FARMED AND DANGEROUS

Human Health Risks Associated With Salmon Farming

A Report Prepared for Friends of Clayoquot Sound
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SUMMARY

Consumers should be made aware that the salmon they purchase is increasingly being supplied from salmon farming instead of commercial wild fisheries. As we change our supply of salmon from wild to farmed, we expose ourselves to health risks which were not present when relying solely on wild salmon. These risks include:

• contributing to the development of antibiotic resistant strains of bacteria which cause disease in humans. Such resistant strains can lead to human diseases that cannot be treated with conventional antibiotics.

• introduction of antibiotic and other chemical residues in farmed salmon and collateral introduction to wild seafood consumed by humans.

• lower nutritional value of farmed salmon compared to wild salmon.

• global net loss of seafood available for human consumption.

While many of these risks are similar to those encountered when consuming farmed land-based animals, consumers have not had to deal with such risks when eating salmon.

The current system of antibiotic residue monitoring conducted by Health Canada does not prevent the public from being exposed to such residues from farmed salmon. Also, there is no monitoring of farmed salmon for the presence of bacteria which have developed antibiotic resistance due to the use of such drugs on salmon farms.

Many studies have linked the use of antibiotics on salmon farms with an increase in antibiotic resistance in bacteria present in salmon, as well as those residing in the environment near salmon farms. It has also been shown that when a bacterium has developed resistance to an antibiotic used on a farm, the resistant strain that arises can often show resistance to other antibiotics which were not used on the farm. In one study, the bacterium which causes furunculosis disease in salmon was shown to have developed multiple antibiotic resistance, including resistance to several antibiotics

never used on salmon farms but that are commonly used on humans.

While most of the bacteria present in salmon do not cause disease in humans, some bacteria such as *E. coli*, *Salmonella* and *Serratia*, are of concern to both humans and fish. All three of these types of bacteria have shown increases in antibiotic resistance as a result of animal farming, including the farming of salmon. In addition, studies have shown that antibiotic resistance can be transferred between different types of bacteria. This means that even if the antibiotic resistant strains carried by salmon cannot cause human diseases, these bacteria can transfer their resistance to other bacteria that do. If humans eat farmed salmon containing antibiotic resistant strains of bacteria, they make it more likely that bacteria carried by humans can develop the same resistance. This increases the risk that human bacterial diseases will evolve which cannot be treated with conventional antibiotics.

Switching from wild salmon to farmed salmon also reduces the nutritional benefits to the consumer. Not only do farmed salmon have a higher fat content than wild salmon, but the ratio of good fats (such as omega-3 fats) to bad fats (saturated fats) is also lower in farmed salmon.

Salmon are carnivorous, and the feed that is given to farmed salmon contains significant quantities of fish meal and oil. For every kilogram of farmed salmon produced, 3 kilograms of wild fish, such as anchovies, sardines and mackerel, are used to make the feed. The result is that salmon farming results in a net loss of seafood available for human consumption.

One human health risk not currently associated with salmon farming but which may be of concern in the near future, is the farming of genetically engineered, or transgenic, salmon. Currently, there are no salmon farms which commercially produce transgenic salmon. However, there has been much research in this area conducted by both industry and government, including the Canadian federal Department of Fisheries and Oceans. Transgenic strains of salmon have been developed and tested, and a few bio-engineering companies are ready to provide them for commercial use. Since it is a relatively new field, there has been virtually no research done into the health risks from eating genetically modified foods.

Based on the risks discussed in this review, and the evidence presented, we recommend that:

- BC develop an aquaculture system that is dominated by the farming of species that have wild fish input to farmed fish output of less than one. This does not mean the elimination of farming carnivorous species like salmon, but such species should not dominate aquaculture.

- antibiotics be eliminated from aquaculture production. About 80% of global aquaculture production is currently done without the use of antibiotics or other drugs.

- until such time as the use of antibiotics is eliminated, Health Canada begin conducting antibiotic residue tests on wild seafood caught in salmon farming areas, in addition to the testing of farmed salmon.

- until such time as the use of antibiotics is eliminated, the current system of testing for antibiotic residues for seafood heading for market be changed so that salmon which contains such residues can be prevented from being consumed by the public.

- the Canadian government put aquaculture under the jurisdiction of Agriculture Canada rather than the Department of Fisheries and Oceans (DFO). This will allow all DFO resources to be directed toward wild marine resource management. This is a key recommendation for assuring that proper emphasis is put on such management.

INTRODUCTION

This review will look at the human health implications of shifting the market supply of salmon from wild stocks to farmed salmon. Many consumers are not aware that the salmon they purchase is increasingly produced by farming. Between 1988 and 1998, farmed salmon production in British Columbia (BC) increased from 6,600 to 42,300 tonnes (BCEAO, 1997; Anon., 2000). In 1998, farmed salmon accounted for 58% of the total salmon production in BC.

