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Market solutions to public policy problems

Escaped Farmed Salmon: A Threat to BC's Wild Salmon?

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Main Conclusions

Atlantic salmon escapes

- **Although the number of Atlantic salmon produced in BC has increased radically since their introduction to this area, the number of escapes has not.**
- **It seems highly unlikely that Atlantic salmon have the potential to hybridize with Pacific species in the natural waters of British Columbia.**
- **There appears to be little risk of Atlantic salmon establishing viable populations in the Pacific Northwest at this time.**

Pacific salmon escapes

- **The number of accidental aquaculture releases is insignificant in comparison to the magnitude of deliberate yearly public hatchery releases.**
- **Public hatchery releases appear to have a greater potential to exert a detrimental effect on wild Pacific salmonids.**

Disease

- **The chance of diseased aquaculture escapees interacting with wild fish long enough to transmit disease or surviving long enough to reach spawning grounds is very remote.**

Overall

- **Overall, the risk of escaped salmon detrimentally affecting wild stocks in BC is currently low.**

Salmon farming, or aquaculture, has become a regular news feature in British Columbia. Headlines such as "Fish farming threatens wild salmon…" (Hume, 2004) and "…disease and parasites will devastate wild stocks..." (Cox, 2004) portray an environmentally destructive industry. But is this really the case? What concrete scientific evidence do we have for such claims? As we dig deeper, it appears that scientific research does not back up the supposed threat of escaped farmed salmon. In this *Alert*, we draw on information from a team of scientists, from BC and Europe, to present the facts behind the issues.

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Introduction

Accidental releases or "escapes" of farmed salmon have been deemed to wreak havoc on wild fish (Langer, 2003; Volpe, 2001). However, as we examine the scientific research on this topic, the evidence suggests otherwise. Farmed salmon production in BC has increased by 26 percent in the last 5 years, from 49,000 tonnes in 2000 to 61,800 tonnes in 2004, with a wholesale value of $294 million (Ministry of Agriculture, Food and Fisheries, 2004; Ministry of Environment and Ministry of Agriculture, Food and Lands, 2005). These increases have fuelled existing concerns over the effect that escaped farmed fish could have on wild fish stocks.

The effects that escaped farmed fish could have on wild fish can be split into three categories: ecology, genetics, and disease transmission (Hutchison, 1997; Matthews *et al.*, 2000; Butler, 2002; Otteraa *et al.*, 2004).

Ecologically, key biological issues such as survival, food availability, and growth are strongly dependent on the number of animals in a given area. Therefore, the sudden release of thousands of farmed fish has the potential to change the natural equilibrium of the ecosystem. In British Columbia, the freshwater stage of the salmon's life cycle occurs in hatcheries where escapes are rare; most escapes occur from cages during the marine stage of production. Each cage houses tens or hundreds of thousands of salmon, depending on their size. Therefore, escape incidents, although relatively few and far between, have the potential to release hundreds of thousands of fish when they do occur. Such incidents can occur as a result of adverse weather, predation, or human error.

Genetically, wild fish have evolved over millions of years, developing physical and behavioural characteristics that allow them to maximize their survival in their natural environment. In comparison with other domesticated species such as chicken and cows that have been intensively farmed since the 1800s, salmon have been farmed since the 1960s. As a result, farmed salmon are relatively undomesticated compared to other agriculturally-farmed species. However, farmed salmon have been selected through generations for traits such as fast growth and disease resistance (reviewed by Gross, 1998). Therefore, if farmed fish were to breed with wild fish, they may influence the genetics of wild fish, resulting in individuals that are potentially less well adapted to the natural environment. Indeed, in Europe, inter-breeding of wild and escaped farmed fish is thought to have diluted the genetic pool of wild fish (Hutchings, 1991; Saunders, 1991; McGinnity *et al.*, 1997; Youngson & Verspoor, 1998; McGinnity *et al.*, 2003).

Legislation requires farmers to take several measures to prevent escapes during routine husbandry.

