MARINE AQUACULTURE

ENVIRONMENTAL IMPACTS: SEA LICE and ESCAPEMENT

and

RECENT FEDERAL ACTIONS

By

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Preface: The information presented in this document focuses on two issues associated with marine net pen aquaculture: sea lice and farmed fish escapes (with emphasis on Atlantic salmon). Information is also included on recent federal actions pertaining to offshore aquaculture. Past PSMFC publications on environmental impacts of marine aquaculture and marine aquaculture are listed at http://www.aquaticnuisance.org/articles (see "Marine Aquaculture").

Credit: OceanSpar -- http://www.oceanspar.com/

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I. INTRODUCTION

World aquaculture has grown dramatically in the last 50 years, with aquaculture accounting for 47 percent of the world's fish food supply in 2006 (FAO 2009). From a production of less than 1 million tons in the early 1950s, production in 2006 was reported to have risen to 51.7 million tons, with a value of US $78.8 billion. While capture fisheries production stopped growing in around mid-1980, the aquaculture sector has maintained an average annual growth rate of 8.7 percent worldwide (excluding China, 6.5 percent) since 1970 (FAO 2009).

Given projected worldwide population growth over the next two decades, it is estimated that an additional 40 million tons of aquatic food will be required by 2030 to maintain the current per capita consumption (FAO 2006). Further driving aquaculture industry growth is the fact that capture fisheries worldwide are fully exploited and aquaculture products will be needed to meet much of the increased seafood demand of a growing global population (See **Figure 1**). U.S. aquaculture production has remained relatively steady (NMFS 2008) with the U.S. share of worldwide aquaculture production[1] (and farmed salmon[2]) being small. British Columbia is the fourth largest farmed salmon producer worldwide, with wholesale sales being valued at $507 million in 2008[3] (BCSFA 2009). While there isn't any indication that U.S. aquaculture production will significantly increase in the near term in our coastal waters, there is significant potential, according to NOAA, to increase commercial aquaculture production in the U.S. using today's technology.

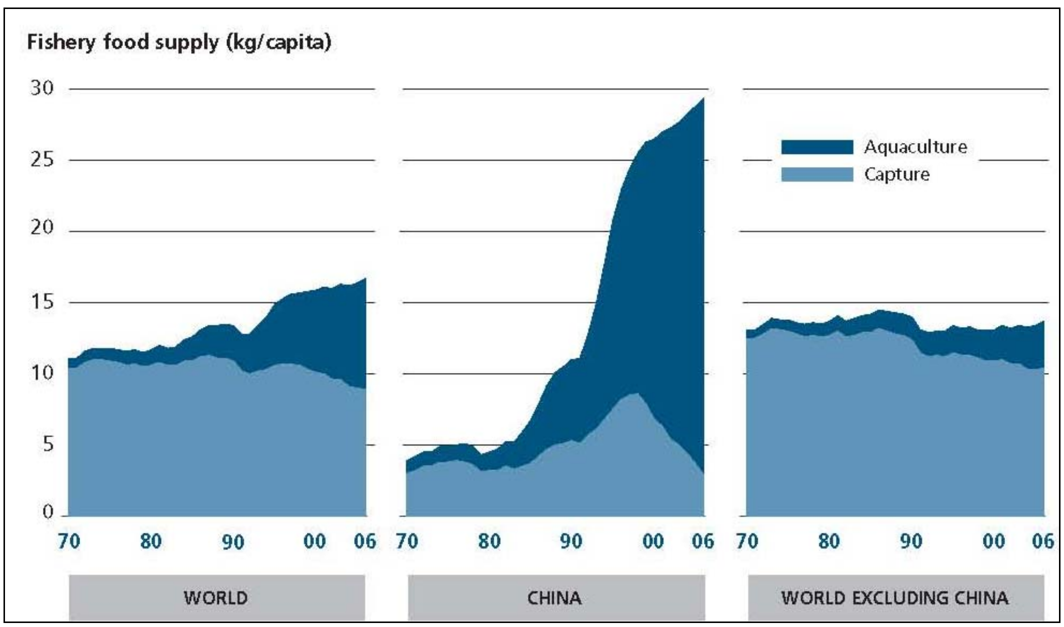

Figure 1: Relative contribution of aquaculture and capture fisheries to food fish consumption (FAO 2009).

[1] 2004 combined percentage of U.S. and Canada world aquaculture production was 1.3 percent (FAO 2006).
[2] 2007 U.S. farmed **salmon** production comprised 0.66% of world production, and Canada 6.53% (Barry 2008).
[3] The estimated value of Washington State's farmed salmon industry is $20 - $30 million.

