FISHERIES RESEARCH SERVICES

FINAL REPORT OF THE AQUACULTURE HEALTH JOINT WORKING GROUP SUB-GROUP ON DISEASE RISKS AND INTERACTIONS BETWEEN FARMED SALMONIDS AND EMERGING MARINE AQUACULTURE SPECIES

Submitted to the Deputy Minister for Environment and Rural Affairs of the Scottish Executive, British Marine Finfish Association, Scottish Quality Salmon, Shetland Salmon Farmers Association, Western Isles Aquaculture Association, British Trout Association, Association of Scottish Shellfish Growers and other members of the Scottish aquaculture industry and associated stakeholders.

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FOREWORD

Diversification has become an important factor in the sustainability of the aquaculture industry and the continued economic revival of rural communities. Atlantic halibut, Atlantic cod and haddock are all species recently introduced into aquaculture and other fish and invertebrate species are currently in the “demonstration” phase of development where the animals’ commercial potential is being evaluated by research institutes. Whilst the former species are common fish at the fishmonger and popular fish across Northern Europe, the data available for these species from the research environment is extremely scarce. Consequently, little is known about the likely disease risks from, and to, these species once they are placed in the intensive conditions of modern commercial fish farms. This is particularly so of niche species such as Lemon sole, Lumpsucker, Sea Urchins or Abalones, all of which are being investigated as potential suitable species for temperate water aquaculture.

To assist in our assessment of the disease risks between aquaculture species, the Aquaculture Health Joint Working Group (AHJWG) established an New Species Interactions Sub-group to review the current state of the art of our understanding of the infectious diseases of emerging species, the risks and potential interactions between the diseases of established and emerging aquaculture species, and to provide a risk analysis of the likelihood of new infectious diseases emerging. The principal purpose of the sub-group was to advise the Ministerial Working Group for Aquaculture, the sub-group’s brief was to produce this review document and provide recommendations towards risk reduction measures and identify areas where research effort is required.

This report is submitted to the Deputy Minister for Environment and Rural Affairs of the Scottish Executive, British Marine Finfish Association, Scottish Quality Salmon, Shetland Salmon Farmers Association, Western Isles Aquaculture Association, British Trout Association, Association of Scottish Shellfish Growers and other members of the Scottish aquaculture industry and its associated stakeholders. It represents a comprehensive review of disease risks and interactions between farmed salmonids and emerging marine aquaculture species with a strong emphasis on the Scottish situation. It should serve as a useful reference source for regulators, aquaculture specialists and veterinarians as well as providing an accessible source of information to other stakeholders.

As always I am exceedingly grateful to the membership of the New Species Interactions Sub-group for their valuable input into this document during its evolution and the subsequent efforts of our editor and graphic designers for the layout and the cover.

Finally, it is my sad duty to reflect the wishes of the AHJWG in dedicating this document to the memories of two of the sub-group’s members. Gordon Rae, who was a founder member of the AHJWG, sadly passed away shortly after the sub-group began its work. Tragically the sub-group also suffered a second loss with the unexpected death of Niall Bromage. The task of the sub-group was made far more difficult with the loss of their valuable insight into the issues considered. I hope that this document reflects their goal of providing a sustainable and dynamic aquaculture industry that makes a vital contribution to the well being of rural communities in Scotland.

Dr Ian Bricknell
Chair AHJWG New Species Interactions Sub-group
March 2005

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AHJWG	Aquaculture Health Joint Working Group
BKD	Bacterial Kidney Disease
CoP	Code of Practice
DAO	Designated Area Order
EC	European Community
EEA	European Economic Area
EU	European Union
FRS	Fisheries Research Services
IHN	Infectious Haematopoietic Necrosis
IPN	Infectious Pancreatic Necrosis
IPNV	Infectious Pancreatic Necrosis Virus
ISA	Infectious salmon Anaemia
ISAV	Infectious Salmon Anaemia Virus
RAS	Recirculation Aquaculture Systems
SCOFCAH	Standing Committee on the Food Chain and Animal Health
SEERAD	Scottish Executive Environment and Rural Affairs Department
SVC	Spring Viraemia of Carp
TDN	Thirty Day Notice
UK	United Kingdom
USA	United States of America
VHS	Viral Haemorrhagic Septicaemia
VHSV	Viral Haemorrhagic Septicaemia Virus

ACKNOWLEDGEMENTS

The AHJWG would like to dedicate this document to the memory of

Mr Gordon H. Rae 1947-2003

and

Professor Niall Bromage 1942-2003

who were inspirational in the development of this report.

We would also like to acknowledge the following who made a valuable contribution to the work of the sub-group and the preparation of this document:

Mr Andrew Grant	Fish Veterinary Society
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Mr Steve Rex	Western Isles Aquaculture Association
Wendy-Louise Smith	SEERAD
Dr Ron Stagg	FRS
Mr Scott Inglis	FRS

Finally, we wish to thank the Institute of Aquaculture for accommodating the sub-group meetings.

SUB-GROUP MEMBERSHIP

Dr Ian Bricknell	FRS (Chair)
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Mr Paul Shave	SEERAD
Mr Richard Slaski	British Marine Finfish Association
Mr Mike Thomson	Marine Harvest (Scotland) Ltd
Mr Dave Wyman	SEERAD

SCHEDULE OF SUB-GROUP MEETINGS

8 May 2002
13 June 2002
15 July 2002
27 November 2002
14 January 2003
19 February 2003
10 June 2003
19 August 2003
7 October 2003
5 November 2003
17 March 2004

TERMS OF REFERENCE

- To define the range of possible interactions between aquaculture species in Scotland.
- To develop a risk assessment matrix for these interactions and to suggest risk-reduction strategies within the following broad categories:
    - Fallowing and stocking options
    - Surveillance and information gathering
    - Husbandry practices
    - Farmed/wild interactions
- To prepare a report for the AHJWG making recommendations on the management of emerging species.

CHAPTER 1: SUMMARY OF RECOMMENDATIONS

1) **There should be continued and ongoing research to establish potential disease risks between emerging and established finfish and shellfish species. The information generated should influence the evolution of policy and regulation.**

2) **All aquaculture sectors should follow the industry Code of Practice for Scottish Finfish Aquaculture (the 'CoP').**

3) **There should be continued and ongoing research to develop and evaluate new vaccines and vaccine strategies for emerging species.**

4) **Where fish, fish parts or tissues are to be used to feed brood fish, these should be pasteurised, irradiated or otherwise processed to a standard which ensures a microbiologically safe product.**

5) **Farmed fish should not be fed to other farmed fish.**

6) **It is recommended that finfish farms should enter into a Farm Management Agreement as described in the CoP.**

7) **Fallowing protocols form an integral part of a Farm Management Agreement.**

8) **There should be continued and ongoing research to develop and evaluate the potential of non-destructive testing to establish the health status of brood stock and potential broodstock animals.**

9) **In the absence of non-destructive testing of newly recruited broodstock, there should be relevant health testing of their progeny and, if available, animals from the same cohort that were not recruited to the broodstock population.**

10) **Newly recruited brood stock should be kept under conditions of high biosecurity.**

11) **The introduction of exotic species for farming purposes is considered to be a major risk to fish health and should only be permitted under strictly controlled conditions.**

12) **Containment facilities should be fit for purpose and regularly checked and maintained to ensure biosecurity and reduce the risk of escapes.**

13) **The importation of live fish poses a greater risk of disease introduction than using fish produced domestically. This risk may be reduced by only stocking single species sites. Prior to the importation of live fish or eggs, the health status of the population should be determined through rigorous testing for diseases of concern.**

14) **Imported live fish should not be moved for an appropriate period to establish whether or not they are infected with any disease agent.**

15) **Dead fish must be disposed of by an approved method in accordance with legislation. Mortality disposal points, for example communal ensiling points, can be a hub of infection and strict biosecurity measures are essential.**

16) **The number of origins of fish on a farm (and ideally in a Management Area) should be limited as far as possible.**

17) **Stress in general reduces the host's ability to fight disease and should be minimised by utilising established welfare indices for the species.**

18) **Research is required to establish welfare indices for new finfish species.**

19) **The slaughter of fish should be carried out under conditions of containment, and all blood and waste water from such activities should be disinfected and disposed of in an approved manner.**

20) **Movements of grower fish for on-growing in a different coastal Management Area should not be conducted unless absolutely essential.**

21) **Vessels and vehicles used to transport live fish should be disinfected between deliveries.**

22) **'Bus stop' deliveries should be avoided. However, deliveries may be allowed *via* a fallow site or series of fallow sites. This does not preclude delivery to a site containing fish as long as the vessel does not subsequently proceed to another site.**

23) **Live fish should not be held in pens at harvest processing sites.**

24) **Liquid effluent from processing plants should be disinfected.**

25) **Inadvertently co-produced species, for example saithe, should be harvested together with the aquaculture species and, if not used for human consumption, they should be disposed of in an approved manner.**

26) **The reporting of abnormal, unexplained mortality of fish to the official service should be mandatory.**

27) **Official movement restrictions should be applied where an unexplained mortality is experienced.**

28) **New broodstock farms should be located out with existing farm Management Areas.**

29) **Cage sites should be single species only. However, the Ministerial Working Group which established *A Strategic Framework for Scottish Aquaculture* agreed that, as an interim measure, for the first three to six years of the development of a particular sector it may be necessary to farm more than one species on a single site.**

30) **Due to the high risk to the trout industry from Viral Haemorrhagic Septicaemia, trout brood fish on marine farms should be stripped on**

site and only fertilised trout eggs that have been properly disinfected should be transferred to fresh water.

31) EC fish health legislation should be amended to take account of the different genotypes of VHS virus. Genotypes 1a and 1b should be maintained as a List II disease.

CHAPTER 2: SPECIES OF FINFISH AND SHELLFISH CURRENTLY BEING CULTURED IN SCOTTISH WATERS

Marine aquaculture in Scotland has undergone a major diversification in the past few years. It has developed from an industry dominated by Atlantic salmon and rainbow trout into an industry which now cultures five major species (those species being cultured on four or more sites), as well as six minor species (those being cultured on less than four sites or being evaluated for research purposes).

The principal species are (in descending order of production):

Rank

1 Atlantic salmon (*Salmo salar*)
2 Rainbow trout (*Oncorhynchus mykiss*)
3 Sea trout (*Salmo trutta*)
4 Atlantic cod (*Gadus morhua*)
5 Atlantic halibut (*Hippoglossus hippoglossus*)

The other species (also presented in descending order of production, which may change as a species is evaluated and accepted or rejected as being suitable for aquaculture) are:

Rank

6 Arctic char (*Salvelinus alpinus*)
7 Cleaner wrasse* (*Ctenolabrus rubertis, Ctenolabrus exoletus*, *Labrus mixtus* and *Labrus bergylta)*
8 Haddock (*Melanogrammus aeglefinus*)
9 Lemon sole (*Microstomus kitt*)
10 Lumpsucker (*Cyclopterus lumpus*)
11 Hake (*Merluccius merluccius*)

* Not cultured but wild caught and used as a biological control for ectoparasites.

Shellfish culture in Scotland has also undergone significant diversification, and now four major species are cultured (those species being cultured on four or more sites), as well as six minor species (being cultured on less than four sites or being evaluated for research purposes).

The principal species are (in descending order of production):

Rank

1 Mussels (*Mytilus edulis*)
2 Pacific oysters (*Crassostrea gigas*)
3 King scallops (*Pecten maximus*)
4 Queen scallops (*Aequipecten opercularis*)
5 Native oysters (*Ostrea edulis*)

The species also presented (in descending order of production, which may change as the species are evaluated and accepted or rejected as being suitable for aquaculture) are:

Rank

6 Manila/Native clams (*Venerupis philippinarum & Corbula gibba*)
7 Cockles (*Cardium edule*)
8 Lobster (*Homarus gammarus*)
9 Urchins (*Strongylocentrotus sp. et al*)
10 Abalone (*Haliotis tuberculata*)

As Scottish aquaculture develops over the next ten years to increase production of these animals (and possibly other species) the risk of inter-species disease interaction may also increase.

CHAPTER 3: DEFINITIONS OF POSSIBLE AQUACULTURE PRACTICES

It is appropriate to review the types of aquaculture practices that occur in Scotland.

3.1 Single Species Finfish Cage On-growing

Cage farms with just one species of fish being grown, but within areas or bodies of water which are also used for farms growing other species. The combination of species could cover the full range: Atlantic salmon, sea trout, rainbow trout, cod, haddock, halibut as well as shellfish.

3.2 Mixed Species Cage Farms or Co-culture

Mixed species cage farms, later referred to in this report as co-culture, is a scenario (probably of short-term relevance) where a farmer wishes to test a small crop of one species of fish in one or more cages attached to a farm, which is predominantly growing another species. Currently, the most likely scenario would be cod on a salmon farm though other combinations might occur.