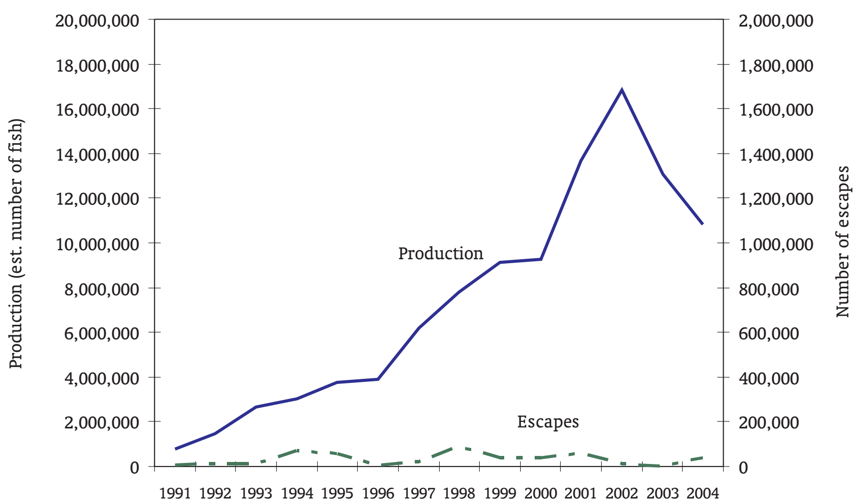
Finally, as farmed fish are held in large groups in close proximity, disease, when it does occur, spreads rapidly through the population. Escapes during an outbreak of disease may expose or introduce disease, if it is present, to wild fish.

Current legislation and farm practice

The BC aquaculture industry is regulated and monitored. For example, the reporting of escape incidences (including those that are only suspected) is mandatory, within 24 hours of discovery. In a 2004 publication, the provincial Ministry of Agriculture, Food and Fisheries and Ministry of Water, Land and Air Protection found no evidence of unreported escapes in 2003. (A total of 40 escapes were reported in 2003.)

Legislation requires farmers to take several measures to prevent escapes during routine husbandry. The nets which make up the cages must meet a minimum strength, tested by a specified net strength testing protocol. When fish are transferred from one cage to another, additional nets must be placed on any area over which a fish passes to prevent accidental escapes. In addition, individual workers designated as "spotters" are responsible for locating potential escape areas and actual escapes. Predation by seals or sea lions, which can allow other fish to escape, is prevented by tightening the nets (which can stop seals pushing in to get at the fish) or by using steel nets. If these criteria are not met, provincial inspectors have the authority to remove sub-standard net cages from the water.

Figure 1: Atlantic Salmon Production and Reported Escapes in British Columbia from 1998 to 2004



Note ten-fold difference in scales.

Sources: Ministry of Agriculture, Food and Fisheries, 2004; DFO, 2004; Ministry of Environment and Ministry of Agriculture, Food and Lands, 2005; and author's calculations.[2]

The loss of farmed fish represents a substantial economic cost for the fish farmer; therefore, farmers put measures in place to minimize escapes. The freshwater stage of fish farming occurs in hatcheries, so by the time the fish are transferred to the sea, they represent an extensive investment in man-hours and feed costs. Because many fish are housed in each cage, each escape incident results in a significant loss of fish.

In addition to specific instances of fish escaping, "leakage" can occur when fish are transferred from their cages, when they are graded (which ensures that all the fish in a cage are of a similar size), or through small holes in the net. Data on these small losses is sparse, although in 1995, Ludwig (cited in Lough and Law, 1995) suggested 0.5 to 1.0 percent of caged populations are lost per year in BC.

