INDUSTRIAL DISEASE:

The Risk of Disease Transfer from Farmed Salmon to Wild Salmon

A Friends of Clayoquot Sound Report

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"The risk of disease transmission is strictly a numbers game – the greater the number (of Atlantic salmon egg or milt imports), the greater the risk...who is going to accept responsibility when the first exotic disease outbreak occurs, because for certain it will."

Dr. David Narver, Director, Recreational Fisheries Branch, BC Ministry of the Environment, writing in a November 7, 1986, letter to Mr. Bruce Hackett, Assistant Deputy Minister of the Environment, BC.

SUMMARY

This report looks at the risk of disease transfer from open netcage salmon farms to wild salmon. Evidence is presented which shows that salmon farms act as disease amplifiers, where disease pathogens can reach high population levels that are rarely found in the wild. Disease can then be spread from the farm to wild salmon by:

- farmed salmon escaping into the wild
- wild fish swimming near salmon farms
- flushing of salmon farm sewage into the marine environment
- flushing of fish processing plant effluent into the marine environment.

Disease amplification and transmision can occur with diseases that already exist in the marine environment where salmon farming takes place, or from non-native, exotic diseases that can be brought in from other areas. The latter can arise from the importation of live fish or eggs for hatchery and fish farming purposes. Examples from Norway highlight the severe impact that introduction of exotic diseases can have on wild salmon stocks. Such disease transfers have brought wild salmon runs in many rivers in Norway to the point of extinction. In New Brunswick, the transfer of Infectious Salmon Anemia from farmed to wild salmon has recently been documented.

Proponents of the salmon farming industry argue that disease outbreaks on salmon farms pose little risk to Pacific salmon stocks in BC. As evidence, they point to the lack of confirmed farmed to wild salmon disease transfers in BC. This is a myopic viewpoint. Examples of confirmed disease transfers outside of BC have shown that the conditions setup by open netcage salmon farming can lead to severe impacts on wild salmon stocks. The lack of examples in BC may be due to the fact that no one has looked for the evidence.

Since salmon farming began in the late 1970's, there has been no monitoring in BC of the effects that diseases on salmon farms can have on wild salmon. The argument that the risk of such transfers is low is, therefore, not based on scientific evidence and is put forward for economic and political reasons. One must also consider that lack of past impact, for a relatively recent industry such as salmon farming, does not mean that significant risk of future impact does not exist. A precautionary approach requires that any risk of severe, irreversible impacts must be eliminated before it is too late.

As a result of the risks to the environment, and specifically to wild salmon, associated with open netcage salmon farming, this report recommends:

- That open netcage systems of salmon farming be replaced by land-based closed loop systems with sewage treatment facilities.

- That the importation of Atlantic salmon eggs and the farming of Atlantic salmon not be allowed in BC.

- That use of antibiotics, pesticides and other deleterious chemicals be eliminated from salmon farming practices.

- That fish processing plant effluent be treated, to avoid the spread of diseases from fish blood and viscera.

- That an independent system of monitoring be set up to assess the environmental impacts associated with salmon farming, and that any information gained from this should be included as part of an adaptive management model for the industry.

- That any information, such as frequency and intensity of disease outbreaks that is collected by salmon farm operators be made available to the public.

INTRODUCTION

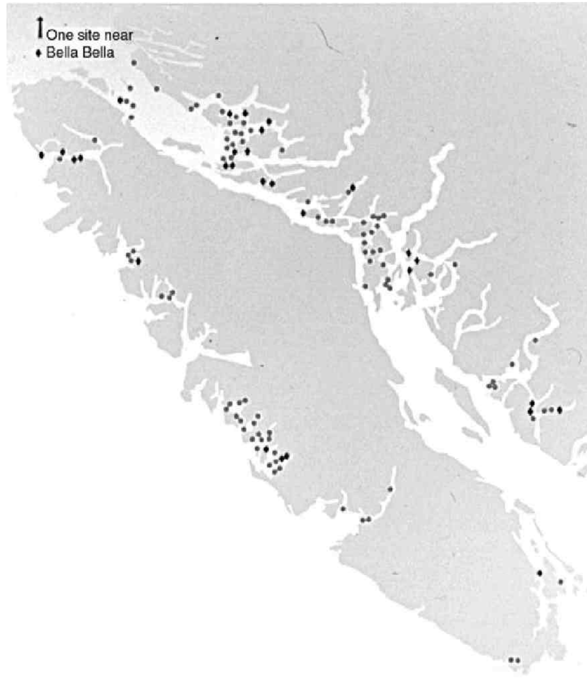
The purpose of this report is to assess the risk of disease transfer to wild salmon from open netcage salmon farming, the first of the three possible impacts to wild salmon mentioned below. New evidence will be presented that was not available at the time of the BC government's 1995 Salmon Aquaculture Review (SAR) (see box on next page). Examples of impact from outside of BC will also be presented, evidence that the SAR had access to, but failed to take into account in its assessment. The introduction of salmon farming to BC in the late 1970's, and its expansion in the mid 1980's, has led to a great deal of concern over this activity's impact on the environment (Ellis 1996; SLDF 1997). The concerns stem mainly from the fact that salmon farming is currently conducted in pens or cages that are open to the marine environment. Also, 80% of the salmon farmed in BC are Atlantic salmon.

Given that salmon farming is a relatively recent, poorly studied activity on the BC coast, we should be concerned about the risks it poses to salmon populations that are already depleted by climate change, overfishing, and habitat destruction.

Among the threats that open netcage salmon farming poses is that of negative impact to wild Pacific salmon populations. The three main ways that salmon farming could impact wild salmon are:

- transfer of disease from farmed to wild salmon
- genetic damage from farmed Pacific salmon interbreeding with wild Pacific salmon (Ellis 1996) (20% of BC farmed salmon production is chinook and coho)
- displacement of Pacific salmon from their habitat by farmed Atlantic salmon escaping and breeding in the wild.

Not surprisingly, a recent paper by Department of Fisheries and Oceans scientists (DFO) concluded that the main causes for



Salmon farming tenure sites in BC in 1995
Source - "Net Loss: The Salmon Netcage Industry in BC", The David Suzuki Foundation.

