Chapter 5

Net Risk: Assessing potential impacts of fish farming on BC's Wild Salmon

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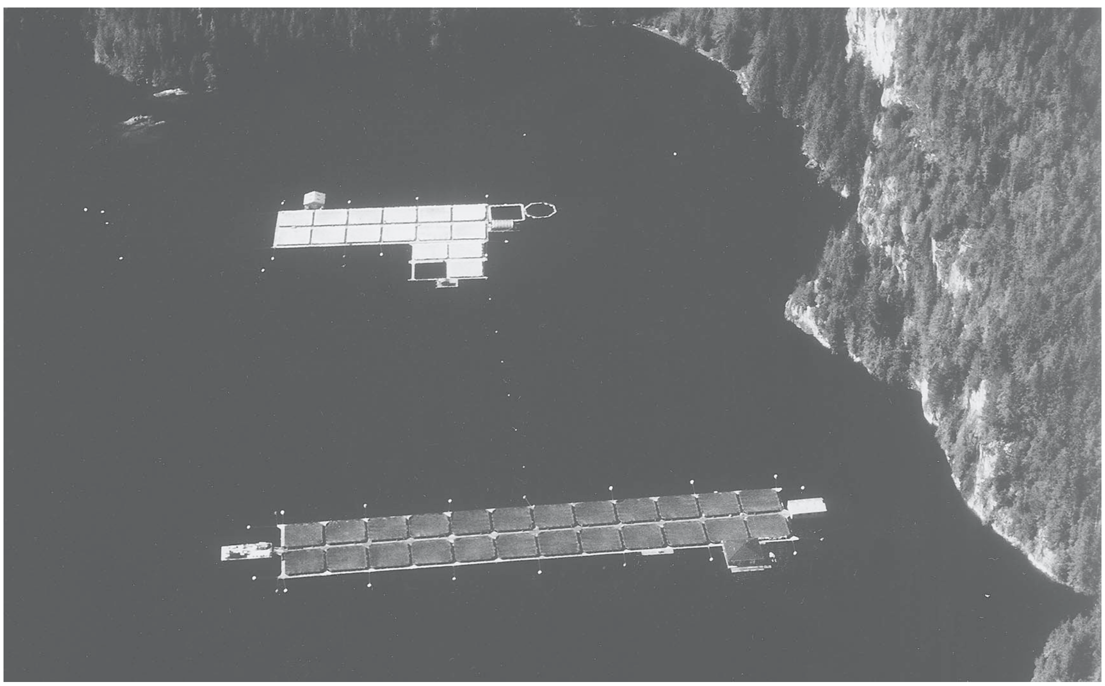


Fish farming has grown rapidly in BC, even under the moratorium on expansion. This fish farm in Cliff Bay was approved for 12 30x30 net cages in 2000. In July 2001, the BC government expressed concern about the presence of 14 (instead of 12) net cages. The same summer, another 10 100x100 super pens were documented in addition to the 14 net cages. In March 2002, 37 net cages were documented and the 10 super pens were moved to an adjacent bay. Heritage Farms has approval for only 12 net cages. PHOTO: Otto Langer

Introduction

As described in this report and elsewhere, many of British Columbia's wild salmon stocks are in decline. This is not due to salmon farming, but rather to over-harvesting, habitat impacts, hatchery supplementation, changing ocean conditions, and poor fisheries management (Glavin 1996, Slaney et al. 1996, NRC 1996, Lichatowich 1999, Noakes et al. 2000). However, many conservation groups, scientists and fisheries managers are questioning whether the salmon farming industry is an additional challenge to wild salmon.

I have studied salmon farming in BC and in other parts of the world for 20 years (Fleming and Gross 1992, 1993, Fleming et al. 1996, Gross 1998, Gross 2000) with the objective of developing scientific information that will be of value to decision-makers in protecting wild fish, as well as guiding the fish farming industry toward a sustainable and productive future. This chapter discusses BC salmon farming, the potential colonization by Atlantic salmon, the issue of farming native Pacific species, and the likely future for wild salmon if the situation continues. There is, however, an unfortunate lack of data on many issues. As such, there is a great need for BC to develop a comprehensive risk assessment model, tested and supported by targeted empirical research on ecological, pathological and genetic interactions between farmed and wild fish. The chapter ends with some suggestions for the operation of fish farms in BC coastal waters.