Atlantic salmon escapes

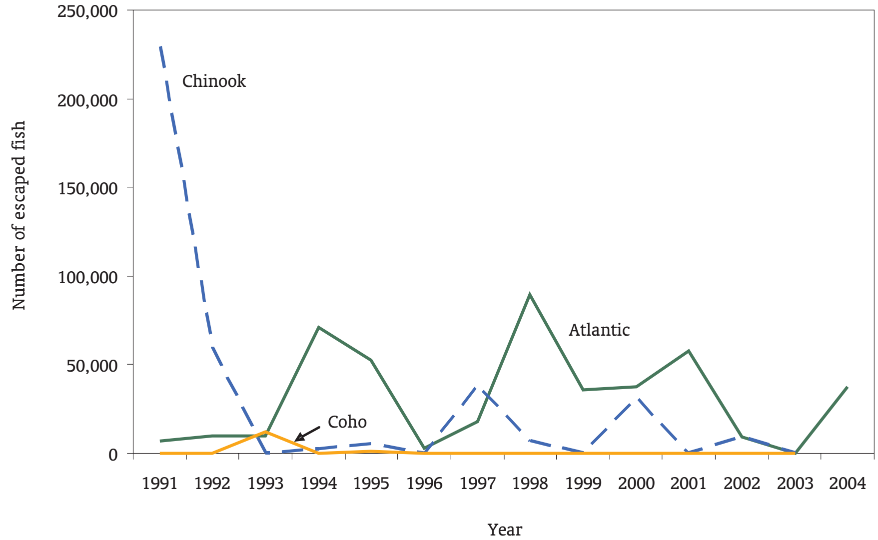
Atlantic salmon dominate salmon production in British Columbia. In 2004, 46,065 tonnes of Atlantic salmon accounted for 75 percent of the total provincial production of farmed fish compared with 14,065 tonnes of chinook (23 percent of production) and 1,400 tonnes of coho (2 percent of production) (Ministry of Environment and Ministry of Agriculture, Food and Lands, 2005).

Since Atlantic salmon farms were established in British Columbia in 1984, Atlantic salmon releases have been accidental rather than intentional.[1] Although the number of Atlantic salmon produced in BC has increased radically (from 33,100 tonnes in 1998 to 46,065 tonnes in 2004) since their introduction to this area, the number of escapes has not. The federal Department of Fisheries and Oceans reports that the number of escaped fish has fallen from 89,000 fish in 1998 to 34 fish in 2003 (DFO, 2004). Figure 1 shows the number of escaped Atlantic salmon in British Columbia from 1991 until 2004 in relation to the number of Atlantic salmon produced.[2]

Juvenile offspring of escaped adults appear to have been observed in rivers in BC (Volpe *et al*., 2000; Harrower, 2005). However, there is no evidence to date of escaped Atlantic juveniles returning to rivers to spawn after migrating to the sea.

If any individual is to survive in the natural environment, it must be able to feed. In British Columbia, large numbers of small forage fish, such as herring, smelt, and eulachon, which are known prey of Atlantic salmon, have been observed freely entering Atlantic salmon pens, presumably to shelter from predators (Alverson and Ruggerone, 1997). This suggests that farmed Atlantic salmon will not eat wild prey. Indeed, Atlantic salmon that have escaped from marine farm facilities do not appear to be proficient feeders. McKinnell *et al.* (1997) found that just 5.8 percent of a sample of 445 Atlantic salmon caught in BC waters had eaten natural prey.

Figure 2: Number of Escapes of all Three Fish Species Farmed in BC from 1991 to 2003



Note: Data for Atlantic salmon are available, and included, to 2004.

Source: DFO, 2004.

Atlantic salmon colonization

There is a lack of experimental data on the colonization of Atlantic salmon in British Columbia, but data on Atlantic salmon in other areas of the world, such as Chile and the Great Lakes region of Canada and the United States, may provide clues about the colonization potential of Atlantic salmon in this region.

In Chile, research indicates that escaped farmed fish do not readily establish reproductive populations. The Chilean ecosystem is thought to have opportunities for colonization as it has no native salmonids. Salmonid farming (rainbow trout, Atlantic, coho, and chinook salmon) has taken place in Chile since approximately 1980. After extensive data collation and surveying of farm and non-farm areas, Soto *et al.* (2001) concluded that all Atlantic salmon caught were escapes; there were no established populations. These results suggest that escaped Atlantic salmon do not survive to reproduce.

Research in the Great Lakes indicates that Atlantic salmon, which are native to the area, have lost out to competition from non-native Pacific species such as steelhead and chinook (Jones and Stanfield, 1993). Furthermore, several studies in the Great Lakes have determined that the Pacific salmonids now resident in the Great Lakes are detrimental to the re-introduction of Atlantic salmon to this area (Stanfield and Jones, 2003; Scott *et al.*, 2003; Beall *et al.*, 1989).