The impact of open net-cage salmon farming on the marine environment and on wild salmon in particular has been looked at in detail by many authors (Ellis, 1996; SLDF, 1997; FOCS, 2000) and will not be treated in this review. Some of these impacts are transfer of diseases from farmed salmon to wild salmon, escape of farmed salmon into the marine environment, accumulation of fish farm sewage under the marine net-cages, and impact on predators, such as seals and sea lions, which prey on the farmed salmon and are killed by the salmon farmer (The Province, 2000).

Many of the risks associated with salmon farming are similar to those that arise from the farming of land-based animals. But consumers of salmon have not had to deal with these risks until very recently. The trend toward salmon production based on farming reduces the consumer's choice of selecting meats that are free of many of the health risks associated with the production of land-based food animals. For farmed salmon these risks include:

The trend toward salmon production based on farming reduces the consumer's choice of selecting meats that are free of many of the health risks associated with land-animal farms.

- antibiotic residues in farmed salmon, and other seafood, like shellfish, that are wild but live in the vicinity of the salmon farm
- increases in antibiotic resistance among bacteria carried by farmed fish and which can influence human disease-causing bacteria
- exposure of salmon farm workers to antibiotics and other chemicals used on the farm
- changes in the nutritional value of farmed salmon relative to wild salmon
- net loss of protein for human consumption as a result of feeding wild fish to farmed salmon.

These risks can be divided into two categories. Some risks, like chemical residues in, and the nutritional value of, farmed salmon are of concern mainly to the individual who chooses to consume it, or works in the salmon farming industry. Other risks, however, have broader global and social implications, and should also be of concern to those who do not eat farmed salmon. In this second category fall the risks associated with the development of antibiotic resistance, and the risk of depletion of global seafood supplies.

In addition to these current risks, there are the dangers associated with production of genetically engineered, or transgenic, salmon. Currently, none of the farmed salmon produced in BC or globally are transgenic. However, government funding is directed towards transgenic salmon research in BC, and some biotechnology companies are currently developing strains of transgenic salmon for industrial production. This important issue will be looked at briefly in this review with references given to more extensive treatments of the topic.

The remainder of this review is organized into 3 main sections. The first looks at human health risks associated with the use on antibiotics. The second looks at nutritional concerns and includes a treatment of the fat composition of farmed salmon, net loss of global seafood supplies and a brief look at the transgenic salmon issue. The third section consists of conclusions and recommendations for reducing or eliminating the human health risks discussed in this review.

USE OF ANTIBIOTICS

The amount of antibiotics used on salmon farms in BC each year varies depending on the number and severity of bacterial disease outbreaks. In 1998, salmon farmers in BC used a total of 6.4 metric tonnes of antibiotics for their salmon production (Sheppard, M.E., 2000). Of this total, oxytetracycline accounted for 90%, with the remaining 10% consisting of sulfonamides and fluorfenicol. In addition to the human health concerns over using such quantities of antibiotics, the impact on the marine environment must not be overlooked.

Antibiotics are administered to farmed salmon only when a bacterial disease outbreak is identified. In contrast, other animal farming industries also administer antibiotics as prophylactics (to prevent disease before it happens) and as a growth promoter (sub-therapeutic levels of antibiotics, which increase animal rate of growth). A veterinarian prescribes the medicated feed used to administer the antibiotic to the salmon and a farm must keep records of what antibiotic was used, how much was used and at what time it was administered. The time between the salmon heading for market and the last drug treatment is important, to allow for a drug to be worked out of the salmon's system. This drug withdrawal time can vary but, according to the BC provincial Aquaculture Regulations, it must be no less than 105 days.

Antibiotic Residues

Use of antibiotics in the production of animals for food consumption has lead to concerns that residues of the antibiotic may remain in the meat headed for market. Although no one wants antibiotic residues in food and the goal of practices, such as the 105-day withdrawal period mentioned above, is to not have any residues, they can at times be detected in salmon headed for market. The issue of antibiotic residues is covered by the Canadian federal Fish Inspection Act, which prohibits the selling of fish for human consumption that are tainted, decomposed or unwholesome. Regarding the use of antibiotics on salmon farms, the maximum concentration allowed, before the fish is considered 'tainted', for market ready salmon is 0.1 parts per million (ppm).

Between 1991 and 1996, the Canadian Department of Fisheries and Ocean (DFO) tested about 200 samples of farmed fish per year in BC. This was conducted at random and the fish samples were taken from processing plants. Of the samples looked at during this time period, 11 (about 2 per year) showed oxytetracycline residues of .1ppm or greater (BCEAO, 1997-b). Since 1996, the newly created Canadian Food Inspection Agency (CFIA) has taken responsibility for testing food for antibiotic residues. The recent random sampling by CFIA continues to reveal about 1 to 2 samples per year with residues above 0.1ppm (Anon., 2000-b).