Preliminary production estimates by NOAA (citing Nash 2004) indicate that domestic aquaculture production of all species could increase from about 0.5 million tons annually to 1.5 million tons per year by 2025. The additional production could include 760,000 tons from finfish aquaculture, 47,000 tons from crustacean production, and 245,000 tons from mollusk production. Of the 760,000 tons of finfish aquaculture, 590,000 tons could come from marine finfish aquaculture. Go to http://aquaculture.noaa.gov/us/welcome.html for further information. Operation of offshore marine aquaculture facilities remains a divisive resource management issue. On the West Coast, Atlantic salmon (*Salmo salar*) fish farms, especially those in British Columbia, have been at the center of the controversy. Concerns about Atlantic salmon farms include sea lice transfer to wild stocks, pollution from net pen facilities, competition with native fish by escaped fish, and cumulative ecosystem impacts. Information presented in this document focuses on the issues of sea lice and farmed fish escapes (with emphasis on Atlantic salmon) as well as recent federal actions pertaining to offshore aquaculture.

II. Atlantic Salmon Escapes and Interceptions

Periodically, and sometimes in large numbers, farm-raised Atlantic salmon escape into the wild. Please refer to **Table 1** for escape-related information from Europe and North America. No escape events have been reported by industry in Washington State since 2005, when 2,500 fish escaped from marine net pens. Over the past six years, numbers of Atlantic salmon escapees reported in British Columbia have varied widely with 17-30 in 2003, 2005 and 2006 and 19,223-73,507 in 2004, 2007 and 2008 (**Table 2**). Commercial and recreational fishermen continue to intercept adult Atlantic salmon in Washington, Alaska and British Columbia (**Table 3**). It is noteworthy that in recent years Atlantic salmon continue to be caught in Puget Sound[4], occasionally caught near net pen sites, even with no reported escapes from Washington net pen facilities. These fish may be attributable to "leakage" from net pens (fish that jump out of the pens or swim through the mesh openings). A cursory web search of the literature did not turn up any formal studies on leakage. However, some leakage estimates have been put at 0.5 % to 1.0% of the net pen population (Alverson and Ruggerone 1997). Based on the number of fish being reared, this translates to tens of thousands of fish escaping from British Columbia and Washington fish farms, <u>if</u> leakage estimates cited above are assumed to be accurate.

Atlantic salmon have moved impressive distances after escaping, as evidenced by an escaped Atlantic salmon caught near the Pribilof Islands in the Bering Sea (Brodeur and Busby 1998) and a Puget Sound-raised fish caught in Cook Inlet (Alaska) after apparently travelling over 1,000 miles in two months (**Table 1**).

Concerns have been raised about the impacts to wild salmon stocks from these escapees. Volpe *et al*. (2000) reported that Atlantic salmon escapees successfully spawned in the wild in British Columbia. Fisheries and Oceans Canada reported juvenile Atlantic salmon on Vancouver Island in the Tsitika River (1998-2000), Amor de Cosmos (1999-2000) and

[4] Atlantic salmon adults that are occasionally caught on Washington's Green River are likely escapees from transfer events to a processing plant located there (Meacham 2008).

Adams River (1999) (Waknitz et al. 2002). It is suspected that these fish were naturally produced. There have been concerns raised about competition between steelhead and Atlantic salmon juveniles (Volpe 2000). However, Cubitt *et al*. (2006) concluded that "there appears to be little risk of Atlantic salmon establishing viable populations in the Pacific Northwest at this time." Also, according to Waknitz *et al*. (2002), the risk of anadromous Atlantic salmon establishing self-perpetuating populations anywhere outside their home range has been shown to be extremely remote, given that substantial and repeated efforts over the last 100 years have not produced a successful self-reproducing anadromous population anywhere in the world. Still, concerns remain that if escape events continue, at some point the constant propagule pressure could result in the establishment of a viable Atlantic salmon population. According to Bisson (2006):

> The relative risk of Atlantic salmon becoming an invasive species of concern can therefore be partitioned into short (<5 years) and long-term (>5 years) time horizons. The current risk to national forest streams from Atlantic salmon invasions is low and limited to a few forests in northwest Washington and southeast Alaska. However, the long-term risks may be substantial if fish continue to escape from marine rearing pens or freshwater hatcheries. The two greatest risks appear to be that (1) Atlantic salmon may introduce a serious pathogen to native populations, and (2) escaped salmon will eventually adapt to local conditions as selection favors the survival and reproduction of a few individuals. Salmonids in general are capable of rapid evolution because their gamete production is relatively large, they have ample opportunity to hybridize, they are occasionally capable of polyploidy, and they have somewhat flexible life histories. Despite a long history of failure to establish Atlantic salmon from single or a few deliberate introductions, it seems possible that continuous recruitment of fish escaping from farming operations may eventually lead to locally adapted stocks. At that point, the species may rapidly become a dangerous invasive—a pattern that is often seen in other aquatic plants and animals where a prolonged early colonization period is followed by a rapid phase of exponential growth.