There is only one reported self-sustaining Atlantic salmon colony outside this species' natural range; in the mountains of New Zealand (Lever, 1996). Furthermore, a strain of Atlantic salmon used in net-pen farms in the Puget Sound area of the northern Washington coast is now under consideration for listing under the 1974 United States Endangered Species Act (ESA) (Department of the Interior and Department of Commerce, 2000). Overall, the evidence presented here suggests that Pacific salmon are able to colonize areas much more readily than Atlantic salmon, even in areas in which Atlantic salmon are native.

As Atlantic salmon are a distinct species from Pacific salmon, the genetics of the Pacific species could only be affected through the interbreeding (hybridization) of Pacific and Atlantic species. To date, there are no reported cases of hybridization between Atlantic and Pacific species in the Pacific Northwest in the wild. Furthermore, laboratory studies carried out in controlled and optimal conditions have failed to cross Atlantic salmon with the Pacific pink, chum, or coho salmon (Chevassus, 1979; Loginova and Krasnoperova, 1982; Gray *et al.*, 1993). Therefore, it seems highly unlikely that Atlantic salmon have the potential to hybridize with, and thus influence the genetics of, Pacific species in the natural waters of British Columbia.

Pacific salmon escapes

Coho and chinook salmon are the only Pacific salmonids produced commercially in British Columbia. In 2003, the last year for which monetary data are available, 15,700 tonnes of chinook and 1,400 tonnes of coho were produced, with a farm gate value[3] of $36.8 million and

$6.1 million respectively (Ministry of Agriculture, Food and Fisheries, 2004). Production of Pacific salmon is much smaller than that of Atlantic salmon, and apart from 1991, the number of escapes is also lower for Pacific compared to Atlantic salmon (see figure 2).

Although Pacific species are native to the Pacific Northwest, particular traits, such as fast growth and disease resistance, have been selectively chosen during generations of farming. Therefore, escaped farmed fish can potentially exert genetic, ecological, and disease pressures on their wild equivalents.

As farmed Pacific salmonids are the same species as those found in the wild, they are able to breed, or hybridize with each other. Studies comparing wild, farmed, and hybrid coho salmon found that hybrids showed intermediary growth; slower than wild coho, yet faster than farmed coho. Hybrid fish also took an intermediate length of time to recover from predator exposure; slower then wild coho, but faster than farmed coho (Tymchuck *et al.*, 2006). However, these hybridization effects diminished within two generations (Tymchuk *et al.*, 2006). Therefore, assuming escapes continue to be few and wild stocks remain numerous, the genetic effects of escaped farmed coho on wild fish are likely to be short-lived.

While there is the potential risk of ecological, genetic, and disease disturbances from escaped farmed fish, scientific evidence suggests that observed fluctuations in the wild Pacific salmon stocks are natural, and are influenced by factors such as environmental change (Beamish *et al.*, 1999). Around 1990, wild stocks started to decline with particularly marked decreases in chinook and coho salmon. In 1998, the total Canadian salmon catch was at its historic low for this century. This recent decline does not

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appear to be related to aquaculture (Noakes *et al.*, 2000) as it appears that the issues of disease transfer between wild and farmed fish and of escapes are minor (as discussed earlier in this *Alert*). Instead, declines in wild stocks are attributed to habitat degradation, changing oceanic conditions, and effects from breeding with public hatchery fish (Beamish *et al.*, 1997; Reisenbichler, 1997), together with high harvest rates and a decrease in adult size (Ricker, 1981).

Any environmental impacts from escaped farmed Pacific salmonid are likely to be dwarfed by the number of releases by public hatcheries, which are breeding native, wild species. Public hatcheries are part of the Department of Fisheries and Oceans' strategy to enhance salmon stocks. These facilities fertilize and then incubate eggs from local fish, rearing them until the fish can be released into the wild (DFO, 2005). In 2003, for each chinook that escaped from a fish farm, the public hatcheries released 25 million such fish, and for each coho that escaped, the hatcheries released 20 million coho (DFO, 2004; Lehmann and Irvine, 2004).