3.3 Marine Finfish Hatcheries and Nurseries

It is very likely that marine finfish hatcheries will hold several different species of fish as brood stock and undertake rearing of some or all of the species during a year. Good management would suggest that actual commercial larval rearing runs would be mono-species within any one season, although the prospect of small production batches of related species is likely. Good site selection, tank separation and hygiene practices will minimise the risk of inter-species effects from a health point of view within a hatchery or nursery farm.

3.4 Land-based On-growing Units

Several studies(1) illustrate that land-based on-growing of any seawater fish species adds significantly to the production cost of the fish. With current market values of farmed salmon and likely future values of farmed cod and haddock, this addition to production cost is commercially non-viable. Consequently, it is likely that land-based marine finfish on-growing farms will be restricted in number in Scotland and will only be concerned with production of high value species such as halibut and possibly turbot**.** Land-based on-growing units are most likely to be single species but there is always the possibility that experimental batches of other species will be grown at the same time. Such farms are multi-year class in operation and have to remain so to be economically viable. Thus, fallowing of entire land-based sites is not commercially possible.

Individual tanks or ponds can be readily isolated and empty tanks or ponds are routinely disinfected before introducing new fish. Good tank separation and hygiene practices on site will minimise the risk of inter-species effects, from a health point of view, within a farm. Whilst there is a risk of disease transmission in effluent and influent water it is not usual to disinfect this water due to the large volume required. However, sea-water may act as a vector for pathogens such as Infectious Pancreatic Necrosis Virus (IPNV) and a risk remains.

A new subset of land-based farming is the use of recirculation aquaculture systems (RAS). These use much lower volumes of new water and offer prospects for temperature control, thus widening the choice of species that might be farmed.

However, the RAS approach adds a significant amount to the production cost of the fish and is, thus, likely to remain small scale in Scotland.

3.5 Shellfish Farms Close to Cage Finfish Farms

The concept of nutrient balancing in terms of nitrogen has been highlighted for Scottish aquaculture. Finfish contribute nitrogen to the marine environment and harvesting shellfish removes nitrogen. In fact, the mass balance equations do not provide much hard scientific support for this concept – natural nitrogen fluxes are much more important and the inputs of nitrogen from finfish farms are only a very small component of the total. There are current guidelines about separation between finfish and shellfish farms, but if some farmers adopt the policy of co-culture, they may wish to grow shellfish in close proximity to their finfish cages. This raises a number of points:

- Can bivalve molluscs bio-accumulate and replicate finfish pathogens and, therefore, act as vectors for finfish pathogens and *vice versa*? If they do, are they vectors for the transmission of these diseases?
- The crop cycles may be very different, so co-ordinated harvesting and fallowing is not possible;
- Potential bio-accumulation of materials, such as licensed anti-foulants and medicines, from the finfish farm into the adjacent shellfish might be an area for concern to the shellfish industry.

3.6 Macroalgae Close to Cage Finfish Farms

Another possible way of sequestering nitrogen released from finfish farming is to cultivate macroalgae nearby and harvest and remove the algae from the aquatic environment on a regular basis. There are practical challenges — the algal crop would potentially have to be very close to the finfish farm to capture the immediately released nutrients. These nutrients are quickly incorporated into the natural processes occurring in the coastal waters and are difficult to detect any significant distance from cage farms. The other major challenge is what to do with the seaweeds that are harvested if they have no immediate market potential. They may actually pose a more difficult environmental question than the one they are trying to overcome.

3.7 Polyculture

The subjects addressed in the previous two sections are sometimes combined under the heading of 'polyculture' but for the purpose of this report polyculture is better described as: "*The cultivation of two or more distinct and significant biomasses of marine organism within the same rearing enclosure*". The previous two sections are not necessarily polyculture but the following are considered to be polyculture:

- Cultivation of molluscs or echinoderms on finfish cage structures;
- Deliberate introduction of cleaner species, such as wrasse in a salmon farm;
- Accidental population of any finfish cage with opportunistic species such as saithe;

- Deliberate cultivation of flatfish and round fish species together in the same sea cage or tank.

This definition of polyculture raises distinct questions about animal welfare, accumulation of residues and hosting/replication of disease organisms. These issues need to be resolved.

3.8 Effluent Bio-scrubbing

Although perhaps a sub-set of polyculture, there have been several examples (in other countries) of land-based finfish farmers growing other species in the effluent streams from their farms. These examples include rag worms, bivalve molluscs and terrestrial plants such as samphire. This report cannot comment on other aspects of this type of system but it would be unlikely to affect inter-species health issues within areas of coastal water around Scotland.

CHAPTER 4: DISEASE INTERACTIONS BETWEEN FINFISH SPECIES

Some pathogens, such as the salmon sea louse, *Lepeophtheirus salmonis*, are host specific, whilst other pathogens, such as IPNV, are ubiquitous in nature, affecting all species so far investigated.[2-6] Bringing new species onto a site will provide the opportunity for existing diseases to meet a new host for example IPNV and cod. On the other hand it could provide a pool of infection if one species is not seriously affected by a pathogen but can act as a carrier for the disease. A second species may be highly susceptible to the disease and show clinical signs following co-habitation with the carrier.

The most serious threats to Scottish finfish aquaculture come from the List I and List II diseases, infectious salmon anaemia (ISA) for salmon and viral haemorrhagic septicaemia (VHS) for other species as set out in the Commission Directive 91/67[7]. Recent improvements in the scientific knowledge regarding VHS virus (VHSV) have enabled scientists to differentiate between strains of VHSV that affect different species of fish. Thus, halibut and cod appear to be resistant to the rainbow trout strain of VHSV, as do salmonids to the marine strains of the virus (Table 1), although the current regulations do not distinguish between the strains. The pending review of Council Directive 91/67/EEC[7] is expected to take account of these developments. In the event of Infectious Salmon Anaemia virus (ISAV) being isolated from a salmon farm, any marine finfish species farm within one tidal excursion would be monitored closely – but there is no evidence as yet of any effect of ISA on these species.

The major fish diseases and the known resistance or susceptibility of UK marine aquaculture species are shown in Table 1. It is known from the scientific literature that Atlantic halibut are more resistant to *Aeromonas salmonicida*[8] and VHSV infection than Atlantic salmon, but more susceptible to *Vibrio anguillarum*[9,10] and IPNV infection[2,11-14] than salmonids, at least at the juvenile stages. Infection by *A. salmonicida* and *V. anguillarum* may be controlled by vaccination, using commercially available vaccines originally developed for use in salmonids. There is currently only one vaccine licensed for IPNV in the UK and none for VHSV.

Atlantic cod have been shown to be susceptible to marine rhabdoviruses[15] (but only from Atlantic cod isolates and only then when directly injected into the animal). Work elsewhere has shown that *V. anguillarum* is a potential pathogen of cod but vaccines against *V. anguillarum* are known to be very effective in this species.[16-18] The sea louse, *Caligus elongatus,* has been shown to infect all three species considered in this example[19,20] but conversely the salmon sea louse (*L. salmonis*) will only affect Atlantic salmon[21] and only poses a minimal risk to Atlantic cod and halibut. Cod also have their own, apparently, species-specific caligid ectoparasite, *Caligus curtis*[20], which is found in UK coastal waters.[20] It is not known whether this parasite only has a single host (cod) or could infect other species of fish on the same farm given appropriate conditions. It appears that this experiment is in progress in Scotland as cod is now being farmed in association with Atlantic salmon and this question may be answered under field conditions shortly.

Eighty tonnes of Atlantic halibut were produced in 2001 and production is set to rise to between 6,000 and 10,000 tonnes by 2008 (British Marine Finfish Association projections). Cod production, currently at around 30 tonnes per annum is also expected to rise rapidly due to the current pressures on wild stock availability and the associated price rises. There is an increased official requirement for advice on the management of emerging marine species and salmon farms in shared coastal waters, as well as enquiries as to vaccination strategies and disease risks.

The anticipated harvest size for halibut is 3-4kg achieved over a growing cycle of 3-4 years. Though this effectively rules out synchronous fallowing of halibut and salmon production sites in the same Management Area at the present time, the production cycle for marine finfish species is likely to shorten with improved diets, stock selection and husbandry. Halibut share diseases with salmon, in particular Infectious Pancreatic Necrosis (IPN). There are questions about the susceptibility of halibut to VHSV and ISAV. However, nodavirus remains an issue for the developing industry, especially for hatchery operations where nodavirus has been shown to cause mass larval mortalities. Cases of nodavirus infection have been identified in halibut larvae in Norway(22) and cod in Norway and the UK.(23-27-26) This virus may be vertically transmitted(27) and there has been a single report of nodavirus-like particles in Atlantic salmon also exhibiting cardiomyopathy syndrome.(29) The current status of nodavirus classification is very intricate. There are at least three distinct serotypes isolated from fish(24,30) and numerous genotypes.(27,31,32) It is likely that this is a very complex group of viruses with the different genotypes and serotypes either infecting different species of fish or being geographically distinct.

CHAPTER 5: DISEASE INTERACTIONS BETWEEN FINFISH AND SHELLFISH

Although shellfish have been shown to bioaccumulate bacterial and viral pathogens[33-36] it is unknown whether pathogens of finfish can replicate in shellfish, or be shed in a viable form. In the interest of good fish health practice to minimise the risk of transmission of serious fish disease, a risk assessment based approach to the cultivation of more than one species on site is recommended. However, the perceived risk of transmission of disease through cells carried in the body cavity of molluscs is low.

Movements of fish or shellfish on and between such sites may also increase the risk of introduction of novel pests/diseases or non-indigenous species.

Synchronous fallowing may be of benefit on co-culture sites to avoid cross infection between fish and shellfish populations. The risk of disease transmission could be from shellfish to finfish or *vice versa*. Further research is required before any conclusions can be made. What is clear is that we are not dealing with potential human pathogens in these scenarios, but with the diseases set out in Tables 1 and 3.

CHAPTER 6: DISEASE INTERACTIONS BETWEEN SHELLFISH SPECIES

The native oyster (*Ostrea edulis*) is the shellfish species listed under Directive 91/67/EEC(7) as susceptible to the List II disease *Bonamia ostrea*e and *Marteilia refringens,* (i.e. diseases of serious economic importance present in the community). Scotland enjoys Approved Zone status for both of these diseases. There is a derogation specifically for Pacific oyster (*Crassostrea gigas*) movements from a Non-approved Zone for these species. There is no scientific evidence that any species except *C. gigas* is non-susceptible to *Bonamia* or *Marteilia*. All species, including *C. gigas* may carry the pathogen, however the perceived risk of transmission through cells carried in the body cavity of molluscs is low.

Annex D of Council Directive 95/70/EC lists serious diseases of shellfish occurring in Third Countries (Table 2). Because of an increase in trade between the European Union (EU) and Third Countries, member states must report all cases of abnormal mortalities observed in bivalve molluscs (sudden mortalities observed in approximately 15% of stocks) such that diagnostic and epidemiological investigations can be carried out.

The Manila clam (*Ruditapes philippinarum*) and native clam (*Tapes decussates*) are susceptible to brown ring disease, caused by *Vibrio* sp. (*Vibrio* isolate P1), present in France and possibly Spain. Scallop species have been reported to be susceptible to *Rickettsia* and *Chlamydia* like organisms. The native lobster is susceptible to *Gaffkaemia* and high mortality may occur if held with the more resistant *Homarus americanus* species.

Recommendation

1) There should be continued and ongoing research to establish potential disease risks between emerging and established finfish and shellfish species. The information generated should influence the evolution of policy and regulation.

2) All aquaculture sectors should follow the appropriate industry Code of Practice (the CoP).

CHAPTER 7: CONTROL MECHANISMS THAT CAN BE INSTIGATED TO PREVENT THE SPREAD OF DISEASE AND REDUCE THE RISK OF EXPOSURE

Control measures currently employed for major diseases of marine finfish aquaculture in European waters are shown in Table 3.

7.1 Movement Restrictions

Official movement restrictions prohibit the movement of live fish or their eggs to or from a farm under suspicion of infection with a notifiable disease without written authorisation from the Scottish Ministers. For salmon farming, there is a presumption against seawater movements[(36)]. Whilst movements between marine farms are essential for the stocking of marine finfish species, movements of animals between on-growing sites is presumed against.

7.2 Clearance of a Farm

In the case of the List I and List II diseases of finfish, official confirmation will lead to controlled compulsory removal of all the fish on the farm.

7.3 Fallowing

In salmon sea cage farming, it is common practice to fallow a site to break the infection cycle after a production cycle. This is particularly important for sea lice control but is also effective in controlling bacterial and viral diseases. Fallowing is compulsory following clearance of a site under official suspicion or confirmation of a List I or List II disease.

