COALITION
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Finfish Aquaculture Environmental and Human Health Impact Documentation

Serious adverse impacts to the environment and wild fish stocks have been extensively studied and well documented world wide. The following review provides ample support for regulators to not allow open cage aquaculture in Washington waters which puts iconic wild salmon populations at risk.

Wild Salmon People Website
Alexandra Morton, a well known scientist, continues to document the consequences of allowing open cage finfish farms in British Columbia. Her work is relevant to the risks our wild stocks face from open cage aquaculture.
http://www.salmonaresacred.org/

Monterey Bay Aquarium Seafood Watch® Farmed Salmon Report **April 27, 2004**
http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedSalmonReport.pdf

Risk of Escaped Fish to Wild Stocks: Farmed salmon are jeopardizing the health of endangered salmon populations in the Atlantic through interbreeding. By reducing the fitness
of wild stocks, farmed salmon may imperil remaining wild Atlantic salmon stocks. In the Pacific, escaped farmed salmon represent a potentially invasive species. The potential for negative effects from interbreeding of farmed and wild salmon in the Atlantic and invasive behavior of escaped farmed Atlantic salmon in the Pacific poses a **Critical Conservation Concern**.

Risk of Disease Transfer to Wild Stocks: Salmon farming operations can serve as a vector for diseases and ectoparasites, notably sea lice, which can negatively affect wild salmon. While biosafety controls reduce the risks of translocating disease, evidence that sea lice from salmon farms are harming wild salmonid populations is substantial. The threat of disease to already stressed wild salmon populations also presents a substantial risk. The threat of disease to wild fish populations and ecosystems is thus of **High Conservation Concern.**

Use of Marine Resources: Salmon reared in captivity are carnivorous fish and farmed salmon are fed diets largely comprised of processed wild fish. The implicit demand salmon aquafeeds place on marine ecosystems off of South America and the Gulf of Mexico is both a practical and ethical issue that affects the sustainability of farming practices, and thus is of **High Conservation Concern**.

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Risk of Pollution and Habitat Effects: Because salmon are raised in open marine net-pens, wastes, organic and chemical, are not collected or treated. Organic wastes from uneaten feed and feces can accumulate on sediments and affect the species distribution within the immediate vicinity of net pens. Infaunal species diversity is typically lower beneath and down current from net pens with low to moderate flushing rates. Overall, pollution from organic and chemical wastes is of **High Conservation Concern**.

Effectiveness of the Management Regime: Management practices vary significantly between nations. Management has increased in recent years but concerns remain regarding the density of net-pen sites in specific regions, the approval of pesticide and antibiotic use, and the use of acoustic predator deterrent devices which may affect non-target marine mammals. The current management climate is of **Moderate Conservation Concern**.

Global Assessment of Organic Contaminants in Farmed Salmon--
Global Assessment of Organic Contaminants in Farmed Salmon
Hites, Ronald A; Foran, Jeffery A; Carpenter, David O;M Coreen Hamilton; et al. **Science**303. 5655 (Jan 9, 2004): 226-9.

Abstract (summary)
The annual global production of farmed salmon has increased by a factor of 40 during the past two decades. Salmon from farms in northern Europe, North America, and Chile are now available widely year-round at relatively low prices. Salmon farms have been criticized for their ecological effects, but the potential human health risks of farmed salmon consumption have not been examined rigorously. Having analyzed over 2 metric tons of farmed and wild salmon from around the world for organochlorine contaminants, we show that concentrations of these contaminants are significantly higher in farmed salmon than in wild. European-raised salmon have significantly greater contaminant loads than those raised in North and South America, indicating the need for further investigation into the sources of contamination. Risk analysis indicates that consumption of farmed Atlantic salmon may pose health risks that detract from the beneficial effects of fish consumption. [PUBLICATION ABSTRACT]

Headnote
The annual global production of farmed salmon has increased by a factor of 40 during the past two decades. Salmon from farms in northern Europe, North America, and Chile are now available widely year-round at relatively low prices. Salmon farms have been criticized for their ecological effects, but the potential human health risks of farmed salmon consumption have not been examined rigorously. Having analyzed over 2 metric tons of farmed and wild salmon from around the world for organochlorine contaminants, we show that concentrations of these contaminants are significantly higher in farmed salmon than in wild.

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European-raised salmon have significantly greater contaminant loads than those raised in North and South America, indicating the need for further investigation into the sources of contamination. Risk analysis indicates that consumption of farmed Atlantic salmon may pose health risks that detract from the beneficial effects of fish consumption.

Between 1987 and 1999, salmon consumption increased annually at a rate of 14% in the European Union and 23% in the United States (1). Currently, over half the salmon sold globally is farm-raised in Northern Europe, Chile, Canada, and the United States, and the annual global production of farmed salmon (predominantly Atlantic salmon, Salmo salar) has risen from ~24,000 to over 1 million metric tons during the past two decades (2). The health benefits of eating fish such as salmon have been well documented (3, 4). However, salmon are relatively fatty carnivorous fish that feed high in the food web, and as such, they bioaccumulate contaminants (5). The potential risks of eating contaminated farmed salmon have not been well evaluated. Three previous studies reporting contaminants in salmon are inconclusive because of their very small sample sizes and narrow geographic representation (6-8). As a result, the extent of this problem and the potential risks to human health remain unclear.

We measured organochlorine contaminants in approximately 700 farmed and wild salmon (totaling ~2 metric tons) collected from around the world. We do not report on other important contaminants, such as methylmercury, because our preliminary study (9) showed no significant difference in methylmercury levels between farmed and wild salmon. Using the data on organochlorine contaminants, we assessed the variation in contaminant loads between farmed and wild salmon and among geographic regions, and we calculated the human health risks of salmon consumption. Farmed Atlantic salmon from eight major producing regions in the Northern and Southern hemispheres were purchased from wholesalers that could obtain fish of the appropriate size within the sampling period; in addition, farmed Atlantic salmon fillets were purchased at supermarkets in 16 large cities in North America and Europe. For comparison, samples of five wild species of Pacific salmon [chum (Oncorhyncus keta), coho (O. kisutch), chinook (O. tshawytscha), pink (O. gorbuscha), and sockeye (O. nerka)] were obtained from three different geographic regions. Wild Atlantic salmon were not studied because few are available commercially; nor did we analyze farmed Pacific salmon because they are not raised in any substantial amounts (2, 10).

A total of 594 individual whole salmon were purchased from wholesalers and filleted; an additional 144 fillets were purchased from retailers in Boston, Chicago, Denver, Edinburgh, Frankfurt, London, Los Angeles, New Orleans, New York, Oslo, Paris, San Francisco, Seattle, Toronto, Vancouver, and Washington, DC. Composites of fillets from whole salmon were made on the basis of the location where they were produced (farmed salmon) or purchased (wild salmon). Composites of fillets from retailers were made on the basis of the retail outlet

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where they were purchased. Each composite sample consisted of fillets from three salmon per location or three fillets per retail outlet, giving 246 measurable samples. All samples were homogenized and analyzed by gas chromatographic high-resolution mass spectrometry (11). Strict quality assurance and quality control procedures were followed (11). Thirteen samples of salmon feed were purchased from the European, North American, and South American outlets of the two major fish feed companies, which together have ~80% of the global market for fish feed (12), and were analyzed as above.