Pacific salmon population depletion in the 1990's were climate change, overfishing and habitat destruction (Noakes *et al*. 2000). This conclusion, and the fact they couldn't find any studies to show direct cause and effect (i.e., salmon farming having caused recent salmon population declines), led them to conclude that "salmon farming, as currently practiced in BC, poses a low risk to wild salmon stocks particularly when compared to other potential factors". Such a conclusion is irresponsible. In a proper risk assessment, one doesn't wait for impact to be proven before taking action. At that point it may be too late. Given that salmon farming is a relatively recent, poorly studied activity on the BC coast, we should be concerned about the risks it poses to salmon populations that are already depleted by climate change, overfishing, and habitat destruction.

Several countries in Europe have acknowledged the threat posed to wild fish stocks by disease transfer from farmed salmon, and have taken measures to reduce the risk

(Windsor *et al*. 1995). In Norway, marine areas restricted to salmon farming have been created. These “no fish farm” zones are located near salmon streams to minimize the chance of farmed to wild salmon disease transmission.

There are other ways in which the DFO paper by Noakes *et al*. fails to properly assess the risk salmon farming poses to wild stocks. These gaps are discussed insome of the boxes which appear throughout this report.

The Salmon Aquaculture Review

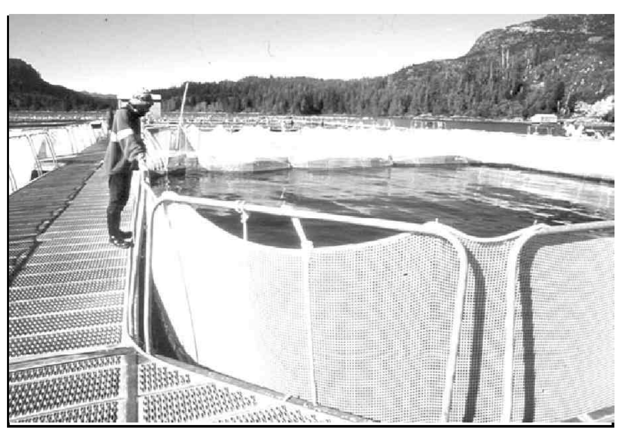
In 1995, due to increasing concern over the environmental impacts of salmon farming, the BC government imposed a moratorium on further expansion of the salmon farming industry. The government directed its Environmental Assessment Office to conduct a Salmon Aquaculture Review (SAR), to address the environmental concerns arising from salmon farming. Among the conclusions reached by the SAR was that, “at current levels of production, salmon farming in BC poses little risk to the environment”. The SAR strongly cautioned, however, that its conclusion was made within the context of “severe gaps in knowledge”. It then recommended that about 81 new studies be conducted to better understand the environmental impacts of salmon farming. This is hardly a strong endorsement for expanding the industry. Nevertheless, the BC government lifted its salmon farming moratorium in October, 1999.

The “low risk” conclusion made by the SAR has been strongly criticized (ELC, 1998). One could only make such a conclusion if studies on the impact to wild salmon had been conducted and no evidence could be found. But the lack of evidence at the time of the SAR was due to lack of studies. Given this, the SAR’s “low risk” conclusion was a political decision, with no scientific basis.

SALMON FARMS AS DISEASE AMPLIFIERS

There are many diseases that affect farmed salmon, for which pathogens already exist in the wild on the BC coast (Kent *et al*., 1998). Bacteria, viruses, and other pathogens are a natural part of any ecosystem. After countless generations in which they evolved together, a dynamic balance has been reached between these pathogens and host species like salmon. At any given time, a healthy salmon will be carrying a number of these. The pathogens are opportunistic, however, and disease outbreaks can occur when added stress to a fish tips the balance in the pathogens’ favour and they multiply. In the wild, such added stress can result from increased population densities, changes in food availability, or other sudden changes in environmental conditions.

Compared to natural conditions, salmon farming sets up an artificial environment in which fish are more stressed than in the wild (Saunders, 1991; Finlay, 1989). Except during spawning, wild salmon are not subjected to the high population densities found on farms. For farmed salmon, densities are typically from 2 to 5 adult salmon per cubic metre. Such year-round high density increases the stress above natural levels. When stressed, the fish will produce certain hormones which have been shown to suppress the animal’s immune system (Barton, 1991). Not only does this increase the risk of disease for each individual salmon, but it also provides a mechanism for rapid disease transmission once some salmon become ill. This



Salmon open-netcage operation in Clayoquot Sound, British Columbia has been referred to as disease amplification (BC government memorandum, 1997). In the wild, lower population densities mean lower risk of healthy fish encountering diseased ones. Also, in the wild, weak diseased fish are often taken out of the population by predators. Large disease outbreaks can occur in nature, but the incidence is low compared to intensively cultured fish (Windsor 1995).

In addition to physical stress from crowding, salmon farming introduces other conditions which amplify pathogen populations, increasing the risk of disease outbreaks. The most important of these is the accumulation of fish sewage under the farm. The sewage consists mainly of fish feces and uneaten food, but can also contain disease pathogens and drugs used by fish farmers when disease outbreaks occur. Studies have shown that this sewage can severely impact the benthic (sea floor) ecosystem under the farm (Findlay *et al*. 1997), and in some cases the marine biodiversity beyond the fish farm site itself (Pohle *et al*. 1997).

Salmon farmers are aware that accumulated sewage increases the incidence of disease outbreaks on the farm (Needham 1995; Caine 1993). Deaths can also occur as a result of outgassing, whereby decomposing sewage can release large quantities of hydrogen sulfide and ammonia, which poison the fish. The incidence of disease and outgassing can be reduced by the practice of fallowing, whereby active farms are rotated among the tenure sites held by a company. At any given time some sites are inactive, to allow the accumulated sewage to disperse. In addition to reduced fish deaths of farmed salmon, fallowing reduces the risk of disease transmission from the farm to wild fish.