When CFIA finds residues at or above 0.1ppm, the policy is to recall any salmon from the batch that went to market and to not allow any remaining salmon from that batch to be distributed. In practice, however, this isn't always feasible. It can take some time from when a sample is taken from a fresh batch of salmon to when the residue results are known. To prevent any salmon from spoiling, all farmed salmon is allowed to market before test results are known (Anon., 2000-b). It is often the case that, when a sample result shows unacceptable residue levels, the batch from which it came has been distributed, sold, and even consumed. Consequently, there are times when consumers unknowingly purchase farmed salmon that contains antibiotic residues at or above 0.1ppm. But the exposure of consumers to antibiotic residues from farmed salmon is even greater than this scenario implies. The two main reasons are as follows:

- The few hundred or so random samples conducted each year cannot cover all of the farmed salmon which is processed. If the random sampling which is done shows 1 or 2 positive results per year then, statistically, there must be some batches that have 0.1ppm antibiotic levels that are never tested. Using the random sampling to make an estimate, we see that about 1% of processed salmon is tainted. Of the 48,300 tonnes of farmed salmon produced in 1999, about a half tonne contained antibiotic residue levels at or above 0.1 ppm.

- In addition to the test results that show antibiotic residue levels at or above 0.1ppm, some test results from the random sampling show antibiotic levels above 0.05 ppm but below 0.1ppm. When this occurs, CFIA gives the salmon farm a warning that the levels are starting to get too high. These residue concentrations, however, do not result in any consumer warning.

Residues in Wild Shellfish and Other Fish

Since farmed salmon are raised in an open net-cage system in the marine environment, the effects to that environment as a result of accumulation of antibiotics and other chemicals, as well as accumulating fish farm sewage, must be considered. Many studies have shown that this accumulation negatively impacts the marine environment in the vicinity of the farm (Hansen, 1992; Findlay, 2000; Collier, 1998; Davies, 1998). When marine organisms that are affected are also used by humans as food, then human health concerns arise as well. First Nations in BC have expressed a great deal of concern over the impacts that salmon farms have on their traditional fisheries.

As a precautionary measure, Environment Canada has imposed a ban on any shellfish harvesting within 300 metres of a salmon farm. Very little research has been done on the effects of antibiotics and other chemicals (such as copper-based antifoulants used on net-cages) on marine organisms used for human food. The 300 metre no-harvest zone is based on concern over possible shellfish contamination from salmon farm sewage, mainly human sewage from the farm workers.

The research that has been done on chemical residues in marine organisms near salmon farms has shown that shellfish and crabs near the salmon farm accumulated high levels of antibiotics after the drugs were used on the farm (Coyne *et al.*, 1997; Capone *et al.*, 1996; Samuelsen *et al.*, 1992). For shellfish, residues levels dropped with distance from the farm, and no residue was found in shellfish more than 100 metres from the farm.

Box 1: Other Chemicals and Shellfish

In addition to antibiotics, there are other chemicals used on salmon farms or produced by them, that can contaminate shellfish. To prevent marine growth on the salmon net-cages, antifoulant paints are used which contain poisonous metals such as copper. Since shellfish filter feed, they can accumulate such chemicals to many times the level found in their environment. No studies have been done which look at how these chemicals contaminate shelfish found near salmon farms.

In addition, the sewage which accumulates under salmon farms releases ammonia when it decomposes. This ammonia acts to fertilize the growth of marine microbes, including the algae that cause shellfish poisoning. Continuing research in Scotland is looking into the role that such fish farm pollution is playing in the recent algae blooms that have resulted in the closure of thousands of kilometres of the Scottish coast to shellfish harvesting. There are many natural factors that also play a role in such algae blooms, and the extent to which salmon farms increase such blooms has to be determined. It is clear, however, that salmon farm sewage does increase the amount of algae nutrients, such as ammonia.

In these studies, strings of oysters or blue mussels were suspended in the water column near a farm, and analyzed for residue at different days following antibiotic use. This may not give a proper measure of how far the influence of antibiotics extends beyond a farm, since studies have shown that antibiotics accumulate to higher concentrations and persist for much longer in marine sediment than in the water column. Of great importance to First Nations is the harvesting of clams, which live in marine sediments. No studies have looked at chemical residues in clams near salmon farms.

In looking at how far from a salmon farm antibiotics can influence the food chain, it is important to look at organisms which are much more mobile than shellfish. In the above study, antibiotic residues in crabs near salmon farms in Puget Sound, Washington were looked at, but sampling was only conducted underneath the farms. Crabs will feed on accumulating sewage under farms, which will contain salmon feces as well as uneaten food pellets fed to the salmon. Many of the crabs sampled in the study contained oxytetracycline residues of between 0.8 and 3.8ppm, many times the levels allowed for marketable seafood, during antibiotic use on a farm and up to 12 days after. An important question that still has to be answered is how far from the farm will these crab travel before the antibiotic residue levels disappear. It is very likely that a 300 metre no-harvest zone for crab is not far enough after a salmon farm has used an antibiotic.

Wild fish will also feed on waste food and feces under salmon farms. One study in Finland looked at this and, while it did not analyze for antibiotic residues, it found antibiotic resistant bacteria in intestines of wild fish (Bjorklund, 1990). There have been calls in BC for antibiotic residue testing of seafood caught in areas where salmon farming occurs, but this has yet to occur (Keller *et al.,* 1996).