Since 2003, WDFW, with funding from PSMFC and NOAA, has been monitoring for the presence of Atlantic salmon in selected Washington freshwater streams. As of December 12, 2008, a total of 882 surveys (483 by snorkel) have been completed in 194 streams and rivers (**See Table 4 and Appendix 1**). In 2003, hundreds of Atlantic salmon juveniles (**Figure 2**) were found in Scatter Creek (Chehalis River basin) and three Atlantic salmon juveniles were also found in Cinnabar Creek (Cowlitz River basin). The sources of the Scatter and Cinnabar Creek fish were Atlantic salmon hatcheries located in both watersheds. Since 2003, escapes from the Scatter Creek hatchery have declined, with three fish captured in 2007 and none in 2008. Scoop traps on both the Chehalis and Cowlitz Rivers have captured Atlantic salmon for a number of years (**See Table 4**), but the numbers in recent years are down. There is no evidence to date that any juvenile Atlantic salmon captured in Washington State is wild progeny.

Table 1: Global salmon escape events and other data (mostly Atlantic salmon).

LOCATION	EVENT
New Brunswick, Canada (October 2005) *Source: Atlantic Salmon Federation (2005)*	The Atlantic Salmon Federation claims that farmed Atlantic salmon escapees from the Bay of Fundy accounted for more than 80% of salmon returns in 2005 in the St. Croix and Magaguadavic Rivers. Only nine wild salmon have returned to the Magaguadavic as of 10/13/2005, which, as recently as the 1980s, supported runs of 800 or more wild salmon annually.
Cook Inlet, Alaska (July 2006) *Source: Alaska Invasive Species Working Group (2006)*	An Atlantic salmon caught in a set net in Cook Inlet, Alaska that had been marked (via thermal technique) was eventually traced to the Rochester, Washington (Scatter Creek) Atlantic salmon hatchery (currently owned by American Gold Seafood). Scatter Creek fish are eventually transferred to marine net pens in Puget Sound, and it is thought that the Cook Inlet fish escaped in May 2006 from a net pen during transfer to a barge.
Campbell River, BC, Canada (November 2007) *Source: Drews (2007)*	Closed containment aquaculture is seen as a way to reduce environmental impacts of customary marine aquaculture. However, closed containment systems were shown to not be immune to escapes when in November 2007, two Chinook salmon escaped from the Middle Bay Sustainable Aquaculture Institute's facility (http://www.sustainable-aquaculture.ca/). The closed containment system failed when storm activity snapped off a waste trap, allowing the salmon to escape.
Worldwide (2000-2006) *Source: Kavanaugh et al. (2007)*	The Pure Salmon Campaign, a group often opposed to marine aquaculture, estimates at least 10.2 million farmed salmon and trout escaped from open net cages in 262 escape events, worldwide, between 2000 and 2006.
Norway (2007) *Source: Marine Harvest (2008)*	Aquaculture industry giant, Marine Harvest, estimates that escapes from its Norway operations resulted in 935,000 salmon and trout escaping in 2006 and 407,000 in 2007.
Scotland (2006, 2007) *Sources: SSPO (2008); Fish Farmer (2007)*	The Scottish Salmon Producers Organization (SSPO) reports over 70 million smolts were put to sea at various times during 2006 and 2007, and breaches of containment where fish were known to have escaped during 2007 corresponded to approximately 0.2% [or 140,000 fish] of the total amount of farmed salmon in Scottish waters during this period. *[Also in 2007, the Scottish based Salmon Farm Protest Group, claimed more than one million salmon and trout escaped or died in 2005 in Scottish fish farms]*.
Chile (2008/2009) *Source: Carvajal (2009)*	In Chile, on December 31, 2008, 198,000 farmed salmon (species not known) escaped from salmon cages owned by Mainstream Chile (owned by CERMAQ). More than half were reportedly recaptured.

Table 2. Reported Number of Atlantic salmon escaping from Washington and British Columbia fish farms, 1996 through 2008.

Year	Washington State(1)	British Columbia(2)
1996	107,000	13,137
1997	369,000	7,472
1998	22,639	80,975
1999	115,000	35,954
2000	0	31,855
2001	0	55,414
2002	0	11,257
2003	0	30
2004	24,552	43,969
2005	2,500	21
2006	0	17(3)
2007	0	19,223(4)
2008	0	73,507(5)

(1) Source: Washington Department of Fish and Wildlife http://wdfw.wa.gov/fish/atlantic/comcatch.htm

(2) Province of British Columbia, Ministry of Agriculture and Lands: http://www.agf.gov.bc.ca/fisheries/aqua_report/2004-5/index_2004-5.htm

(3) BC Ministry of Agriculture and Lands and Ministry of Environment (2007)

(4) BC Ministry of Agriculture and Lands and Ministry of Environment (2008)

(5) 30,000 Atlantic salmon escapes were reported on July 1 (387 of which were recaptured by the operator, Marine Harvest Canada (DiPietro 2008). On December 20, 43,507 Atlantic salmon reportedly escaped (DiPietro 2009)

Table 3. Reported number of marine and (freshwater) Atlantic salmon adult captures from Washington and British Columbia fish farms, 1987 through 2008.

