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Options for Controlling Disease and Improving Health in Farmed Salmon, as a Means of Reducing Risks Posed by Escapes

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ABSTRACT

Wherever possible, the prevention of infection is preferable to treating established disease in fish farms. As regional variations exist in the natural occurrence of fish disease, the prevention of the spread of new diseases to new areas should form a cornerstone of sensible disease control. At the international, national and local levels, there has been considerable success in controlling the spread of important diseases both by regulation and by voluntary codes of practice. Failures have occurred, leading to the appearance of previously exotic diseases and the evaluation of such cases has led to the continued evolution of preventative measures.

Most farmed fish are continually exposed to the range of naturally occurring infections present in the local environment and these are the main cause of disease in fish farms. Of potential importance to wild salmon is the risk of an abnormally high focus of infections being established in an area. However, not all of these infections can cause significant pathogenicity. The development of a disease condition from an infection and its severity is a consequence of the complex interaction between environment, host and pathogen. Options for control of disease can lie in any one of these areas. Management of stress in farmed fish populations is a recurring theme in disease control in fish farms, although it is inevitable that the level which can be achieved has to be tempered by commercial reality. Similarly, the interruption of disease cycles on individual farm sites or in larger areas, through management policies such as fallowing, has both financial implications and consequences on the number of sites required. Many significant infections have responded well to treatment with chemicals. In general, such an approach to disease control should be considered to be a temporary way of achieving respite and that longer term solutions should lie in achieving enhanced resistance in the farmed fish or in management approaches.

RÉSUMÉ

Il est toujours préférable, dans la mesure du possible, de prévenir la maladie dans les installations piscicoles plutôt que de procéder à des traitements une fois celle-ci établie. La présence naturelle des maladies du poisson fluctuant selon le lieu, la prévention de la propagation de nouvelles maladies dans de nouveaux endroits devrait être le fondement de toute lutte. Tant à l'échelle internationale qu'aux niveaux national et local, la réglementation et l'application volontaire de codes de bonnes pratiques ont permis d'obtenir des succès considérables dans la lutte contre la propagation d'importantes maladies. Il y a cependant eu des échecs qui ont donné lieu à l'apparition de maladies exotiques et l'évaluation de ces incidents s'est traduite par une évolution constante des mesures de prévention.

La plupart des poissons d'élevage sont continuellement exposés à toute une gamme d'agents infectieux naturellement présents dans le milieu et ce sont eux qui sont la principale cause de maladie dans les élevages. L'apparition d'un foyer d'infection anormalement important dans une région donnée présente un risque particulier pour le saumon sauvage. Mais toutes ces infections ne sont pas cause d'un pathogénécité importante. L'apparition et la sévérité d'une maladie découlant d'une infection dépendent d'une interaction complexe entre le milieu, l'hôte et l'agent pathogène. Des possibilités de lutte contre ces maladies peuvent être trouvées en agissant sur l'un ou l'autre de ces facteurs. La gestion du stress chez les populations d'élevage est un thème récurrent de la lutte contre la maladie chez les poissons d'élevage, mais le niveau de réussite à cet égard est inévitablement limité par la réalité commerciale. De même, l'interruption des cycles de maladie dans des installations individuelles ou des zones plus vastes, par le moyen de politiques de gestion comme la mise en repos, suppose une augmentation des coûts et du nombre de sites. Bon nombre d'infections assez importantes réagissent bien aux traitements chimiques. De façon générale, une telle démarche à la lutte contre la maladie devrait être considérée comme un moyen d'obtenir un répit, la solution à long terme devant prendre la forme d'une augmentation de la résistance des poissons d'élevage ou de l'application de mesures de gestion.