Antibiotic Resistance

There are an increasing number of human bacterial diseases that are resistant to the antibiotics that medicine has relied on to fight them (Jones, 1996; Craig, 1996). Many countries and international health bodies acknowledge the severity of the problem and have set up programs to try and deal with it. While use of antibiotics on humans plays the main role in development of antibiotic resistance of human disease-causing bacteria, it is acknowledged that the use of these drugs in livestock production also adds to the problem (WHO, 1999; WHO, 1997).

Repeated use of antibiotics to treat bacterial diseases leads to the selection of resistant forms of bacteria. The way it works is that within the population of bacteria being treated, there is a natural variation in the genetic makeup. While the drug may kill most of the bacteria, a few may have genes which give them the ability to withstand the antibiotic. These surviving bacteria will then multiply and become more common in subsequent populations (Prescott, 1999-a). As this process is repeated, with continued use of the drug, the remaining population of bacteria will be dominated by the resistant strain, and the antibiotic is no longer effective.

An example of a fish disease for which antibiotic resistance is well documented is furunculosis, caused by the *Aeromonas salmonicida* bacterium (Starliper, 1999) (see Box 2). From a human health point of view a key question is, can the use of antibiotics on salmon farms lead to resistant strains of bacteria which can affect diseases in humans? The salmon farming industry argues that there is little risk to humans

Box 2: Growing Resistance

Furunculosis is a deadly disease which can affect salmon. The disease has affected salmon farms in BC and elsewhere and has been treated extensively with antibiotics. Studies have shown that antimicrobial resistance in *Aromonas salmonicida*, the bacteria which cause furunculosis, is widespread. *A. salmonicida* has shown resistance to several drugs such as Romet-30, tetracycline, sulfa drugs, trimethoprim, Tribrissen, and oxytetracycline. Among this list are the main antibiotics used in BC by the salmon farming industry. Several strains of the bacteria have shown multiple resistance to several of these drugs.

In June 1993, Atlantic salmon in a farm in the Broughton Archipelago, near Vancouver Island, developed triple-antibiotic resistant furunculosis, spreading the disease through the marine environment to nearby sites. The extent to which antibiotic resistance has developed among bacterial salmon disease in BC has not been well studied.

since fish diseases such as furunculosis and bacterial kidney disease (BKD, the most common bacterial disease affecting salmon farms in BC), are not known to cause disease in humans. While this is true, there are other mechanisms by which antibiotic use on salmon farms increases the risk of antibiotic resistance for human diseases. These include:

- development of antibiotic resistance among bacteria like *Salmonella* or *E. coli*, which are of concern to humans and can also be found in food animals including fish
- exposure of salmon farm workers to antibiotics contained in the medicated feed they handle
- resistant strains of bacteria carried by farmed fish transferring the genes responsible for resistance to bacteria which affect humans.

These mechanisms arise from the fact that, in addition to targeting the bacteria which cause fish diseases, there are other types of bacteria on the fish and in the vicinity of the fish farm that get exposed to the antibiotics. The first two mechanisms directly give rise to antibiotic resistant bacteria which are of concern to humans. The third mechanism leads to resistance in bacteria which cause human disease, by genetic transfer from antibiotic resistant bacteria found in farmed fish.

Direct Rise of Resistance in Bacteria of Concern to Humans

One family of bacteria which are found in many places in nature, including human intestines, and which can cause serious human diseases are enterobacteria. Among this family are included various strains of *E. coli*, *Salmonella*, and *Serratia* bacteria. Some of the diseases these bacteria can cause are food poisoning, respiratory diseases, and urinary tract infections. Since these bacteria occur widely, they are often found on many animals besides humans. For example, *Salmonella* can be a problem within the poultry industry, although many animals, including fish, can carry the bacteria.

Disease in humans results if the food animal is not properly processed and stored. Research shows an increase in antibiotic resistance among these bacteria worldwide (Boonmar et. al., 1998; Amara *et al.*, 1995; Cox *et al.*, 1996; Hefferman, 1991), including Canada (D'Aoust *et al*., 1986-89). Some of this research has shown that some antibiotic resistant strains of *Salmonella* and *E.coli* that have shown up in humans are those which can also be identified in some food animals, especially chickens, which have undergone antibiotic treatment. Consuming the animal provides a way for these resistant bacteria to get into humans.

In 1999, Alexandra Morton, a Vancouver Island biologist, caught a farmed salmon shortly after an escape from a salmon farm. Samples from the salmon were sent for analysis. The results showed that the salmon was infected with *Serratia liquefaciens* and *Serratia plymuthia*, two enterobacteria. The alarming part of the results was that the bacteria showed resistance to 11 of the 18 antibiotics tested on them, including several antibiotics used to treat human diseases (Morton, 1999).