Year	**WA**	**BC**	**AK**
1987		1 (1)	
1988		106 (0)	
1989		8 (0)	
1990	453	2 (3)	1
1991	1029	31 (8)	7
1992	166	349(48)	2
1993	250	4,543 (23)	27
1994	378	1,037 (50)	27
1995	207	678 (57)	23
1996	138 (1)	673 (211)	135
1997	2356 (1)	2,664 (129)	77
1998	48	136 (90)	155

1999	42 [1]	190 (184)	19
2000	16	7,834 (131)	81
2001	20	179 (116)	35
2002	2	562 (40)	6
2003	19	46 (36)	3
2004	22	148 (0)	1
2005	0	27 (2)	3
2006	11	225 (1)	1
2007	2	21 (5)	3
2008	4	No Data	40

(1) Includes hatchery recoveries.

Sources: Washington Department of Fish and Wildlife, Department of Fisheries and Oceans, Canada; Alaska Department of Fish and Game (*some data may be subject to revision).*

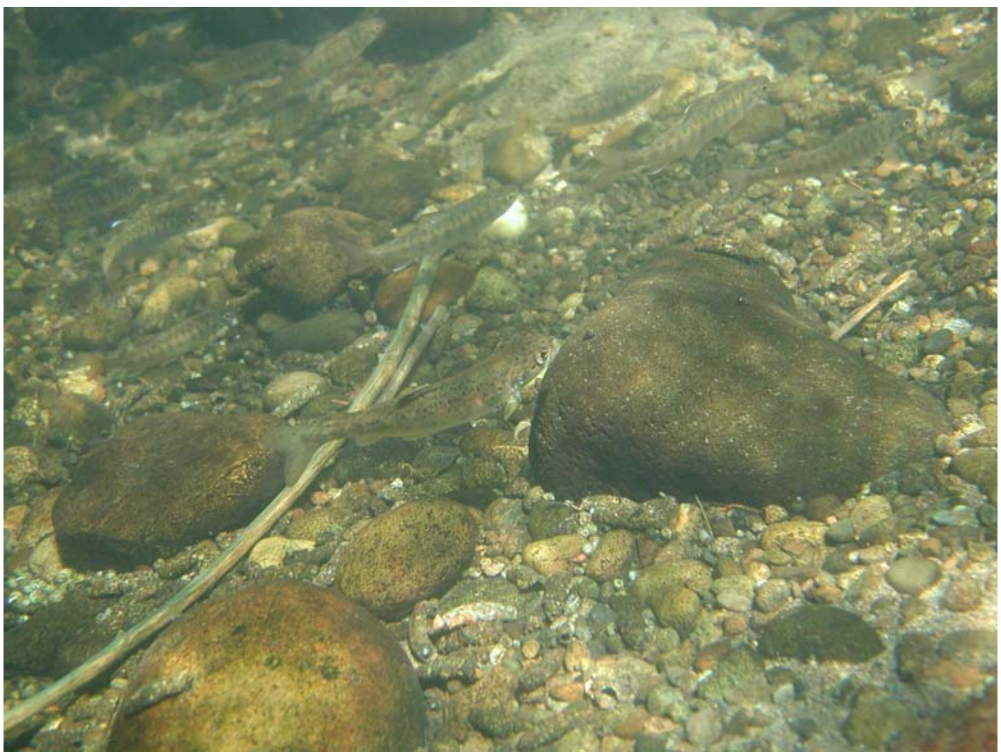

Figure 2: Atlantic salmon juvenile (foreground), with coho salmon in background. Scatter Creek, Washington, below hatchery (source: S. Phillips, PSMFC/J. Schultz, WDFW, 2003).

Table 4: Freshwater juvenile Atlantic salmon recoveries from Washington and British Columbia, 1987 through 2008.

	Washington [1]				**British Columbia** [2]
			Snorkel Survey		
Year	**Mayfield Trap (Cowlitz)**	**Chehalis River Trap**	**Cinnabar Creek**	**Chehalis**	
1987		18			
1988		22			
1989		No Data			
1990		No Data			
1991		No Data			
1992	18	No Data			
1993	17	5			
1994	49	8			
1995	58	24			
1996	8	183			54
1997	2	5			23
1998	25	7			114
1999	59	9			150
2000	125	22			12
2001	18	0			3
2002	10	17			No Data
2003	4	1	3	142 captured (414 observed)	No Data
2004	17	12	0	3 captured (28 observed)	No Data
2005	3	2	0	0	No Data
2006	8	4	0	4 captured (25 observed)	No Data
2007	3	1	0	3 captured	No Data
2008	10	No data	0	0	No Data

Sources:

1. Washington Department of Fish and Wildlife (*some data may be subject to revision*).
2. Waknitz et al. (2002)

Note: Chehalis River Fish Trap: It is impossible to estimate the number of juvenile Atlantic salmon (presumed escapes from the Scatter Creek hatchery) that migrate past the trap, because the scoop traps that are used only reach 2-3 feet into the water column and do not span the entire river.