7.4 Site Selection

Currently, planning applications for marine fish farm sites are processed by the Crown Estates Commission for mainland Scotland, Orkney Islands Council for the Orkney Islands and Shetland Islands Council (SIC) for the Shetland Islands (planning will be devolved to local authorities in the near future). The Scottish Executive Locational Guidelines (see www.scotland.gov.uk/about/ERAD/FFAME/00015513/page1841062677.aspx) specify a minimum separation distance of 8,000 metres between finfish farms, 3,000 metres between finfish and shellfish farms and 1,500 metres between shellfish farms. SIC policy allows for a minimum separation between finfish farms of 1,000 metres where no management agreement exists, with no minimum separation where a management agreement is in force between farms. The Scottish Executive guidelines allow for closer siting between small-scale farms and in large loch systems or open water. The emphasis should lie with area-wide mitigation of disease interactions such as inter-site production management agreements and maintenance of disease firebreaks, rather than solely on a site-specific basis.

Where farms are located within two tidal excursions of one another it is recommended that farmers enter into a Management Agreement covering Management Areas of mutual concern. An example management agreement can be found in the *Final Report of the Joint Government/Industry Working Group on Infectious Salmon Anaemia (ISA)*, pp 109, Box 5.1a.

In addition to the question of separation, there are other issues to consider. Any site must give reasonable shelter from adverse weather and sea conditions to give appropriate conditions for the growth and welfare of the species to be farmed. This is to maintain the integrity of the site and to allow the site to be operated and serviced with regard to good husbandry practice on a daily basis. Currently, there are no true open water fish farms in Scotland, although as advances in cage technology are made, sites are being located in more exposed areas.

7.5 Vaccination

There are many effective vaccines available for the control of fish diseases. Vaccines are administered early in the production cycle and under ideal conditions will provide protection throughout the growing cycle. Re-vaccination strategies are also a possibility in marine finfish culture and may provide a valuable method for reducing disease risk in long-lived batch spawning animals. However, it should be noted that there are no vaccines licensed for new species and currently they are used under the cascade system. The routine use of vaccines in approved zones for List I and List II diseases is not permitted in the EU as this may adversely interfere with monitoring exercises to detect evidence of the presence of the virus. The legal and preferred control strategy is to eradicate these diseases by withdrawal of fish and by putting in place strict hygiene and disease control measures on infected farms. However, vaccination may be a useful risk reduction measure that could complement sanitary measures in farms, particularly on farms in the coastal zone that are sharing waters and, therefore, have the potential to share disease. Vaccination against ISA may be authorised in accordance with national contingency plans approved by the Commission. The purpose of such vaccination would be to protect stocks in non-affected cages on an infected farm or to protect farms that are already stocked adjacent to an infected farm (*i.e.* ring vaccination) .[37]

Recommendation

3) There should be continued and ongoing research to develop and evaluate new vaccines and vaccine strategies for emerging species.

7.6 Authorised Veterinary Medicines

For some bacterial diseases there are no effective vaccines. In this case the disease may be treated with antibiotics. However, it should be noted that there is only a restricted number of antibiotics licensed for use in fish in the UK and this number is likely to decrease in future as licences may not be renewed when they expire. In addition, a limited range of authorised veterinary medicines is available for the treatment of ectoparasites.

7.7 Husbandry Practices

In most cases, a range of good husbandry practices can restrict the spread of disease. These could include, in appropriate situations, the following:

- Disinfection of equipment and ova;[28,38]
- Use of appropriate stocking densities;
- Site selection;

- Site rotation;
- Fallowing;
- Sourcing stock animals from certified disease-free sources;
- Removal and safe disposal of moribund and dead fish;
- Minimising stress;
- Single sourcing of juvenile animals where possible.

7.8 Nutrition

Diet and feeding can affect the susceptibility of fish to diseases. Dietary additives, such as immunostimulants, may be useful if used strategically. This is a field, which is in its infancy, and targeted research may be of benefit in establishing the efficacy of immunostimulants in disease control. There is a significant risk of introducing pathogens in the feed when using wet fish based diets.

Recommendation

4) Where fish, fish parts or tissues are to be used to feed brood fish, these should be pasteurised, irradiated or otherwise processed to a standard which ensures a microbiologically safe product.

5) Farmed fish should not be fed to other farmed fish.

CHAPTER 8: APPLICATION OF STATUTORY CONTROL MEASURES FOR NOTIFIABLE DISEASES IN FISH FARMS IN SCOTLAND

The area of statutory disease control is a complex one. An explanation of the statutory controls for notifiable diseases is presented in Annex 1. A number of scenarios are outlined below that may apply or be applied to fish farms containing marine species. It should be noted that, in practice, each case will be considered on its merits and veterinary surveillance and disease control measures will be implemented as deemed appropriate by the official service.

Scenario 1. A freshwater farm in the same area as a pump ashore site holding marine finfish species becomes infected or suspected of being infected with a List I or List II disease. Initially, the sites would be visited and inspected to assess the potential for the infection spreading to the marine site. Where site-to-site contact can be established through the transfer of fish, personnel or equipment**,** the marine site would come under official surveillance. Where no such contact can be established, no further action would be taken. Risk assessment of the possible transfer of a List I or List II pathogen to sea water by flow through the catchment would need to be carried out.

Scenario 2. A marine farm in the same tidal excursion as the intake for a pump ashore site holding marine finfish species becomes infected or suspected of being infected with a List I or List II disease. Initially the pump ashore site would be visited and inspected. If there is adequate disinfection of the influent water in place then no further action would be taken. Where no or insufficient disinfection of the influent water is in place, the site would come under official surveillance.

Scenario 3. A pump ashore site holding marine finfish species becomes infected or suspected of being infected with a List I or List II disease. Initially, the pump ashore site would be visited and inspected to assess the potential for the infection to spread to other sites. If site-to-site contact can be established through the transfer of fish, personnel or equipment**,** the other sites would come under official surveillance. Where no such contact can be established, no further action would be taken. Where adequate disinfection of the effluent water is in place, the marine sites within one tidal excursion of the outflow would not come under official surveillance. Where no, or inadequate disinfection of the effluent water is in place, the marine sites (whether cage sites or pump ashore sites) within one tidal excursion of the outflow would be subject to official surveillance. In the case of pump ashore sites, the scenario as presented at Scenario 2 above would apply.

Scenario 4. A marine cage site holding any species becomes infected or suspected of being infected with a List I or List II disease. All other cage sites whose tidal excursion overlaps with that of the infected site would come under official surveillance.

CHAPTER 9: FALLOWING AS A FACTOR IN DISEASE CONTROL

Farms that share the same water body will be at risk of being exposed to similar pathogens. A range of mechanisms can spread infectious agents from farm-to-farm and the close proximity of farms increases the risk presented by some of these mechanisms.[39] Fallowing plays an important role in disease control, or more correctly, the reduction of disease risk on a marine fish farm. The principles of fallowing rely on removing the farmed stock where a pathogen may have become endemic, from a site or whole loch system, allowing any pathogens to decline naturally in the environment. While some benefit can be obtained by fallowing individual sites, fallowing is much more effective if all the farms in a loch system are fallowed synchronously. There are industry-based management agreements for several areas in Scotland, mostly on the scale of a single sea loch. A primary element of these agreements is the synchronising of stocking and harvesting to ensure that fallow periods between production cycles are synchronous throughout the whole Management Area.

Single farm fallowing regimes may be advantageous, but only the area around the fallow farm will benefit. A major risk from infected farmed fish is water, which acts as a vector for the spread of pathogens between sites. There is also the possibility that wild fish that have been in contact with neighbouring infected sites will move into the area after the fallow period. Therefore, when animals are reintroduced there is an increased risk of a disease outbreak compared to a loch system where all the farms were fallow synchronously.

As noted already, there is already a number of Farm Management Agreements in place in Scotland. These were instigated by the aquaculture industry on a pragmatic basis to reduce some of the risks associated with salmon farming. *The Final Report of the Joint Government/Industry Working Group on Infectious Salmon Anaemia (ISA)* contains recommendations for a system of hydrographically defined Management Areas to assist in the management of ISA.[40]

Recommendations

6) It is recommended that finfish farms should enter into a Farm Management Agreement, as described in the CoP.

7) Fallowing protocols must form an integral part of a Farm Management Agreement.

9.1 Atlantic Salmon Broodstock Sites

Although there are about 25 Atlantic salmon broodstock cage sites in Scotland, they pose a particularly difficult problem with regard to the practice of fallowing. Most Atlantic salmon broodstock sites, and all marine fish broodstock sites, practice continual production, introducing a new cohort as required, and can be considered as multi-year-class sites. The continuing presence of broodstock fish in a Farm Management Area, in which all other farms are fallow, clearly has the potential to reduce the efficacy of fallowing as a disease risk reduction measure. However, the biomass of brood stock at a typical site is low compared to on-growing production sites. As one of the main benefits of fallowing is disease control, it is conceivable that Management Agreements covering such existing situations could require the operator of the broodstock site to undertake strategic treatments for disease, such as the use of chemotherapeutants or vaccines, to ensure that the potential infectious load is as low as possible at the end of the fallow period.

Vaccination is a major risk reduction strategy in salmon and existing vaccines are effective in many marine species,[41,42] although they may not be licensed for use in these species. It is possible to administer chemotherapeutants toward the end of the broodstock growing cycle, at least in salmon, to prevent the outbreak of bacterial disease and to control ectoparasites. Re-vaccination strategies are available to broodstock sites where the use of chemotherapeutants is not feasible.

9.2 Marine Finfish Broodstock Sites

Broodstocks of marine finfish species share a number of key attributes, which differentiate them from Atlantic salmon:

- They are all repeat spawners and have a useful life of several years of spawning in captivity.
- They are all very fecund – a relatively small number of female fish produce a very large number of eggs. In practice, there is always a significant over-allowance of breeding stocks.
- In order to achieve economic hatchery operations (and as a bonus in providing year-round consistency in on-growing harvests), marine hatcheries normally keep several distinct broodstocks under different photoperiod-controlled regimes.

Brood stocks are regularly augmented with new, carefully selected fish from the wild or from other farm stocks, so it is possible that potential future brood stocks of marine species such as cod, halibut and haddock might be held for a time on an on-growing farm. The disease risks to potential broodstock animals are similar to those for on-growing animals except that their longevity increases the risk of exposure to pathogens with time. However, the most likely scenario is that potential broodstocks of these species will be transferred to tanks on shore at a relatively early point in their growth cycle.

Recommendations

8) There should be continued and ongoing research to develop and evaluate the potential of non-destructive testing to establish the health of broodstock and potential broodstock animals.

9) In the absence of non-destructive testing for newly recruited broodstock, there should be relevant health testing of their progeny and, if available, animals from the same cohort that were not recruited to the broodstock population.

10) Newly recruited broodstock should be kept under conditions of high biosecurity.

CHAPTER 10: FALLOWING AS A TOOL TO LIMIT INTER-SPECIES DISEASE INTERACTIONS

Since the salmon-farming sector is increasingly moving into a regime of synchronisation of production cycles and fallowing within Farm Management Areas. The integration of marine finfish species production will have to be carefully planned.

Synchronous fallowing is economically feasible for large companies with multiple sites, where the production cycles are similar between the farms within the area. This is not possible for some farms which lack multiple sites. However, these sites should be included in Farm Management Agreements.

At present, it would appear that the following growth cycles might be considered realistic for cage farming in Scotland:

Atlantic salmon	18 – 24 months
Atlantic halibut	24 – 60 months
Atlantic cod	18 – 36 months
Haddock	(24 months +)

The marine finfish species production cycles are not yet certain and the following points need to be considered:

- The production cycle will depend upon the growth rate of the species and upon the eventual requirement for certain harvest sizes to suit market demands.

- Marine species ‘year classes’ will be difficult to define, since juvenile fish will be available from hatcheries on a year-round basis. Acceptable stocking strategies will need to take account of this. It is suggested that a year class is based on the calendar year of the animals hatching.

- Growth rates of these species are becoming better understood as the sector matures but they are also likely to improve in the future, as diets and management practices evolve and as stock selection begins to have an effect.

- In the short term, the scale of operations of marine finfish species farmers is unlikely to be able to support the type of management regime that involves synchronous fallowing.

It is unlikely that there is much realistic prospect of Management Areas with farms holding different species of fish having synchronous fallowing strategies given the longer grow out periods for some of the marine species. However, it may be possible to incorporate a synchronous fallow period at distinct time points, within individual Farm Management Areas.

CHAPTER 11: CULTIVATION OF NEW SPECIES AND THE EMERGENCE OF DISEASES AND PARASITES IN AQUACULTURE

As aquaculture has developed, new and potentially serious diseases have emerged. Among salmonids, diseases such as ISAV and IPNV[(43)] and the parasitic sea louse, *Lepeophtheirus salmonis*,[(44)] have become particularly serious problems. The Scottish ISAV epidemic of 1998/9 cost the industry at least £20m[(45)] and sea lice infestation cost £15-30m per annum.[(44)] However, it must be recognised that these losses are set against a relatively new industry which generates more than £500m of turnover per annum through the 'farm gate' and secondary processing[(46)] and which provides a valuable economic contribution to Scottish coastal and rural communities. No innovative and valuable human activity is without some cost and element of commercial risk.

