Merrill, Hannah

From: zSMPC
Sent: Thursday, January 31, 2013 1:00 PM
To: zSMP
Subject: FW: Coalition Public Comments: SMP Update-Aquaculture
Attachments: Finfish Environmental Impact Documentation.doc

From: Laura Hendricks [redacted]]
Sent: Thursday, January 31, 2013 12:12 PM
To: Jones, Jim; zSMPC
Subject: Coalition Public Comments:SMP Update-Aquaculture

January 31, 2013

Clallam County Shoreline Master Program Planning Staff
Re: Clallam County Shoreline Master Program Public Comments-Finfish Aquaculture

Dear Staff,

The Coalition To Protect Puget Sound Habitat is requesting that open cage finfish aquaculture not be allowed in Washington waters. The diseases and risks to native salmon populations are too great to allow commercial enterprises to endanger these iconic species. The economic value of our native salmon populations far outweigh the economic benefits that would be derived from commercial operations.

The intent of the Shoreline Master Program Update is to add protections, not provide an opportunity for industry to degrade the diminishing aquatic resources that so many citizens are trying to restore. We have attached a summary of the multitude of adverse impacts from finfish aquaculture operations around the world that supports our request.

If you have any questions, please do not hesitate to contact us.

Sincerely,
Laura Hendricks
Coalition To Protect Puget Sound Habitat
[redacted]

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
Alexander 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**.

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**.

<><><><><>

Hawaii

Temporal changes in the polychaete infaunal community surrounding a Hawaiian mariculture operation

Han W. Lee1, Julie H. Bailey-Brock1, 2,*, Michelle M. McGurr2.

.

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. 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.

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.
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 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 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).

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.

><><>><><><

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).

><><>><><><

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 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 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).

><><><

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.

><><><><><

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

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.

<>><><

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 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 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

><><><><><
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).

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

><>>><>

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 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.

<><>><><
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-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 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.

Volpe, J.P., B.W. Glickman and B.R. Anholt. 2001. Reproduction of Atlantic salmon (*Salmo salar*) in a controlled stream channel on Vancouver Island, British Columbia. **Transactions of the American Fisheries Society** 130: 489-494. (PDF | 61KB)

Volpe, J.P., B.R. Anholt and B.W. Glickman. 2001. Competition among juvenile Atlantic salmon (*Salmo salar*) and steelhead trout (*Oncorhynchus mykiss*): Relevance to invasion potential in British Columbia. **Canadian Journal of Fisheries and Aquatic Sciences** 58: 197-207. (PDF | 193KB)

Volpe, J.P. and B.R. Anholt. 2001. Atlantic salmon (*Salmo salar*) in British Columbia. *In* **Marine Bioinvasions: Proceedings of the First National Conference** (January 24-27 1999; edited by J. Pederson). Massachusetts Institute of Technology, Cambridge, MA. pp. 256-259.

Volpe, J.P., E.B. Taylor, D.W. Rimmer, B.W. Glickman. 2000. Natural reproduction of aquaculture escaped Atlantic salmon (*Salmo salar*) in a coastal British Columbia river. **Conservation Biology** 14: 899-903. (PDF | 319KB)

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

Ø. Jensen1, T. Dempster1, 2,*, E. B. Thorstad3, I. Uglem3, A. Fredheim1
1Centre for Research-based Innovation in Aquaculture Technology (CREATE), SINTEF Fisheries and Aquaculture, 7465 Trondheim, Norway
2Department of Zoology, University of Melbourne, Victoria 3010, Australia
3Norwegian Institute for Nature Research, 7485 Trondheim, Norway

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.

><><><><

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 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. 2008 Elsevier Ltd. All rights reserved.

REFERENCES FROM SEAWATCH USED IN PRECEEDING REPORTS

Alderman, D. J., H. Rosenthal, et al. (1994). Chemicals used in mariculture, ICES Working Group Environmental Interactions of Mariculture. Alverson, D. and G. Ruggerone (1997). Escaped farm salmon: Environmental and ecological concerns. Technical Advisory Team Discussion Papers. B. C. E. A. Office.