Contaminant concentrations in farmed and wild salmon were compared by analysis of variance. In comparing wild and farmed salmon, farmed salmon were considered as a single group. In addition, locations at which salmon were farmed were compared by analysis of variance with multiple comparisons of means to test for differences among locations in contaminant levels. In all analyses of variance, the replicate composites from each source were not assumed to be independent observations. Differences between farmed and wild salmon and differences among farming locations were consistently substantial and highly significant.

Figure 1 shows the concentrations of 14 organochlorine contaminants in the samples of farmed and wild salmon. Thirteen of these contaminants were significantly more concentrated in the farmed salmon as a group than in the wild salmon [$F = 3.75$, $P = 0.0573$ for lindane; $F = 9.93$, $P = 0.0025$ for hexachlorobenzene (HCB); and F > or = 11.71, P < or = 0.001 for the other 12 contaminants, with df = (1, 64) for all]. Concentrations in farmed salmon from Europe and from North America were significantly higher than those in wild salmon for all 14 contaminants ($P < 0.05$ for all 28 comparisons). Concentrations in farmed salmon from South America were significantly higher than those in wild salmon for six contaminants [polychlorinated biphenyls (PCBs), dioxins, dieldrin, cis-nonachlor, total DDT, and mirex] but significantly lower for two contaminants (HCB and lindane) ($P < 0.05$ for each). In addition, concentrations of all contaminants in farmed salmon from Europe were significantly greater than concentrations in farmed salmon from both North and South America [$F = 8.31$ to 65.87, with df =(2, 48); $P < 0.001$ for all 14 contaminants].

We focused additional analysis on PCBs, dioxins, toxaphene, and dieldrin because the patterns of their occurrence in farmed and wild salmon are similar to the patterns of all contaminants evaluated in this study and because an abundance of human health risk information is available for these compounds (13-19).

The average measured concentrations for these four contaminants are shown in Fig. 2, A to D, as a function of location. As noted above, total PCBs, dioxins, toxaphene, and dieldrin were consistently and significantly more concentrated in

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the farmed salmon as a group than in the wild salmon [F = 60.53, 26.80, 15.03, and 32.22, with df =(1, 64) for all; P < or = 0.0003 for all]. Salmon fillets obtained from commercial outlets in the various cities generally clustered with the farmed samples, not with the wild samples.

PCB, dioxin, toxaphene, and dieldrin concentrations were highest in farmed salmon from Scotland and the Faroe Islands and lowest in farmed salmon from Chile and Washington state. Salmon produced in Europe had significantly higher contaminant levels than those produced in both North and South America [F = 26.15, 23.36, 64.42, and 59.26, with df =(2, 48) for all; P < 0.0001 for all]. Even the least contaminated farmed salmon, from Chile and Washington state, had significantly higher contaminant loads of PCBs, dioxins, and dieldrin than wild salmon [F = 28.55, 8.61, and 4.66, with df =(1, 26); P < 0.0001, P = 0.0069, and P = 0.0402, respectively]. Farmed salmon fillets purchased from supermarkets in Frankfurt, Edinburgh, Paris, London, and Oslo were generally the most contaminated, although those purchased in Boston and San Francisco approached these concentrations.

Those purchased in New Orleans and Denver were the least contaminated of the store-bought samples. The concentrations of PCBs, dioxins, toxaphene, and dieldrin in salmon fillets purchased in cities in Europe were significantly higher than in those purchased in cities in North America [F = 22.08, 31.46, 116.80, and 36.50, with df=(1, 14); P < 0.0001 for all]. Most of the salmon sold in European stores comes from European farms, which produce the more contaminated salmon, whereas much of the salmon sold in U.S. stores comes from Chile and Canada (20, 21).

Some of the concentrations in the store-bought farmed samples were quite variable. For example, dieldrin concentrations in the three samples purchased in Washington, DC, were 4.63, 0.61, and 0.46 ng per gram of wet weight (ng/g wet weight). Based on information from the retailer, the two Washington, DC, samples with the lowest concentrations came from farms in Chile, and the one with the highest concentration came from a farm in Iceland. This is further evidence that farmed salmon from the North Atlantic had higher contaminant concentrations than those from Chile.

The large differences between the farmed and wild salmon contaminant concentrations are most likely a function of their diet. Farmed salmon are fed a concentrated feed high in fish oils and fish meal, which is obtained primarily from small pelagic fishes (22). We analyzed 13 samples of commercial salmon feed (Fig. 3). Although the concentrations in these feed samples were quite variable, they were generally similar to or greater than those in the farmed salmon. The concentrations in feed purchased from Europe were significantly higher than those in feed purchased from North and South America [F = 7.05, 11.16, 31.35,

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and 6.78, with df = (1, 11); P = 0.022, 0.007, 0.001, and 0.024, respectively]. This may reflect higher contaminant concentrations in forage fish from the industrialized waters of Europe's North Atlantic as compared to forage fish from the waters off North and South America-the primary sources of fish harvested for fish meal and fish oil (23). Uptake of organic contaminants from water to fish is a minor accumulation pathway (24), so we did not analyze contaminants in water where farmed and wild salmon live.

The human health effects of exposure to PCBs, toxaphene, and dieldrin in salmon tissues are a function of contaminant toxicity, concentration in fish tissues, and fish consumption rates. We used the approach of the U.S. Environmental Protection Agency (EPA) (25) to assess the comparative health risks of consuming farmed and wild salmon. Individual contaminant concentrations in farmed and wild salmon do not exceed U.S. Food and Drug Administration (FDA) action or tolerance levels for PCBs and dieldrin (26). However, FDA action and tolerance levels are not strictly health-based, do not address the health risks of concurrent exposure to more than one contaminant, and do not provide guidance for acceptable levels of toxaphene and dioxins in fish tissue (27-29). The U.S. EPA approach (25) is designed to manage health risks by providing risk-based consumption advice regarding contaminated fish (for example, one should limit consumption of a particular species to a specified number of meals per month or week).
The combined concentrations of PCBs, toxaphene, and dieldrin trigger stringent consumption advice for farmed salmon purchased from wholesalers and for store-bought farmed fillets. This advice is much more restrictive than consumption advice triggered by contaminants in the tissues of wild salmon (Fig. 4, A and B). The most restrictive advice (less than one-half meal of salmon per month), which reflects the highest health risks, was generated for farmed salmon fillets purchased from stores in Frankfurt, Germany, and for farmed salmon from Scotland and the Faroe Islands. The concentrations of PCBs, toxaphene, and dieldrin trigger EPA consumption advice of no more than 1 meal per month for all samples of farmed salmon and for all but two samples of store-bought salmon, for which the advice is no more than 2 meals per month.

The methods used to develop this consumption advice for PCBs, toxaphene, and dieldrin are based on estimates of potential cancer risks and on an assumption of risk additivity (25). A variety of noncancer health effects have also been associated with exposure to PCBs (19), toxaphene (30), dieldrin (31), and other contaminants found in salmon. Some of these noncancer endpoints, such as adverse neurobehavioral and immune effects and endocrine disruption, occur at lower concentrations than those implicated in cancer (17). However, these hazards were not considered in the present analysis because quantitative risk or threshold levels are not available regarding these effects.

Our data indicate that farmed salmon have significantly higher contaminant burdens than wild salmon and that fanned salmon from Europe are significantly more contaminated than farmed salmon from South and North America. Fish that is not contaminated is a healthy food, high in nutrients, such as omega-3 polyunsaturated fatty acids, that are known to have a variety of beneficial human health effects (3, 4). However, this study suggests that consumption of farmed salmon may result in exposure to a variety of persistent bioaccumulative contaminants with the potential for an elevation in attendant health risks. Although the risk/benefit computation is complicated, consumption of farmed Atlantic salmon may pose risks that detract from the beneficial effects of fish consumption. This study also demonstrates the importance of labeling salmon as farmed and identifying the country of origin. Further studies of contaminant sources, particularly in feeds used for farmed carnivorous species such as salmon, are needed.