In other developing sectors of aquaculture other disease problems have emerged, for example white spot syndrome [(47)] and other viral diseases of shrimps, which have cost that industry many hundreds of millions of dollars. It can be expected that as more species come under intensive production diseases will emerge in these sectors – but it should be anticipated that these sectors will not truly 'emerge' if the costs associated with regulatory control outweigh the commercial and socio-economic value of the sectors.

The risk that some of the diseases associated with aquaculture may affect wild stocks must be considered. Escapes of exotic species can result in populations that may harbour diseases. Crayfish plague wiped out many European crayfish populations after American crayfish [(48)] were introduced. French oyster populations suffered mass-mortality from diseases associated with imported Pacific oysters.[(49)]

All live aquaculture animals from other countries must meet the existing legislative requirements before they can be imported into Great Britain. Imported live fish or their products must be accompanied by an original movement document or health certificate, depending on the origin of the stocks. In addition, the farming of non-native species is subject to a licence under The Prohibition of Keeping or Release of Live Fish (Specified Species) (Scotland) Order 2003. To minimise further the risk of introduction of disease, all imported eggs of salmonid fish should be disinfected according to recommended protocols and the packaging disposed of by incineration. Imported eggs of other species should also be disinfected as development of effective protocols allows.

Wild fish recruited for broodstock should be sourced from locations at least one tidal excursion from any fish farm to reduce the possibility that the fish may be infected. Broodfish should always be kept under conditions of high biosecurity but this is particularly important for wild caught fish while their health status is determined. Testing a proportion of the wild fish gives an indication of whether disease is particularly prevalent but does not guarantee the health status of all the fish. Ideally, non-destructive testing of all wild caught fish would be carried out. However, until the necessary techniques are developed, sentinel populations of susceptible fish may be kept with, or in the same water as, quarantined fish to detect potential infection.

Recommendations

11) The introduction of exotic species for farming purposes is considered to be a major risk to fish health and should only be permitted under strictly controlled conditions.

12) Containment facilities should be fit for purpose and regularly checked and maintained to ensure biosecurity and reduce the risk of escapes.

13) The importation of live fish poses a greater risk of disease introduction than using fish produced domestically. This risk may be reduced by only stocking single species sites. Prior to the importation of live fish or eggs, the health status of the population should be determined through rigorous testing for diseases of concern.

14) Imported live fish should not be moved for an appropriate period to establish whether or not they are infected with any disease agent.

11.1 Exacerbation of Existing Diseases

Spread of an infectious disease depends on the duration of infectivity and the number of contacts made over time with susceptible individual fish[.50,51] Such diseases can be prevented by removing infection, or by reducing its rate of spread. Infected individual fish and dead fish are a source of pathogens. In aquaculture, infection can be prevented from spreading by removal of infectious individuals. Treatment using anti-microbials,[52] or other therapeutics,[53] may remove infection but for emerging diseases such treatments may be unavailable. In the absence of treatment, culling may be necessary to eliminate the disease or limit its spread. Farms with clinically diseased individual fish were culled to eradicate ISAV[40] and culling may take place after isolation of the pathogen in the absence of disease.[54] *Gyrodactylus salaris* has been controlled in Norway by using rotenone to cull entire fish populations in 23 rivers.[55] Less drastically, removal of dead fish from cages may keep infection pressure low enough to prevent disease outbreaks. For example, in Norway during the summer months the risk of ISAV outbreaks is tripled on farms that do not remove dead fish daily.[56]

Recommendation

15) Dead fish must be disposed of by an approved method. Mortality disposal points, for example, communal ensiling points, can be a hub of infection, and strict biosecurity measures are essential.

The spread of infection can also be curbed by preventing uninfected and infected individual fish from mixing, or at least reducing the rate at which this occurs. Stocking with fish from multiple sources increases the risk of infection[53] being present on a farm and may increase the risk of evolution of pathogenic strains of disease agents where multiple strains of a potential pathogen occur.

Recommendation

16) The number of origins of fish on a farm (and ideally in a Management Area) should be limited as far as possible.

In aquaculture, increasing fish population density increases the contact rate between infected and susceptible fish, thus increasing the rate of disease transmission. This is fundamental to the theory of epidemics.[50] Appropriate stocking densities will vary according to the species being farmed, but reducing the stocking density may alleviate disease problems if the fish show signs of stress or if clinical signs of disease are already present.

Recommendations

17) Stress in general reduces the host's ability to fight disease and should be minimised by utilising established welfare indices for the species.

18) Research is required to establish welfare indices for new finfish species.

Confinement of fish in one geographic location may allow a local build up in pathogen numbers. VHSV outbreaks in caged Pacific herring may have been due to the build up of the virus in the local environment.[57] Pelagic fish may also be held in coastal environments where pathogens are more common and from which they cannot escape.[58] *Lernaeocera branchialis*, a serious copepod parasite of cod,[20] may increase in number in farms if the intermediate flat fish hosts are attracted to the vicinity of cages by waste food.

Infection also spreads at a larger scale. Confined populations cannot spread disease directly between each other. Pathogens may spread through the water in tidal currents.[59] Sea lice may spread between farms in their planktonic larval phase.[44] The presence of blood[60] or sediments[61] in the water may greatly improve survival of pathogens. On-site harvesting may result in the release of pathogens and improve their survival if blood is spilt. Thus, on-site harvesting poses a particular risk to neighbouring farms[86].

Recommendation

19) The slaughter of fish should be carried out under conditions of containment and all blood and waste from such activities should be disinfected and disposed of in an approved manner.

Animals may transport pathogens, sometimes over considerable distances. Within the farm, parasites such as sea lice reduce immunity to diseases and may spread diseases such as ISAV[60] between fish. Parasitic infections should be treated promptly where possible. Adult sea lice are probably not effective vectors over longer distances; an exception may occur if inadequately treated, viable lice detach from their host [53] and then find a new host. Treatment of sea lice infestations is most effective when all farms holding salmonids within a Management Area are treated synchronously.

More serious potential vectors at the larger scale are fish and sea birds. Fish such as sea trout with ISAV may actively excrete virus,[62] while other fish and sea birds act as passive carriers of viruses. For example, IPNV can be detected in sea gull faeces.[63] These animals, attracted by waste feed, may actively seek out farms and so carry pathogens over relatively long distances. Escaped fish may pose a particular risk for spreading disease between sites or spreading disease to wild stocks. Sea gulls may also move between fresh and saltwater sites or forage at waste dumps. Scavenging of processing waste by sea gulls is believed to be the route by which white spot syndrome virus of shrimps entered the USA.[64] It is therefore important that fish food is stored securely to prevent access by scavenging animals and nets should be regularly checked and well maintained to prevent escapes.

Strategic design of aquaculture must take into account both the large and small scale transmission processes. The greatest risk of transfer of disease is through movements of fish. Long distance exchanges could result in the introduction of disease into a previously uninfected area. 'Bus stop' deliveries pose a high risk where there are fish already on one or more of the sites visited.

Recommendations

20) Movements of grower fish for on-growing in a different coastal Management Area should not be conducted unless absolutely essential.

21) Vessels and vehicles used to transport live fish should be disinfected between deliveries.

22) 'Bus stop' deliveries should be avoided. However, deliveries may be allowed via a fallow site or series of fallow sites. This does not preclude delivery to a site containing fish as long as the vessel does not subsequently proceed to another site.

Anthropogenic vectors include the exchanges of equipment or visits by well boats to farms.[59,65] Most serious is the movement of live fish,[66,67] but dead fish may also (especially if used as fish feed or bait) spread pathogens.[68,69] Poor biosecurity increases the risk of spread of disease between farms and from farmed fish to wild fish populations. Hubs that could result in widespread infection are harvest processing sites and hatcheries, simply because they have contacts with many farms.[86] It is particularly important to ensure that these sites have strict biosecurity measures in place and are frequently inspected.

Recommendations

23) Live fish should not be held in pens at harvest processing sites.

24) Liquid effluent from processing plants should be disinfected.

25) Inadvertently co-produced species, for example saithe, should be harvested together with the aquaculture species and, if not used for human consumption, they should be disposed of in an approved manner.

In the event of an outbreak of a novel disease, or an abnormal mortality of unknown cause, it is necessary to prevent movements, particularly of fish, off a farm until the cause of the mortality has been established and the risk of disease transmission has been removed. Vaccination, if it is available, may be used in farms perceived to be at risk. For novel diseases, since the likelihood of an effective treatment or cure cannot be known, farmers must consider culling of affected stocks as an option.

Recommendations

26) The reporting of abnormal, unexplained mortalities of fish to the official service should be mandatory.

27) Official movement restrictions should be applied where an unexplained mortality is experienced.

11.2 Evolution of Virulence

In the previous section, aquaculture practices that can lead to disease transmission were described. The parameters of infection such as infectiousness and mortality inflicted can also change due to evolution of the pathogen.[70] This is an essential part of the emergence of new diseases, such as ISAV. Similarly, disease resistance characteristics of a host can change due to natural selection or artificial breeding programmes.[71,72] However, pathogens can evolve much more rapidly, compared with their hosts.[70,73] In particular, the transmission rate may increase with increased host mortality at high host densities if transmission and mortality are traded off against one another (for example, ulceration may increase transmission but endanger the host[74,75]). This increased transmission rate and mortality means that a disease may become particularly damaging – not only does it spread more rapidly, it is also, more likely to result in mortality. Conversely, pathogens that are new to a particular host may evolve reduced virulence as they may initially be excessively virulent for optimal transmission, for example, myxomatosis in Australian rabbits.[76] Virulent pathogens are likely to be strongly selected against when transmission is low precisely because they are more likely to kill their hosts, although they may be able to persist in carrier hosts [77] or in the environment (for example in sediments).[61]

Pathogens may evolve resistance to treatments if these are relied on excessively and not alternated with other treatments[78] (for example, bacteria to antimicrobials[79] or sea lice to medicines.)[53] They may also evolve in response to resistant host strains or vaccines, which may thus lose their effectiveness. It is possible that strains capable of resisting treatment may be more virulent than those that do not. So misused treatments may not only lose their effect, they may also result in a more serious disease.[80] To reduce the likelihood of development of resistance to any veterinary medicine it is important to follow the recommended course of treatment.

Multiple pathogens, or strains of pathogens, may compete for hosts.[74] The more rapidly a pathogen exploits a host, the more of the resources it obtains relative to a competitor. Virulent strains may emerge from such competition.[74,81] Multiple pathogens in a population may become an increasing problem as contacts between farms and populations of fish are increased.

Evolution is most likely to occur where populations persist for long periods. Circulation of pathogens within a population is a particularly effective means of increasing the likelihood that new diseases will evolve. If fallowing breaks transmission, particularly synchronous fallowing of a coastal Management Area, selection for virulence is interrupted. In this respect broodstock farms may be reservoirs of infection and can pose a risk of infection to neighbouring farms. They also pose a risk of evolution of pathogens due to the presence of multiple generations on site.

Recommendation

28) New broodstock farms should be located out with existing farm Management Areas.

11.3 Opportunistic Infections and Disease

Diseases can emerge as microorganisms respond to stress on their host by producing more virulent infections, without evolution. This response to stress increases transmission under aquaculture conditions but evolved for other reasons before such physiological pathways were developed. With dense host populations available, increased production of pathogen at increased cost to the host is adaptive for the pathogen. Virulence is an adaptive response to stress, even in the absence of aquaculture, because if the host is likely to die, well adapted pathogens would exploit it to produce more infective pathogens as fast as possible. These can be released and may find a fresh host. This exploitation will accelerate the decline of the host but if the pathogen does not spread its genes will be lost when the host dies. As a result, under stress, microorganisms that might normally be harmless under wild conditions may become a source of disease in the conditions found in aquaculture. The deployment at sea of anadromous salmon smolts is a good example – outbreaks of fatal IPNV in Europe(82) or of amoebic gill disease (AGD) in Australia(83) frequently occur when these fish are first put in salt water probably owing to the stress of smoltification.

These diseases are best avoided by good husbandry practices, which avoid stress to the fish. If the microorganisms that cause the disease are widespread, biosecurity measures may be ineffective. However, particular infections can be treated by attacking the pathogens, for example, AGD with freshwater.(83) When the disease challenge is low and the fish is not stressed, the immune response can normally prevent clinical disease occurring. Many pathogens are opportunistic to some extent in that manifestations of most clinical diseases often requires environmental stress in combination with the pathogen.(83)

11.4 Cross-species Infection

Co-culture can result in the emergence of disease in a number of ways:

- A known pathogen of existing aquaculture species can cause disease in a new species.

- A parasite or microorganism, which causes no disease in existing aquaculture species (commensal), can cause disease in a new species.

- A known pathogen of a new species can cause disease in established aquaculture species.

- An unknown pathogen, or a commensal organism, of new species can cause disease in established species.