Anderson, J., F. Whoriskey, et al. (2000). "Atlantic salmon on the brink." Endangered Species UPDATE 17(1): 15-21.

Angulo, F. and P. Griffin (2000). "Changes in antimicrobial resistance in Salmonella enterica Serovar Typhimurium." Emerging Infectious Diseases 6(4): 436-437.

Arthington, A. H. and D. R. Bluhdorn (1996). The effect of species interactions resulting from aquaculture operations. Aquaculture and Water Resource Management. D. J. Baird, M. C. M. Beveridge, L. A. Kelly and J. F. Muir, Blackwell Science, U.K.: 114-139.

Bakke, T. A. and P. D. Harris (1998). "Diseases and parasites in wild Atlantic salmon (Salmo salar) populations." Can. J. Fish. Aquat. Sci. 55 (Suppl. 1): 247-266.

Barlow, S. (2002). The world market overview of fish meal and fish oil. Second Seafood Byproducts Conference

Alaska.Benbrook, C. M. (2002). Antibiotic Drug Use in U.S. Aquaculture, The Northwest Science and Environemental Policy Center.

Birkeland, K. (1996). "Consequences of premature return by sea trout (Salmo trutta) infested with salmon louse: migration, growth, and mortality." Can. J. Fish. Aquat. Sci. 53: 2808-2813.

Black, K. D., M. C. B. Kiemer, et al. (1996). Benthic impact, hydrogen sulphide and fish health: field and laboratory studies. Aquaculture and Sea Lochs. K. D. Black, Scottish Association for Marine Sciences: 16-26.

Boesch, D., R. Burroughs, et al. (2001). Marine Pollution in the United States: Significant Accomplishments, Future Challenges. Arlington, VA., Pew Oceans Commission.
Bowden, T., D. Small, et al. (2002.). "Development of a reproducible infectious pancreatic necrosis virus challenge model for Atlantic salmon, Salmo salar L." Journal of Fish Diseases 25: 555-563.Bridger, C. and A. Garber (2002). Aquaculture escapement, implications and mitigation: The salmonid case study. Ecological Aquaculture. B. Costa-Pierce. Oxford, UK, Blackwell.

Butler, J. (2002). "Wild salmonids and sea louse infestations on the west coast of Scotland: sources of infection and implications for the management of marine salmon farms." Pest Management Science 58: 595-608.

Carlton, J. (2001). Introduced Species in U.S. Coastal Waters. Arlington, VA, Pew Oceans Commission.

Carr, J. W., J. M. Anderson, et al. (1997). "The occurrence and spawning of cultured Atlantic salmon (Salmo salar) in a Canadian river." ICES J. Mar. Sci. 54: 1064-1073.

Costa-Pierce, B. A. (1996). Environmental Impacts of nutrients from aquaculture: Towards the evolution of sustainable aquaculture. Aquaculture and Water Resource Management. D. J. Baird, M. C. M. Beveridge, L. A. Kelly and J. F. Muir, Blackwell Science, U.K.: 81-113.
Costanza, R., R. d'Arge, et al. (1997). "The value of the world's ecosystem services and natural capital." Nature 387(6630): 253-260.

Crozier, W. W. (1993). "Evidence of genetic interaction between escaped farmed salmon and wild Atlantic salmon (Salmo salar L.) in a Northern Irish river." Aquaculture 113: 19-29.

CRU (2002). Review and Synthesis of the Environmental Impacts of Aquaculture. Edinburgh, Scotland, Scottish Executive Central Research Unit.

DAFA (2003). Bay of Fundy Marine Aquaculture Site Allocation Policy, New Brunswick Department of Agriculture, Fisheries and Aquaculture.
Dayton, P., S. Thrush, et al. (2002). Ecological Effects of Fishing in Marine Ecosystems of the United States. Arlington, VA, Pew Oceans Commission. DMR (2003). Environmental Research and Monitoring, Maine Department of Marine Resources. 2003.