Salmon farming in BC — an overview

The salmon dynamic in BC has undergone radical change in less than 20 years. Production has shifted from wild stocks to fish farms and from Pacific salmon to Atlantic salmon. Before the 1980s, almost 100% of the world's supply of salmon came from wild stocks. By 1999, the majority of the world's salmon supply came from salmon farms (Figure 5-1). Before 1985, BC produced 15% of the world's salmon, yet virtually none of this came from farms. In 1999, BC produced 5% of the world's farmed salmon and only 1% of the world's wild salmon. Between 1990 and 2000, commercial landings of BC wild salmon declined by over 80%, while output from salmon farming increased over 80% (23,300 tonnes to 43,900 tonnes; Egan 2001). BC farms have become very successful, and their production continues to increase. Farm stocks, while biased toward an exotic species (81% Atlantic salmon), also include a native component (19% Pacific salmon in 1999).

Although farming of salmon poses some unique challenges, such as the use of public resources and the escape of farm fish, the concept differs little from farming chickens, cows and other agricultural commodities. Farmers purchase or produce young salmon (smolts) that they raise to market size in net pens that typically float in protected areas off the coast. The fish are fed concentrated feed, which is formulated from fish, vegetable and other products (e.g., soy). Medication is also administered. Feed is expensive, and the production objective is to maximize the conversion of feed into growth while minimizing loss of fish due to disease, parasitism and escapes. To this end, farmed salmon brood stock are selected for performance traits such as high food conversion rate, rapid growth, delayed age of maturity, and resistance to diseases and parasites. Their behaviour, physiology and morphology are significantly altered from those of wild fish, partly through genetic selection and partly through the rearing they experience (Fleming et al. 1994, Gross 1998).

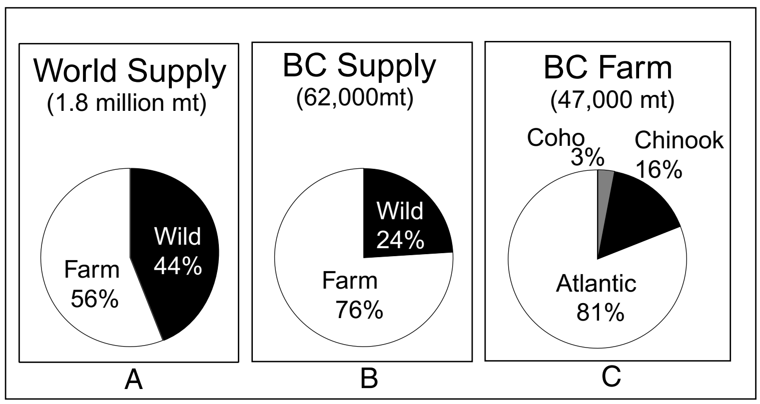


Figure 5-1 Salmon Production in 1999. Data from Egan (2000); mt= metric tonnes.

Escapes

Many of the concerns around fish farming arise from the tens of thousands of salmon that escape each year. Effluent from feed, feces, drugs, etc., and the physical impact farm facilities have on marine spaces are also concerns. While escapes are certainly not desired by industry, the industry feels that land-based farms or further protective measures are not cost-effective, at least at this time.