These scenarios are illustrated and expanded in Table 4. Serious diseases can emerge when an infectious agent succeeds in transferring too from one species to another. This is the fourth source of pathogens (after existing, evolving and opportunistic infections already discussed) and one that is likely to change as new species are brought into production. Some of these diseases are extremely virulent when they first emerge. After emerging their virulence characteristics may evolve and this may include reducing virulence.(76)

11.5 Scenarios

In the original host, the infection can either cause disease or be sub-clinical (*i.e.* the host is a carrier). Sub-clinical infections of the original host may not have been identified, or if they are known, they may not be considered potential pathogens for a co-cultured species. Thus, an assessment of the disease risks associated with co-culture will fail to identify as a hazard a sub-clinical infection in one species, which is pathogenic for a co-cultured species.

In the secondary host the pathogen may or may not cause disease. If it does so, the disease may become established in that host, or it may require repeated infection if it transmits poorly. It is also possible for a disease agent to use the second host as a carrier, without serious disease problems, but complicating disease management. Most often, however, it is likely that the pathogen will simply fail to infect a secondary host with which it is brought into contact.

The result is eight categories of infection (Table 4). Carrier status may or may not be transmissible, but separating such scenarios is not practicable and is not shown.

The first scenario is that disease transmits freely between species. A good example would be IPNV which first appeared in trout and has since spread to a wide variety of fish species.(84) The disease may remain able to transmit freely between the old and new host, or it may split into two lineages, each distinct to one host. Virulent freshwater VHSV may have originated as a result of feeding rainbow trout with marine fish.(68) The result is a new disease. Such diseases may go on to affect wild stocks.

The second scenario is that the disease transmits from a permanent host to a second species, but that it does not transmit, or transmits poorly within that species. An example is gaffkaemia of American lobster, which can be transmitted to European lobster, causing disease, but has not become established in European populations.(48)

The third scenario is that the new host can serve as a carrier. An example is ISAV which emerged as a disease in Atlantic salmon and for which sea and rainbow trout can be carriers.(62) Carriers may put both farmed and wild stocks of the original host at risk, since it may be difficult to detect the status of carriers.

The fourth scenario is that the second species cannot be infected by the pathogen. For example ISAV appears unable to infect saithe.(85) There is no new disease problem, indeed cultivation of a non-susceptible species in rotation with a susceptible species can break the disease's cycle.

The fifth scenario is perhaps the most worrying. In this there is no (serious) disease in the original host, but that disease breaks out as the agent transfers to the second host. Risk analysis fails in these cases because the hazard is not identified. Examples include the crayfish plague which has almost wiped out many populations of European crayfish when it spread from introduced American crayfish.(48) In France, Pacific oyster spread pathogens to native Portuguese oyster, with similar mass mortality.(49) In Norway, *Gyrodactylus salaris* has badly damaged stocks of wild Atlantic salmon(55) when introduced with Baltic salmon stocks on which the parasite has limited effect. The result is a new disease, apparently from nowhere (hence risk assessment is not possible) and both farmed and wild stocks may be put at risk.

In the sixth scenario a pathogen may cross the species barrier, but not permanently establish in the new species. Examples are difficult to be certain of in aquaculture because the epidemiology may be very hard to trace, although many examples are known from diseases affecting humans. A possible example is pilchard herpes virus (PHV) in Australia. PHV may have been imported to Australia with imported pilchards. The disease rapidly spread then disappeared, perhaps because there were too few pilchard left to support it.(86) Phocine distemper virus is endemic in the Arctic harp seal population, which may have been the source for the outbreak in the North Sea common seal population.(87) However, the disease did not persist in the latter, although it has recurred. Many cross species outbreaks are likely to be small and perhaps go almost unnoticed. Experience will show when species should not be mixed.

The seventh and eighth scenarios do not involve disease in either host and are only of interest if there is a third host involved. The secondary host might act as a conduit or barrier between the primary host and a tertiary host. For example, ISAV in carrier sea trout might pass to carrier rainbow trout, or be blocked by resistant gadoids, lying between the sea trout and a susceptible salmon population. Such factors will be important for the design of species rotation schedules that minimise pathogen persistence.

11.6 What Conditions Allow Transfer Between Species?

Fish species should never be brought into proximity if one species is showing, or has shown, signs of disease, unless there is strong evidence that the other species is not susceptible. However, there may be no obvious signs of disease in the first species and still a risk of transfer of infection may exist.

Pathogens are most likely to spread to close relatives of the original host and in particular, to different stocks of the same species when these are mixed. Also, closely related groups of species may transfer pathogens for example, ISAV and *L. salmonis* are transferred between salmonids(44,62) but not easily to other species (Snow *et al*. 2002). Some diseases, however, have a wide host range. For example IPNV infects many species of fish(84) and even invertebrates.(88) Opportunistic bacterial infections might have a wide host range and could even be zoonotic. It is, therefore, not possible to rule out any mixing of fish species as a risk of disease emergence, although specific pathogens such as ISAV or sea lice are known to have limited host ranges (as shown in Table 3) and known pathogens' host ranges can be investigated experimentally.

Recommendation

29) Cage sites should be single species only. However, the Ministerial Working Group which established *A Strategic Framework for Scottish Aquaculture* agreed that, as an interim measure, for the first three to six years of the development of a particular sector it may be necessary to farm more than one species on a single site.

Exchange of pathogens between sites will depend on the nature of the pathogen and levels of biosecurity. Processes and practices discussed in section 10.2 control this exchange. Particular risks are spillage of blood during harvesting, escape of fish, scavenging birds and sharing equipment or shipping. These processes may allow pathogens to cross to fish in different cages or even sites.

Imported fish stocks are more likely to carry microorganisms capable of causing disease in local fish stocks, compared to stocks obtained from the same area.(67,69) Local fish may have had no previous exposure to the microorganisms, so if they are pathogenic these fish may not be able to resist their attacks. Wild fish, too, may be at risk from imported pathogens.

Carrier hosts may present very serious conflicts of interest. Producers of the carrier species have little interest in control of the pathogen, which may require expensive and complex regulation. However, producers of the species suffering disease have a very strong interest in control. Effective disease regulation requires that all parties collaborate and government acts as a third party. Ideally, parties to potential conflicts should develop codes of practice prior to the emergence of a problem.

Introduction of a new species into an aquaculture site will result in exposure of the new aquaculture species to diseases present in the original farmed populations. These disease risks can be identified and to a degree assessed if the necessary laboratory investigations have been undertaken. It should be understood that the impact of a disease in a laboratory environment may provide little information on morbidity and mortality that may occur under farm conditions. Our ability to identify all the disease hazards related to culture of new species and co-culture is limited. An analysis of the disease risks presented by culture of new species cannot identify disease agents that cause little or no problem in the fish's natural environment but result in disease under aquaculture conditions. Similarly, it is possible that a disease agent causes no or little clinical effect in its natural host and therefore has not been recognised. This agent may, however, cause clinical disease in another species. Co-culture creates an environment that allows transmission of potential disease agents between species, which would not normally occur in their natural environment. Therefore, it must be concluded that there are disease risks associated with culture of new species and these risks extend to existing aquaculture species. Since it is only possible to evaluate the disease risks of co-culture *a priori* to a limited degree, it is important that measures are taken to minimise disease transmission and to detect disease outbreaks early.

CHAPTER 12: IMPLICATIONS OF POTENTIAL CHANGES TO STATUTORY FISH HEALTH CONTROLS

Chapter 12 summarises the main issues concerning the current statutory fish health controls, as they relate to species diversification within the Scottish aquaculture industry. It considers:

- The current control regime;
- The impact of possible changes to the control regime;
- The consequences of withdrawal of Approved Zone status for certain notifiable fish diseases;
- Recommendations for future Scottish policy on fish health controls.

12.1 Current Control Regime

12.1.1 Council Directive 91/67/EEC concerning the animal health conditions governing the placing on the market of aquaculture animals and products.

In 1973 Great Britain entered the Common Market and in 1993 the single market was established with the intention "*to promote economic and social progress*". This meant that it was illegal to prevent free trade between member states of the EU. It was acknowledged, however, that free trade could lead to the spread of disease if live animals, including fish, were transferred between countries having different health status.

In recognition of the fact that the animal health status for aquaculture animals was not the same throughout the territory of the Community, the concept of Approved and Non-approved Zones was introduced in Council Directive 91/67/EEC concerning the animal health conditions governing the placing on the market of aquaculture animals and products. This Directive was transposed into domestic legislation as The Fish Health Regulations 1992, amended by The Fish Health Regulations 1997 and The Fish Health Amendment (Scotland) Regulations 2001, which apply only to Scotland. Annex A of Council Directive 91/67/EEC groups the diseases of fish that have a significant economic impact into three lists.

12.1.2 List I (ISA)

List I diseases are defined as those diseases having a serious economic impact for which there must be eradication measures. Infectious salmon anaemia (ISAV) is currently the only List I disease. Originally, List I diseases were described as exotic to the EU, since ISAV was only known to occur in Norway. Since then it has been found in Canada in 1994, Scotland in 1998, the Faroes in 2000, Maine, USA, in 2001, Ireland in 2002 and the virus has been reported in Chile. Atlantic salmon is the only species listed as susceptible to ISAV. However, movement controls and fallowing requirements affect other farmed species in close proximity to infected salmon during an outbreak.

12.1.3 List II (VHS and IHN)

The List II diseases are viral haemorrhagic septicaemia (VHS) and infectious haematopoietic necrosis (IHN). They also have a serious economic impact but are present in the Community. Movements of live fish are permitted between zones of equal status or from a zone of higher health status to a zone of lower health status. Fish farms can be Approved Farms within Non-approved Zones. Salmonid species, grayling (*Thymallus thymallus*), whitefish (*Coregonus* spp), pike (*Esox lucius*) and turbot (*Scophthalmus maximus*) are the species listed as susceptible to VHS, while salmonid species and pike fry are listed as susceptible to IHN.

In 1992, Great Britain was granted Approved Zone status for List II diseases based on historical freedom from VHS and IHN (Commission Decision 92/538/EEC). The island of Gigha was subsequently removed from the Approved Zone following an outbreak of VHS in a turbot farm on that island in 1994. The farm was cleared of fish and disinfected under the supervision of the official service. Approved Zone status for the whole of Great Britain was re-established in 2000 (Commission Decision 2000/188/EC). Having Approved Zone status has trade benefits for British fish farming companies because they can export fish to any other zone and imports are only allowed from zones of equal health status.

12.1.4 List III (IPN, BKD, SVC, furunculosis and *G. salaris*)

List III comprises bacterial kidney disease (BKD), spring viraemia of carp (SVC), infectious pancreatic necrosis (IPN), furunculosis and *Gyrodactylus salaris*. Member States may apply for additional guarantees on imports provided their territory is free of the disease in question or if they have a control programme in place with a view to eradicating the disease. Great Britain was granted additional guarantees for BKD, SVC and *G. salaris* in April 2004 under Commission Decision 2004/453/EC.

12.1.5 Commission Decision 2001/183/EC laying down the sampling plans and diagnostic methods for the detection and confirmation of certain fish diseases and repealing Decision 92/532/EEC

Commission decision 2001/183/EC describes the inspection and sampling plans and diagnostic methods required to achieve and to maintain Approved Zone status for VHSV and IHN. To achieve Approved Zone status all the fish farms within a zone must be inspected and have tested negative twice a year for two years. The sample size is 150 fish. Alternatively, in zones where there is a documented history of freedom from the disease the sample size may be reduced to 30 fish.

Maintenance of Approved Zone status requires two health inspections per year on sites with broodstock and one inspection per year on all other sites holding susceptible species. Samples of 30 fish are required to be tested for the presence of VHS or IHN virus annually from broodstock farms and once every two years from farms without broodstock.

12.1.6 Directive 93/53/EEC introducing minimum Community measures for the control of certain fish diseases

In the event that a List I disease is found in the European Community, or a List II disease is found in an Approved Zone, measures are taken to eradicate the disease. These measures are laid down in Council Decision 93/53/EEC introducing minimum Community measures for the control of certain fish diseases (Control Directive).

In May 1998, the official service was notified of the suspicion of ISA at a fish farm in Scotland. This was the first case of ISA in the European Community. The official authority followed the procedures laid down in the Control Directive, which was transposed into domestic legislation as The Diseases of Fish (Control) Regulations 1994. The following procedures were required:

- Investigation to confirm or rule out the presence of the disease;
- Census of the stock on site;
- Designated Area Order (DAO) made to restrict movements of fish, eggs or gametes into and out of the suspect farm;
- Gate Notice served on the owners of the farm restricting the entry and exit of fish foodstuffs, equipment and personnel;
- Supervision of mortality disposal;
- Disinfection at entrances and exits of the farm;
- All farms in the same water catchment or coastal area placed under surveillance;
- DAO made to restrict the movement of fish, eggs or gametes into or out of farms within the surveillance area;
- An epizootic investigation to determine the source and spread of the infection.