Douglas-Helders, G., D. Dawson, et al. (2002). "Wild fish are not a significant reservoir for Neoparamoeba pemaquidensis (Page, 1987)." Journal of Fish Diseases 25: 569-574.

Einum, S. and I. A. Fleming (1997). "Genetic divergence and interactions in the wild among native, farmed and hybrid Atlantic salmon." Journal of Fish Biology 50: 634-651.

EPA (2002). EPA Press Release: EPA Issues Aquaculture Permit for Maine Fish Farm, Environmental Protection Agency.

Ernst, W., P. Jackman, et al. (2001). "Dispersion and toxicity to non-target aquatic organisms of pesticides used to treat sea lice on salmon in net pen enclosures." Marine Pollution Bulletin 42(6): 433-444.Ferguson, A., P. McGinnity, et al. (1997). Will interbreeding between wild and cultured fish have negative consequences? ICES/NASCO Symposium Final abstracts: Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. NASCO.

Findlay, R. H. and L. Watling (1997). "Prediction of benthic impact for salmon net-pens based on the balance of benthis oxygen supply and demand." Marine Ecology Progress Series 15: 147-157.

Findlay, R. H., L. Watling, et al. (1995). "Environmental Impact of Salmon Net-Pen Culture on Marine Benthic Communities in Maine: A Case Study." Estuaries 18(1A): 145-179.

Flagg, T., B. Berejikian, et al. (2000). Ecological and behavioral impacts of artificial production strategies on the abundance of wild salmon populations, U.S. Department of Commerce: 92.

Fleming, I. A. and S. Einum (1997). "Experimental tests of genetic divergence of farmed from wild Atlantic salmon due to domestication." ICES J. Mar. Sci. 54: 1051-1063.

Fleming, I. A., K. Hindar, et al. (2000). "Lifetime success and interactions of farm salmon invading a native population." Proceedings of the Royal Society London 267: 1517-1523.

Fleming, I. A., B. Jonsson, et al. (1996). "An experimental study of the reproductive behaviour and success of farmed and wild Atlantic salmon (Salmo salar)." Journal of Applied Ecology 33(4): 893-905.

Folke, C., N. Kautsky, et al. (1994). "The costs of eutrophication from salmon farming: Implications for policy." Journal of Environmental Management 40(2): 173-182.FWS (1999). Status Review of Altantic Salmon, U.S. Fish and Wildlife Service.

Gajard, G. and L. Laikre (2003). "Chilean aquaculture boom is based on exotic salmon resources: A conservation paradox." Conservation Biology 17(4): 1173-1174.

Garant, D., I. Fleming, et al. (2003). "Alternative life-history tactics as potential vehicles for speeding introgression of farm salmon traits into wild populations." Ecology Letters 6: 541-549.
Gaudet, D. (2002). Atlantic Salmon, A White Paper, Alaska Department of Fish and Game.

GESAMP (1997). Towards safe and effective use of chemicals, GESAMP (IMO, FAO, UNESCO-IOC, WMO, WHO, IAEA, UN, UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution).

Glover, K., L. Hamre, et al. (In Press). "A comparison of sea louse (Lepeophtheirus salmonis) infection levels in farmed and wild salmon (Salmo salar L.) stocks." Aquaculture.

Goldburg, R. J., M. Elliott, et al. (2001). Marine Aquaculture in the United States. Arlington, VA, Pew Oceans Commission.

Gonzalez, L. and J. Carvajal (2003). "Life cycle of Caligus rogercresseyi (Copepoda: Caligidae) parasite of Chilean reared salmonids." Aquaculture 220: 101-117.

Gowland, B., L. Webster, et al. (2002). "Uptake and effects of the cypermethrin-containing sea lice treatment Excis in the marine mussel, Mytilus edulis." Environmental Pollution 120: 805-811. Grant, A. (2002). "Medicines for sea lice." Pest Management Science 58: 521-527.Haya, K., L. Burridge, et al. (2001). "Environmental impact of chemical wastes produced by the salmon aquaculture industry." ICES Journal of Marine Science 58: 492-496.