Introduction

Salmon farming is a relatively new activity in several areas of the world and it is an inevitable consequence that some associated change to the locality occurs in comparison to the pre-fish farming period. These changes may involve visual, physical and biological aspects, and the latter may include the possibility of disease changes. The extent and consequences of change has been a matter of extensive interest and speculation, with polarisation of views on what may constitute a significant alteration and not. Much of the controversy is linked to the interpretation of the generally inadequate data which are available and the rigour of application of a precautionary approach. However, increasing research effort is now beginning to provide more substantiated results in this area and Hastein and Lindstad (1991) and McVicar (1997a) gave overviews of the general topic.

Before considering the mechanisms for controlling disease and improving health in fish farming, specifically to reduce risks associated with escapes, some evaluation of the current evidence of the potential, or extent of an existing problem in this area is required. Any additional special measures added to established fish farming health management practices may be disruptive and resource demanding, and some evidence should be provided for both the need for and benefit being accrued from these changes.

Although a major risk of disease transfer of infectious agents from farms to the local environment is through wild fish populations coming into contact with water coming from fish farms (McVicar 1997b), the terms of reference given for this paper restricted consideration to the role escaped fish may have in this area. The information presented is largely based on personal experiences of the salmon farming industry in Scotland and an awareness of similar problems in other countries.

Available evidence for escaped farmed fish posing a disease problem.

As the fish stocks are normally the most valuable asset on a fish farm, it is self evident that farm owners put considerable effort into preventing escapes to protect their investment. However, only rigorous conditions of containment, equivalent to those of quarantine facilities, could guarantee prevention of all escapes. As such conditions are impractical on commercial fish farms, it is almost inevitable that at some time, live fish will escape from most farms. It is also inevitable that at least some of these will contain infections which were present in the farm at the time of escape. The level of escapes, and hence an indication of the level of risk of disease transfer from farm to the wider environment is given by the proportion of salmon of farm origin which appear in salmon catches in the wild.

The immediate fate of escaped diseased salmon and their contained infectious agents will also greatly influence the level of risk from these fish to wild salmon. It is generally understood that the spread of infection and the development of disease in fish farms is closely associated with the concentration of infective agent and fish in confined conditions enhancing the opportunity for new hosts being challenged and also with increases in the susceptibility of hosts to infection through the effects of stress on the defence mechanisms of fish. However, these factors assume less importance in the natural environment where the generally wider dispersion of fish is against infection spread and disease occurrence. In addition, whereas sick fish can have a prolonged existence, continually shedding infection in fish farms before finally succumbing to a disease, the high predation pressures commonly found in the natural environment is likely to rapidly remove any abnormally behaving or weak sick fish which have escaped. Any major source of potential infection from sick fish could be expected to be rapidly and substantially reduced. It can therefore not be assumed that the infection level of fish in a farm at the time of an escape is the level to which wild fish are being exposed. It is likely to be considerably lower.

Assessment of the effects of disease in wild fish populations.

Infection is part of the natural ecosystem and wild salmon are naturally open to external and internal challenge from a wide range of organisms. In 1992, the ICES Working Group on Pathology and Diseases of Marine Organisms listed over 80 infectious conditions in Atlantic salmon in the North Atlantic, covering almost all main types of infectious agent (Anon 1992). Many of the reports are single case records and few indicate the pathological significance of the infection. Most infections carry the inherent risk that they will cause pathogenic effects to their host but some show greater potential than others, particularly these where replication is possible directly on or in the host.

There are major difficulties in determining which infections are actually causing significant effects in wild fish populations. As indicated, any sick fish is particularly vulnerable to predation in the wild, it can be expected that these will normally be rapidly removed from the natural environment. Any samples which are taken are therefore unlikely to reveal evidence of the most pathogenic infections. Contrary to popular perception, infections which are commonly present at higher levels in individual fish and in a fish population are probable of least significance to the survival of the fish and the viability of the population. Exceptions are when there is an epidemic in progress (these are characteristically of short duration) or where a major reservoir of infection exists in another host. Because of the removal of natural mortality in tanks as a main cause of death of sick fish, it is not possible to simply extrapolate experimental data on pathogenicity to natural situations. Other more complex methods of assessing disease incidence and consequences have to be used. These may involve either an extended determination of trends in disease and fish populations which is highly resource demanding, or a determination of the actual rate of progress of the disease in individual fish in the wild population (McVicar 1988).