In BC, fallowing is not legally required for salmon farming and the choice is left to the operator. Unfortunately, the incentive of reduced mortality of farmed fish is offset by short-term economic gain. Overall, a company can produce more tonnes of fish by farming all of their sites. Accepting higher death rates on the ones in need of fallowing is more lucrative in the short-term than not farming them. This purely economic reasoning could apply regardless of how many sites the industry was given. This is why a survey of all BC sites showed that only a minority of salmon farmers practiced fallowing (Ellis 1996).

When fallowing does occur, it is usually done for a short period of time. In Clayoquot Sound, 5 to 8 farms, out of 23, are left fallow at any given time (Anon. 2000). The fallowing time averages about 2 months. European studies have shown that this is far too short a time to allow disease pathogens to disperse from a farm site. The studies looked at the dispersal rate of vibriosis and furunculosis, two diseases that also affect salmon farms in BC. It was found that the disease pathogens could be detected in marine bottom sediments for 1.5 to 3 years after the salmon farm was abandoned (Husevag *et al.*

The Big Bad Wilderness

The recent (Feb., 2000) Noakes/DFO paper refutes the idea that more stressful conditions on fish farms lead to disease amplification by claiming that, “There is no evidence to support the assertion that farmed fish are more stressed than the ‘fight or flee’ world of wild salmon.” This statement comes from a view of the wild as a nasty, competitive world in which animals live in constant fear of being attacked or eaten. The statement is anthropocentric and misleading. In fact, farmed salmon are also exposed to many of the same stresses that affect wild salmon, including ‘fight or flee’. The difference is that farmed salmon can’t take actions to try and relieve the stress. When a wild salmon encounters a predator (not a constant occurrence in their life), they can try to swim away and escape (often the case). In open netcages, farmed salmon are also approached by predators such as seals and sea lions. Since the farmed salmon can’t escape, the predator-prey interaction is usually longer than in the wild. When adverse changes in temperature, water acidity, dissolved oxygen and other fluctuations in the marine environment are encountered, a wild salmon can migrate to better waters to relieve the stress. In addition to this, farmed salmon encounter stresses such as handling, transportation and other unnatural conditions.

1991; Husevag *et al.* 1995). These studies concluded that fish farm sediments can act as reservoirs for disease pathogens.

Salmon farms are localized areas in the marine environment where disease pathogens can attain population levels very rarely encountered in nature. These pathogens may be transmitted to wild fish when they swim near the salmon farm, when water currents disperse fish sewage, or when farmed fish escape the netcage. In the next section we describe some cases where disease transfer has happened.

DISEASES FROM FARMED TO WILD: EXAMPLES

Not much research has been done in BC which looks at disease transfer from farmed to wild fish. One of the main reasons is that much of the research money provided by government and industry is directed towards improving and promoting aquaculture production. Also, company records of disease outbreaks on fish farms are considered proprietary information and are not easily available (see box below). But evidence from other jurisdictions with salmon aquaculture is accumulating. Below are some examples of diseases being spread from farmed to wild fish.

Infectious Salmon Anemia (ISA)

Infectious salmon anemia (ISA) is a contagious viral disease, first detected on Norway salmon farms in 1984. The virus is of a type that is known to be capable of frequently mutating (ASF 1999). There is no known cure for ISA, which in salmon can cause hemorhages in the kidney and spleen, leading to anemia and death.

It was assumed that ISA was confined to Norway until it started appearing on New Brunswick salmon farms in 1996. Since then, the virus has also been found on salmon farms in Scotland (May 1998) and in Chile (March 2000). By 1998 the disease had spread to so many farms in New Brunswick that 25% of the industry was temporarily shut down and over 1.2 million farmed salmon were slaughtered in an effort to control the disease. The New Brunswick government also announced a $10 million bailout package for the industry. Between April and July, 1999, an additional 120,000 fish had to be destroyed. For a detailed account of these events see our previous fish farm report (FOCS 1998).

In Scotland, 24 salmon farm sites have been confirmed as having ISA. Evidence shows that in all but one site, the source for these infections can be traced back to a single farm in Loch Nevis that was infected in May, 1998. A £9 million program to assist Scottish farmers affected by ISA has been set up.

The recent discovery of the ISA virus in Chile was made by scientists at the Atlantic Veterinary College at the University of Prince Edward Island. The virus was discovered in farmed coho salmon. *How widespread the ISA epidemic is in Chile cannot be known at this time because of a confidentiality agreement between the scientists and the fish farm companies involved.*

In Whose Interest?

A David Suzuki Foundation Report chronicles the difficulty in obtaining information on disease outbreaks.* It gives the example of a 1995 sea lice outbreak on a salmon farm near Campbell River. The Sierra Legal Defence Fund found out about the outbreak from a Freedom of Information request. When an article then appeared in the media about the outbreak, the BC Salmon Farmers Association formally complained to the province and asked for an inquiry. They claimed that the province had an obligation to maintain the "confidentiality of its clients". The government carried out an investigation of the matter.

*****For a detailed account of these events, with references, see "Net Loss: The Salmon Netcage Industry in BC" by David Ellis and associates, a report prepared for the David Suzuki Foundation, 1996.

In October, 1999, biologists with the Atlantic Salmon Federation discovered wild Atlantic salmon infected with the ISA virus in New Brunswick's Megaguadavic River (ASF 1999). This was the first documentation of wild salmon containing this deadly virus. The biologists also discovered escaped farmed salmon with ISA in the river. The Megaguadavic River is located near the centre of New Brunswick's aquaculture industry in the Bay of Fundy.

The recent ISA discovery has dealt a major blow to efforts at rehabilitating the Megaguadavic salmon stocks. In 1999, only 24 wild salmon returned to the river! Of these, 14 were selected as broodstock for a breeding and reintroduction program. Twelve of the 14 collected had the ISA virus, and two of them died before breeding (ASF, 1999). With such a low return for the wild salmon, one would expect a low incidence of encounters between them and farmed Atlantics. The fact that most of these wild salmon contracted ISA points to the efficiency of transmission for this disease.