On confirmation of ISA further steps were taken in compliance with the Control Directive:

- All the stock on farms confirmed as infected with ISA was withdrawn under the supervision of the official service;
- Harvest-size fish showing no clinical signs of disease were processed for human consumption;
- Cleaning and disinfection of farms confirmed or suspected of being infected with ISA was supervised by the official service;
- Farms confirmed as infected with ISA were not allowed to restock for a minimum of six months and all farms within the control zone were fallow synchronously for a minimum of six weeks.

The Control Directive specified that immediate and effective action must be taken as soon as the presence of ISAV is detected on a farm, in particular, that all fish must be immediately withdrawn. Experience gained during the ISA outbreak showed that it was possible to conduct withdrawal over a period of time where the presence of the virus was demonstrated but there were no clinical signs of disease, without impairing efforts to eradicate the disease. Thus, the Control Directive was amended by Council Directive 2000/27/EC to permit the withdrawal of fish from a farm confirmed infected with ISAV according to a scheme established by the official service and approved by the Commission. Also included in the amendment was a derogation permitting vaccination for ISA in accordance with procedures specified in approved contingency plans in the case of an outbreak of the disease. The amendments to European legislation were transposed into domestic legislation in Scotland as The Diseases of Fish (Control) Amendment (Scotland) Regulations 2000. The withdrawal scheme submitted by the UK authorities for fish farms confirmed infected with ISA was approved in 2001 (Commission Decision 2001/186/EC).

In the event of an outbreak of a List II disease, such as the outbreak of VHS on Gigha, the control measures specified in the Control Directive are very similar to those for ISA. In addition, the infected area must be excluded from the Approved Zone. Although the Control Directive allows for the fattening of fish showing no clinical signs of disease for processing for human consumption, domestic legislation requires the immediate withdrawal of stocks infected with VHS or IHN. As a matter of principle this may well be the preferred option as re-instatement of the Approved Zone as soon as possible may be required. In accordance with domestic legislation, all the stocks on the VHSV-infected turbot farm on Gigha were removed. Harvest-sized fish showing no signs of disease were processed over a two-month period while fish that had not reached market size were culled and incinerated. Since the movement of un-eviscerated fish from an infected zone to an Approved Zone is not permitted, the fish were processed on site. During the two-month period effluent water from the site, which was a land-based tank site pumping seawater, was disinfected.

The company, Booker Aquaculture Ltd, launched a court action for compensation for the destruction of fish stocks infected with VHS against the then Scottish Office. The case was eventually referred to the European Court of Justice by the Court of Session along with a similar case lodged by Hydro Seafood GSP Ltd against the Scottish Ministers for compensation for destruction of fish infected with ISA. The final ruling by the European Court of Justice was that there was no legal requirement for compensation to be payable to fish farmers in the event of compulsory slaughter of farmed fish under statutory disease controls. Compensation has not been paid by the UK Government to fish farmers for losses due to ISA or VHS and insurance companies in the UK do not cover losses due to compulsory slaughter. Thus, such losses must be borne by the fish farming companies themselves.

12.2 Impact of Possible Changes to the Control Regime

In the following section VHS will be used as an example to illustrate the impact potential changes to the statutory disease controls might have on the aquaculture industry. Knowledge of VHS gained since the outbreak on Gigha in 1994 suggests that it might be unnecessary to employ the same control regime if VHSV were to be detected on a marine finfish farm today.

VHSV has been isolated from wild fish in the North Sea and in the Atlantic Ocean off the west coast of Scotland, although clinical disease has not been observed in wild fish in northern European waters. The VHSV isolates from wild marine finfish are not equivalent to the isolates found on the continent with regard to pathogenicity for rainbow trout[(89,90)]. The marine isolates are non-pathogenic, or have a low pathogenicity, for rainbow trout, although rainbow trout in mariculture in Sweden have experienced an outbreak caused by a putative marine isolate. Marine flatfish species, such as turbot, are susceptible to marine isolates of VHSV but Atlantic salmon are generally regarded as resistant to both marine and freshwater isolates. The main candidates for marine finfish aquaculture in Scotland, Atlantic halibut and Atlantic cod, appear to have a very low susceptibility to marine isolates of VHSV[(15,91)].

Nevertheless, it is unlikely there would be widespread industry support for any proposed changes in the control regime in Scotland if these posed any commercial threat to the established aquaculture sectors, specifically Atlantic salmon and rainbow trout.

12.2.1 Changes to the disease listings

Council Directive 91/67/EEC does not distinguish between isolates of VHSV. VHSV isolates can be distinguished by genetic analysis, the genotypes roughly correlating with the geographical region of isolation, but marine isolates are indistinguishable from freshwater isolates by traditional serological means. Council Directive 91/67/EEC is under review at the time of writing. The diseases listed in Annex A of the Directive could be amended to distinguish between the different genotypes of VHSV. Any amendments are subject to agreement by the Standing Committee on the Food Chain and Animal Health (SCOFCAH).

12.2.2 Risk analysis to determine timing of withdrawal of infected fish

The introduction of more flexibility in the control regime would allow for a risk analysis to be carried out by the official authority in the event of an isolation of VHSV from a marine on-growing fish farm. The infected farm and other fish farms within the same coastal Management Area could be placed under official surveillance and movement restrictions applied while the risk assessment and any necessary research required to identify the genotype or pathogenicity of the virus was conducted. If the virus was deemed to pose a low risk to stock on neighbouring farms or to the wild fish population, fish showing no clinical signs of disease could be fattened for harvest for human consumption. European legislation already allows for the fattening of non-clinically affected fish, but domestic legislation would have to be amended.

Extending the period when an infected population is in the sea will inevitably increase the risk to other populations of fish in the same vicinity. This risk must be weighed against the impact of the loss of all stock on the infected site without compensation to the company concerned. In practice, a withdrawal scheme may be of limited benefit to the fish farmer as supermarket chains are reluctant to purchase fish from infected sites because of perceived public opinion, however misguided, that the fish may be unfit for consumption.

The prospect of a withdrawal period for fish affected by VHSV in Scotland does not provide a commercially acceptable solution for the overall industry, and is therefore unlikely to be widely supported, because:

- Processing of harvested fish may require to be undertaken within the Non-approved Zone which might be created, and this could cause significant additional costs to the salmon farms within the zone;
- Experience from the ISA incident in Scotland suggests that the market would be unwilling to purchase salmon harvested from such a Non-approved Zone;
- The requirement for two years inspection and sampling in order to regain Approved Zone status could have serious commercial consequences for lease holders within the zone.

12.2.3 Broodstock sites

In the event of VHS, or any other disease for which there is an eradication policy being detected on a broodstock farm the impact could be particularly severe, especially if the infected farm is the company's only source of brood fish. Potentially, years of stock selection and improvement work and millions of pounds worth of investment could be lost. The importance of biosecurity at broodstock sites cannot, therefore, be underestimated. Not only is there a need to protect brood fish from infection because of the risk of loss of the stock due to a disease eradication policy, but there is a need to ensure that infection is not spread *via* the progeny of an infected population that has gone undetected.

Whether or not true vertical transmission of VHS occurs has yet to be determined but VHSV is shed in the sexual fluids of infected fish, and transmission may occur at the point of fertilisation. Thus, flexibility to on-grow VHSV-infected brood fish to maturity so that their ova or milt can be stripped is not appropriate due to the risk of spread of disease *via* the progeny. There is, therefore, no conceivable modification of current controls, which would prevent total loss of the broodstock unit in the event of VHSV isolation while the current absence of a distinction between marine and freshwater VHSV persists within the EC Directives.

There is no evidence to suggest that ISA is vertically transmitted. Therefore, the introduction of more flexibility in the control regime could allow ISAV-infected fish to be on-grown to maturity, providing a risk assessment was conducted that suggested the timing of withdrawal of the fish could be prolonged without undue risk to others and the fish show no clinical signs of disease. The eggs would require to be disinfected and transferred to a separate site for on-growing. However, the risk associated with eggs from ISAV-infected stock must be considered to be higher than with eggs from negative fish. Indeed, the Standing Committee on the Food Chain and Animal Health (SCOFCAH), formerly the Standing Veterinary Committee, concluded that the risk was unacceptable. Commission Decision 2003/70/EEC, which instructs EU Member States to authorise the importation of live salmonid eggs from Norway, subject to the eggs being disinfected twice, prohibits the importation of live eggs from farms that are suspected or confirmed as being infected with ISAV.

12.2.4 Hatcheries and nursery sites

Increased flexibility in the control regime to allow on-growing of fish showing no clinical signs of disease from populations infected with VHSV would be unlikely to benefit hatcheries, since no movement of infected fish out with the Non-approved Zone would be permitted. Where there are no facilities for on-growing the fish, culling of the stocks on site would be required. This would almost certainly be the case on land-based freshwater salmon or trout hatcheries and pump-ashore finfish hatcheries. This problem emphasises the importance of biosecurity at hatchery and nursery facilities.

12.2.5 Rainbow trout

The greatest risk from VHS is probably to farmed rainbow trout in fresh water. VHS is spread primarily by transport of infected farmed fish and the trade regulations have been successful to date in maintaining freedom from VHS in the continental Approved Zone. Trout farmers should recognise the risk associated with the transfer of trout, as commonly occurs if brood fish are reared in the sea, from marine Approved Zones to fresh water.

Recommendation

30) Due to the high risk to the trout industry from Viral Haemorrhagic Septicaemia, trout brood fish on marine farms should be stripped on site and only fertilised trout eggs that have been properly disinfected should be transferred to fresh water.

12.2.6 Processing of fish from infected populations

Suspension of the island of Gigha from the coastal Approved Zone for VHSV meant that no whole fish could leave the infected zone and all the fish had to be processed on site. There are approximately 20 processing plants in Scotland processing farmed fish. There are at least 46 coastal Management Areas as defined by the *Joint Government/Industry Working Group on Infectious Salmon Anaemia (ISA)*. Obviously, many coastal Management Areas will not be serviced by a processing plant and even where a plant exists it may not be able to cope with the increased volume of fish in the event that a farm in the area is found to be infected with VHSV. Increased flexibility to allow the processing of fish from infected populations out with the infected zone would prevent the considerable additional costs of providing new processing facilities. It could also reduce the time taken to clear the stock from an infected site.

The transport of infected fish for processing would be subject to conditions of full containment to prevent escapes of fish or spillage of blood or ice water if the fish have already been killed. It would also be limited to transfer to the nearest appropriate processing plant. Effluent from a processing plant processing infected fish must be disinfected and solid waste must be disposed of in an approved manner.

Fish farms in the same coastal Management Area as a processing plant processing infected fish are exposed to a greater risk of infection, even if the effluent from the processing plant is disinfected. Where there are fish farms within one tidal excursion of the discharge from a processing plant processing infected fish, those farms should be subject to increased frequency of health inspections. Movement restrictions and suspension of the Approved Zone would be required in the coastal Management Area around a processing plant processing infected fish. It is unlikely that the Atlantic salmon sector would benefit from any attempts to move in this direction.

12.2.7 Vaccination

Currently, the use of vaccines against the List II diseases is prohibited under EU legislation. This was also the case for ISA in the past but Council Directive 2000/27/EC, which amends the Control Directive, introduced the possibility of vaccination against ISAV in the event of an outbreak of disease, subject to contingency plans being approved by the Commission. To date, the vaccines developed for ISA are of only moderate efficacy and protection is not conferred immediately following vaccination, although infection pressure could still potentially be reduced through their use. In practice, there are currently no vaccines for ISA licensed for use in the UK.

Deoxyribonucleic acid (DNA)-type vaccines for VHSV are highly effective in rainbow trout[(92,93)] and confer protection very rapidly. They could be used in the event of an outbreak of disease to ring fence an infected site or zone, although this would require a change to EU legislation. In addition, this type of vaccine has not yet been licensed for use in the UK.

12.3 Consequences of Withdrawal of Approved Zone Status

The Approved Zone status of Great Britain (includes Scotland, England and Wales) would be withdrawn by the Commission if either:

- VHS or IHN were to become established such that stamping out was not a viable option, or;
- The inspections and sampling currently carried out to demonstrate the absence of these diseases were to cease.

It would not be possible for the continental and coastal zones of Great Britain to have different status since there is regular movement of salmon between the zones, in the form of brood stock from seawater to fresh water and smolts from fresh water to seawater.

12.3.1 Impact on exports

Loss of Approved Zone status for the whole of Great Britain would mean that other Approved Zones or third countries (countries out with the EU or the EEA) with the equivalent of Approved Zone status, would not accept trade in live fish, eggs of fish, or non-eviscerated fish of susceptible species from Great Britain. In recent years, there have been export consignments of live Atlantic salmon and trout (ova and fish), Arctic char, halibut and cod ova to the Republic of Ireland, Chile, Northern Ireland, Jersey, Germany, Italy and the Isle of Man. It is highly unlikely that other markets would open up if Approved Zone status were withdrawn.