The *Serratia* bacteria are interesting in that, until recently, they were always suspected as being harmless to humans. They have been known to cause disease in fish, including farmed Atlantic salmon in Scotland, wild turbot in France and wild rainbow trout in Spain (Morton, 1999). In recent years it has also become clear that the *Serratia* bacteria are opportunistic and have resulted in severe illness, such as respiratory and urinary tract infections, in humans (Daschner, 1980). In 1999 a report released by the American Red Cross in collaboration with other United States health institutions, showed that *Serratia liquefaciens* was the bacterium responsible for 5 blood transfusion related deaths. The researchers stated that, for humans, "*S. liquefaciens* is a previously under-recognized cause of transfusion-related sepsis and is associated with a high mortality rate" (Roth, 1999).

There is an increasing awareness of the dangers that food-borne bacteria pose. In 1999 the

Scottish government began a 5 year £3.1 million program to look at the mechanism of how food-borne infections occur. This type of research is especially needed to determine to what extent these food-borne bacteria show antibiotic resistance. There has been no research of this type done on farmed salmon and Health Canada has just begun to look at this problem (see Box 3).

Bacteria that are common to both humans and other animals are developing antibiotic resistance from the use of these drugs on farms. The implication for human health is a higher risk of developing human diseases that cannot be treated with conventional antibiotics.

Box 3: Health Canada Study

Health Canada has recently begun a study on human health threats from the use of antibiotics in salmon farming. In the first phase of the study, farmed salmon samples will be taken from processing plants and analyzed for antibiotic residues, as well as the presence of antibiotic resistant bacteria. Of particular interest is any resistance that may show up in *Salmonella* or *E.coli* bacteria, since these can lead to human disease.

In phase 2 of this study, antibiotic residues and resistant bacteria will be investigated at salmon farm sites themselves. The purpose will be to better understand how factors such as antibiotic type, amount used, length of treatment and physical conditions in the marine environment in the vicinity of the farm influence residue accumulation and antibiotic resistance development. It will be about 1 to 2 years before the results of this study are known.

Transfer of Resistance to Human Bacteria

The mechanism described above, by which an antibiotic selects for resistance, is only one way in which resistant strains of bacteria can be spread. A more alarming mechanism occurs when bacteria that have developed antibiotic resistance transfer the genetic material responsible for it to other bacteria that don't already have that resistance (Prescott, 1999-b). As shown in Box 4, this transfer can occur when the gene responsible for the resistance is carried on a DNA segment known as an R-factor. The transfer of R-factors is known to happen between bacteria of the same species as well as between different species of bacteria. In this way, antibiotic resistance can spread beyond the population of bacteria that were treated with the drug.

This transfer of antibiotic resistance from bacteria that have it to ones that do not has prompted researchers, such as professor Stuart B. Levy, director of the Center for Adaptation Genetics and Drug Resistance at the Tufts University School of Medicine, to state:

> **"The exchange of genes is so pervasive that the entire bacterial world can be thought of as one huge multicellular organism in which the cells interchange their genes with ease."**

Any activity which results in an increase of antibiotic resistance for any type of bacteria, increases the reservoir of antibiotic resistance genes available to all bacteria.

The sharing of R-factors between bacteria of different species is the bridge by which a resistant strain of bacteria carried by farmed fish can result in resistance in bacteria which are of concern for human health. Such transfers have been observed. A recent study has observed antibiotic resistant strains of *A. salmonicida* transferring R-factors to *E. coli* (Starliper *et al.*, 1999). The transfer resulted in a strain of *E. coli* having resistance to the same antibiotics for which the *A. salmonicida* had developed resistance. The *E. coli* bacterium is a type that is common in the human digestive tract. By consuming salmon that have developed resistant strains of bacteria, humans increase the risk of transferring that resistance to bacteria of concern to their health.

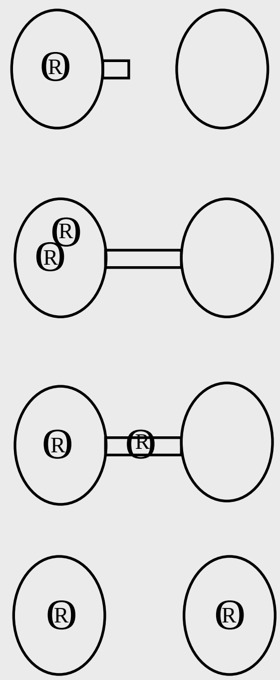
Box 4: Transfer of genetic material from bacterium with antibiotic resistance (containing R-plasmid) to one without.

Step 1: Connecting microfibre begins to form that will join bacterium with antibiotic resistance to one without.

Step 2: Bacteria connected by microfibre. R-plasmid with antibiotic resistant gene replicates.

Step 3: R-plasmid transfers from bacterium with antibiotic resistance to one without.

Step 4: Microfibre breaks. Antibiotic reistance spreads to other bacterium.



Ⓡ – This symbol represents the R-plasmid, the genetic material which allows any bacterium containing it to be antibiotic resistant.

It is possible for a single R-factor to contain many resistance genes, allowing for multiple resistance to many antibiotics. This means that, even if only one of those antibiotics is used to treat a disease, and the bacteria develop a resistance to it, they will be resistant to the other antibiotics as well. This was observed in the *A. salmonicida* study mentioned above, where the genes responsible for resistance were observed to be carried on R-factors. One of the strains looked at in the study showed resistance to 19 different antibiotics.