One month after the discovery of ISA in wild salmon in New Brunswick, the virus was found in various species of wild fish in Scotland as well, including sea trout and eel. The discovery has prompted the Scottish government to state:

> " ...we are urgently considering the implications of this new evidence that the virus is present in wild fish. That means we will be reviewing our controls and will be taking stock of what action may be necessary in relation to wild fish."
> (Scottish Executive 1999)

The rapid spread of ISA, and its transmission from farmed to wild fish can occur through contact with infected fish or with water contaminated with particles shed by infected fish (ASF 1999). Since the blood and viscera of infected fish are also very contagious, fish processing plant effluent can carry the disease. This has led Norway to require treatment of processing plant effluent. Scotland has also recently identified ISA transmission from processing plants as cause for concern (Scottish Executive 2000).

In British Columbia, ISA has not been detected in either farmed or wild salmon. The implications of the possible introduction of this disease to BC will be discussed later in this report.

Sea Lice

Sea lice are small crustaceans that can be found as parasites on salmonids. They are found naturally in many marine environments, including coastal BC. But high fish densities found on farms result in higher sea lice population densities than normally found in BC. Amplification of this disease is compounded by the fact that Atlantic salmon, which represent 80% of farmed salmon production in BC, are especially susceptible to the disease.

Sea lice can cause large losses on salmon farms, both as a result of direct parasitism, and because they can carry other diseases such as ISA and furunculosis. Researchers in Norway have found that wild salmon found in areas where there is fish farming, have 10 times the level of sea lice infestation that wild salmon have in areas where no such farming occurs (Windsor 1995; Jakobsen 1993).

In Ireland, the infestation of sea trout with sea lice has been studied. In the late 1980's the Irish sea trout fishery experienced a major collapse. A 1992 study found that sea trout smolts which were returning prematurely to fresh water were severely infested with sea lice (Windsor 1995). Subsequent studies at sea revealed that the highest levels of infestation were found for wild trout in the vicinity of salmon farm cages. In some areas, salmon farms had increased sea lice populations to 20 times their natural level. As distance from farms increased, the level of infestation decreased (Anon 1993). The nature of the evidence was so compelling that it prompted Ireland's Western Regional Fisheries Board to reject claims from the Irish Salmon Growers Association that the collapse was "multifactorial". The Board stated that, "All available evidence clearly points to an increase in sea lice … from salmon farms … being the sole cause of the sea trout stock collapse." A Sierra Legal Defence Fund report also noted the following points about the Irish sea trout crisis (SLDF 1997):

- fallowing of a salmon farm in Killarey Harbour, Ireland, in 1992 resulted in sea lice larval production falling to zero and infestation of wild sea trout in that area reduced by 75%

- reintroduction of salmon farms in Clew Bay caused sea lice larval production to increase from zero in 1991 to significant levels in 1992. Levels of sea trout infestation increased from about 6 to 55 lice per fish during that same period.

Similar studies on sea trout decline in Scottish waters are also telling. Researchers have used genetic markers to show that sea lice taken from wild sea trout had originated on farmed salmon (Todd *et al*. 1997).

These examples clearly show that salmon farms can act to amplify disease pathogens in the marine environment, and that disease can be transfered to wild populations. No such studies have been conducted in BC, even though salmon farms in this area are experiencing sea lice problems. *When sea lice outbreaks occur on BC farms, pesticides such as Ivermectin are used. This pesticide can remain in the environment for long periods of time. It has been shown to have extremely adverse effects on the marine environment* (Davies *et al*. 1998).

EXOTIC DISEASES

Of all the possible ways in which diseases from salmon farms can affect wild salmon, the possible introduction of exotic disease pathogens has the potential to cause the most severe impacts. An exotic disease is one that does not naturally exist in an area and is brought in from a region where the disease naturally occurs. In such cases, the wild salmon could be exposed to disease pathogens to which they have no natural immunity.

The best examples which show the impact that exotic diseases can have on wild salmon stocks come from Norway. Two diseases, furunculosis and another caused by a flatworm (*Gyrodactylus salaris*) have resulted in catastrophic wild fish losses when the parasites were brought from Scotland and Sweden, respectively. The transfers were the result of importation of live salmon for hatchery and fish farm purposes.

Gyrodactylus salaris

At about 0.5 mm in length, *Gyrodactylus salaris* is a flatworm parasite that spends its entire life cycle on the host's skin, and occasionally on the eyes and gills (Windsor *et al*. 1995). The parasite was first discovered on a fresh water salmon farm in northern Sweden in the 1970's. Although outbreaks of this disease would periodically occur in Sweden, the parasite could be treated with pesticides. In the mid-1970's, the salmon farming industry in Norway imported live Atlantic salmon smolts from Sweden. Since *G. salaris* is a fresh water parasite, it dies when placed in salt water. But not all of the imported salmon smolts went to salmon sea cages. Some were taken to a freshwater hatchery used to breed salmon smolts for farming. In 1975, a *G. salaris* outbreak in the hatchery led to high salmon mortality. Within a month, the disease was found in wild salmon in a river next to where the initially affected hatchery was located (Johnsen *et al.* 1991). By the end of 1980, 20 rivers were infected resulting in catastrophic wild salmon mortalities. In was estimated that in 1984 alone, *G. salaris* had resulted in a loss of 250 – 500 tonnes to the wild salmon fishery (Johnsen *et al.* 1986).

The rapid spread of *G. salaris* and its devastation of wild salmon is thought to be due to the fact that Norwegian wild salmon are genetically distinct from those in Sweden. Wild Atlantic salmon in Sweden seem to have evolved a natural resistance to the parasite while those in Norway, who were not previously exposed to it, did not.

To date, 40 Norwegian rivers have been infected by *G. salaris*. In many of these rivers, wild Atlantic salmon have been driven to the point of extinction. In an attempt to contain the disaster, the Norwegian government has ordered that many rivers be treated with rotenone. This powerful poison is being used to kill most life in the rivers, and then efforts will be made at restocking them. Whether the poison will remove all of the *Gyrodactylus salaris* in the rivers remains to be seen.