Disease of importance to farmed Atlantic salmon.

Legislation covers many aspects of farm operations such as use and discharge of chemicals, animal welfare, environmental impact and control of listed disease, other aspects may be dealt with through quality assurance schemes and trade association codes of practices, while others are the responsibility of the individual farmer. Avoidance of disease through the use of disease-free stock and the recognition and early treatment of diseases when they do occur, are the basic disease-related components of good stock management which any fish farmers would ignore at their peril.

The control of stress levels in fish is a frequently recurring theme in disease management in fish farms. Fish in farm environments are not in natural conditions and it is inevitable that a level of stress on them has to be accepted as a consequence. It is always necessary for a compromise balance to be reached between the commercially practicalities of farming salmon and the disease consequences of a level of stress. However, stress is not easily defined and as subtle changes may be involved, not necessarily easily recognisable in a population of fish. Some of the factors affecting disease outbreaks on farms are outwith the control of the fish farmer (eg weather) but others may be manipulated either directly or indirectly. It is self evident that healthy fish in the salmon farming industry reduces any potential risk of disease interaction from farms to wild fish.

(A) Exotic diseases.

It is notable, when an infectious agent has been in close contact with a host for an extended period in evolutionary terms, that a mutual adaptation is usually apparent. As both species normally then co-exist without serious selective pressures on either, it is unusual for serious pathogenicity or epidemics to occur in natural conditions. As this relationship takes time to develop, probably the greatest disease dangers to local stocks of wild and farmed fish occurs when new infections are first introduced to an area. The dangers are well illustrated by the massive disease epidemics which occurred in isolated indigenous human populations when first contact from outside was made (Mims 1987). At the national and at the international level, considerable emphasis has been given to prevent the introduction of exotic fish disease. Live stocks have long been recognised to carry the greatest risk of transferring fish disease from one location to another. Legislation (eg UK Diseases of Fish Acts 1937, 1983, Canadian Fish Health Regulations [Blue Book], EU Directive 91/67/EEC, OIE International Aquatic Animal Health Code) has been directed at this by implementing controls on fish movements linked to disease testing. Because of finite levels of disease detection and the possibility of occasional failures in control procedures, there is a level of risk associated with the translocation of any live fish. On this basis, and to be precautionary, it could be argued that trade in all live fish should be banned. However, this is unrealistic and likely to come into conflict with international trade agreements, such as the General Agreement on Tariff and Trade (GATT), EU, EEA and other regulations. Instead, it is necessary firstly to identify these areas which are most contributing to risk from fish disease and then to control and manage these. The legislation referred to above all identify which fish diseases are sufficiently important to warrant restriction in trade, and proscribe standardised surveillance and diagnostic methods to ensure freedom from these in any fish being moved. For a receiving area to require that these conditions are met, it is necessary to demonstrate that the area meets the same standards, or is at least has a programme in place leading towards this. As new disease conditions are being continually recognised in fish and more knowledge becomes available about known diseases, it is inevitable that some of these will be considered to be sufficiently important to warrant controls. Alternatively, there can be a desire to relax controls on other diseases. The legislative framework generally recognises the need for continual revision of lists of controlled diseases and of detection methods. This places a considerable responsibility on scientific advisors to be continually and fully aware of any new developments in fish disease, both at the national and international levels. As changes in law take time to process, there is a need for emergency procedures to enable rapid reaction when particularly dangerous disease conditions are first detected. Again, most fish disease control legislation encompass such provisions.