III. Sea Lice

Sea lice (**Figure 3**) are crustacean parasites that feed on fishes' mucous and skin. The most commonly occurring of the sea lice species are *Lepeophtheirus salmonis* and *Caligus clemensi*. Sea lice occur naturally on anadromous salmonids in the Pacific Ocean and commonly infect both wild stocks and farmed fish. Intensive cage culture of salmonids results in higher densities of sea lice and, left untreated, will result in increased susceptibility to other farmed fish diseases (such as infectious salmon anemia and salmonoid rickettsial septicemia), higher mortality, reduced growth and reduced profitability (Johnson *et al.* 2004). Sea lice infestations are a global problem for the marine aquaculture industry. Annual losses related directly to sea-lice infestations in Norwegian salmon farms have been estimated at more than one billion dollars NOK (MacroGard 2008).

Concern has been raised that salmon farms can act as reservoirs for sea lice, which may infect wild fish stocks as they migrate past the farms. Pearsall (2008) cites several studies in Ireland, Norway, and Scotland that support this contention (Birkeland, 1996; Pike and Wadsworth, 1999; Tully *et al*., 1999; Tully *et al*. 1993; Bjorn *et al*., 2001; Bjorn and Finstad, 2002). Costelloe *et al*. (1998) and Mackenzie *et al*. (1998) also reported the heaviest sea lice infestations on wild fish and the greater prevalence of larvae were found in salmon farming areas versus non-farmed areas in Ireland[5] and Scotland respectively.

The west coast of North America, specifically Canada's Broughton Archipelago (**Figure 4**), has been a focal point for the sea lice controversy. There are 31 fish farms in the Broughton region which raise mostly Atlantic salmon. Poor returns of pink salmon (*Oncorhynchus gorbuscha)* in 2002 resulted in assertions that sea lice from Atlantic salmon net pens in the area were the main culprit in the low returns. Numerous studies have been published regarding sea lice impacts to wild fish stocks, particularly salmonids, with many focusing on the Broughton area (See **Table 5** for a synopsis of some of these studies). Most recently, the BC Pacific Salmon Forum (2009) stated that "One of the most important findings from our commissioned independent science is that while there is strong indirect evidence that salmon farms operating in the Broughton Archipelago contribute to increased sea lice levels, farms can manage their operations in such a way that reduces risk of sea lice infection." In addition the Forum says in its study:

> To date there is no scientific consensus concerning the impact of sea lice on salmon populations. Some peer reviewed research supports the hypotheses that sea lice from farmed salmon significantly impact the health of wild salmon and that a single louse will cause death to a small, juvenile salmon. Other peer reviewed research contradicts these findings.

[5] Note: Ireland's cage-farmed salmon are monitored 14 times yearly as part of a sea-lice management program (http://www.marine.ie/home/services/operational/sealice/)

Figure 3: Sea lice (*Lepeophtheirus salmonis*) on the skin of an Atlantic salmon (*source: Fisheries Research Services*).

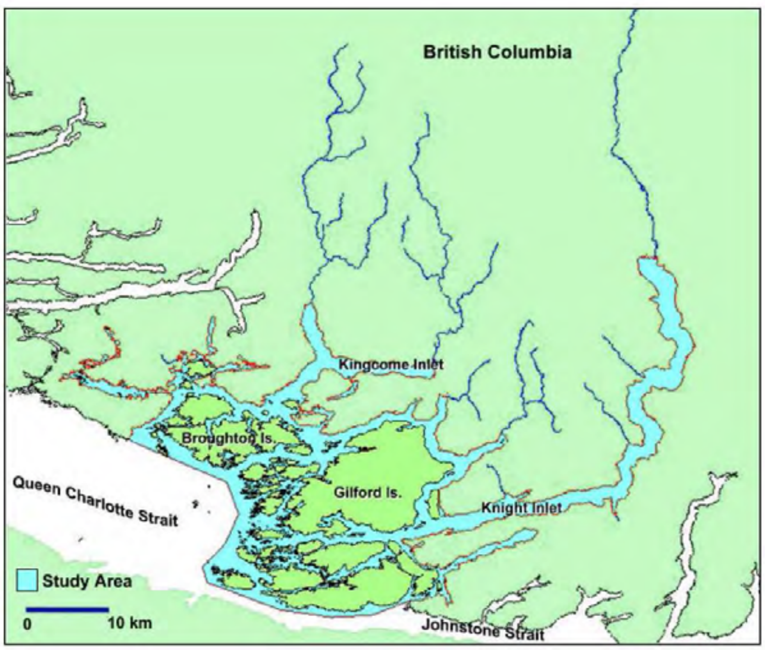

Figure 4. Broughton Archipelago, Canada (From Williams *et al*. 2003).