Furunculosis

Furunculosis (*Aeromonas salmonicida*) is a bacterial fish disease first described scientifically in the 19th century (Olafsen *et al.* 1995). The disease occurs naturally in many areas, including Europe and North America. In the 1980's furunculosis infected salmon smolts from Scotland were imported into Norway for use in salmon farming. Although the disease is not exotic to Norway, it deserves mention in this section because the Scottish strain of the disease was found to be genetically different, and more virulent, than the one found in Norway (Ellis 1996). The disease quickly spread from salmon farms to wild Atlantic salmon. By 1989, salmon runs in 22 rivers were affected and by 1992, the number had reached 74 (Johnsen 1994).

Risks for BC

Although importation of live Atlantic salmon is prohibited in BC, Atlantic salmon eggs are allowed to be brought in by the salmon farming industry. The industry is, however, heavily lobbying the Canadian federal government to allow the importation of live fish as well (see box on this page). Currently, there is no evidence showing that exotic diseases have been brought to BC by such importations. *But this does not mean that no risk exists, and given the potential for irreversible devastating impact, the risk must be taken seriously.* Current policy allows importation of Atlantic salmon eggs from jurisdictions such as New Brunswick, Scotland and Ireland. We saw earlier how ISA outbreaks in New Brunswick and Scotland have led to significant impacts to both farmed and wild salmon.

The ISA virus hasn't been detected in BC and its introduction here would be catastrophic. The government assures us that the risk is made negligible by chemically disinfecting the surface of the eggs before importation. But this only addresses part of the problem. Bacterial and viral fish diseases can be transmitted from eggs to other fish by two methods, vertical and horizontal. Horizontal transmission refers to disease pathogens on the surface of the egg being transmitted to other fish that come into contact with the eggs. This type of transmission has a chance of being controlled by surface disinfection. But surface disinfection does not work in the case of vertical transmission. In this case, the disease pathogen is contained inside the egg and can be transmitted from parent to offspring. It has also been found that even when surface disinfection eliminates up to 99.98 % of a horizontally transmitted pathogen, the small amount left over

Norwegian Roulette?

Although Norway is having severe problems with diseases such as furunculosis, *Gyrodactylus salaris*, and ISA, the Canadian salmon farming industry and Canada's Office of Aquaculture continue to lobby the federal government to allow the importation of live Atlantic salmon for breeding stock. *Gyrodactylus salaris* and ISA are not known to exist in British Columbia, and the introduction of these exotic diseases would have catastrophic impacts to wild Pacific salmon stocks. Salmon farmers in Canada want the "superior" Norwegian farmed Atlantic salmon stocks to "improve" their stocks. The goal is to increase production and global market competitiveness. This is an irresponsible position given the history Norway itself has had with the introduction of exotic disease pathogens from the importation of live salmon from other jurisdictions.

can still present a risk for transmitting the disease (Goldes *et al.* 1995).

The ISA outbreaks in New Brunswick and Scotland show the inadequacy of federal policy in dealing with the possible importation of exotic disease pathogens. For years the Canadian government has allowed the importation of Atlantic salmon eggs from areas where ISA occurs. But it wasn't until this month (March, 2000) that scientists obtained preliminary results on whether ISA is vertically or horizontally transmitted (ASF 2000). The fact that Atlantic salmon eggs were allowed to be imported into BC, even though the issue of vertical or horizontal transmission of ISA was not resolved, shows negligence.

In addition to chemical disinfection, government regulation calls for a quarantine period of up to 1 year, during which 4 fish health inspections are done. Although this does reduce the chance of a vertically transmitted disease being imported, it does not eliminate the risk. Many fish health experts have stated that the inspections are too infrequent to adequately detect the presence of disease pathogens (Ellis, 1996). This is especially the case if the pathogen is being carried by the fish, but there is no visible sign of the disease.

The discovery of "new" diseases must also be considered when assessing the risk associated with importation of salmon eggs. As technology improves and the focus on fish diseases increases, pathogens never before described are being found. The presence of as yet undiscovered pathogens in the marine environment must also be considered when assessing the risk associated with importation of eggs from one region to another. Such pathogens could, of course, not be tested for during the quarantine period mentioned above.

Many government scientists understand this, but political pressure, not science, is what often drives policy. But some scientists have spoken out. A report from the David Suzuki Foundation (Ellis 1996) has quoted Dr. David Narver, Director, Recreational Fisheries Branch, BC Ministry of the Environment, as saying the following in a February 26, 1985 letter to Mr. E.D. Anthony, Assistant Deputy Minister of the Ministry of the Environment, BC:

> "I am getting increasingly anxious about our importing of Atlantic salmon eggs. My concern is shared by many of my colleagues in both Provincial and Federal agencies...The fish health measures agreed to by DFO and ourselves in the fall of 1984 are not foolproof. They are based on statistical sampling, so we are taking a risk when it comes to the introductions of a virus. That means a risk to the nearly one billion-dollar wild salmonid fisheries of British Columbia."

At a conference of the Association of Professional Biologists of BC, in April, 1995, Dr. Narver further stated:

> "I conclude that the farming of Atlantic salmon in BC has been handled in a very cavalier fashion by the industry and by certain supportive federal and provincial biologists and bureaucrats. I believe this is one of the most serious biological and ethical issues currently confronting biologists in BC. We are playing Russian Roulette with our native (salmon) populations by continuing to import 0.4 to 1.7 million eggs per year."

ANTIBIOTIC RESISTANCE

Antibiotics and other types of drugs for non-bacterial diseases are often used when disease outbreaks occur on fish farms. The antibiotic is usually administered to the salmon by including it in the feed. Information regarding the quantity of antibiotics used for any given farm in BC is difficult to obtain, since the records kept by companies are considered proprietary information. The Feb., 2000 paper by D. Noakes *et al.*, however, states that in 1995, 156 grams of antibiotics were used for each tonne of salmon produced. This means that in 1995 alone, the 23,822 tonnes of salmon produced in BC resulted in 3.7 metric tonnes of antibiotics being used. As a result of uneaten food and fish feces, a lot of these antibiotics end up in the marine environment. Oxytetracycline (OTC) accounts for about 80% of the antibiotics used on BC salmon farms (Noakes *et al.* 2000).