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Supporting Online Material
www.sciencemag.org/cgi/content/full/303/5655/226/
DC1
Materials and Methods
Table S1

Reference
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Scientific Information from the United States and Globally

United States
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Hawaii
Temporal changes in the polychaete infaunal community surrounding a Hawaiian mariculture operation
Han W. Lee1, Julie H. Bailey-Brock1, 2,*, Michelle M. McGurr2.
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Monterey Bay Aquarium Seriola Issues.pdf Introduction to Seriola Aquaculture Issues.

LD09-OceanLeasingRpt.pdf - This is a State of Hawaii report on ocean leasing/OOA prepared in 2008 for the 2009 legislature that mentions: "The researchers share the general findings that "the bottoms under the fish cage show a partial, but not full recovery with fallowing of the bottom space after experimentation." Page 5. This is an official state report that acknowledges that some benthic impacts have occurred from OOA operations in Hawaii.

Organic loading under aquaculture cage.pdf Measurement of organic loading , etc. Documents benthic impacts from cobia farming off Puerto Rico.

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Also mentions findings from a study by Lee, et al of an OOA project in Hawaii , finding that "the sediment directly under the cage to be 'grossly affected' after 11 months. Another area 80m downstream was found to be 'heavily impacted' after 23 months." I have not been able to obtain the Lee study itself, however. MundyEtAl2003. **Diseases of Tunas.** Relevant since a tuna OOA project has been approved in Hawaiian waters.

MAINE

In 2000, a series of poor wild salmon returns led the U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) to officially list Atlantic salmon populations in Maine as endangered. The status assessment noted interactions with farmed Atlantic salmon as one of several credible threats to the remaining wild fish population (FWS 1999; NRC 2004).

In 2001, the state of Maine ordered over 900,000 diseased farmed salmon killed in Cobscook Bay in an attempt to prevent further spread of the disease to nearby farmed or wild salmon. In addition to ISA, farmed and hatchery salmon are affected by numerous diseases and parasites such as sea lice (Gryodactylus salaries; Bakke and Harris 1998)

US Fish and wildlife report on farming of Atlantic salmon in Maine: Diseases, interbreeding with wild salmon, disruption of wild salmon: See Report

Available genetic data and visual observations indicate that aquaculture escapees

may have successfully interbred with wild Atlantic salmon. Under current aquaculture practices, this problem will persist because the escapement of aquaculture salmon, and their interactions with wild stocks, is expected to increase with the continued operation and growth of the industry in the State of Maine.

There is a significant potential for escaped aquaculture salmon to disrupt wild salmon, compete with wild salmon for food and habitat, interbreed with wild salmon, and transfer disease or parasites to wild salmon. Comprehensive protective solutions to minimize the threat of interactions between wild and aquaculture salmon have not been implemented. The threat of these interactions is considered critical, given the fact that wild salmon stocks within the DPS are at low abundance levels, and are particularly vulnerable to genetic intrusion or other disturbances caused by escaped aquaculture salmon.

Sea lice from salmon farms were listed by the U.S. Fish and Wildlife Service as one of the threats to Maine’s wild salmon populations (FWS 1999).

The Pew letter also challenges the exception for Maine salmon farming companies to use emamectin benzoate, currently allowed under an Investigational New Animal Drug permit from the FDA.

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Washington

Escaped fish: On the Western Coast of North America, escapes have not been accurately recorded but are believed to be substantial (Volpe, Taylor et al. 2000). In July 1997, for example, over 350,000 Atlantic salmon escaped in Puget Sound from a single farm (Gross 1998). U.S. records indicate that 600,000 farmed salmon escaped in the Pacific Northwest between 1996 and 1999, and over a million fish escaped between 1990 and 2000 (Nash, Brooks et al. 2001).

Official policy: The Washington State departments of Agriculture, Ecology, and Natural Resources, along with individual counties, help to regulate the eight salmon farms in the state. Washington issues discharge permits for salmon net pens, and requires the development of pollution prevention plans in compliance with best management practices (BMPs). Periodic assessments review carbon levels in sediments and other indicators; observable impacts from effluents are only allowed to extend 100 feet from salmon net pens. In addition, in 2003, Washington added new rules to existing salmon farming regulation. These included: A requirement for the prior approval of the species, stock and race of marine fish to be grown; A prohibition on growing transgenicfish; Required escape prevention, escape reporting, and escape recapture plans. (WDFW 2003)

American Gold Seafoods operates two hatcheries near Rochester Washington and has 120 pens off Bainbridge Island, Port Angeles, Cypress Island and Hope Island all within the waters of Washington states Puget Sound. At our offshore salmon farms, the fish dine on a mixture of anchovy, herring, wheat, soybeans and corn. They receive no hormones or steroids and are NOT genetically engineered. http://www.icicleseafoods.com/locations/ags/default.aspx

Atlantic salmon (*Salmo Salar*) are raised in marine net pens in Washington State and British Columbia. In Oregon, however, they are listed as one of the “100 Most Dangerous Invaders to Keep Out of Oregon in 2005.” Alaska currently has a ban on finfish farming. In 2003, California passed a bill (SB 245) which prohibits spawning, incubating, or cultivating anadromous or transgenic fish species, or any exotic species of finfish in waters of the Pacific Ocean that are regulated by the state.

http://www.aquaticnuisance.org/fact-sheets/atlantic-salmon

Industry reported number of Atlantic salmon escaping from Washington and British Columbia fish farms, 1996 - 2006.

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613,000 escaped fish in 4 years in Wa. Ongoing “leakage” likely, industry doesn’t report all escapes, farmed salmon caught in commercial and recreational fishing gear.
http://wdfw.wa.gov/ais/species.php?Name=salmo_salar

GLOBAL PROBLEMS
NMFS Risk Analysis for Marine Aquaculture.pdf
This is a 2005 NMFS document focusing specifically on the risk assessment of marine fish aquaculture. While it mostly deals with methodology, rather than actual findings, and speaks of risks "perceived by the public and public administrators," it does list 10 areas of risk associated with marine fish aquaculture.

A Global Assessment of Salmon Aquaculture Impacts on Wild Salmonids, Ford and Myers, Feb 2008.
"Through a meta-analysis of existing data, we show a reduction in survival or abundance of Atlantic salmon; sea trout; and pink, chum, and coho salmon in association with increased production of farmed salmon. In many cases, these reductions in survival or abundance are greater than 50%." The study includes fish populations from Scotland and Ireland, as well as Canada."

Dramatic Declines In Wild Salmon Populations Linked To Exposure To Farmed Salmon

http://www.sciencedaily.com/releases/2008/02/080212085841.htm

ScienceDaily (Feb. 13, 2008) — Comparing the survival of wild salmonid populations in areas near salmon farms with unexposed populations reveals a large reduction in survival in the populations reared near salmon farms. Since the late 1970s, salmon aquaculture has grown into a global industry, producing over 1 million tons of salmon per year. However, this solution to globally declining fish stocks has come under increasing fire. In a new study Jennifer Ford and Ransom Myers provide the first evidence on a global scale illustrating systematic declines in wild salmon populations that come into contact with farmed salmon.