Even with the above controls on live fish in place it is difficult to achieve absolute protection against diseases being introduced. This is well illustrated by two examples from Norway where preventative measures have failed, probably as a result of the translocation of live fish for farming or restocking. From 1985, the bacterial disease furunculosis spread into numerous Norwegian rivers after the importation of allegedly latently infected Atlantic salmon smolts from Scotland (Hastein and Lindstad 1991). Similarly, the appearance and spread through many rivers of the monogenean skin fluke *Gyrodactylus salaris,* probably originally from Sweden, has been directly linked to movements of live fish from infected hatcheries (Johnsen and Jensen 1991). Regulatory authorities need to maintain high levels of vigilance and anticipation of potentially significant diseases. Companies or individuals involved in moving live fish between areas also have a major role to play in preventing the introduction of exotic disease by maintaining high levels of responsibility in their compliance with the regulations.

Lower in the scale of risk, but still of major significance, is the possibility of disease transfer with dead fish and equipment contaminated with infection. With import of fish carcasses, a direct relationship can be established between risk with the location in the body where infection is concentrated in relation to the parts of the body being imported and the amount of material being rejected at the receiving area. Recognising the risk associated with viscera, and in particular blood rich organs, EU legislation has required that salmonid carcasses be gutted prior to importation into areas of higher health status regarding the viral diseases Viral Haemorrhagic Septicaemia (VHS) and Infectious Haematopoietic Necrosis (IHN) and for Infectious Salmon Anaemia (ISA) into the whole EU from Norway. There are still risks associated with gutted carcasses and several countries (such as Australia and New Zealand) have applied comprehensive risk analyses to address the dangers from fish disease associated with the importation of farmed and wild salmon into these countries. In these, the main areas of risks have been identified, ways of reducing these have been found and restrictive measures on imports proposed.

Many pathogens are able to survive away from their host for a period of time and any equipment which infected fish have come into contact with may be capable of transferring infection between areas. The recent spread of ISA within several Scottish salmon farms has been closely associated with the multiple use of wellboats and other fish farming equipment between different fish farms. Although the primary origin of this infection has not yet been established, the possibility of accidental introduction of the virus with contaminated equipment is one possibility still being considered. A knowledge of the duration of survival of the infectious agent away from the host, and of factors affecting this, are critical in any decision making on how to reduce the disease risk associated with equipment. When the efficacy of disinfectants at different concentrations and the reaction of the pathogen to physical changes such as temperature, drying, UV light, pH etc have been established, it is possible to select the most appropriate measure or combination of measures to ensure destruction of the infection. Thus for ISA, the use of heat and a pH of less than 4.0 have become important aspects of the disinfection process of contaminated equipment and biological material. Cleanliness of equipment prior to commencing disinfection is an essential. When particulate organic material is present such as faeces, mucus, blood and parts of fish these may shield the pathogen from the aggression of the external environment. Codes of practice on disinfection in general recommend an initial cleaning step, usually involving pressure washing and the use of a surfactant or detergent. It is essential that this is properly carried out.

It is not only fish farm equipment which may pose a risk as any materials which have been in contact with infection may transfer this between areas. Thus the Icelandic Freshwater Fisheries Law, 1970 prohibits the use of angling equipment which has been used abroad without it being certified as adequately disinfected. It is not always possible to enforce such tight restrictions especially where there are multiple entry points from abroad. Instead, for example where a significant risk is identified, as with *Gyrodactylus salaris* which can survive free from its salmonid host for several days in cool and damp conditions, information on the risk associated with angling equipment and ways to reduce this have been released, for example in Scotland and Finland, in the form of an official advisory notes to the main target group causing the risk, ie fishery owners and anglers.

(B) Endemic diseases.

It is well recognised that the main source of infection to salmon farms is from the surrounding natural environment and it is reasonable to assume that such infections will form the majority of these which may transfer to the wild with escaped fish (McVicar 1997a). Most infectious agents which have a free living infective stage are liable to infect farms which are not supplied with protected waters. However, not all of these are likely to be significant to the health and survival of the fish. The importance of the interaction between fish, pathogen and environment in the epidemiology of fish disease is well recognised and any alteration to any of these three components could lead to a change in the disease situation in a population of fish whether within a farm or in the wild.