When antibiotics are repeatedly used to fight bacterial diseases, bacteria can develop resistance to the drug. One way in which this can happen arises from the fact that, like any organism, there can be a wide variation in genetic makeup for individuals within a population. Although most of the bacteria might be killed by the antibiotic, a few may have genes that allow them to survive the drug. These survivors may then multiply and become more dominant in subsequent populations of the bacteria. With each treatment of the drug, these resistant bacteria are repeatedly selected to survive, and the drug becomes increasingly ineffective.

In addition to the above mechanism, there are two other ways in which antibiotic resistance can occur. Bacteria that have developed antibiotic resistance can transfer the genes responsible for it to other bacteria that don't already have resistance. The two bacteria don't have to be of the same type for this to happen, and it has even been found that live bacteria can obtain drug resistance from gene fragments of dead bacteria (Margulis 1986).

Many studies have found that antibiotics can persist in the marine environment for some time after they are used on fish farms (Capone *et al*. 1996; Hektoen 1995; Coyne 1994; Bjorklund *et al*. 1990; Samuelson 1989). The half-life of oxytetracycline (the time it takes for half of the drug to disappear) varies from 5 to 16 days in sea water, and 9 to 419 days in marine sediments. The variation is a result of differing environmental conditions encountered in the various studies.

Antibiotic resistant bacteria can accumulate in the vicinity of fish farms in two ways. Residual antibiotics found in fish farm sewage can cause the bacteria which live in marine sediment to develop resistance. The second way is for disease causing bacteria carried by the fish to develop resistance when the fish are treated with antibiotics. Fish sewage can then deposit these resistant bacteria in the vicinity of the farm. Many studies have confirmed that marine sediment in the vicinity of fish farms contains various strains of antibiotic resistant bacteria (Herwig 1997; Kerry 1996; Barnes 1994; Nygaard 1992). Another study looked for antibiotic resistant bacteria in marine sediments around abandoned salmon farming sites. Of the 9 abandoned sites tested, 6 showed increased levels of resistant bacteria (Lunestad 1991). These had been abandoned from 2 to 3 years. One study in Finland has even found oxytetracycline resistant bacteria in the intestines of wild fish (Bjorklund 1990). The wild fish had also been observed feeding on

Publicly Funded - Industry Biased

When researching this report, 5 papers were found which showed that antibiotics can persist for long periods of time in the marine environment, and 19 papers which found varying degrees of antibiotic resistance in many strains of bacteria in the vicinity of fish farms. In one paper, resistant bacteria were found in the intestines of wild fish.

When discussing the issue of risks associated with using antibiotics on salmon farms, the recent Department of Fisheries and Oceans (DFO) paper (see Introduction) (Noakes *et al*. 2000) does not mention any of the above papers. It simply references 4 papers that looked at how magnesium and calcium in marine water bind to oxytetracycline (OTC) and "render it biologically unavailable". This is a red herring. It selectively looks at a small part of the problem (OTC in marine water) and does not mention any studies which show that antibiotic residues (OTC and others) end up in marine sediments under farms, as well as marine vertebrates and molluscs in the vicinity of farms. The DFO paper also does not mention antibiotic resistance or the 1993 outbreak of triple-resistant bacteria on a BC fish farm (see text on page 10). While this type of bias might be expected from industry spokespeople, there is no place for it in publicly funded government labs such as those funded by DFO.

Don’t Eat That Salmon*

Alexandra Morton, a Vancouver Island biologist, has revealed new evidence showing the risk farmed salmon can pose to human health. Ms. Morton sent bacteria swabs from farmed Atlantic salmon, recently escaped from a BC salmon farm, to a University of Guelph lab in Ontario. The lab identified two strains of bacteria that were resistant to 11 of the 18 antibiotics tested on them, including penicillin, erythromycin and amphicillin. All three of these antibiotics are used in human medication. If humans are exposed to such resistant bacteria, it increases the chances of not being able to use such antibiotics to fight certain human diseases.

Since the bacteria were resistant to antibiotics used in human medication, the question arises as to how farmed salmon could have been carrying these resistant bacteria. Exposure to human sewage is the likely source. But the salmon were caught immediately following their escape, and the salmon farm from which they escaped is far from any town. The most likely place where they encountered human sewage is from workers on the fish farms. More studies are needed to resolve this issue.

*This account is based on a letter which Alexandra Morton submitted to the December 10th, 1999 issue of “The Fisherman”.

waste feed and feces of farmed salmon.

In general, the development of antibiotic resistant bacteria is important to consider because:

- as antibiotic resistant bacteria levels increase, larger quantities of drugs have to be used to combat disease outbreaks. If resistance becomes too high, new drugs may have to be developed.
- since they are more difficult to fight, antibiotic resistant bacteria populations on farms can build to even higher levels than non-resistant bacteria. This increases the risk of disease transmission to other farms and to wild salmon.
- exposure of fish farm workers to antibiotics can lead to the development of resistant bacteria that are of consequence to humans. No research has been done for fish farms, but evidence supporting this, from land based animal farms, exists (Levy 1992).

Most of the studies on antibiotic resistance have been performed outside of BC. As with other aspects of the environmental effects of fish farming, much work has yet to be done here. The fact that antibiotic resistant fish pathogens are in BC has been confirmed. The following excerpt from the book ”Sea Silver” speaks of the damage caused by a triple-resistant strain of furunculosis on a salmon farm in the Broughton Archipelago, on the east coast of Vancouver Island. It also illustrates the way political pressure can influence science.

As the book describes (Keller *et al*. 1996):

> In June 1993, Atlantics in a Scanmar farm in the Broughton Archipelago developed triple-resistant furunculosis, spreading the disease through the marine environment to nearby sites. When BC Packers bought this farm and attempted to move it, the pens broke up and the diseased fish were released into the wild. It is unknown what impact this release had on wild stocks, although commercial and sports fishermen in that area reported diseased fish in their wild catches throughout the following year. Attempts to have specimens of these wild fish examined by government or private labs, to determine whether or not they suffered from the same disease, were unsuccessful. In one documented case, a private laboratory which was asked to examine a diseased fish for an environmental coalition refused to accept the work, even though the group was willing to pay their $200 test fee. A lab spokesman’s stated reason for refusal was that the lab did not want to jeopardize future contract work with the Department of Fisheries and Oceans (DFO).