Heuch, P., C. Revie, et al. (2003). "A comparison of epidemiologic patterns of salmon lice, Lepeophtheirus salmonis, in Norway and Scotland." Journal of Fish Diseases 26(9): 539-552.

Hites, R., J. Foran, et al. (2004). "Global assessment of organic contaminants in farmed salmon." Science 303: 226-229.

Hjeltnes, B., O. Bergh, et al. (1995). "Susceptibility of Atlantic cod Gadus morhua, halibut Hippoglossus hippoglossus and wrasse (Labridae) to Aeromonas salmonicida subsp. salmonicida and the possibility of transmission of furunculosis from farmed salmon Salmo salar to marine fish." Diseases of Aquatic Organisms 23: 25-31.

Hutchinson, P. (1997). "Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues."

ICES J. Mar. Sci. 54: 963-1225.Jacobs, M., A. Covaci, et al. (2002). "Investigation of selected persistent organic pollutants in farmed Atlantic salmon (Salmo salar), salmon aquaculture feed, and fish oil components of the feed." Environmental Science Technology 36(13): 2797-2805.

Johnson, S. C., R. B. Blaylock, et al. (1996). "Disease induced by the sea louse Lepeophtheirus salmonis in wild salmon stocks of Alberni Inlet, British Columbia." Can. J. Fish. Aquat. Sci. 53: 2888-2897.

Johnston, D. (2002). "The effect of acoustic harassment devices on harbour porpoises (Phocoena phocoena) in the Bay of Fundy, Canada." Biological Conservation 108: 113-117.Kelly, L. A., J. Stellwagen, et al. (1996). "Waste loadings from a freshwater Atlantic salmon farm in Scotland." Water Resour. Bull. 32(5): 1017-1025.

Kent, M. L. (1994). The impact of diseases of pen-reared salmonids on coastal environments. Canada-Norway workshop on environmental Impacts of Aquaculture, Havforskningsinstututtet

Bergen.Lassuy, D. R. (1995). Introduced species as a factor in extinction an endangerment of native fish species. Am. Fish. Soc. Symp.

Marin, S., F. Sepulveda, et al. (2002). "The feasibility of using Udonella sp. (Platyhelminthes: Udonellidae) as a biological control for the sea louse Caligus rogercresseyi, Broxhall and Bravo 2000, (Copepoda: Caligidae) in southern Chile." Aquaculture 208: 11-21.

Maund, S., M. Mamer, et al. (2002). "Partitioning, bioavailability, and toxicity of the pyrethroid insecticide cypermethrin in sediments." Environmental Toxicology and Chemistry 21: 9-15.

Mazzola, A., S. Mirto, et al. (2000). "Fish-farming effects on benthic community structure in coastal sediments; analysis of meiofaunal recovery." ICES J. Mar. Sci. 57: 1454-1461.

McDowell, N. (2002). "Stream of escaped farm fish raises fear for wild salmon." Nature 416: 571.

McGinnity, P., P. Prodohl, et al. (2003). "Fitness reduction and potential extinction of wild populations of Atlantic salmon Salmo salar as a result of interactions with escaped farm salmon." Proceedings of the Royal Society, London B DOI 10.1098/rspb.2003.2520.

McGinnity, P., C. Stone, et al. (1997). "Genetic impact of escaped farmed Atlantic salmon (Salmo salar L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment." ICES J. Mar. Sci. 54: 998-1008.

Milewski, I. (2002). Impact of Salmon Aquaculture on the Coastal Environment: A Review. New Brunswick, Conservation Council of New Brunswick: 34.

Miranda, C. and R. Zemelman (2001). "Antimicrobial resistant bacteria in fish from the Conception Bay, Chile." Marine Pollution Bulletin 42(11): 1096-1102.

