages/Hazardous-substances-and-new-organisms.aspx

Ministry for Primary Industries website:
http://mpi.govt.nz/

Health and Safety in Employment Act 1992
http://legislation.govt.nz/act/public/1992/0096/latest/DLM278829.html

For further information see Department of Labour website:
http://www.dol.govt.nz/hs/law/quickguide/index.shtml

Marine Mammals Protection Act 1978
http://www.legislation.govt.nz/act/public/1978/0080/latest/DLM25111.html

For further information see the Department of Conservation website:
http://www.doc.govt.nz/conservation/native-animals/marine-mammals/sharing-our-coasts-with-marine-mammals/

Marine Reserves Act 1971
http://www.legislation.govt.nz/act/public/1971/0015/latest/DLM397838.html

For further information see Department of Conservation website:
http://www.doc.govt.nz/publications/conservation/marine-and-coastal/marine-protected-areas/review-of-the-marine-reserves-act-1971/
http://www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/

Maritime Transport Act 1994
http://www.legislation.govt.nz/act/public/1994/0104/latest/DLM334660.html

For further information see Maritime New Zealand website:
http://www.maritimenz.govt.nz/Rules/
http://www.maritimenz.govt.nz/Rules/List-of-all-rules/List-of-rules.asp#marine_protection

Māori Commercial Aquaculture Claims Settlement Act 2004
http://www.legislation.govt.nz/act/public/2004/0107/latest/DLM324349.html

For further information see Ministry for Primary Industries website:
http://www.fish.govt.nz/en-nz/Aquaculture+Reform/Maori+Commercial+Aquaculture+Settlement.htm

Medicines Act 1981 and its Regulations 1984
http://www.legislation.govt.nz/act/public/1981/0118/latest/DLM53790.html
http://www.legislation.govt.nz/regulation/public/1984/0143/latest/DLM95668.html

For further information see:
http://www.health.govt.nz/our-work/regulation-health-and-disability-system/medicines-act-1981

Misuse of Drugs Act 1975
http://www.legislation.govt.nz/act/public/1975/0116/latest/DLM436101.html

Resource Management Act 1991 (RMA)
http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

The Resource Management Act 1991 (RMA) is the primary legislation which governs the establishment of marine farms. The RMA aims to promote the sustainable management of the natural and physical resources of our environment. Under the RMA, New Zealand's regional councils and unitary authorities are responsible for managing marine farms within their coastal marine area - the zone between the line of highest tide water mark and the 12 nautical mile limit.

For information regarding planning and consenting see Ministry for Primary Industries website:

http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/Marine-based+Aquaculture/Planning+and+Consenting.htm

For further information see Ministry for Primary Industries website:
http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/default.htm
http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/Marine-based+Aquaculture/default.htm

Resource Management Act (Marine Pollution) Regulations 1998 (Amendment Regulations 2002)
http://www.legislation.govt.nz/regulation/public/1998/0208/latest/DLM253727.html
http://www.legislation.govt.nz/regulation/public/2002/0099/latest/DLM121477.html

For further information see Ministry for the Environment website:
http://www.mfe.govt.nz/rma/central/marine-pollution-regulations.html

Te Ture Whenua Māori Amendment Act 1993
http://www.legislation.govt.nz/act/public/1993/0004/latest/DLM289882.html

Veterinarians Act 2005
http://www.legislation.govt.nz/act/public/2005/0126/latest/DLM363859.html

Wildlife Act 1953
http://www.legislation.govt.nz/act/public/1953/0031/latest/DLM276814.html

For further information see Department of Conservation website:
http://www.doc.govt.nz/about-doc/role/legislation/wildlife-act/

For further information see Fish and Game website:
http://hunting.fishandgame.org.nz/wildlife-act-1953