Considerably controversy surrounds the question whether fish farms focus or enhance the level of indigenous disease to the danger of local wild stocks. Undoubtably, for infections which do not require intermediate hosts, the prevalence and intensity of infection of locally occurring disease conditions within farmed salmon populations tend to be higher than that in wild populations. Identification of the mechanisms contributing to such a difference can indicate where there may be opportunities for changes in farm management practices to alter the balance and reduce disease occurrence.

Disease reduction in fish farms

It is well understood that farm management actions which fall under the general heading of good husbandry practices have a major influence on the occurrence of disease in farms. Inevitably, the success which individual farmers achieve in ensuring good practices are followed is variable, partly depending on the level of knowledge of an operative, on commercial pressures being imposed at any one time and on the particular characteristics of the farm. Progress will occur when it is recognised that there is always room for improvement in any operation and that established practices should be subjected to regular challenge and development.

1. Susceptibility of fish.
As selection of strains and families for desirable farm traits advances in all salmon farming areas, progressive domestication of stocks has occurred. Increasing adaptability to farm conditions, as linked to growth performance and survival in particular, is becoming evident. Reduction in stress levels in these stocks is inextricably linked to these developments. In addition, variations in the level of disease resistance in salmon of different origin has been evident for some time in stocks from different areas. For example. this is seen in extreme with Baltic salmon and *Gyrodactylus salaris* (Bakke and MacKenzie 1993), to a lesser extent with diseases such as Proliferative Kidney Disease (PKD) in Scottish strain salmon compared to Norwegian and with furunculosis and other bacterial infections in different families of salmon (Gjedrem 1997). There is considerable interest in fish farming to the further development of such disease resistant traits and many genetic selection programmes are incorporating these parameters. Although there is some scope in this area to contribute to disease reduction, progression will probably only be slow, with no major or spectacular developments in disease resistance directly affecting disease levels in farmed stock likely to occur in the immediate future.

2. Disease characteristics.
Farm conditions places a different range of selective pressures on infectious agents present and it has been frequently asked if there are changes are occurring in the characteristics of disease which could pose particular threats to wild fish. There is no evidence of changes in pathogenicity of infective agents occurring and spreading to local wild stocks. The extensive use of antibiotics to combat furunculosis and vibriosis, particularly during the late 1980s, led to the widespread development in farms of bacterial strains resistant to the range of antibiotics available for use in farms (Aoki 1997; Alderman and Hastings 1998). Similarly, there is evidence for the development of onganophosphorous tolerant strains of sea lice *Lepeophtheirus salmonis* where this chemotherapeutant has been extensively used (Jones *et al.* 1992). Again there are no concrete data for such strains spreading to or persisting in wild stocks of salmon. Removal of the farm-specific selective pressures in the wild environment may be a factor in restricting their spread, but it has to be noted that there has been no extensive research in this area. From currently available evidence, there would therefore appear to be limited opportunity for a farmer to substantially affect risks to wild stocks from changes in disease characteristics in farms.

3. Farm environment.

The local environment within a fish farm has a major influence on the health of fish and hence on the level of occurrence of disease (Lumb 1989). Good water quality is a pre-requisite to any fish farming operation and as illustrated by the way Atlantic salmon are affected by water quality in their natural environment, this species is particularly sensitive to changes. Anything a salmon farmer does to compromise water quality is therefore likely to jeopardise the fish farm at an early stage. With sea sites, problems associated with water quality are reduced by the careful positioning of farms where there is a good water exchange and the maintenance of good water circulation within cages by limiting net fouling through regular net changing or use of appropriate anti-fouling compounds. Similarly any significant impact on the sea bed in the vicinity of a farm should be avoided as it is liable to have a direct impact on the water quality within the farm. Gas bubbles being released from anoxic sediments have been known to cause problems to sea cages, particularly during the early development phases of salmon farming in Norway. These problems are now mostly avoided through careful siting of farms where there is good scouring of the sea bed, improvements in feeding regimes and increasingly assisted by rotational use of sites.