CANADA'S INTERNATIONAL OBLIGATIONS

Salmon farming industry proponents point to the lack of measurable cause and effect with respect to the impact on BC's wild salmon populations, and argue that their industry poses little threat. As we saw with the recent paper by Noakes *et al.*, other factors that have contributed to the recent decline of wild salmon are emphasized, while the risk that salmon farming poses to the already depleted stock is downplayed. Following such an approach, we would only act on a problem when it was too late. This is not a proper risk analysis, given the irreversible nature of some of the problems associated with salmon farming.

In 1982, the United Nations tackled the problem of assessing risk and came up with the Precautionary Principle. As found in the World Charter of Nature, the Precautionary Principle states:

> Activities which are likely to pose a significant risk to nature shall be preceded by an exhaustive examination; their proponents shall demonstrate that the expected benefits outweigh potential damage to nature, and where potential adverse effects are not fully understood, the activities should not proceed. (General Resolution, 37/7, 1982)

The Convention on Biological Diversity, to which Canada is a signatory, also incorporates the Precautionary Principle. This Convention states:

> Where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to minimize or avoid such a threat.

The SAR report made it clear that significant gaps in knowledge exist when it comes to understanding the potential adverse effects of salmon farming. That is why it recommended 81 new studies be done, almost all of which have yet to begin. *Industry proponents are using the lack of full scientific certainty, and ignoring the evidence that shows significant risk, when they claim that salmon farming poses low risk.*

RECOMMENDATIONS AND CONCLUSIONS

There are clear examples from outside of BC where transmissions of disease from farmed to wild salmon have occurred. In the most recent example of ISA transmission in New Brunswick, it is too soon to tell what the impact on wild salmon will be. But since ISA is so contagious, and has never previously been found in wild salmon, the prognosis is poor. The continued importation into BC of Atlantic salmon eggs from New Brunswick presents a significant risk to wild Pacific salmon.

The term *significant* is important. The Precautionary Principle does not mean that no economic activities are conducted until they are proven to have no risk. All activities have risk, but some have higher risk than others. The highest level of risk arises from potential impacts that, once manifest, are irreversible. With open netcage fish farming, these irreversible changes could come from:

- Importation of exotic disease pathogens into BC, especially from the continued importation of Atlantic salmon eggs.
- The transmission of diseases already in BC, but whose amplification could result in disease outbreaks in wild salmon. Given the extremely low salmon runs in some BC rivers, this could cause irreversible change (extinction of that run).
- Displacement of Pacific salmon by Atlantic salmon escaping and breeding in the wild.

Although we have not treated this here, recent evidence shows that displacement of wild salmon can occur (Volpe 1999).

- Detrimental genetic modification of wild salmon caused by escaped farmed salmon interbreeding with wild ones. Evidence that interbreeding can occur between Atlantic and Pacific salmon is scant, but the risk cannot be ignored.

Given that the risks are significant, and an exhaustive examination of them has yet to occur, we conclude that salmon farming in BC is a high risk venture which should not continue in its present form. We make the following recommendations on how the industry must change.

WE RECOMMEND:

- That open netcage systems of salmon farming be replaced by land-based closed loop systems with sewage treatment facilities.

- That the importation of Atlantic salmon eggs and the farming of Atlantic salmon not be allowed in BC.

- That use of antibiotics, pesticides and other deleterious chemicals be eliminated from salmon farming practices.

- That fish processing plant effluent be treated, to avoid the spread of diseases from fish blood and viscera.

- That an independent system of monitoring be set up to assess the environmental impacts associated with salmon farming, and that any information gained from this should be included as part of an adaptive management model for the industry.

- That any information, such as frequency and intensity of disease outbreaks, that is collected by salmon farm operators be made available to the public.

REFERENCES

Anonymous 1993. Sea Trout Working Group Report. Department of the Marine, Dublin, Ireland.

Anonymous 1999. Status Report on Maine Salmon. US Fish & Wildlife Service and the National Marine Fisheries Service, released October 8, 1999.

ASF (Atlantic Salmon Federation) 1999-A. ISA Found in Wild Atlantic Salmon. Press release, December, 1999.

ASF 2000. Personal communication from Dr. Fred Whoriskey, Jr., of the Atlantic Salmon Federation.

Barnes, A.C., Hastings, T.S., and Amyes, S.G.B. 1994. Amoxycillin resistance in Scottish Isolates of *Aeromonas Salmonicida.* J. Fish Dis. 17: 357-363.

Barton, B.A., and Iwama, G.K. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. Annu. Rev. Fish. Dis. 1: 3-26.

Bjorklund, H., Bondestam, J., and Bylund, G. 1990. Residues of oxytetracycline in wild fish and sediments from fish farms. Aquaculture 86: 359-367.

BC government memorandum, from the Ministry of Environment, Lands and Parks to Daphne Stancil, Project Assessment Director, BC Environmental Assessment Office. March 11, 1997.

Caine, G. 1993. Healthy Farm, Healthy Fish. Canadian Aquaculture. January, 1993.

Capone, G.D., Weston, D.P., Miller, V., and Shoemaker, C. 1996. Antibacterial residues in marine sediments and invertebrates following chemotherapy in aquaculture. Aquaculture, 145:55-75.

Davies, I.M., Gillibrand, P.A., McHenery, J.G., and Rae, G.H. 1997. Environmental risk of Ivermectin to sediment dwelling organisms. Aquaculture 163(1-2): 29-46.

ELC (Environmental Law Centre: A Society of University of Victoria Law Students) 1998. Critical Analysis of the Salmon Aquaculture Review.

Ellis, D. and Associates 1996. Net Loss: The Salmon Netcage Industry in British Columbia. A report to the David Suzuki Foundation.

Findlay, R.H., and Watling, L. 2000. Prediction of benthic impact for salmon netpens based on the balance of benthic oxygen supply and demand. Marine Ecology Progress Series 155: 147-157.