Miranda, C. and R. Zemelman (2002). "Bacterial resistance to oxytetracycline in Chilean salmon farming." Aquaculture 212: 31-47.

Molver, J., A. Stigebrandt, et al. (1988). On the excretion of nitrogen and phosphorus from salmon. Aquaculture International Congress and Exposition, Vancouver, B.C.

Naylor, R., J. Eagle, et al. (2003). "Salmon aquaculture in the Pacific Northwest: A global industry with local impacts." Environment 45(8): 18-38.

Naylor, R. L., R. J. Goldburg, et al. (1998). "Nature's Subsidies to Shrimp and Salmon Farming." Science 282(5390): 883-884.

Naylor, R. L., R. J. Goldburg, et al. (2000). "Effect of Aquaculture on World Fish Supplies." Nature 405: 1017-1024.

Naylor, R. L., S. L. Williams, et al. (2001). "Aquaculture--A Gateway for Exotic Species." Nature 294: 1655-1656.

Pohle, G. and B. Frost (1997). Establishment of standard benthic monitoring sites to assess long-term ecological modification and provide predictive sequence of benthic communities in the inner Bay of Fundy. St. Andrews, Cana, Huntsman Marine Science Centre: 119.

Pohle, G., B. Frost, et al. (2001). "Assessment of regional benthic impact of salmon mariculture within the Letang Inlet, Bay of Fundy." ICES J. Mar. Sci. 58.

Rae, G. (2002). "Sea louse control in Scotland, past and present." Pest Management Science 58(515-520).

Revie, C., G. Gettinby, et al. (2002). "The epidemiology of the sea lice, Caligus elongates Nordmann, in marine aquaculture of Atlantic salmon, Salmo salar L., in Scotland." Journal of Fish Diseases 25: 391-399.

Sepulveda, F., S. Marin, et al. (In Press). "Metazoan parasites in wild fish and farmed salmon from aquaculture sites in southern Chile." Aquaculture Accepted September 5, 2003.

Sepulveda, F., S. Marin, et al. (In Press). "Metazoan parasites in wild fish and farmed salmon from aquaculture sites in southern Chile." Aquaculture Accepted September 5, 2003.

Skaala, O. and K. Hindar (1997). Genetic changes in the R. Vosso salmon stocks following a collapse in the spawning population and invasion of farmed salmon. ICES/NASCO Symposium Final abstracts: Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. NASCO.

Skog, T., K. Hylland, et al. (2003). "Salmon farming affects the fatty acid composition and taste of wild saithe Pollachius virens L." Aquaculture Research 34: 999-1007.

Soto, D., F. Jara, et al. (2001). "Escaped salmon in the inner seas, Southern Chile: Facing ecological and social conflicts." Ecological Applications 11(6): 1750-1762.

Sutherland, T., A. Martin, et al. (2001). "Characterization of suspended particulate matter surrounding a salmonid net-pen in the Broughton Archipelago, British Columbia." ICES Journal of Marine Science 58: 404-410.

Volpe, J. P., E. B. Taylor, et al. (2000). "Evidence of Natural Reproduction of Aquaculture-Escaped Atlantic Salmon in a Coastal British Columbia River." Conservation Biology 14: 899-903.

Weston, D. P. (1996). Environmental Considerations in the Use of Antibacterial Drugs in Aquaculture. Aquaculture and Water Resource Management. D. J. Baird, M. C. M. Beveridge, L. A. Kelly and J. F. Muir: 140-165.

Weston, D. P. (1996). Environmental Considerations in the Use of Antibacterial Drugs in Aquaculture. Aquaculture and Water Resource Management. D. J. Baird, M. C. M. Beveridge, L. A. Kelly and J. F. Muir: 140-165.

Whoriskey, F. G. (2000). Infectious Salmon Anemia: A review and the lessons learned from wild salmon on Canada's east coast. Aquaculture and the Protection of Wild Salmon. P. Gallaugher and C. Orr, Simon Fraser University: 46-51.