4. Stocking density.

The confined conditions of fish farms is an obvious major difference between the environments of farmed and wild fish. As indicated above, the higher densities of fish within a fish farm tend to be conducive both to the spread of infection and to alteration of the susceptibility of the fish through stress effects on the fish. Reduction in stocking densities will influence both of these factors and ceilings on the biomass within a farm are imposed in most farming areas. However, a balance has to be achieved between the ideal (normally low) stocking density helpful to achieve reduction in risk from disease and the commercial reality where a certain number of fish are required to recover investment. This area has led to considerable conflict between fish farming and other interests which is difficult to resolve. There is no defined cut-off point at which disease becomes significant and a stocking density which is acceptable in one location, may be inappropriate in another. Differences associated with other factors such as season, age of fish and sensitivity of an area may also have to be taken into account.

5. Disease levels.

Disease is a major loss factor in salmon farming and farmers have every incentive to keep this at a minimum. However, this has not always been achieved. For example, in Scotland disease problems reached an extreme level in the late 1980s when over 40% of fish put into sea cages as smolts did not survive to harvest, principally due to furunculosis being out of control (Anon 1997). This loss was considered to be totally unacceptable, and was threatening the viability of the fish farming industry. The control measures implemented to reduce this mortality rate to less than 10% over a four year period in the early 1990s included the introduction of an efficacious vaccine and improvements to management practices. The frequent removal of mortalities from cages to reduce the level of bacterial release into the water and the greater use of single year class sites with a fallow period between fish generations to break the cycles of disease on a site were probably the two most important changes. The latter is being further developed to incorporate the concept of area management agreements where binding agreements on stocking, disease treatments and fallowing are reached between farm operators in hydrographically defined areas. Even short periods of fallowing (6+ weeks) of sites, or areas where there is disease interaction between sites, has also been shown to be effective in breaking cycles of several other diseases such as Infectious Pancreatic Necrosis (IPN), Pancreas Disease (PD) and to be greatly reduce the level of sea lice on a farm, particularly during the first year after restocking (Grant and Treasurer

1993). The controversy surrounding the difficult question of whether there should be a *cordon sanitaire* surrounding farms and about what size this may be, can be at least partly resolved by the more widespread introduction of such agreements.

6. Chemotherapy.

As in most intensive food production systems, chemotherapy has had a widespread use throughout fish farming. Although there have been various actual and perceived problems with their use associated with environmental effects, consumer confidence, cost, development of resistant strains, safety and with pathogen resistance, there has been and still is a considerable dependancy on them to maintain the health status of farm stocks. With the introduction of new approaches such as the introduction of more efficacious vaccines and changes to farming practices to reduce disease occurrence, there has been a spectacular reduction in the level of use of chemicals in all salmon farming areas shown graphically for Norway and Scotland by Alderman and Hastings (1998). This is particularly welcome as it is clearly apparent that the use of chemicals to control disease should be considered to be a temporary way of achieving respite. Longer term solutions should lie in achieving enhanced resistance in farmed fish through stock selection or enhancement of immunity and in management approaches.

Conclusions

1. The movement of live fish and equipment between areas associated with fish farming activities carries the greatest risks of introducing new infectious agents and disease to an area. The main risks linked to live fish movements have been identified and are being controlled by legislation, several serious disease incidents in wild salmon populations have been directly associated with these.

2. Fish farms often carry elevated levels of locally endemic disease in their stocks which are likely to transfer to the wild with any escaped fish. No serious disease incidents have been shown in wild populations associated with the escape of such fish. However, there has been little research effort directed at this question.

Research Recommendations

1. There is a need for continual improvement in the diagnostic screening methods for infectious agents in live fish populations which are being moved between different areas, to further reduce the risk of the introduction of exotic diseases.

2. There is a need for improvement in disease prevention methods in fish farms to reduce the levels of infectious agents present and to progressively replace chemotherapy.

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