Recently, an escaped farmed Atlantic salmon in the Broughton Archipelago, off the east coast of Vancouver Island, was caught and on analysis was shown to harbour two strains of bacteria that were resistant to 11 antibiotics. These included penicillin, erythromycin, and amphicillin, three antibiotics used in human medicine which have never been used on salmon farms. R-factor resistance could be the explanation for this, but studies to look into this possibility have not been done. Since R-factors can be transferred among many types of bacteria, any antibiotic use which increases the population of any bacteria with R-factor antibiotic resistance, increases the risk for such resistance among human pathogen bacteria as well.

The amount of antibiotic resistant bacteria humans consume when they eat farmed salmon has not been studied. This shows a neglect for a very important health risk to consumers. Studies on the consumption of other foods produced by methods which include antibiotic use have shown that these foods contribute a large portion of the antibiotic resistant bacteria found in humans. A study published in the *New England Journal of Medicine* looked at the intestinal bacteria of people eating regular (non-sterilized) food compared with those of people eating sterilized (containing no bacteria) food (Corpet, 1988). The results showed that, after shifting to sterilized food for 17 days, the amount of antibiotic resistant bacteria in the feces went down by a factor of 1,000.

The use of antibiotics for farmed salmon production results in salmon that contain antibiotic resistant bacteria. Consuming farmed salmon will increase the amount of antibiotic resistant bacteria to which humans are exposed. This increases the risk of developing antibiotic resistance in bacteria which cause human diseases. Along with the other uses of antibiotics in our environment, their use in farmed salmon production contributes to the development of human diseases that cannot be treated with conventional antibiotics.

NUTRITIONAL RISKS

Fat Content

The feed given to an animal and the conditions under which it is kept will influence the animal's composition. It is well known that wild land-based animals are leaner than their domestic counterparts. Not surprisingly this is also the case for salmon. As early as the 1980's, Canadian consumer groups and health agencies expressed concern over the fat content of farmed versus wild salmon. It isn't just that the fat content of farmed salmon is higher than wild salmon, but the composition of farmed salmon fat is less healthy than the same amount of wild salmon fat.

We all need to eat some amount of fat to survive, but not all fats are the same. The fats which are the least healthy for us are saturated fats. Saturated fats are found in meat and are also produced by the body from carbohydrates. The average North American diet tends to supply much more saturated fats than the body needs. Saturated fats contribute to many human health problems including heart disease and stroke. Poly-unsaturated fats are much healthier for us, especially the ones known as the essential fatty acids (EFA's). The body cannot produce EFA's and we must get them from our diets. Seafood has traditionally been the main source of EFA's for humans.

The EFA's are divided up into omega-3 and omega-6 fatty acids. While both are needed, health experts agree that it is important to consume foods that are high in the ratio of omega-3 to omega-6. Medical research has discovered that omega-3 fatty acids reduce the likelihood of high cholesterol, atherosclerosis, high blood pressure, heart disease and rheumatoid arthritis. Too much consumption of omega-6 fatty acids can aggravate these health problems.

Table 1: Fat composition comparison among various fish. Data obtained from the United States Food and Drug Administration nutrition database. Based on a 100 gram serving of raw fish.

Type of Fish	Total fat content (grams)	omega-3 to omega-6 fatty acid ratio	% of total fat that is omega-3 fatty acids
farmed Atlantic salmon	10.85	1.1	18%
wild Atlantic salmon	6.34	3.9	32%
farmed coho	7.67	2.3	17%
wild coho	5.93	3.2	25%
wild chinook	10.44	4.1	16%
wild chum	3.77	4.7	20%
wild pink salmon	3.45	5.2	33%
wild sockeye	8.56	2.3	15%
wild mackerel	7.89	5.0	20%
wild anchovies	4.84	9.3	33%

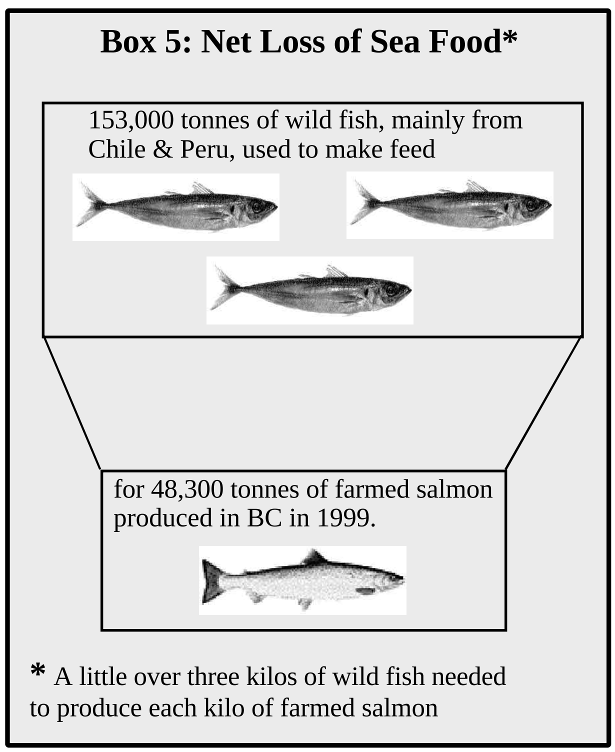
Table 1 compares the fatty acid composition for various types of fish. It can be seen that farmed Atlantic salmon has 70% more fat than wild Atlantic salmon, and farmed coho has 30% more fat than wild coho. Of specific interest to BC, however, is the comparison of farmed Atlantic salmon (which accounts for 85% of farmed salmon production in BC) to the five Pacific species of salmon. Farmed Atlantic salmon is about 200% higher in fat than wild pink or chum salmon, 83% higher than wild coho, 27% higher than wild sockeye, and about the same in total fat as wild chinook. It is also interesting to note that farmed Atlantic salmon has significantly more fat than jack mackerel and anchovies, two of the species that are used to make feed for farmed salmon