FEED
Atlantic, chinook, and coho salmon are carnivorous fish (Halver and Hardy 2002); in the wild, juvenile salmon feed on a range of animals including crustaceans, insects, mollusks, and other fish. (Other species of salmon, such as sockeye, chum and humpies eat plankton and small crustaceans and cannot be reared for their lifecycle in cages) A third of global fisheries landings are converted into fish meal and fish oil annually (FAO 2002). Fish meal is produced primarily from

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pelagic fish that live near the surface waters or at mid-water depths in the ocean (IFFO 2001). The fish species that comprise most fish meal include anchovy, sardine, menhaden, jack mackerel, sandeel, sprat, capelin, and whiting (IFFO 2001).
The extraction of anchovies and other forage fish for feed for confined animals and fish affects the Southeast Pacific marine ecosystem. Intensive fishing currently reduces the quantity of prey available to large fish such as tunas, and the sizable populations of guano birds and pelicans that depend on Peruvian anchovies (Froese and Pauly 2003). Similarly, in U.S. waters menhaden form a key dietary component for several species of carnivorous fish including striped bass, tunas and swordfish, as well as marine birds (Franklin 2001; Froese and Pauly 2003).

Several recent reviews have been critical of aquaculture's use of wild fish for both practical and ethical reasons (Naylor, Goldburg et al. 1998; Naylor, Goldburg et al. 2000; Tidwell and Allan 2001). Concern has centered over the ecosystem consequences of removing wild fish for use as poultry, livestock and aquaculture feeds (Naylor, Goldburg et al. 1998; Naylor, Goldburg et al. 2000; Franklin 2001; Dayton, Thrush et al. 2002). The removal of forage fish leaves less prey available for wild predators such as seabirds, marine mammals, and predatory fish. The removal can also have top-down effects on ecosystems, potentially encouraging the growth of plankton and zooplankton (Franklin 2001; Dayton, Thrush et al. 2002).

Ethically, some have objected to the fact that farming carnivorous animals results in a net loss of protein (Naylor, Goldburg et al. 1998). An additional component to the debate has been the effect of fish meal use on food security. The use of fish meal and fish oil has been criticized for depleting the amount of protein available for human consumption (Naylor, Goldburg et al. 2000), The aquaculture industry could transition away from farming carnivorous animals such as salmon and shrimp, and instead focus on herbivorous and omnivorous fish with lower fish meal and fish oil requirements such as catfish, tilapia, and carp (Naylor, Goldburg et al. 1998; Goldburg, Elliott et al. 2001).

PNAS-2009-Naylor.et.al. **Aquafeeds.pdf Feeding Aquaculture in an era of finite resources.** Naylor is one of the preeminent authorities on the impacts of finfish OOA on forage fish, though she is cautiously optimistic that this problem might be overcome through use of alternative foodstuffs now under development. The fish in/fish out issue is major, though I don't know whether it is classified as an environmental impact issue.

Chemical Pollution
Aquaculture, like terrestrial agricultural and livestock industries, routinely employs a variety of chemicals for multiple purposes, such as promoting growth and

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preventing disease. The range of chemicals that can be used on a salmon farm includes antibiotics, pesticides, fungicides, vitamin supplements, coloring agents, spawning hormones and anaesthetics. Tacon and Forster (2003) In net pen systems, chemicals are generally applied in water, where they can disperse and affect non-target species (NRC 1999). However, not all of the chemicals listed by Tacon and Forster are used on salmon farms or in other marine net pen systems and many of the chemicals that are used are not considered hazardous. With respect to salmon farming, concern over chemical use has centered on the effects of specific drugs, most notably antibiotics and pesticides, on human health and the surrounding environment (NRC 1999).

These pesticide and antibiotic residues are of concern due to their potential harm to human health and the environment. For example, the pesticide emamectin benzoate, which is used to treat sea lice, is "very toxic to aquatic organisms" and "may cause long-term adverse effects in the environment," according to the manufacturer's safety data. The non-therapeutic use of antibiotics in farmed fish destined for human consumption also raises concerns about the possibility of antibiotic resistant bacterial infections in humans. Earlier this year through a Freedom of Information Act request, Pew obtained FDA documents revealing that three Chilean salmon farming companies, including the two largest Chilean producers of farmed salmon, used drugs not approved by the U.S. government. While attention has focused on Chile, the Pew Environment Group now has information showing that drugs unapproved for the U.S. market are also being used on salmon farms in Canada, Norway and Scotland. In 2008, more than half of farmed salmon imported to the U.S. came from those countries.

Use of "unapproved" drugs in aquaculture. One issue is whether the FDA will consistently require all companies exporting salmon to the U.S. to adhere to the FDA/Center for Veterinary Medicine Approved Drugs in Aquaculture list; another is how the FDA reconciles its current requirement that Chilean salmon companies use only "approved" drugs in aquaculture with permitting the Maine salmon farming industry to use one of these unapproved drugs, emamectin benzoate.
http://www.pewtrusts.org/news_room_detail.aspx?id=51366

Environmental and health effects of antibiotics
Depending on the antibiotic used, between 60% and 85% of a drug can be excreted through feces, unchanged (Alderman, Rosenthal et al. 1994; Samuelsen 1994; Weston 1996). Some drugs, such as oxytetracycline, are poorly absorbed through the intestinal tract of salmon, and consequently must be administered at high dosage rates for up to two weeks (Miranda and Zemelman 2002).

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With respect to human health, antibiotic use encourages the growth of antibiotic resistant strains of bacteria. Some criticism has been leveled at the aquaculture industry for promoting the development of antibiotic resistant bacteria (Angulo and Griffin 2000; Goldburg, Elliott et al. 2001; Miranda and Zemelman 2002).

Pesticides
Along with antibiotics, salmon farms often use pesticides to control parasites such as sea lice (Roth 2000). A year 2000 review of pesticides used in salmon farming showed that the global industry currently uses at least eleven different chemical compounds, representing five pesticide types, to treat sea lice (Roth 2000). Pesticides included are: two organophosphates (dichlorvos and azamethiphos); three pyrethrin/pyrethroid compounds (pyrethrum, cypermethrin, deltamethrin); one oxidizing agent (hydrogen peroxide); three avermectins (ivermectin, emamectin and doramectin); and two benzoylphenyl ureas (teflubenzuron and diflubenzuron). The number of compounds routinely available in any one country is highly variable, ranging from 9 in Norway, to 6 in Chile and the United Kingdom, to 4 in Ireland, the Faeroe Islands and Canada, to 2 in the United States (formalin and hydrogen peroxide) (Roth 2000). For reference, cypermethrin use is authorized in Norway, Scotland, Ireland, and the Faeroe Islands. Additionally, it is under a trial permit in Chile and Investigational New Animal Drug status in the United States. Azamethiphos is authorized in Norway, Scotland, Canada, the Faeroe Islands, and Chile (Grant 2002).

Once released into the marine environment, pesticides may be toxic to non-target organisms (GESAMP 1997). Though there is very little information on the environmental impacts of pesticides, some have been shown to be harmful to other animals such as shrimp and lobsters, especially during early life stages (Abgrall, Rangeley et al. 2000). Specifically, synthetic pyrethroids and organophospates interfere with the nervous system of crustaceans and insects (Grant 2002).
The effects of pesticides can vary with the specific chemical used, the amount and duration of application, and the local water conditions.