The issue even ended up in the Canadian legal system, as farmed-salmon opponent and researcher Alexandra Morton took salmon farmers and the BC government to court, arguing that the farms were illegally releasing sea lice into the environment. In August 2006, a BC Special Prosecutor was appointed to the case but, after reviewing evidence on the issue, decided against proceeding with the case, finding that "…there is no substantial likelihood of conviction."

Table 5: Recent North American studies on the impacts of sea lice on salmon and other species.

Author	Findings
Brooks (2005)	Recent reports claim that pink salmon fry are heavily infected by *Lepeoptheirus salmonis* as they pass salmon farms in the Broughton Archipelago. Hydrodynamic studies reveal that the top 25 to 40 m of water generally flows seaward through the archipelago under the influence of freshwater, reducing surface salinity from 15-25% from June through November of most years. Sea lice larvae do not consistently develop to an infectious stage at salinities < 30 ppt - providing a natural control in the archipelago. A particle-tracking model predicts that nauplii released in the vicinity of two farms located deep in the archipelago are carried 10-40 km from the farms before they become infective. These predictions are consistent with the European experience and suggest little potential for salmon farms to be self-infecting or to infect migrating wild fish in their immediate vicinity, except where net current vectors are zero.
Krkošek *et al.* (2006b). [response to Brooks, (2005)]	Counter to the conclusions in Brooks (2005), the modeling and empirical work to date on sea lice interactions between wild and farm salmon are consistent and point to a strong association between salmon farming and recurrent infestations of wild juvenile salmon in the Broughton Archipelago.
Brooks *et al.* (2006) [response to Krkošek *et al.* (2006b)]	The mathematical model of Krkošek *et al.* (2006b) is flawed because it does not adequately consider sea louse life history (for example molting rate and the time-dependence of development to the copepodid stage), low survival to copepodid stage at salinities less than 30 ppt, effects at salinities less than 25 ppt or empirical evidence of hydrodynamics in Knight Inlet and Tribune Channel, especially around the site of the Doctor Islets farm. The author presents a conceptual model of larval dispersion and reiterates that infection is unlikely to occur near the point of larval hatching. [Taken from Harvey (2008)].
Butterworth *et al.* (2006)	There is no doubt that sea lice transfer from wild salmon to farmed salmon. Therefore, there are two crucial questions that should be the focus of future research. First, are sufficient numbers of sea lice transferred from farmed salmon to wild Pacific stocks to have an impact on the endemic infestations on those wild stocks? Second, what is the minimum number of sea lice on individual Pacific salmon species at which the health of the salmon is compromised? Because there is as yet no answer to either question, it is currently not possible to conclude that sea lice on BC salmon farms are having a significant impact on the parasite loads of the wild Pacific salmon.
Beamish *et al.* (2006)	The exceptional returns of the brood year suggest that pink salmon populations and farmed Atlantic salmon coexisted successfully during 2003 within an environment that included sea lice and farmed Atlantic salmon.
Krkošek *et al.* (2006)	The high pathogenicity and abundance of lice resulted in a farm-induced cumulative epizootic mortality of wild juvenile salmon that ranged from 9% to 95%.
Krkošek *et al.* (2007)	Industrial aquaculture may contribute to declines in ocean fisheries and ecosystems. Recurrent louse infestations of wild juvenile pink salmon all associated with salmon farms, have depressed wild pink salmon populations and placed them on a trajectory toward rapid local extinction. The louse-induced mortality of pink salmon is commonly over 80% and exceeds previous fishing mortality. If outbreaks continue, then local extinction is