If we now look at the last two columns in Table 1, which show the percentage of total fat that is composed of omega-3 fatty acids, and the omega-3 to omega-6 ratio, the nutritional difference among the different fish becomes even clearer. The highest percentage (32 to 33%) of omega-3 fats is found among wild pink salmon, anchovies, and wild Atlantic salmon. The group with the second highest percentage range (20 to 25%) is wild coho, chum, and mackerel. The lowest percentage (15 to 18%) of omega-3 fats is found among farmed Atlantic and farmed coho salmon, as well as wild chinook and sockeye. Also, compared to Atlantic salmon, the other fish in table 1, including chinook and sockeye salmon, have much higher omega-3 to omega-6 fat ratios, an important factor for health considerations. For nutritional quality based on total fat, percentage of omega-3 fats, and the omega-3 to omega-6 fat ratio, farmed Atlantic salmon gets the lowest score.

There are ways to increase the omega-3 fatty acids contained in farmed salmon (Higgs, 1989). Since, like humans and other animals, fish cannot manufacture their own omega-3 or omega-6 fatty acids, the main way to increase omega-3 fats in farmed salmon is to add them to their feed. But there is a crucial problem with this approach. The way to add more omega-3 fats to the feed is to increase the amount of concentrated fish oils it contains. Currently, about 25% of the weight of feed pellets consists of these oils, obtained from fish such as jack mackerel, anchovies and sardines. But, as we see in the next section, this use of wild fish for making farmed salmon feed also has a negative impact on the ocean ecosystem, as well as on the supply of fish for human consumption.

Net Loss of Seafood

A recent paper in the journal *Nature* looked at the effect of aquaculture on world fish supplies (Naylor *et al*., 2000). The paper compared how much fishmeal and oil, obtained from wild fish, was used in the production of the 10 most commonly farmed fish and shellfish. Of note was the ratio of the weight of wild fish used in feed to the weight of farmed fish produced. If this ratio is less than one, then farmed fish represent a net contributor to world fish supply for human consumption. A ratio of greater than one means that more wild fish are consumed for feed than the farmed fish produced. The best ratios were for filter feeding carp and molluscs which required no wild fish for feed, and ate microscopic organisms low on the marine food chain. Farmed fish which were given feed supplemented with wild fish, but for which the wild to farmed conversion ratio was less than one, were nonfilter-feeding carp, catfish and milkfish. Being carnivorous, farmed salmon are fed a diet high in fishmeal and oils. As a result, the wild fish consumed to farmed fish produced is 3.16 for farmed salmon. That means that 153,000 tonnes of wild fish was consumed to raise the 48,300 tonnes of farmed salmon produced in BC in 1999.



It can be argued that if humans were to eat wild salmon, this too would represent a loss of wild fish, since they are after all carnivorous. This is true; given the high global human population, eating lower on the food chain will result in more food overall. But if the comparison is strictly between eating wild or eating farmed salmon, it is more sustainable to eat wild. When we fish for wild salmon we are taking part in a predator-prey relationship that is influenced by the many ecological factors that affect wild salmon supply. The complex checks and balances of nature are such that salmon represent a certain amount of the marine biomass. As the many factors that determine this biomass fluctuate, the amount of salmon also fluctuates in a very complex way. This puts a cap on how much salmon is available for our consumption. If we overfish, if there are global weather changes or if the organisms that wild salmon feed on are not as plentiful for some reason, there is less salmon for us to use, until the system can recover. But when we farm salmon, we are artificially setting a production level that is mainly determined by market rather than ecological forces. Rather than fluctuating with nature's checks and balances, the production level is relatively steady and can grow as demand grows. The salmon biomass, and that of the organisms that salmon use for food, is no longer ecosystem-based. The salmon farm becomes a sink for other ocean biomass and we determine how much of that biomass should be salmon.