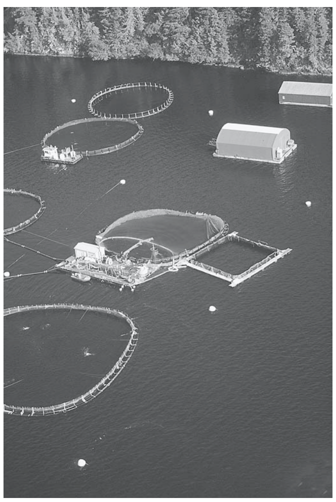
How many fish are escaping? No one really knows. The 30,689 fish per year that are reported as escaped (average from 1991-1998; Noakes et al. 2000) is surely a significant underestimate. Some members of the industry estimate a 0.3-0.5% escape rate (Wilson 2000a); however, various sources of data suggest that 2-5% or even higher may be likely. Leakage, or continuous small-scale escape, may itself exceed 0.5%. Some escapes are quite massive, such as the 390,000 farmed chinook salmon escaping in BC in 1989 (Wilson 2000b), or the 360,000 Atlantic salmon escaping from a single farm in Washington State in July 1997 (Gross 1998). A conservative estimate of 3% per year, the upper limit recommended by the 1997 Salmon Aquaculture Review, suggests that roughly 350,000 fish may have escaped in BC in 2000 (calculations partially based on quotes that industry claims the 35,000 escapees by 24 August 2000 represent 0.3% of their production; Hauka 2000, Hasselback 2000). There is need for a more reliable method of assessing escapement rates.

Box 1 A Short History of Salmon Farming in BC.

Production from salmon farms is growing rapidly, even under the restrictions to BC farm licenses that were in place. In the 1970s, the government first approved farming of coho and chinook salmon. In 1985, the failure of farmed coho and chinook stocks led to the government approving Atlantic salmon farming, which had been successfully developed in Norway. The industry began rapid expansion but escapes and effluent raised concerns. In 1995, the BC government launched the Salmon Aquaculture Review (SAR) and imposed a moratorium on further licensing of salmon farms. At that time, the number of farm licenses was 121, of which 85 were in operation.

In 1997, the government released the SAR report, which expressed mild caution about fish farming. Interpretations of the report varied widely. Some conservation groups felt it was cause to stop expansion while some in industry suggested it was a green light. In October 1999, the government released its policy response to SAR, which included the re-siting of tenures with unproductive sites and 10 new licenses for farms testing new technology. The new policy also laid down more stringent operating conditions, including those regarding the escape of fish. Several major escapes of Atlantic salmon during the summer of 2000 led the Minister of Fisheries to repeal 5 of the licenses. In spite of the moratorium on expansion, however, the production of farm salmon continues to climb; 1999 production, for example, was up 19% from 1998 (dressed weight basis). In 1999, salmon farming generated about $350 million in sales and 1800 direct and 1600 indirect jobs in BC. The moratorium expired in October 2001 and is expected to be lifted by the provincial government in 2002.

How well do these escaped fish survive? Scientifically valid data on survival of escaped fish are generally lacking. A joint Provincial-Federal program called Atlantic Salmon Watch (ASW) is helpful but under-funded and limited in scope. Adult Atlantic salmon have been captured in the Bering Sea (Brodeur and Busby 1998) and in marine and fresh waters of Alaska despite the absence of fish farms in Alaska (W. Loy, Anchorage Daily News May 2002). In 2001 ASW recorded 179 adult Atlantic salmon in the year's marine catch, 116 in 13 BC rivers, and 35 in the Alaska marine In the previous year Atlantic salmon made up 1.6% of the catch of salmon in a 24-hour fishery in the Strait of Georgia due to an undetected escape (K. Scarfo, President West Coast Trollers Association, 4 August 2000). Unfortunately, farmed chinook and coho are more difficult to identify and go largely undetected in catch records.



This farm in the Burwood Islands is one of 23 fish farms in the Broughton Archipelago. This region of Northern Vancouver Island supports the province's highest concentration of fish farms. PHOTO: Natalie Fobes

Will non-native Atlantic salmon become established and spread through BC, displacing native fish? In the past, some industry and government leaders have denied that colonization is possible, yet by 1996 all life stages of Atlantic salmon (alevins, parr, and adults) had been reported escaping and by 1998 adults had been found in 75 rivers. By 1999, feral (wild-born) juvenile Atlantic salmon were found in several rivers (Volpe et al. 2000). Escaped Atlantic salmon can therefore survive in the Pacific Ocean, migrate at an appropriate time into fresh water, perform appropriate intraspecific reproductive behaviour, produce embryos and alevins that survive, and the resulting juveniles can successfully obtain food, avoid predators and survive across years. What remains to be shown is whether the juveniles will reach adulthood and reproduce. The complete colonization cycle has therefore not been shown, but this is a likely outcome based on mathematical models of invasion probabilities (Gross 2000). The central issue about Atlantic salmon is probably not whether they can colonize, but the degree of impact that they may have on wild Pacific salmon stocks (and other species) if they do.