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Health concerns over the concentration of PCBs in farmed salmon, originating from contaminated fish meals and fish oils (Easton, Luszniak et al. 2002; Jacobs, Covaci et al. 2002; Hites, Foran et al. 2004).

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A study published in the journal "**Environmental Science and Technology" concludes that, in spite of the heart healthy benefits of omega-3 fatty acids in all salmon, frequent consumption of farmed salmon is more likely than**

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wild to boost levels of PBDEs. Farmed salmon are contaminated with much higher levels of chemical flame retardants than most wild salmon, new research demonstrates. Ronald Hites, distinguished professor at Indiana University and lead researcher on the study, studied polybrominated diphenyl ethers (PBDEs), a group of flame retardant chemicals used in electronics, upholstery, and other consumer products. He determined that the contamination is linked to the high fat diet that farmed salmon are fed. PBDEs are structurally similar to PCBs, which have been linked to cancer and to reproductive, neurological, and developmental effects in humans," said Hites.

PCBs, PCDD/Fs, and Organochlorine Pesticides in Farmed Atlantic Salmon from Maine, Eastern Canada, and Norway, and Wild Salmon from Alaska

S U S A N D . S H A W , * , † D I A N E B R E N N E R , † M I C H E L L E L . B E R G E R , † D A V I D O . C A R P E N T E R , *Environment, University at Albany, Rensselaer, New York*

Total PCB concentrations were significantly higher in the farmed salmon samples (as a group)…. The highest POP concentrations were found in organically grown salmon
from Norway,… These observations suggest that purchasing higher priced organically farmed salmon, even when monitoring results are provided, does
not necessarily protect the consumer from toxic exposure.
http://www.puresalmon.org/pdfs/bravo_present_sealice_WAS.pdf

DISEASES

Research shows that the prevalence of disease in cultured species tends to be significantly higher than in wild species (Stephen and Iwama 1997). This phenomenon presumably occurs in part because farmed salmon experience more physiological stress, in part due to unnaturally high salmon density in net pens.

The spread of infectious salmon anemia (ISA), for example, which attacks the kidneys and circulatory system of fish, led to the intentional destruction of millions of farmed fish throughout Europe, Canada, and the United States.

(Butler 2002; Revie, Gettinby et al. 2002; Heuch, Revie et al. 2003), infectious hematopoietic necrosis (IHN) (Naylor, Eagle et al. 2003), furunculosis, bacterial coldwater disease (Flagg, Berejikian et al. 2000), bacterial kidney disease (BKD) (Olafsen and Roberts 1993), salmon swimbladder sarcoma virus (SSSV), amoebic gill disease (Douglas-Helders, Dawson et al. 2002), and infectious pancreatic necrosis virus (Bowden, Small et al. 2002.).
Certain parasites and pathogens from farmed salmon have a demonstrated potential to infect wild salmon (Brackett 1991; Hjeltnes, Bergh et al. 1995; Bakke

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and Harris 1998). Several accounts have suspected that outbreaks of the following diseases may have originated at salmon farms and infected wild salmon populations: furunculosis (Bakke and Harris 1998); monogean parasites (Bakke and Harris 1998); sea lice (Birkeland 1996; Johnson, Blaylock et al. 1996); and the virus that causes infectious salmon anemia (Whoriskey 2000).

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Diseases affecting Atlantic salmon reared in captivity include bacterial, parasitic, viral, fungal and nutritional diseases (Roberts 1993). The development of a disease epizootic results from an interaction between the host, environment and the disease agent. In farmed salmon, the occurrence of disease is generally due to the high densities at which fish are reared (Hastein and Lindstad 1991). Bacteria may be released to the environment during and after epizootic diseases and may survive and persist (Olafsen 1993; Egusa 1992). The occurrence and spread of infectious diseases increases due to the high densities at which farmed salmon are raised (Institute of Aquaculture 1988; Lura and Saegrov 1991; Hastein and Lindstad 1991; Mork 1991; NASCO 1993; Olafson 1993).

The disease interaction between wild and farmed salmon will likely occur through the water, fish, and other sources such as nets and fishing or handling gear. The transmission of diseases through water can take place over long distances, and transmission has been documented to occur over at least seven km (Hastein and Lindstad 1991.

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Heart and Skeletal Muscle Inflammation of Farmed Salmon Is Associated with Infection with a Novel Reovirus
http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0011487#s5

Atlantic salmon (*Salmo salar L.*) mariculture has been associated with epidemics of infectious diseases that threaten not only local production, but also wild fish coming into close proximity to marine pens and fish escaping from them. Heart and skeletal muscle inflammation (HSMI) is a frequently fatal disease of farmed Atlantic salmon. First recognized in one farm in Norway in 1999[1], HSMI was subsequently implicated in outbreaks in other farms in Norway and the United Kingdom[2].
Unlike terrestrial animal farming, where contact between domestic and free ranging wild animals of the same or closely related species is easily monitored and controlled, ocean based aquaculture is an open system wherein farmed fish may incubate and transmit infectious agents to already diminishing stocks of wild fish.
SeaWeb. "Fish Farms Drive Wild Salmon Populations Toward Extinction." *ScienceDaily* 16 Dec. 2007. Web. 9 Apr. 2011

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PARASITES: SEA LICE are among the most easily identifiable, and perhaps most problematic of these wide spread, native parasites (NASCO 2003). Sea lice are parasitic copepods that feed on the mucous, skin, and blood of salmon. Infestations of these ectoparasites reduce the fitness of salmon and, on highly infested individuals, can be fatal (Wagner, McKinley et al. 2003; Glover, Hamre et al. in press). Various species of sea lice are endemic to Europe, North America, and South America; however pre-aquaculture observations of sea lice epizootics on wild fish are virtually non-existent. The development of salmon aquaculture may have increased the incidence of sea lice epizootics, however there is no baseline for comprehensive comparison (Butler 2002; Naylor, Eagle et al. 2003).

PARASITE AND PATHOGEN SPREAD

Professor Neil Frazer of the Department of Geology and Geophysics at the University of Hawaii at Manoa explains how farm fish cause nearby wild fish to decline. The foundation of his paper is that higher density of fish promotes infection, and infection lowers the fitness of the fish.
http://www.sciencedaily.com/releases/2008/12/081215091017.htm

Conservation Biology: Sea-Cage Aquaculture, Sea Lice, and Declines of Wild Fish, L. NEIL FRAZER Article first published online: 10 DEC 2008
http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2008.01128.x/abstract;jsessionid=FDEC8EB400FB1EE066A8CAD5DE7FCD55.d03t02

Farm fish share water with wild fish, which enables transmission of parasites, such as sea lice, from wild to farm and farm to wild fishes. Sea cages protect farm fish from the usual pathogen-control mechanisms of nature, such as predators, but not from the pathogens themselves. A sea cage thus becomes an unintended pathogen factory. Basic physical theory explains why sea-cage aquaculture causes sea lice on sympatric wild fish to increase and why increased lice burdens cause wild fish to decline, with extirpation as a real possibility. Theory is important to this issue because slow declines of wild fish can be difficult to detect amid large fluctuations from other causes. The important theoretical concepts are equilibrium, host-density effect, reservoir-host effect, and critical stocking level of farmed fish (stocking level at which lice proliferate on farm fish even if wild fish are not present to infect them). Declines of wild fish can be avoided only by ensuring that wild fish do not share water with farmed fish, either by locating sea cages very far from wild fish or through the use of closed-containment aquaculture systems. These principles are likely to govern any aquaculture system where cage-protected farm hosts and sympatric wild hosts have a common parasite with a direct life cycle.