	certain, and a 99% collapse in pink salmon population abundance is expected in four salmon generations. These results suggest that salmon farms can cause parasite outbreaks that erode the capacity of a coastal ecosystem to support wild salmon populations.
BC Pacific Salmon Forum (2007) [response to Krkošek 2007]	Interim findings from ongoing Pacific Salmon Forum research to be released in early January 2008 [see Harvey, below], do not support the Krkošek *et al*. (2007) prediction of rapidly declining pink and chum salmon stocks in the Broughton.
Brooks and Jones (2008) [response to Krkošek *et al.* 2007]	An examination of returns to all of the documented Broughton Archipelago watersheds indicates that following exceptionally high returns in 2000 and 2001, pink salmon populations declined to very low numbers in 2002 and 2003. Contrary to the conclusions reached by Krkošek *et al.* (2007), Broughton pink salmon returns have steadily increased since then, with no indication that they are threatened with extinction. Other unsubstantiated assumptions used in Krkošek *et al.* (2007) are also discussed in light of additional scientific reports and theoretical considerations.
Riddell et al. (2008)	Krkošek *et al*. (2007) overstated risks to wild pink salmon from sea lice and salmon farming. Furthermore, their predictions are inconsistent with recent observations of pink salmon returns to the Broughton Archipelago. Their alarming statements of extinction of pink salmon in the BA are only possible with highly selective use of available data and extrapolation of their results to all pink salmon in the BA. In assessing and managing pink salmon in the BA, all potential impacts on the productivity to the pink populations, including sea lice, should be acknowledged in developing an effective management strategy.
Harvey (2008)	• Salmon farms in the Broughton produce large numbers of sea louse larvae; • Encounters between those farm-produced larvae and juvenile pink and chum salmon cannot yet be observed but are completely plausible biologically and in all current mathematical models; • The percentage of sea lice on wild salmon that come from salmon farms can't be quantified; • The role of alternate, "natural" sources of sea lice needs to be understood and quantified.
Morton *et al.* (2008)	Reports of infestations of sea lice in juvenile salmonids in Pacific Canada have been restricted to pink and chum salmon from one salmon-farming region, the Broughton Archipelago. Here, we report on two years of sea louse field surveys of wild juvenile pink and chum salmon, as well as wild sockeye salmon and larval Pacific herring in another salmon farming region, the Discovery Islands region of British Columbia. Fish exposed to salmon farms were infected with more sea lice than those in the peripheral category. Sea louse abundance on sockeye salmon and Pacific herring followed the same trends, but sample sizes were too low to support formal statistical analysis. These results suggest that the association of salmon farms with sea lice infestations of wild juvenile fish in Pacific Canada now extends beyond juvenile pink and chum salmon in the Broughton Archipelago.
Connors *et al.* (2008)	Sea lice on small pink salmon escaped predation by swimming away or moving onto predatory cutthroat trout and coho salmon in approximately 70% of the trials in which these predators ate a parasitized pink salmon prey. These findings highlight the potential for sea lice to be transmitted up marine food webs in areas of intensive salmon aquaculture, with implications for louse population dynamics and predatory salmonid health.

Pearsall (2008)	This report presents the various sources of sea lice data that are currently publicly available for the Broughton Archipelago. A bibliography on sea lice produced by the Centre for Aquaculture and Environmental Research, BC, Canada (CEAR) is provided in an appendix for 2002-2006. See Harvey (2008) for more recent publications.
BC Pacific Salmon Forum (2009)	To date there is no scientific consensus concerning the impact of sea lice on salmon populations. Some peer reviewed research supports the hypotheses that sea lice from farmed salmon significantly impact the health of wild salmon and that a single louse will cause death to a small, juvenile salmon. Other peer reviewed research contradicts these findings.

However, the Special Prosecutor wrote in his assessment of the evidence: "It appears to us that there is validity to Ms. Morton's assertions that sea lice from fish farms are having a deleterious effect on the pink salmon population in the Broughton Archipelago" (Palmer 2006). In February 2009, the BC Supreme Court ruled that the federal government, not the BC government as is currently the case, has the right to regulate fish farms. The ruling was a result of a case brought by Alexandra Morton. The plaintiffs see the ruling as a victory because now farmed fish will be regulated as a federal fishery and that according to Morton the federal government is "mandated to put wild salmon first" (Pynn 2009). Though salmon farmers did not appear to be overly concerned about the decision, Marine Harvest Canada, BC's largest aquaculture company, appealed the ruling in March 2009.

One of the most objective and comprehensive reviews of the sea lice issue is an analysis by Harvey (2008). This study was sponsored by the BC Pacific Salmon Forum (http://www.pacificsalmonforum.ca/) and had the following findings:

1. Salmon farms in the Broughton produce large numbers of sea louse larvae;
2. Encounters between those farm-produced larvae and juvenile pink and chum salmon cannot yet be observed but are completely plausible biologically and in all current mathematical models;
3. The percentage of sea lice on wild salmon that come from salmon farms can't be quantified;
4. The role of alternate, "natural" sources of sea lice needs to be understood and quantified;
5. Drawing a direct link between sea lice produced on salmon farms and the status of wild salmon populations will be a lively area of research.

Chilean salmon farms have been severely impacted by sea lice in recent years. In 2007, it was reported that mortality rates from sea lice infestations at Chilean salmon farms were over 30 percent above 2006 levels, and there was evidence that sea lice had developed resistance to the lice-killing chemical, emamectin benzoate (Carvajal 2007). More recently, however, reports are that the sea lice epidemic has been brought under control (Seymour 2008).