With the focus on Atlantic salmon, escapes of farmed Pacific salmon have largely been ignored, yet one of five farmed salmon that escape is probably a chinook or coho. (Figure 5-1). Roughly 70,000 farmed Pacific salmon may be escaping each year (1/5 of 350,000 total escapees). Ironically, while the federal government attempts to restrict escapes from farms, its own Salmon Enhancement Program (SEP) deliberately and legally releases millions of Pacific salmon a year. These hatchery salmon also differ from wild salmon in genetics, morphology and behaviour and are therefore a concern for wild salmon conservation (Fleming and Gross 1993, Waples 1999, Hard 2000, Utter this report). Some industry leaders point out that if hatchery fish have already replaced wild salmon, then fish farms are being asked to reduce the impact on hatchery, not wild, salmon. This is a point for conservationists, fisheries managers and the public to consider.

Potential impacts of escaped farm fish

Numerous scientific publications and conferences around the world have addressed the potential impacts of escaped farm and hatchery-raised fish on wild salmon. These impacts can be divided into three categories: ***genetic effects***, ***ecological effects*** and ***effects of diseases and parasites***. Table 5-1 suggests the likely levels of concern for BC wild stocks from escaped farm Atlantic and Pacific salmon. There are two important concepts: first, the level of concern is different for different categories of impact; and second, farmed Pacific salmon are probably a greater concern than farmed Atlantic salmon.

Table 5-1
The level of concern from farming Atlantic, chinook and coho on wild salmon stocks in BC

Category of Impact	Concern for wild salmon (Low to High)	
	Farm Atlantic	*Farm Chinook and Coho*
Genetic	Low	High
Ecological	Medium	High
Diseases and Parasites	High	High

The main ***genetic*** concern is that farmed fish will interbreed with wild fish, disrupting their genetic adaptations, replacing their genetic adaptations with farm adaptations, and/or reducing their genetic variability and thus their future evolutionary potential. How likely is it that such homogenization and domestication will occur? Comparative evidence suggests that it will occur between farmed and wild Pacific salmon; escaped farm Atlantic salmon in Norway have bred widely with wild Atlantic salmon and both hybrid and pure offspring of farmed Atlantic salmon can survive in the wild.

In a recent experiment where farmed fish were introduced into a natural river, the lifetime reproductive success (from one adult generation to the next) of farmed fish was only 16% that of wild fish (Fleming et al. 2000). While the reduced reproductive success of farmed fish in the wild will slow the spread of their genes, the annual introduction of these genes may saturate native genetic adaptations. In BC, while escaped farmed Pacific salmon have not yet been studied, we do know that hatchery coho interbreed with wild coho, and that hatchery coho are less reproductively 'fit' than wild individuals (Fleming and Gross 1993).

It is therefore likely that escaped farmed Pacific salmon can interbreed with wild chinook and coho and thereby genetically compromise wild stocks. The genetic concerns with escaped farm Pacific salmon are therefore classified as high. In contrast, farmed Atlantic salmon that escape in BC are unlikely to breed with wild Pacific salmon (although hybridization attempts by precociously mature Atlantic male parr is likely); and while genetic concerns do exist, they can be classified as low.

There are many possible ***ecological*** impacts of escaped farm fish, including competition for food and space and altered habitat and predation. These concerns are particularly strong in the freshwater environment. In Norway and elsewhere, juveniles of farmed Atlantic salmon are known to eat similar foods and to displace juveniles of wild Atlantic salmon (Einum and Fleming 1997), and hatchery coho juveniles are known to be more aggressive than wild juveniles in BC (Riddell and Swain 1991).