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Impacts of organic wastes

Localized impacts of waste from salmon farms are the most apparent environmental impact of cage-based aquaculture, and as such are relatively well documented (Kelly, Stellwagen et al. 1996; McDonald, Tikkanen et al. 1996; Silvert and Sowles 1996; Burd 1997; Findlay and Watling 1997; Hansen, Ervik et al. 2001). Organic matter often accumulates under and around net pens, increasing carbon levels in the sediments and reducing their oxidation-reduction (redox) potential. Sediments and biota can move into a state of overloading, anoxia, and outgassing of carbon dioxide, methane, and hydrogen sulfide (Chang and Thonney 1992; Black, Kiemer et al. 1996). In documenting these impacts, many studies have noted the ecological impacts in terms of changes in infaunal species biomass and species diversity within the impacted area (Findlay, Watling et al. 1995; Costa-Pierce 1996; Burd 1997; Mazzola, Mirto et al. 2000).

The primary effect of chemical and biological accumulation in nearfield sediments is an increased level of organic carbon and sulfides, and consequently altered patterns of species diversity in the benthos (Brooks, Stierns et al. 2003; Wildish, Hargrave et al. 2003). Species diversity in the benthic environment directly beneath salmon net pens with moderate to poor flushing is usually reduced to two taxa: the polychaete complex; and a few nematode species (Findlay, Watling et al. 1995; Pohle and Frost 1997; Mazzola, Mirto et al. 2000). Researchers have found these two taxa occur without fail at salmon farms worldwide (Burd 1997). Research in Scotland shows major loss of seabed flora and fauna from salmon farm wastes, even in strongly tidal areas.
*Hall-Spencer, J., N. White, E. Gillespie, K. Gillham and A. Foggo. (2006) Impacts of fish farms on maerl beds in strongly tidal areas. *Marine Ecology Press Series*. 326:1-9.
The waste from feed and feces has been linked to increased mercury levels in rockfish, a main component in the diets of many coastal people

*DeBruyn, A.M., M. Trudel, N. Eyding, J. Harding, H. McNally, R. Mountain, C. Orr, D. Urban, S. Verenitch and A. Mazumder. (2006). Ecosystemic effects of salmon farming increase mercury contamination in wild fish. *Environmental Science and Technology*. 40(11): 3489-3493. In sites without adequate currents there can be an accumulation of heavy metals on the benthos (seafloor) near the salmon farms, particularly copper and zinc

ESCAPED FISH

The International Convention on Biological Diversity has identified invasive species as one of the fundamental threats to biodiversity. Globally, it has been estimated that invasive species are second only to habitat destruction in causing

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the loss of biodiversity (Vitousek, Mooney et al. 1997). In marine waters, the introduction of invasive species has resulted in “fundamental impacts on fisheries resources, industrial development and infrastructure, human welfare, and ecosystem resources and services” (Carlton 2001).
Some researchers have argued that the risk of establishment is substantial enough to warrant measures being taken against escapes (Volpe, Taylor et al. 2000; Soto, Jara et al. 2001; Gajard and Laikre 2003).

In the North Atlantic up to two million salmon are believed to escape annually (Schiermeier 2003). In some years 30-40% of Atlantic salmon caught in Norway have originated from fish farms (Hansen, Reddin et al. 1997; Naylor, Williams et al. 2001).

According to the intergovernmental North Atlantic Salmon Conservation Organization, concerns about salmon farming center on the risk of disease and parasite transmission, particularly sea lice, to wild stocks, and **effects on the genetic composition of wild stocks caused by interbreeding with escaped farmed salmon**. Interbreeding can disrupt the transmission of adaptive traits important for the survival and reproduction of wild fish, thereby depressing population fitness. “The latest scientific research suggests that such interbreeding and poorly planned stocking practices could have serious consequences for the
wild salmon which are adapted to the conditions in each river” (NASCO 2003).
While a variety of interactions between farmed and wild salmon exist, the scientific consensus is that, “As a general rule, interactions (between introduced and wild Atlantic salmon) are likely to be negative in their effect on the viability of wild populations” (Youngson and Verspoor 1998, through competition and displacement. Researchers have shown that escaped farmed fish can alter the natural stream environment of wild salmon by elevating densities and increasing overall levels of competition for food and habitat (Einum and Fleming 1997; McGinnity, Stone et al. 1997). In addition, **escaped farmed salmon arrive later than wild salmon at spawning grounds. While the timing of spawning varies considerably, if farmed salmon spawn later they can dig up the gravel that contains the nests of wild females and replace the wild-salmon eggs with their own** (Webb, Hay et al. 1991). As a consequence of these various interactions, the survival and reproduction rate of wild Atlantic salmon is likely to be depressed.
More importantly, escaped salmon can **affect wild populations through interbreeding**. As a result of selective breeding programs, domesticated Atlantic salmon strains are now genotypically and phenotypically distinct from wild populations.

Farmed strains grow roughly three times faster than their wild counterparts, and have significantly higher pituitary growth hormone levels (Fleming, Hindar et al. 2000). In recent years there has been mounting evidence that male wild Atlantic

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salmon are mating with escaped farmed Atlantic female salmon, and a shift in the gene pool of the species is occurring,

Gene flow from farmed to wild fish can harm wild salmon populations in at least two ways. First, **hybrid farmed-wild salmon can out compete wild fish in the freshwater environment. Hybrid Atlantic salmon grow faster and tend to be larger than their wild counterparts** (Ferguson, McGinnity et al. 1997; Fleming, Hindar et al. 2000). Empirical evidence indicates that the faster-growing farmed and hybrid juveniles subsequently displace wild juveniles in rivers through competition. Second, despite the growth advantages of farmed strains in laboratory and freshwater settings, research shows **farmed genetic strains to be less fit than wild stocks in the wild marine environment (Oekland**, Heggberget et al. 1995; Fleming, Jonsson et al. 1996; Fleming, Hindar et al. 2000). Farmed and hybrid strains appear to be less able to compete successfully for food, territory, and mates by a substantial margin. The poor survival of farmed and hybrid salmon in marine environments can lead to a net reduction in the number of returning adults.

Contaminants
Review by Institute for Health and the Environment: **A Global Assessment of Organic Contaminants in Farmed vs. Wild Salmon: Geographical Differences and Health Risks**
Press release: First Global Study Reveals Health Risks of Widely Eaten Farm Raised Salmon *Science* Study Suggests Sharp Restrictions in Consumption. Significantly higher levels of cancer-causing and other health-related contaminants in farm raised salmon have been found than in their wild counterparts. The study, published in *Science* and by far the largest and most comprehensive to date, concluded that concentrations of several cancer-causing substances in particular are high enough to suggest that consumers should consider severely restricting their consumption of farmed salmon.
http://www.albany.edu/ihe/salmonstudy/summary.html

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Previous small peer reviewed studies: A study by Easton et al. in *Chemosphere* examined four farmed and four wild salmon purchased in British Columbia. It reports higher levels of PCBs, some organochlorine pesticides, and PBDEs (flame retardants) in the farmed salmon. The study found that contaminant levels in farmed salmon could be as much as ten times those in wild salmon. The study also suggested that the commercial salmon feed consumed by the farmed fish was responsible for the elevated contaminant levels. Differences between farmed and wild salmon were not notably different for other contaminants such as toxaphene and methylmercury. (M. D. L. Easton, D. Luszniak and E. Von der Geest, Preliminary examination of contaminant loadings in farmed salmon, wild salmon and commercial salmon feed. *Chemosphere* 46, 1053-1074 (2002).