Although the 1997 global production of farmed salmon accounted for 3% of total global aquaculture production, it consumed 19% of the wild fish used to make feed for all aquaculture species. In 1997, world aquaculture production still added to the net global fish supply for humans. But this was because carp and molluscs alone accounted for 80% of total production. As the production of farmed salmon continues to increase, the use of feed that is high in wild fish will make the industry increasingly unsustainable. With regard to this, BC is out of step with the rest of the world. In BC, salmon farming represents over 90% of aquaculture production, the other 10% being shellfish. Among the possible solutions to the problem are:

- Shift aquaculture away from farming carnivorous fish and toward species that are lower in the food chain. In addition to many types of fish and shellfish, aquaculture could also include many varieties of seaweed.

- Reduce the fishmeal and fish oil inputs to make feed for carnivorous species. Vegetable protein sources, such as canola can be added instead.

The second of these choices has some difficult problems associated with it. Vegetable proteins have an amino-acid balance that is not suitable for salmon. These proteins are also not easily digested by salmon. It is very unlikely that wild fish inputs into farmed salmon feed will ever be so low as to result in a wild fish consumed to farmed fish produced ratio of lower than one. Secondly, we saw in the previous section that farmed fish are already low in essential omega-3 fatty acids compared to wild fish. Decreasing the fishmeal content of salmon feed will only make this problem worse.

GENETICALLY MODIFIED SALMON

Aqua Bounty Farms, a company based in Waltham, Massachusetts, and with an experimental hatchery in Canada (Prince Edward Island), has recently applied to the US Food and Drug Administration (FDA) for permission to market its transgenic (genetically engineered) salmon. If the FDA application is approved, it will be the first time that transgenic salmon, created experimentally for several years now, will be commercially produced.

Aqua Bounty Farms has taken growth hormone genes from chinook salmon and placed them into Atlantic salmon, resulting in a new fish that grows at four times the rate of regular Atlantic salmon. The new type of fish is one that never existed in nature before. It is a technological artifact, not having been produced by the natural mechanisms responsible for the evolution of new species in nature.

Transgenic livestock have only been around for 15 years and there is almost no research done on the ecological implications of these new types of animals. The main concern with transgenics has to do with how they may affect the natural ecosystem should they escape from a production facility, but there are also human health risks to consider. Many authors have written on this issue(Smith, 2000; Kuiper, 2000, UCS, 2000) and it will not be treated here. Changing the genetic makeup of a species may lead to qualities that are sought after for commercial applications, but there is no control on what other characteristics may be bestowed on the species as a by-product. The chemical and physiological character of the new transgenic may change so as to give rise to human health effects.

Both the BC Salmon Farmers Association (BCSFA) and the Canadian Aquaculture Industry Alliance (CAIA) have taken a stand of not pursuing the commercial production of transgenic salmon. This is a commendable position but it should be kept in mind that there are several salmon farming companies in Canada that do not belong to either of these groups. The largest salmon farming company in Clayoquot Sound, Pacific National Group, does not belong to BCSFA or CAIA. Also, the Canadian federal government continues to fund research into the production of transgenic salmon.

As we see from the Aqua Bounty Farms application to the FDA, and the continued funding of transgenic research by both government and industry, the production of transgenic salmon may soon be a reality. No comprehensive studies have looked at the effects that transgenic salmon, or other transgenic foods, might have on human health. If the commercial production of transgenic foods is allowed to occur without such comprehensive studies, consumers will be taking part in uncontrolled experiments.

The production of transgenic species is one issue that must lead scientists to not only ask if something is possible, but also whether it is ethical.

CONCLUSIONS & RECOMMENDATIONS

If the source of salmon for human consumption is shifted to farmed salmon, we introduce human health risks which are not present in a salmon supply derived from the wild. None of these health risks are unique to salmon farming and are shared by the production of land-based food animals as well. Unlike land-based animals however, wild seafoods, if they are managed properly, can be used as a sustainable source of food for a large portion of humanity. Aquaculture can also be used to add to seafood supply if it is practiced sustainably and with the minimization or elimination of the risks discussed in this review. To this end we recommend* that:

- BC develop an aquaculture system that is dominated by the farming of species that have wild fish input to farmed fish output of less than one. This does not mean elimination of farming carnivorous species like salmon, but such species should not dominate aquaculture.

- antibiotics be eliminated from aquaculture production. About 80% of global aquaculture production is currently done without use of antibiotics or other drugs.

- until such time as use of antibiotics is eliminated, Health Canada begin conducting antibiotic residue tests on wild seafood caught in salmon farming areas, in addition to testing of farmed salmon.

- until such time as use of antibiotics is eliminated, the current system of testing for antibiotic residues for seafood heading for market be changed so that salmon containing such residues can be prevented from being consumed by the public.

- the Canadian government put aquaculture under the jurisdiction of Agriculture Canada rather than the Department of Fisheries and Oceans (DFO).

This will allow all DFO resources to be directed toward wild marine resource management. This is a key recommendation for assuring that proper emphasis is put on such management.

* These recommendations are based on the consideration of health risks discussed in this review. There are also ecological risks, such as escaped farmed salmon, accumulation of salmon farm sewage in the marine environment, transfer of disease to wild fish, and impact on other marine mammals, that these recommendations do not cover.

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