Escaped farmed Atlantic salmon in Norway and hatchery coho in BC are known to alter habitat by spawning later than wild females and by digging up wild females' redds and destroying eggs. In some cases they may spawn earlier and occupy the best spawning sites (Gross 1998). The lack of appropriate anti-

Box 2. Genetic Issues

There are two broad categories of genetic issues relevant to escapes of farmed salmon: genetic adaptation and genetic diversity. Wild Pacific salmon exist as distinct local breeding populations whose genetic differences reflect adaptations to local environments. The genetic diversity within and between these populations represents the raw material for future evolution. This is especially important given changing environmental conditions. Thus, changes to the genetic makeup of wild stocks by breeding with escaped farm fish will ultimately reduce their capacity to survive in the present and to evolve in the future. Farmed fish differ genetically from wild fish due to the domestication selection they encounter and also due to the novel environment in which they are raised. Traits such as growth rate, disease resistance and age at maturity are heritable differences in farmed and wild fish. Thus, if farmed fish interbreed with wild fish, they can introduce genes that enhance performance in the farm environment but not in the wild environment.

predator behaviour in farmed fish could well lead to increased predation on wild fish. Fleming and co-workers (2000) found a 30% decrease in wild fish production and ascribed this to resource competition and competitive displacement by farmed Atlantic salmon. Healthy wild populations of Pacific salmon may be able to resist or absorb ecological impacts, but this is not true of populations that have already dwindled to a few individuals.

Infestations of sea lice in the UK and Norway have exterminated some wild stocks. Lice is now becoming a major issue on fish farms in BC. This dead, infected chinook smolt was sampled in the Broughton Archipelago in July 2001. Five lice can debilitate a fish of 15 grams or less and 11 or more will kill it. PHOTO: Alex Morton

Diseases and parasites rank high as concerns because of their potentially devastating effects on wild populations. 'Exotic' diseases and parasites are less likely than the amplification and spread of native ones. Two examples of native diseases, both drawn from Atlantic salmon, are infectious salmon anemia (ISA; Whoriskey 2000) and sea lice (Gargan 2000).

ISA is a highly contagious and lethal viral disease that spreads by horizontal transmission (adult to adult) in both freshwater and seawater. The disease was unknown to science before appearing as an epidemic in the Norwegian salmon farming industry in 1984. Within seven years, it had spread to 101 farms and remains a problem today. In Canada, ISA was first observed in New Brunswick in 1996 and spread to 21 farm sites by 1997, and 35 by 1998. Despite widespread culling, 17 sites remain contaminated. In 1999, wild Atlantic salmon in New Brunswick were found for the first time to have the disease, and escaped farmed salmon entering freshwater to spawn were found to carry it. In Scotland, ISA was first reported in 1998. By 1999, about 10% of all Scottish sites were infected, and the disease was found in wild salmon parr. In Chile, ISA was reported in early 2000 in farmed coho salmon. In Maine, USA, ISA appeared in early 2001 and greatly impacted the farming industry. The virus is believed to be carried in mucus, urine and feces and its amplification in farms therefore creates contagious areas for nearby wild salmon, in addition to its transmission by escapees.

The parasitic sea louse *Lepeophtheirus salmonis* is an important example of how salmon farms can threaten wild salmon through parasitism. In Ireland, Scotland and Norway, the development of salmon farming has dramatically increased sea louse infestation of wild stocks of Atlantic salmon and sea trout (*Salmo trutta*). The infestations have had stronger immediate impacts than the ecological and genetic concerns mentioned above, as they have rapidly exterminated some wild stocks. The lice are contracted by wild smolts migrating to the ocean and passing through farming areas; wild Atlantic salmon smolts have been documented in farming areas to have more than 100 lice per fish. Infestation often results in increased mortality and premature return to freshwater. Sea trout adults caught in rivers within 3 km of farms carried about 400 lice per fish compared to 2 lice per fish in rivers more than

20 km from farms. In Scotland, sea trout populations in the vicinity of salmon farms have declined to levels where insufficient eggs are deposited to maintain smolt production and adult return. Currently in BC, lice are one of the major issues challenging the farming industry.