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A study by Jacobs et al. in *Environmental Science & Technology* found relatively high concentrations of PCBs and moderate concentrations of organochlorine pesticides and PBDEs in 13 samples of farmed Scottish and European salmon. (M. Jacobs; A. Covaci, and P. Schepens, Investigation of selected persistent organic pollutants in farmed atlantic salmon (Salmo salar), salmon aquaculture feed, and fish oil components of the feed. *Environmental Science and Technology* 36, 2797-2805 (2002).

Another study by Jacobs et al. in the journal *Chemosphere* found relatively high concentrations of dioxins and PCBs in 10 samples of farmed and wild Scottish salmon. The study concluded that high levels of farmed salmon consumption could lead to intakes of contaminants above tolerable daily and weekly levels when combined with intakes from the typical UK diet. (M. Jacobs, J. Ferrario, and C. Byrne, Investigation of polychlorinated dibenzo-p-dioxins, dibenzo-p-furans (sic) and selected coplanar biphenyls in Scottish farmed Atlantic salmon (Salmo salar).

Chemosphere 47 **plbi-06-02-07.pdf: A Global Assessment of Salmon Aquaculture Impacts on Wild Salmonids, Ford and Myers, Feb 2008.**
"Through a meta-analysis of existing data, we show a reduction in survival or abundance of Atlantic salmon; sea trout; and pink, chum, and coho salmon in association with increased production of farmed salmon. In many cases, these reductions in survival or abundance are greater than 50%." The study includes fish populations from Scotland and Ireland, as well as Canada."

BRITISH COLUMBIA
Predator control: Salmon farmers are granted licenses to kill predators such as sea lions and seals to stop them from eating their fish. According to a report by the Department of Fisheries and Oceans Canada, between 1989 and 2000, BC salmon farmers reported killing
6,243 seals and California and Steller sea lions
*Jamieson, G.S. and P.F. Olesiuk, Department of Fisheries and Oceans Canada. (2001). *Salmon Farm Pinniped Interactions in British Columbia: An Analysis of Predator Control, its Justification andAlternative Approaches.* http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2001/RES2001_142e.pdf

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Wild Salmon Endangered By Failure To Contain Sea Lice From Salmon Farms: http://www.sciencedaily.com/releases/2007/09/070919225321.htm

Science Daily (Sep. 24, 2007) — Eighteen scientists throughout Canada have written an open letter to the Canadian government urging a response to the issue of sea lice from salmon farms threatening wild Pacific salmon. The scientists are

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convinced by the published scientific evidence that the debate is over: sea lice breeding on farmed salmon are threatening BC's wild Pacific salmon

http://web.uvic.ca/~serg/publications/peerreviewed.html

A new study recently published in the journal Public Library of Science ONE by researchers from Raincoast Conservation Foundation, Watershed Watch Salmon Society, and the Universities of Victoria and Simon Fraser provides the first link between salmon farms and elevated levels of sea lice on juvenile Fraser River sockeye salmon in British Columbia.

The article, "Sea Louse Infection of Juvenile Sockeye Salmon in Relation to Marine Salmon Farms on Canada's West Coast," genetically identified 30 distinct stocks of infected Fraser sockeye that pass by open net-pen salmon farms in the Strait of Georgia, including the endangered Cultus Lake population. The study found that parasitism of Fraser sockeye increased significantly after the juvenile fish passed by fish farms. These same species of lice were found in substantial numbers on the salmon farms.

http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0016851

Company	**Headquarters**	**Licences**	**% of BC Industry**
Marine Harvest	Norway	75	55%
Mainstream (Cermaq)	Norway	33	24%
Grieg Seafood	Norway	17	4%
Creative Salmon	Canada	6	4%

A recent study in a peer-reviewed scientific journal, the *Proceedings of the National Academy of Sciences of The United States of America*, found that **sea lice originating from fish farms can kill up to 95% of juvenile wild pink and chum salmon.** Preliminary studies indicate that the disease transfer from the farms is just as prolific and harmful. Salmon farms can increase the exposure of wild juvenile Pacific salmon to sea lice during early marine life when sea lice are normally rare.

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SEA LICE
Fish Farms Drive Wild Salmon Populations Toward Extinction *ScienceDaily (Dec. 16, 2007* http://www.sciencedaily.com/releases/2007/12/071213152606.htm

"The impact is so severe that the viability of the wild salmon populations is threatened," says lead author of a new article in Science (December 14) Martin Krkosek, a fisheries ecologist from the University of Alberta. Krkosek and his co-

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authors calculate that sea lice have killed more than 80% of the annual pink salmon returns to British Columbia's Broughton Archipelago. "If nothing changes, we are going to lose these fish." Previous peer-reviewed papers by Krkosek and others showed that sea lice from fish farms can infect and kill juvenile wild salmon. This, however, is the first study to examine the population-level effects on the wild salmon stocks. Sea lice (Lepeophtheirus salmonis) are naturally occurring parasites of wild salmon that latch onto the fishes' skin in the open ocean. The lice are transmitted by a tiny free-swimming larval stage. Open-net salmon farms are a haven for these parasites, which feed on the fishes' skin and muscle tissue. Adult salmon can survive a small number of lice, but juveniles headed from the river to the sea are very small, thin-skinned, and vulnerable. Sea lice Salmon Canada 2010, etc. "**Evidence of farm-induced parasite infestations on wild juvenile salmon in multiple regions of coastal British Columbia, Canada; M.H.H. Price, A. Morton, and J.D. Reynolds Conclusions: "Sea lice from salmon farms threaten vulnerable wild salmon populations in British Columbia, heightening the urgency required for Canada to develop an effective conservation-based salmon aquaculture policy."**

*Krkosek, M.K., A. Morton, J.P. Volpe, M.A. Lewis. 2009. Sea lice and salmon population dynamics: Effects of exposure for migratory fish. **Proceedings of the Royal Society of London, Series B**. *276:2819-2828* (PDF | 586KB)

Krkošek, M., M.A. Lewis, A. Morton, L.N. Frazer and J.P. Volpe, 2006. Epizootics of wild fish induced by farm fish. **Proceedings of the National Academy of Sciences USA** 103: 15506-15510. (PDF | 1.4MB)

Krkošek, M., M.A. Lewis, J.P. Volpe and A. Morton. 2006. Fish farms and sea lice infestations in wild juvenile salmon in the Broughton Archipelago – A rebuttal to Brooks (2005). **Reviews in Fisheries Science.** 14: 1-11. (PDF | 414KB)

Krkošek, M., A. Morton, J.P. Volpe. 2005. Non-lethal assessment of juvenile Pacific salmon for parasitic sea lice infections. **Transactions of the American Fisheries Society** 134: 711-716. (PDF | 53KB)

Krkošek, M., M.A. Lewis and J.P. Volpe. 2005. Transmission dynamics of parasitic sea lice from farm to wild salmon. **Proceedings of the Royal Society of London, Series B**. 272:689-696. (PDF | 311KB)

Morton, A. and J.P. Volpe. 2002. A description of Atlantic salmon *Salmo salar* in the Pacific salmon fishery in British Columbia, Canada, in 2000. **Alaska Fishery Research Bulletin** 9: 102-110. (PDF | 143KB)

Escaped fish BC

Juvenile Atlantic salmon of two year-classes have been captured in BC rivers (Volpe, Taylor et al. 2000). These juveniles were the natural offspring of escaped

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farmed salmon, indicating that escaped adults have spawned in Pacific rivers on multiple occasions...If Atlantic salmon are able to become fully established, populations of Atlantic salmon could conceivably compete with Pacific salmon populations (some of which are in poor health), prey on native fish species, increase predator densities, or otherwise change the marine ecosystem in ways we cannot currently predict. DFO's own estimates show that Atlantic salmon have been found in over 81 BC rivers and streams that were surveyed.