There are risks associated with escaped, partially-domesticated farmed chinook and coho salmon. Scientific studies suggest that Pacific species reared in public hatcheries have the potential to out-compete their wild counterparts. However, as the ratio of escaped to wild fish is currently very low, these escapes are currently unlikely to effect wild populations. As the number of accidental releases from fish farms is insignificant in comparison to the magnitude of deliberate releases each year from public hatcheries, the fish released from hatcheries have a greater potential to detrimentally affect wild Pacific salmonids than do the escaped farmed fish.

Disease

The healthier and more stress-free a fish is, the faster it grows, the less susceptible to disease it is, and the higher quality it is, and hence it represents a better return for the farmer. It is therefore in the best interests of the fish farmer to produce healthy, stress free salmon. While documentation of disease transmission between farmed and wild fish does exist (Munro *et al.*, 1976), the *direction* of the disease transmission is particularly difficult to ascertain. It is likely that most fish diseases originate in wild populations (Olivier, 2002). Therefore, wild fish have evolved mechanisms to deal with these diseases.

Disease introduction from hatcheries is rare but can occur. The monogean parasite, *Gyrodactylus salaries*, was introduced into northern Norwegian rivers during public hatchery fish stocking programs (Johnsen and Jensen, 1991). However, the volume of young fish released in BC from provincial, first nations, and cooperative hatcheries is so large that the risk of disease being introduced from these sources is much greater than from fish released by aquaculture hatcheries.

In both commercial and public fish rearing facilities, outbreaks of disease are treated quickly, and as a result, the probability of diseased fish escaping is very small. Furthermore, severely diseased fish are unlikely to survive for any length of time. Stephen and Ribble (1995) observed that 68 percent of clinically ill net pen fish died within 48 hours of first observation. Diseased fish do not feed or behave normally, and as a result, are less likely to school or come in close contact with other fish in the wild (Barber and Huntingford, 1996), or even in enclosed aquaculture cages (Stephen and Ribble, 1995). Because they behave abnormally, diseased fish are also more prone to predation (Wolf, 1985; Landeau and Terborgh, 1986), which decreases the likelihood of disease transmission between fish.

Both fish farms and wild hatcheries can use antibiotics, but only in response to disease outbreaks. As a result, hatcheries could potentially enhance the production of antibiotic-resistant disease strains, which could then affect wild fish. However, in the US Pacific Northwest, antibiotic-resistant strains of bacterial fish pathogens have been observed in Pacific salmon hatcheries for over 40 years without any adverse impact on wild salmonids (Waknitz *et al*., 2003).

The likelihood of diseases being transmitted from farmed to wild fish appears to be small.

Conclusion

The potential of escaped farmed Atlantic salmon to detrimentally affect Pacific salmonids does not appear to be realized in British Columbia. Production of viable, Atlantic-Pacific hybrids is not possible, even under ideal, controlled conditions. Atlantic salmon are poor colonizers, whether they have existed in an area previously or not. Further, Pacific salmon appear to have a detrimental effect on the already poor colonization ability of Atlantic salmon.

Escaped farmed Pacific salmonids can interbreed with wild Pacific salmonids. However, laboratory studies suggest that effects on growth and recovery from predator exposure diminished rapidly. Furthermore, any effects on the wild populations of salmonids by escaped farmed Pacific salmonids are likely dwarfed by extensive hatchery releases. Wild Pacific salmon stocks do fluctuate, but this variation does not appear to be related to aquaculture.

The likelihood of diseases being transmitted from farmed to wild fish appears to be small. Disease occurs very rarely in aquaculture. Furthermore, diseased fish behave abnormally and are more likely to suffer predation. Therefore, the chance of diseased fish associating with and infecting other salmonids is low.

The research currently available indicates that the risk of escaped aquaculture salmon detrimentally affecting wild stocks in BC appears to be low.

Notes

1 In British Columbia, the first introductions of Atlantic salmon occurred between 1905 and 1934, when 7.5 million juvenile Atlantic salmon were released by the provincial government on the east coast of Vancouver Island and the Fraser River (MacCrimmon and Gots, 1979).