12.3.2 Impact on imports

If Approved Zone status for VHSV and IHN were withdrawn from the whole of Great Britain, restrictions preventing the importation of live fish, eggs of fish, or uneviscerated fish from zones infected with these diseases would be lifted, although restrictions on imports of live fish from ISAV or *G. salaris* infected zones would still apply. This could potentially open up trade in cheap fish, for example, trout fingerlings, from the European continent. It would also allow the introduction of new bloodlines from other countries, such as Chile. Processors would be able to purchase whole fish from other countries, increasing the reliability of supply of fish and removing any seasonal factors, thereby providing continuous employment throughout the year for more staff.

12.3.3 Impact on domestic trade

Free trade with Non-approved Zones and Third Countries would have an impact on the value of domestically produced aquaculture products, which would have to compete with potentially cheaper products from elsewhere. It is possible that the value of all stages of production from ova, juvenile marine fish, trout fingerlings and salmon smolts through to harvest-sized fish would be affected.

12.3.4 Impact on the health of farmed and wild fish

The consequences of free trade could be particularly serious for the British salmon and trout farming industry if VHSV or IHN were to be introduced. IHN was originally limited to western parts of North America but it has spread to continental Europe and the Far East *via* importations of infected fish and eggs. It principally affects rainbow trout in fresh water but Atlantic salmon reared in freshwater or seawater can be severely affected. Once established in a farm and, therefore, in a water catchment system, both VHSV and IHN usually become enzootic because of the occurrence of virus carrier status in feral or wild fish.

Although losses of farmed fish due to VHSV or IHN are potentially high, it may be that these diseases can be managed such that fish farming is still an economically viable proposition. There would be no compulsory slaughter of fish if the infected farm was in a Non-approved Zone.

12.3.5 Approved farms in a non-approved zone

The likelihood is that if Approved Zone status for the whole of Great Britain was withdrawn, some fish farmers would seek to have their farm(s) designated as approved farms in a Non-approved Zone. The conditions for granting approved farm status are laid down in Annex C of Council Directive 91/67/EEC. In brief, for freshwater farms, the water supply must be from a well, bore hole or spring. There must be a barrier downstream of the farm such that wild fish cannot enter the farm. The farm must have been subject to regular clinical inspections and sampling demonstrating the absence of the disease(s) for which the farm is approved for at least four years. For marine farms, the water supply must be treated to destroy VHSV and IHN virus and the farm must have been subject to regular clinical inspections and sampling, to demonstrate the absence of the disease(s) for which the farm is approved. Approved farms must not have received any fish from a zone or farm of lower health status during the periods of attainment or maintenance of approved farm status.

The scenarios described in this section of the chapter are unlikely to be beneficial to the well established Atlantic salmon and rainbow trout sectors in Scotland. Any recommendations for change in national fish health controls in order to facilitate the safe development of a diversified industry would require the active support of these sectors. Loss of Approved Zone status is not a solution to overcoming the challenges posed by ‘new species’ development in Scotland.

The *Strategic Framework for Scottish Aquaculture* clearly endorses a desire to have a diversified industry. The aspirations of this strategy are hampered by the current fish health regulatory regime as it is set out in Council Directive 91/67/EEC. Whilst future novel diseases might emerge and cause additional regulatory concerns, any fish farmer who wishes to diversify into aquaculture of new marine finfish species in Scotland is constrained by the issue of the eradication policy for VHSV.

This report has identified that there is no satisfactory method of modifying national or even EC regulations in order to foster the development of diversified aquaculture while VHSV remains classified as a single pathogen, which is confirmed only by traditional identification methods. It has also clearly identified the need to retain the strict controls which exist within the EU in relation to the freshwater genotype of VHSV (GT1a & GT1b), since these controls have been demonstrably successful in limiting the spread of this dangerous disease for cultured freshwater rainbow trout and wild fish populations. EC fish health legislation must be amended to take account of the different genotypes of VHSV and the impact that can result from the potential isolation of a marine strain of VHSV from a marine finfish farm. Such an isolation should not trigger the eradication policy which currently prevails in Approved Zones for freshwater VHSV.

Recommendation

31) EC fish health legislation should be amended to take account of the different genotypes of VHS virus. Genotypes 1a and 1b should be maintained as a List II disease.

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Annex 1 Statutory controls for notifiable diseases of fish in Scotland

Notifiable diseases

The diseases of fish that are notifiable in Scotland are infectious salmon anaemia (ISA), viral haemorrhagic septicaemia (VHS), infectious haematopoietic necrosis (IHN), bacterial kidney disease (BKD), spring viraemia of carp (SVC) and Gyrodactylus due to *Gyrodactylus salaris*.

ISA is categorised as a List I disease in Annex A of Council Directive 91/67/EEC (as amended). List I diseases are absent or extremely rare within the EU. VHS and IHN are List II diseases and BKD, SVC and Gyrodactylus are List III diseases. List II diseases are present within the EU but where the absence of VHS and IHN has been demonstrated by regular sampling, approved zones and approved farms within non-approved zones are recognised. Britain is an approved zone for VHS and IHN. The control measures for List I and List II diseases are laid down in Council Directive 93/53/EEC (as amended).

List III diseases are present, although not ubiquitous, within the EU. European legislation makes provision for controls on movements of susceptible species of live fish, their eggs and gametes into zones that are free of a List III disease or where there is a control policy with a view to eradication. These controls, known as additional guarantees, supplement the standard animal health certification requirements. In April 2004, Great Britain was granted additional guarantees in respect of *Gyrodactylus salaris*, BKD and SVC. *G. salaris* has never been found in Great Britain while BKD and SVC are rare and there are official control programmes in place for these diseases.

ISA, VHS and IHN are listed in Schedule 1 of The Fish Health Regulations 1997, which implement Council Directive 91/67/EEC (as amended). Specific control measures, which are laid down in The Diseases of Fish (Control) Regulations 1994 and The Diseases of Fish (Control) Amendment (Scotland) Regulations 2000, are applied to fish farms where the presence of ISA, VHS or IHN is suspected or confirmed. These regulations implement Council Directive 93/53/EEC (as amended).

In the event that ISA is confirmed on a farm, all the stocks on the farm must be withdrawn in accordance with a scheme established by the Ministers. A record of the daily mortality rate on the farm must be kept. Since the whole of Great Britain is an approved zone for the List II diseases of fish, confirmation of VHS or IHN on a farm will result in a notice being issued requiring the immediate withdrawal of all the fish on the farm. Dead fish and fish showing clinical signs of disease must be destroyed. Live fish showing no clinical signs of disease may be slaughtered and marketed for human consumption, under the supervision of the Ministers.

Thirty Day Notices and Designated Area Orders

If there are reasonable grounds for suspecting that any inland or marine waters are or may become infected with a notifiable disease, the Scottish Ministers may designate those waters in order to prevent the spread of the disease. A Thirty Day Notice (TDN) or a Designated Area Order (DAO) may be served on any person who is the occupier of inland waters or any person who carries on the business of fish farming in marine waters situated in the designated area. The power to designate areas is exercised under the Diseases of Fish Acts 1937 and 1983.

A TDN is a temporary notice that may be served as a precautionary measure while an investigation is conducted to confirm or rule out the presence of a notifiable disease. No live fish, or eggs of fish, may be taken into or out of a fish farm and, in addition, no foodstuff for fish may be taken out of a fish farm that is situated in the waters specified in a TDN, without the permission of the Scottish Ministers. In this respect the Fish Health Inspectorate act on behalf of the Scottish Ministers. Applications for permission for movements should be sent to the Fish Health Inspectorate at least 14 days in advance of the proposed movement.

A TDN expires after 30 days but a second TDN may be served when it is not possible to confirm or rule out the presence of a notifiable disease within 30 days. A second TDN extends the period under which the movement controls are effective from 30 days to 60 days from the date on which the first TDN was served. The details of a TDN are confidential and are not published.

A DAO may be made when the presence of a notifiable disease has been confirmed and no action has been taken to remove the stocks and disinfect the farm or, when it is not possible to confirm or rule out the presence of a notifiable disease within the period specified in a TDN. DAOs are published in the Edinburgh Gazette.

DAOs give the Ministers powers to:

- Prohibit the movement of live fish, eggs, or foodstuff for fish, into or out of a farm, without the permission of the Ministers.
- Serve notices requiring the removal of dead and dying fish and the disposal of such fish by a specified method.
- Serve notices (in the case of ISA, VHS or IHN) requiring action to eradicate the disease, including the slaughter of all the fish on a farm.

Gate Notices and Control Notices

Where a Schedule 1 disease is suspected or confirmed on a farm a “Gate Notice” is served in addition to a DAO. A Gate Notice prohibits the movement of dead fish, equipment, personnel and any other material liable to transmit infection, on or off the farm without the written approval of the Ministers.

A control zone, usually equal to one tidal excursion, is established around a suspect or confirmed farm and all farms located within the control zone are subject to movement restrictions in the form of a DAO and a Control Notice. A Control Notice prohibits the movement of dead fish on or off site without the written approval of the Ministers. Both Gate Notices and Control Notices remain in force until varied or revoked by the Ministers.

Restocking of a farm subject to a Gate Notice will not be permitted until the Ministers are satisfied that the farm has been cleaned and disinfected and a fallow period sufficient to prevent re-infection if the farm is restocked has elapsed. The minimum fallow period for a farm where a Schedule 1 disease has been confirmed is six months. Whereas, the minimum fallow period on a suspect site may range from three to six months, depending on the results of a risk assessment conducted by the Fish Health Inspectorate on behalf of the Ministers. Restocking of any other farms in the control zone will not be permitted until all the farms in the zone have been fallow synchronously, usually for a period of not less than six weeks.

A surveillance zone is established such that all farms with overlapping tidal excursions, where one or more farms is suspected or confirmed infected with a Schedule 1 disease, are also subject to a DAO and a Control Notice. Farms in the surveillance zone may not be restocked until they have been cleaned and disinfected and fallow for a period of not less than six weeks. The fallow period is independent of other farms in the surveillance zone.

Revocation of Thirty Day Notices and Designated Area Orders

The restrictions imposed by a TDN will normally lapse if tests undertaken by the Fish Health Inspectorate are negative. A second TDN may be served to allow time to complete the tests. If there remains a strong suspicion that a notifiable disease may be present, but this cannot be confirmed or ruled out for any reason, a DAO may be made. If a DAO is made on suspicion of BKD, the order will be revoked if the disease has not been confirmed within one year.

A DAO will be revoked by a DAO Revocation Order following the removal of all stocks on the farm, the satisfactory inspection of the cleaning and disinfection of the farm and at the end of a fallow period deemed adequate by the Fish Health Inspectorate to ensure that the infection is not likely to recur if the farm is restocked. DAO Revocation Orders are published in the Edinburgh Gazette.

A DAO with respect to BKD may be revoked following withdrawal of all the stocks on the farm and cleaning and, where appropriate, disinfection and fallowing of the farm. Alternatively, the DAO may be revoked following progressive removal of infected stocks and careful management of the farm. Restocking of an infected farm will only be approved if the tanks, ponds, raceways or cages into which the new stock is to be introduced are fallow, cleaned and disinfected prior to the introduction of disease-free stocks. In the case of cages, the nets must be removed, cleaned and disinfected and the surface structures should be scraped clean and disinfected above the waterline. Where feasible, the cages should be removed from the water and cleaned and disinfected to minimise the risk of disease spreading to the new stock. Separate hand nets, buckets etc must be used for the husbandry of disease-free and infected stocked or strict hygiene measures must be employed such that equipment is cleaned and disinfected between batches of fish.

Fish used to re-stock farms subject to a DAO for BKD must be disease-free and must not be mixed with infected stocks on site. It is a condition of approval to restock that grading of disease-free stocks must not result in mixing of disease-free and infected stocks. Where restocking occurs on a frequent basis (*eg* weekly), approval may be granted for the mixing of inputs of disease-free fish over a period of three to four months. Where the farm is restocked continuously with disease-free fish, revocation of a DAO will be possible following an inspection and testing programme according either model A or model B described below.

Model A
Two years of absence of any clinical or other signs of the disease followed by two years of continued absence of signs of disease and negative results of testing of 150 fish twice per year. During the two years preceding the testing programme the farm must have been inspected twice per year.

Model B
Four years of an official health inspection programme documenting historical freedom from the disease followed by two years of continued absence of signs of disease and negative results of testing of 30 fish twice per year. During the four years preceding the reduced sample size testing programme the farm must have been inspected twice per year and a sample of 30 fish tested and found to be negative once per year.

Any farm subject to a DAO for BKD must be inspected twice per year in order that a testing programme can be entered into to allow revocation of the DAO at the earliest opportunity.

A farm subject to a DAO with respect to ISA, VHS or IHN may not be permitted to restock until a fallow period has been completed following disinfection of the farm under the supervision of the Fish Health Inspectorate. Where ISA, VHS or IHN has been confirmed the fallow period will be a minimum of six months. Where one of these diseases is suspected on a farm, the mandatory fallow period will be determined following a risk assessment conducted by the Fish Health Inspectorate and may range from three to six months. Other farms in the control zone established around a farm where ISA, VHS or IHN has been confirmed or suspect will be required to fallow synchronously with the infected farm for a period of not less than six weeks.