*Naylor, R. L., K. Hindar, I. Fleming, R. Goldburg, S. Williams, J. Volpe, F. Whorikey, J. Eagle, D. Kelso and M. Mangel. (2005). Fugitive Salmon: Assessing the Risks of Escaped Fish from Net-Pen Aquaculture. *Bioscience.* 55(5):427-437. There is consistent "leakage" where salmon escape though holes in nets. Industry states this can be anywhere from 1-5% of annual production which would translate into 350,000 fish per year in British Columbia

*Morton, A.B. and J. Volpe. (2002). A Description of Escaped Farmed Atlantic Salmon *Salmo salar* Captures and Their Characteristics in One Pacific Salmon Fishery Area in British Columbia, Canada, in 2000. *Alaska Fisheries Research Bulletin.* 9(2):102–110.

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CHILE

Chile's production of Atlantic salmon has since fallen dramatically due to problems with ISA disease, decreasing by 59%, 40%, and 10% in 2009, 2010, and 2011, respectively.

Escaped nonnative salmon are capable of affecting ecosystems prior to or without actually becoming established. In effect, the continual escape of salmon is the equivalent of a small reproducing population. This population can alter existing food webs in freshwater and marine environments. For example, concern has been raised that through their feeding habits, Atlantic salmon released into Chilean lakes may be affecting native fish species. One review of salmon farming speculates that "Chile could be approaching this critical period of decline for several native species without realizing it or taking measures to stop it because of the lack of baseline data and a strategy to monitor the effects of introduced exotic species" (Gajard and Laikre 2003).

In Chilean marine environments, escaped salmon are the top predator in many areas. As a result, the density of escaped salmon found in the wild is negatively correlated with the abundance of native fish, most likely due to predation of salmon on native fish (Soto, Jara et al. 2001). Cermaq management underestimated the virus outbreak that led to the collapse of the Chilean farmed salmon industry. Instead of responding quickly to the massive outbreaks of infectious salmon anemia in Chile, Cermaq continued to release juvenile salmon into its open-net cages, where many fish became infected by the highly contagious virus. The resulting fish losses translated into a plummeting stock price.

http://www.sciencedaily.com/releases/2010/06/100622112558.htm

NORWAY

Norwegian production increased 2% to 741,000 m.t. from 723,000 m.t. in 2008. Norwegian production is expected to rise 12% in 2009 while UK and Canadian production is expected to relatively stable.
http://salmonfarmers.khamiahosting.com/sites/default/files/SalmonFarmingOverview2009.pdf

AQUACULTURE ENVIRONMENT INTERACTIONS:
http://preventescape.eu/?page_id=53

Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention

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ABSTRACT: The escape of fish from aquaculture is perceived as a threat to wild fish populations. The escapes problem is largely caused by technical and

operational failures of fish farming equipment. In Norway, 3.93 million Atlantic salmon *Salmo salar*, 0.98 million rainbow trout *Oncorhynchus mykiss* and 1.05 million Atlantic cod *Gadus morhua* escaped from 2001 to 2009… there is also a so-called 'escape through spawning'
(Jørstad et al. 2008). This phenomenon has forced a redefinition of the term 'escapes from aquaculture' to include the escapement of fertilized eggs into the wider marine environment.

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A news article in Norway's version of the Financial Times (Dagens Naringsliv) has a hard-hitting article on waste emissions from salmon farming based on a new report from the Norwegian Institute of Water Research:

Article in full (in Norwegian) online via: http://tomcat-pm.intermedium.com/pdf/Dagens_Neringsliv/2011/03/09/Dagens_Neringsliv.2011-03-09.0-0-1-0.0-0-1-0.16-17.pdf

Partial English Translation below:

The Climate and Pollution Agency fear that emissions from fish farms will lead to lifeless fjords. The agency is now asking for help. In a recent report produced by the research foundation IRIS and NIVA (The Norwegian Institute for Water Research) on behalf of the Climate and Pollution Agency (KLIF), it is stated that emissions from fish farming are at a record high. Despite the fact that emissions per fish have been reduced, the total amount increased in line with the total amount of farmed fish has increased. The report also shows that even though there has been a considerable development within the aquaculture industry in recent years, technology has not followed to a large enough degree. Farming of approximately one million salmon still occurs for all practical purposes in open cages in the sea, without waste feed and excrement being collected. Environmental challenges are primarily handled by moving the plants to areas with better current conditions, according to the researchers behind the report – Asbjørn Bergheim from IRIS and Bjorn Braaten and Guttorm Long, both from NIVA.

Straight out

It's not like on land where one has a discharge pipe. Everything goes straight into the water. We are concerned that the emissions together with increasing sea temperature will lead to a reduction in the biological diversity in our fjords, that the sea bed will become lifeless and that the ecological conditions necessary for wild fish disappears, says KLIF director Ellen Hambro. Director of Communications Are Kvistad in the fish farmer organization FHL does not share Hambro's fears: - We don't yet know the contents of the report, but note that the Norwegian Institute of Marine Research, in its recent risk report has concluded that emissions of nutrients does not pose any threat along the Norwegian coast. This is our standpoint, says Kvistad, and stresses that farmers follow all the laws and regulations related to emissions and pollution. The scientists are clear that they believe that efforts to find solutions to collect excrement and waste feed should be prioritized. They also recommend that surveillance cameras should be installed on the cages.

Will monitor

The report also proposes that the industry focuses on moving away from impregnated nets and instead concentrate on developing more environmentally friendly methods to prevent fouling. The scientists reckon that farming on land would be too costly to be sustainable, but points out that in such plants it would be possible to introduce good cleaning solutions. In the hope of attracting more proposals for solutions KLIF are now asking for help concerning how emissions from aquaculture can be reduced. Aquaculture is the largest anthropogenic source of nutrient discharge from Rogaland and northwards. It isn't certain that all the solutions as to how to reduce emissions can be found in this report, and we would therefore like more ideas, says KLIF Manager Ellen Hambro.

CLOSED CONTAINMENT MAY NOT BE A SOLUTION

Assessing alternative aquaculture technologies: life cycle assessment of salmonid
culture systems in Canada
Nathan W. Ayer a,*, Peter H. Tyedmers
http://sres.management.dal.ca/Files/Tyedmers/LC_Impacts.pdf

This study employed life cycle assessment (LCA) to quantify and compare the potential environmental impacts of culturing salmonids in a conventional marine net-pen system with those of three reportedly environmentally-friendly alternatives; a marine floating bag system; a land-based saltwater flow through system; and a land-based freshwater re-circulating system. Results of the study indicate that while the use of these closed-containment systems may reduce the local ecological impacts typically associated with net-pen salmon farming, the increase in material and energy demands associated with their use may result in significantly increased contributions to several environmental impacts of global

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concern, including global warming, non-renewable resource depletion, and acidification.
Although closed-containment systems are currently being described and promoted as environmentally-friendly alternatives to net-pen farming, results of this study suggest that there is an environmental cost associated with employing this technology which should be considered in any further evaluation of their environmental performance.

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