While comparative data are not yet available in BC, there is no reason to believe that the ISA virus and sea louse parasite will not have impacts on wild stocks. It is the degree of impact that is the question. Many other diseases and parasites are also of concern, including bacterial kidney disease (BKD), bacterial furunculous; viral Infectious Hematopoietic Necrosis and Viral Haemorrhagic Septicaemia). Infectious Hematopoietic Necrosis (IHN) is a naturally occurring pathogen in the Pacific Northwest. Wild salmon, especially sockeye, are used to living with background levels of the virus and typically contract IHN on the spawning grounds. An IHN outbreak was reported on a fish farm in January 2002 that resulted in over a million Atlantic salmon smolts being culled from the farm (Ministry of Agriculture, Food and Fisheries, 2002). Approximately a dozen farms in BC may have had outbreaks of IHN in early 2002.

Although salmon farming did not create these viruses, diseases and parasites, high density farming provides conditions that are especially suitable for amplification of disease and its entry into the environment where wild salmon are prone to its effects. As the farming industry develops vaccines or fish with genetic resistance to disease and parasitism, it may increase the survival of farmed fish, but it could make them “Trojan horses” with the potential to decimate wild populations. These and further issues related to disease require research both for the protection of wild fish and to improve the performance of the fish farming industry.

Where is BC headed?

Existing fish farming conditions in BC may lead to the following:

- **Decreased numbers of wild salmon:** Wild salmon in BC may decrease in number due to: (1) exposure to increased levels of diseases and parasites from farmed Atlantic and Pacific salmon; (2) degradation of their genetic makeup through interbreeding with escaped farmed Pacifics; and (3) ecological competition with escaped farmed Pacifics and newly established Atlantics.
- **Extinction of some wild salmon stocks:** Decreasing the number of individuals in some wild stocks may lead to their extinction. For example, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) listed the Interior Fraser coho salmon as ‘endangered’ in May 2001. While

Pacific salmon are not facing extinction as a species, discrete stocks (or populations) are vulnerable to extinction.

- **Increased number of salmon species:** If Atlantic salmon colonize, this increases the number of salmon species by one.

Conclusions

Fish farming is an important player in global salmon production and coastal economies. However, fish farming poses a threat to wild salmon stocks and other marine resources. Therefore, BC needs to find a solution that will accommodate both fish farming and wild salmon. Under what conditions will the impact of fish farms be reduced? What level of risk to wild salmon is society willing to accept? How should BC proceed so that both fish farming and wild salmon can flourish? The following recommendations are suggested:

- **Risk assessment research:** The provincial and federal governments should launch appropriate risk assessment research as soon as possible to quantify the genetic, ecological and pathological impacts on wild salmonids from various levels of fish and substance escapement from farms. It is unlikely that zero escapement can be achieved in fish farming because of the cost of containment. Therefore, this research should aim to provide the data for acceptable levels of escapement. Risk assessment can help identify the range of potential impacts from fish farms, and the subsequent loss in number of wild salmon, so that decisions can be made on the allowable tradeoff between farm and wild salmon. Society can then provide the fish farming industry with allowable thresholds of escapement. Such research has yet to be conducted in BC.
- **Precautionary approach:** When uncertainty exists, BC may benefit from a "precautionary approach" to fish farming. A precautionary approach is an accepted doctrine for dealing with industrial development in terrestrial environments and should also apply to the fish farming industry. When in doubt, decisions should favour wild salmon since these are the most difficult to replace.
- **Protected areas:** "Zoning" of coastal areas in BC may be necessary for the survival of wild salmon and the sustainability of fish farming. Some zones should provide protected aquatic areas similar to terrestrial parks and reserves, while others will be for fish farming. Government should use the knowledge of risk assessment to determine where the protected areas for wild salmon, and industrial areas for fish farming, might best exist.

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