2 Estimated by dividing the total production weight by an estimated market weight of 4.25 kg (after Gross, 1998).

3 Farm gate value, also known as landed value, is the price the aquaculturists are paid for the whole fish.

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Her background in fish behaviour and aquaculture led her to Canada where her research program includes investigation of the ecological, behavioural and social effects of culturing fish in aquaculture and in the laboratory, the conservation of potentially affected species, and the effects of man-made structures on wild fish migration. She is currently leading a multidisciplinary assessment of the potential that organic aquaculture has for Canadian markets. Dr Cubitt has consulted on fish welfare nationally and internationally, for research institutes, the aquaculture industry, associations and councils.

Dr. Kevin G. Butterworth is a Research Associate at the Centre for Aquaculture and Environmental Research at the University of British Columbia in Vancouver. He is a Fellow of AquaNet, a Canadian Network of Centres of Excellence in Aquaculture. Dr. Butterworth was awarded a Joint Honours B.Sc. in Biochemistry and Marine Biology by the University of Wales, Bangor. Subsequently, he read for his Ph.D. at the University of Glasgow, Scotland, and the Heinrich-Heine Universität, Düsseldorf, Germany, where he examined the adaptations of benthic invertebrates to life in sulphidic sediments as a result of anthropogenic impact. These studies were conducted in the Kattegat and Skagerrak that link the Baltic Sea with the North Sea, as well as in the Firth of Clyde, and the Irish Sea.

Dr Butterworth is currently conducting systematic investigations on the distribution, efficacy and control of sea lice on wild and farmed salmonid stocks in the Canadian Pacific Northwest, and Norway. These sealice projects are funded by grants from AquaNet, Canada, the BC Science and Innovation Council, BC Pacific Salmon Forum and the NFR, Norway.

Dr. Bengt Finstad is a Senior Research Scientist at the Norwegian Institute for Nature Research in Tungasletta, Norway. His research interests include environmental physiology, smolt production and releases of fish, pollution and acidification, biotelemetry, aquaculture and sea ranching, salmonids in the ocean, and fish diseases and parasites. Dr. Finstad studies the interactions between aquaculture and wild salmonid fish, and is developing a risk factor model to estimate the impact of sea lice infestation from fish farms on native stocks. He has conducted further studies on the migratory behaviour of fish species using telemetry, produced smolts for enhancement purposes, and studied the impact of pollution and acidification on wild fish stocks. Dr. Finstad has published 51 papers in international scientific journals.

Prof. Felicity A. Huntingford, PhD, is Professor of Functional Ecology with the Fish Biology Group in the Division of Environmental and Evolutionary Biology at the University of Glasgow, Scotland. Professor Huntingford has been involved in research into fish biology for more than 35 years. She has a special interest in using behavioural techniques for improving the production and welfare of farmed fish. Her research receives funding from various agencies including the UK's NERC and BBSRC, the Royal Society of London, the Leverhulme Foundation, the Welcome Trust, the EU, and several industrial enterprises. She has written four books and published more than 200 papers in refereed scientific journals. She has held a number of posts with learned societies and is currently Vice-President of the Fisheries Society of the British Isles.

Dr. R. Scott McKinley is Professor of Aquaculture and the Environment and Director of the Centre for Aquaculture and Environmental Research at the University of British Columbia. He also holds a senior Canada Research Chair in Aquaculture and the Environment and an NSERC Industrial Research Chair in Biotelemetry. Dr. McKinley has successfully promoted Canadian research nationally and internationally with particular emphasis on student development through his position as the Executive Scientific Director of AquaNet, Canada's NCE in Aquaculture.

An environmental physiologist who has frequently demonstrated the use of wireless communication technology that permit scientists to monitor environmental change from the animal's perspective, Dr. McKinley's studies have taken him across Canada and to various parts of the globe including the Amazon, the Mediterranean, and Scandinavia. Dr. McKinley has been widely consulted by many national and international organizations. He received his B.Sc. in fisheries and wildlife from the University of Guelph, an M.Sc. from York University, and a Ph.D. in Environmental Physiology from the University of Waterloo.