Finlay, B.B. and Falkow, S. 1989. Common themes in microbial pathogenicity. Microb. Rev. 53: 210-230.

FOCS (Friends of Clayoquot Sound) 1998. Nightmare in New Brunswick: A Salmon Farming Disease Lesson for BC.

Goldes, S.A. and Mead, S.L. 1995. Efficacy of iodophore disinfection against egg surface–associated infectious hematoietic virus. The Progressive Fish Culturalist 57: 26-29.

Hektoen, H., Berge, J.A., Hormazabal, V., and Yndestad, M. 1995. Persistence of antibacterial agents in marine sediments. Aquaculture 133: 175-184.

Herwig, R.P., and Gray, J.P. 1997. Microbial response to antibacterial treatment in marine microcosms. Aquaculture 152: 139-154.

Husevag, B., and Lunestad, B.T. 1995. Presence of the fish pathogen *Aeromonas salmonicida* and bacteria resistant to antimicrobial agents in sediments from Norwegian fish farms. Bull. Eur. Ass. Fish Path. 15(1): 17-18.

Husevag, B., and Lunestad, B.T. 1991. Simultaneous occurrence of *Vibrio salmonicida* and antibiotic-resistant bacteria in sediments at abandoned aquaculture sites. J. Fish Dis., 14: 631-640.

Jakobsen, P.J. 1993. Lice infestation of wild salmonid populations in Norway. Paper presented to the Northern Rivers Atlantic Salmon Symposium. Utsjoki, Finland. August, 1993.

Johnsen, B.O. and Jensen, A.J. 1994. The spread of furunculosis in salmonids in Norwegian rivers. Journal of Fish Biology 45: 47-55.

Johnsen, B.O. and Jensen, A.J. 1991. The *Gyrodactylus* story in Norway. Aquaculture 98: 289-302.

Johnsen, B.O. and Jensen, A.J. 1986. Infestations of Atlantic salmon, *Salmo salar*, by *Gyrodactylus salaris* in Norwegian salmon rivers. Journal of Fish Biology 29: 233-241.

Keller, B.C., and Leslie, M.R. 'Sea Silver: Inside British Columbia's Salmon Farming Industry.' Horsdal and Schubart, (1996).

Kent, M.L., Traxler, G.S., Kieser, D., Richard, J., Dawe, S.C., Shaw, R.W., Prosperi-Porta, G., Ketcheson, J. and Evelyn, T.P.T. 1998. Survey of salmonid pathogens in ocean caught fishes in British Columbia, Canada. J. Aquat. Anim. Health 10: 211-219.

Kerry, J., Coyne, R., Gilroy, D., Hiney, M., and Smith, P. 1996. Spatial distribution of oxytetracycline and elevated frequencies of oxytetracycline resistance in sediments beneath a marine salmon farm following oxytetracycline therapy. Aquaculture 145:31-39.

Levy, S.B. 1992. The Antibiotic Paradox. Plenum Publications.

Margulis, L. and Sagan, D. 1986. Microcosmos, pp 85-98. Simon and Schuster.

Needham, T. 1995. Management of furunculosis in sea cages. Bulletin of the Aquaculture Association of Canada 95(3): 28-29.

Noakes, D.J., Beamish, R.J., and Kent, M.L. 2000. On the decline of Pacific salmon and speculative links to salmon farming in British Columbia. Aquaculture 183: 363-386.

Nygaard, K., Lunestad, B.T., Hektoen, H., Berge, J.A., and Hormazabal, V. 1992. Resistance to oxytetracycline, oxolinic acid and furazolidone in bacteria from marine sediments. Aquaculture 104: 31-36.

Olafsen, J.A. and Roberts, R.J. 1995. Salmon Aquaculture, Chapter 7. Fishing News Books.

Pohle, G. and Frost, B. 1997. Establishment of standard benthic monitoring sites to assess long-term ecological modification and provide predictive sequence of benthic community succession in the inner Bay of Fundy, New Brunswick. Atlantic Reference Centre, Huntsman Marine Science Centre.

Samuelsen, O.B. 1989. Degradation of oxytetracycline in seawater at two different temperatures and light intensities, and the persistence of oxytetracycline in the sediment from a fish farm. Aquaculture 83: 7-16.

Scottish Executive 1999. November 4, 1999 press release by the Scottish Executive.

Scottish Executive 2000. Joint Government/Industry Working Group report on ISA.

SLDF (Sierra Legal Defence Fund) 1997. Containing Disaster: Global lessons on Salmon Aquaculture.

Smith, P.D. 1985. Fish Vaccination: practicalities and economics. Proceedings of Salmon Farming Conference, Reykjavik, Iceland, September, 1985. Institute of Fresh Water Fisheries.

Saunders, R.L. 1991. Potential interactions between cultured and wild Atlantic salmon. Aquaculture 98: 51-60.

Secombes, C.J. 1991. Current and future developments in salmonid disease control. In: Interactions between Fisheries and the Environment. Proceedings of the Institute of Fisheries Management. 22nd Annual Study Course. University of Aberdeen, September, 1991.

Todd, C.D., Walker, A.M., Wolff, K., Northcott, S.J., Walker, A.F., Ritchie, M.G., Hoskins, R., Abbott R.J., and Hazon, N. 1997. Genetic differentiation of populations of the copepod sea louse *Lepeophtheirus salmonis* ectoparasitic on wild and farmed salmonids around the coasts of Scotland: evidence from RAPD markers. J. Experimental Marine Biology and Ecology 208(1-2): 227-250.

Volpe, J. 1999. Information obtained from an email by John Volpe, PhD candidate doing research on the fate of escaped farmed Atlantic salmon in BC. Breeding of Atlantic salmon has been documented in 3 rivers on the east coast of Vancouver Island, BC.

Windsor, M.L. and Hutchinson, P. 1995 Minimising the impacts of salmon aquaculture on the wild salmon stocks. In 'Sustainable Fish Farming'. Edited by Helge Reinertsen and Herborg Haaland. A.A. Balkema Press, pp. 152-153.