Movements of live fish on or off a farm subject to a Thirty Day Notice or a Designated Area Order

Movements of brood stock from sea water to fresh water

The use of fish subject to movement restrictions due to ISA, VHS, IHN or BKD as brood stock is prohibited.

Movements of fish from fresh water farms

The movement of live fish, their eggs or gametes from fresh water farms subject to restrictions due to ISA, VHS or IHN is not permitted.

Movements of fish from one farm infected with BKD to another infected farm may be permitted where such a movement would facilitate the eradication of disease from the farm of origin of the fish. Such movements will only be permitted where the fish are showing no clinical signs of disease and under the supervision of the Fish Heath Inspectorate. Where approval is granted, conditions may be applied with regard to transport arrangements. For example, there may be a requirement to prohibit any discharge of water en-route and to disinfect vehicles or equipment after use.

Movements of growers between sea water farms

Due to the high risk of disease transfer associated with movements of fish between marine farms there is a general presumption against them. Movements of live fish, which are suspected or confirmed as being infected with ISA, VHS or IHN, from one marine fish farm to another will not normally be permitted.

Exceptionally, movements of grower fish from one BKD-infected farm to another, may be permitted under the supervision of the Fish Heath Inspectorate where such a movement would facilitate the eradication of disease from the farm of origin of the fish. The guidelines laid down in *A Code of Practice to avoid and Minimise the Impact of Infectious Salmon Anaemia*, published by the Crown Estate, will be followed when applications for permission to carry out sea water to sea water fish movements are assessed. Thus, movements of fish between different hydrographic zones (management areas) will not be permitted. Similarly, the movement of live fish from a farm holding multiple generations of fish, to another seawater farm is not permissible. This type of movement poses a high risk of disease transfer and is inadvisable even where there is no suspicion of the presence of a notifiable disease.

In all cases, granting permission will only be considered for the transfer of fish showing no clinical signs of disease. Where approval is granted, conditions may be applied with regard to transport arrangements. For example, if a well boat is used it may have to operate with closed valves and be disinfected afterwards.

Movements of fish for harvest

Where a farm is subject to movement restrictions based on confirmation of the presence of ISA, VHS or IHN, permission to move fish slaughtered on site or transferred live directly to a processing plant will be subject to specific conditions. For example, blood must be contained at slaughter and during transport. If a well-boat is used to transport the fish the valves must be closed to prevent water exchange within 5 km of a fish farm. The well-boat should be slipped and disinfected before any other operations are carried out, such as transferring smolts or grading. The processing plant must have effective effluent disinfection facilities and the viscera and any other solid waste must be disposed of as high risk material in accordance with the Animal By-Products Order 1999.

Fish slaughtered on site for harvest are not subject to the restrictions posed by a TDN or DAO. All live fish movements, however, require written permission, even if the fish are being transported directly to a processing plant. Permission may be granted for multiple return journeys taking place over a period of time and may be subject to specific conditions. For example, well-boats transporting live fish should operate with the valves closed within 5 km of another fish farm and the processing plant may be required to disinfect the blood water effluent.

The movement of live fish to a harvest station (temporary holding cages located near a processing plant) poses a high risk of disease transmission to other farms. Harvest stations can act as reservoirs of infection for pathogens released from the processing plant, even if the plant effluent is disinfected. There is a risk of stress-induced disease occurring at the harvest station and if the fish come from multiple origins the likelihood of disease is increased. Well-boats have been implicated in the spread of disease from harvest stations. Therefore, movements of live fish subject to a TDN or DAO will not normally be permitted.

The movement of live fish from a harvest station to another fish farm is not permissible. This type of movement poses a high risk of disease transfer and is inadvisable even where there is no suspicion of the presence of a notifiable disease.

Table 1 Major fish diseases and the known resistance or susceptibility of UK marine aquaculture species (adapted from Bricknell et al 2005 [94])

Pathogen	Species									
	Turbot		Atlantic halibut		Atlantic salmon		Atlantic Cod		Rainbow trout	
	Susceptible resistant	impact	Susceptible resistant	impact	Susceptible resistant	impact	Susceptible resistant	impact	Susceptible resistant	impact
Aeromonas salmonicida (typical)	S	+	S	+	S	+++	S	+	S	+
Aeromonas salmonicida (atypical)	S	++	S	++	S	+	S	++	S	+
Vibrio salmonicida	?	?	S	+	S	++	?	?	S	+
Vibrio anguillarum	S	++	S	++	S	+	S	++	S	+
Renibacterium salmoninarum (BKD)	?	?	?	?	S	+	?	?	S	+
Moritella viscosa	?	?	?	?	S	++	?	?	S	+
Piscirickettsia salmonis	?	?	?	?	S	+	?	?	S	+
Photobacterium damsela var. piscicida	?	?	?	?	S	+	?	?	?	?
Yersinia ruckeri (ERM)	?	?	?	?	S	++	?	?	S	+++
Sea lice (*L. salmonis*)	R	-	R	-	S	++++	R	-	S	++
Sea lice (*Caligus curtis*)	?R	-	?R	-	?R	-	S	±	?R	-
Sea lice (*L. hippoglossi*)	?R	-	S	+	?	?	?	?	?	?
Sea lice (*Caligus elongatus*)	S	+	S	+	S	+	S	+	S	+
IHN	?	?	?	?	S	++++	?	?	S	++++
VHSV* (GT Ia & Ib)	S	+	?R	?	R	-	?R	?	S	++++
VHSV* (GT II & III)	S	+++	S	+	R	-	S	+	S	+
VHSV* (GT IV)	?	?	?	?	?S^	-^	?	?	?	?
ISAV	?	?	R	-	S	++++	R	-	S	±
IPNV	S	++	S	+++	S	++++	?S	+(+)	S	±
Nodavirus	S	++	S	++	?R	±	S	++	?R	?
Aquareovirus	?	?	S	+	?	?	?	?	?	?
Salmon pancreas disease virus	?	-	?	-	S	+	?	?	S	+++

Table 1 continued

Pathogen	Species											
	Arctic Char		Lemon Sole		Haddock		Sea Trout		Lumpsuckers		Cleaner Wrasse	
	Susceptible resistant	impact	Susceptible resistant	impact	Susceptible resistant	impact	Susceptible /resistant	impact	Susceptible resistant	impact	Susceptible resistant	impact
Aeromonas salmonicida (typical)	S	+++	S	+	S	+	S	+++	?	?	S	+++
Aeromonas salmonicida	S	++	S	++	S	++	S	++	?	?	S	+++
Vibrio salmonicida	?	?	?	?	?	?	S	+	?	?	?	?
Vibrio anguillarum	S	++	S	++	S	+	S	+	?	?	S	+
Renibacterium salmoninarum	S	++	?	?	?	?	S	++	?	?	?	?
Moritella viscosa	?	?	?	?	?	?	?	?	?	?	?	?
Piscirickettsia salmonis	?	?	?	?	?	?	?	?	?	?	R	?
Photobacterium damsela var.	?	?	?	?	?	?	?	?	?	?	?	?
Yersinia ruckeri (ERM)	S	++	?	?	?	?	S	++	?	?	?	?
Sea lice (*L. salmonis*)	S	++	R	-	R	-	S	++	R	-	R	-
Sea lice (*Caligus curtis*)	?R	-	?R	-	?	?	?R	-	?R	?	?R	?
Sea lice (*L. hippoglossi)*	?R	-	?R	-	?R	-	?	?	?R	?	?R	?
Sea lice (*Caligus elongatus*)	S	+	S	+	S	+	S	+	?	?	S	+
IHN	?	?	?	?	?	?	S	++++	?S	?	?S	?
VHSV* (GT Ia & Ib)	?R	?	?R	?	?R	?	?	?	?	?	?	?
VHSV* (GT II & III)	?	?	S	++	S	++	?R	?	?	?	?	?
VHSV* (GT IV)	?	?	?	?	?	?	?	?	?	?	?	?
ISAV	S	±	?R	-	?R	-	S	±	?	?	?	?
IPNV	S	++	S	++	S	++(+)	S	++(+)	?	?	?	?
Nodavirus	?R	?	?S	++	?S	?	?	?	?	?	?S	?
Aquareovirus	?	?	?	?	?	?	?	?	?	?	?	?
Salmon pancreas disease virus	?	?	?	?	?	?	S	+++	?	?	?	?

Key for Table 1

* VHSV classification is based on Snow's genotyping work[95] (Snow *pers. comm.*) Briefly, VHSV GTIa and 1b are the typical freshwater continental VHSV strain and Baltic isolated, which can infect rainbow trout. VHSV GTII & GTIII are and western North Atlantic and primarily infect marine species, although they have been reported from marine rainbow trout in the Baltic. VHSV GT IV is the Pacific West Coast of the USA isolate and infects Pacific herring and has been isolated from Atlantic salmon.

Impact refers to the seriousness of the clinical disease in a population of the host species; it does not consider the legislative consequences.

Susceptible/resistant		Impact	
?	no Data	?	No data
?S	possibly susceptible	-	No impact
?R	possibly resistant	±	insignificant
R	known resistant	+	minor
S	known susceptible	++	moderate
		+++	major
		++++	catastrophic

^ Although it is recognised that there is one publication[96] that suggests the possible infection of Atlantic salmon with GT IV VHSV from the Pacific coast of Canada, the data in this publication do not fulfil Koch's postulates, nor were the affected fish clinically ill, and subsequent virulence challenges failed to induce the disease in Atlantic salmon. However, the decision of the Aquaculture Health Joint Working Group (AHJWG) is to indicate that susceptibility has not been established and the impact of VHSV on Atlantic salmon is unknown.

Table 2. Diseases of shellfish listed in Annex D of Council Directive 95/70/EC

Disease	Pathogen	Susceptible species
Haplosporidiosis	*Haplosporidium nelsoni* *H. costale*	*Crassostrea virginica*
Perkinensis	*Perkinsus marinus* *Perkinsus olseni*	*C. virginica* *Haliotis rubra* *H. laevigata*
Microcytosis	*Microcytosis mackini*	*C. gigas* *Ostrea edulis* *O. puelchana* *O. denselomellosa* *Tiostrea chilensis*
Iridovirosis (Oyster Velar Disease)		*C. gigas*
Marteiliosis	*Marteilia sydneyi*	*Saccostrea commercialis*

Table 3. Control measures for the major fish diseases in European waters

	Control Measure			
Pathogen	Official movement restrictions	Vaccination available	Chemotherapeutants available	Compulsory slaughter
Aeromonas salmonicida	-	+	+	-
Vibrio salmonicida	-	+	+	-
Vibrio anguillarum	-	+	+	-
Moritella viscosa [2]	-	+	+	-
Renibacterium salmoninarum (BKD)	+	-	-	-
Piscirickettsia salmonis [2]	-	+	+	-
Yersinia ruckeri (ERM)	-	+	+	-
Sea Lice (*L. salmonis*)	-	-	+	-
Sea Lice (*Caligus elongatus*)	-	-	+	-
Sea Lice (*Caligus curtis*)	-	-	+	-
Sea Lice (*L. hippoglossi*)	-	-	+	-
IHNV[2]	+	+	-	+
VHSV* (GTIa & GT 1b)[1,2]	+	+	-	+
VHSV* (GT II III)	+	-	-	+
VHSV* (GT IV)	+	-	-	+
ISAV[2]	+	+	-	+
IPNV	-	+	-	-
Nodavirus	-	-	-	-
Aquareovirus	-	-	-	-
Salmon Pancreas disease virus (SPDV)[2]	-	+	-	-

[1] Eliminated after outbreak on Gigha in 1994. [2] Vaccine available but not licensed for use in the UK.

Key for Table 3

* VHSV classification is based on Snow's genotyping work[95] (Snow *pers. comm*.) Briefly, VHSV GTIa and 1b are the typical freshwater continental VHSV strain and Baltic isolated, which can infect rainbow trout. VHSV GTII, GTIII & GTIV are strains isolated from the Baltic and western North Atlantic and primarily infect marine species, although they have been reported from marine rainbow trout in the Baltic. VHSV GT IV is the Pacific West Coast of the USA isolate and infects Pacific herring and has been isolated from Atlantic salmon.

+	Effective
-	Not effective

Table 4. Cross-species infection scenarios

Scenario	Host 1	Host 2	Examples
1	D	D sustained	IPNV, VHSV
2	D	D not sustained	Gaffkaemia
3	D	C	ISAV in trout
4	D	X	Most diseases (*eg* ISAV in gadoids)
5	C	D sustained	*Gyrodactylus*, crayfish plague
6	C	D not sustained	pilchard herpes virus, PDV
7	C	C	Only of interest if 3rd host
8	C	X	Only of interest if 3rd host

D = disease, C = carrier, X = no disease or infection