In British Columbia, fish farmers have taken steps to reduce potential sea lice impacts on wild fish stocks. In June 2008, Marine Harvest Canada, announced that it would "coordinate its operations in the Broughton Archipelago to create corridors during the spring out-migration of wild juvenile fish." According to Marine Harvest (2008a):

> Under its Coordinated Area Management Plan (CAMP), Marine Harvest will create migratory corridors in the Broughton Archipelago during the outmigration season from March 1st to June 30th each year. Beginning in 2010 the company's four farms in Lower Knight Inlet will be emptied of fish during this time period. In odd-numbered years beginning in 2011, Marine Harvest's five farms in Tribune-Fife will be empty during the out-migration. At no time during the out-migration will any Marine Harvest Broughton-area farms contain adult fish. The plan is intended to continue for six years while monitoring the effectiveness of the migration corridors.

In January 2003, responding to concerns about fish farm sea-lice on pink salmon in BC, Fisheries and Oceans Canada (DFO) announced new initiatives designed to assess and protect the health of the wild pink salmon resource in the Broughton Archipelago. Fisheries and Oceans, in collaboration with the

Province of British Columbia, began coordinating monitoring and research activities to further protect wild salmon and monitor sea lice infections. [note: For information on the Province of British Columbia's Broughton Archipelago Sea Lice Action Plan go to http://www.al.gov.bc.ca/ahc/fish_health/]. The marine monitoring program[6] is designed to track migration routes of juvenile salmon from rivers and through the archipelago. Sampling each year has been targeted to coincide with the early marine migration period as wild juvenile pink and chum salmon move out of freshwater systems and enter the ocean, sometimes passing by salmon farms as they migrate (Pearsall 2008). The main findings (into 2006) of the DFO sea lice monitoring program are as follows (source: http://www.pac.dfo-mpo.gc.ca/science/aquaculture/pinksalmon-saumonrose/findings-resultats-eng.htm):

1. Two different species of sea lice, *Caligus clemensi* and *Lepeophtheirus salmonis*, have been found to commonly infect juvenile pink and chum salmon in the Broughton.

2. *Caligus clemensi* was found to be the most abundant sea lice on juvenile pink and chum salmon in 2003, whereas *Lepeophtheirus salmonis* was most abundant in both 2004 and 2005.

3. The 2006 research indicates sea lice levels are the lowest ever among farmed and wild salmon.

4. Several different developmental stages of both species of sea lice were found on juvenile pink and chum salmon. In all years the majority of the sea lice observed on juvenile pink and chum salmon were the early (non-motile) developmental stages.

5. Sea lice were significantly more abundant on juvenile pink and chum salmon in 2004, compared to either 2003 or 2005.

6. Sea lice were also observed to infect other fish species in the Broughton. In all three years (2003-2005), sea lice abundance was significantly greater on threespine stickleback (*Gasterosteus aculeatus*) than on juvenile pink or chum salmon. This research is the first reported case of *L. salmonis* infecting stickleback.

7. The abundance of later development stages of *L. salmonis* generally coincided with growth of pink salmon. Mature (motile) lice occurred more frequently on larger juvenile pink salmon. This pattern was less obvious during growth of chum salmon.

8. The total abundance of the sea lice *L. salmonis* on juvenile pink and chum salmon generally declined sharply as the salmon grew in size.

9. Significant variation in surface seawater salinity was observed in different areas of the Broughton.

10. The abundance of sea lice was minimal on juvenile pink and chum salmon and sticklebacks in areas with the lowest salinity.

[6] For "Biweekly Sea Lice Infection Results" and "Adult Pink Salmon Escapement Update Bulletins" go to: http://www.pac.dfo-mpo.gc.ca/science/aquaculture/pinksalmon-saumonrose/results-resultats/2009/index-eng.htm.

11. Salmon species, size and location, as well as seawater salinity were all found to be significant predictors of the number of sea lice.

IV. RECENT FEDERAL MARINE AQUACULTURE ACTIONS

The National Offshore Aquaculture Act (http://aquaculture.noaa.gov/us/2007.html) was introduced in Congress in 2005 and again in March of 2007. This legislation (H.R. 2010 and S. 1609), which was opposed by some states, citizen groups and many in the fishing industry, did not pass in the 110th Congress. To date (June 2009), legislation has not been introduced into the 111th Congress. Below are summaries of some of those efforts as well other information, including the recent Government Accountability Office (GAO) aquaculture report and a now failed Bush Administration proposal to potentially use oil rigs for aquaculture activities.

1. FISHERY MANAGEMENT PLAN FOR REGULATING OFFSHORE MARINE AQUACULTURE IN THE GULF OF MEXICO: In January 2009, the Gulf of Mexico Fishery Management Council took final action on its Aquaculture Fishery Management Plan (FMP) and submitted it to the Secretary of Commerce for approval and implementation. The Council's plan, if approved, will provide a regional permitting process for regulating offshore aquaculture in the federal waters of the Gulf of Mexico, which begin where state jurisdiction ends and extends 200 miles offshore. According to the Gulf Council (2009):

> The Council's Aquaculture FMP is intended to ensure any aquaculture operations undertaken in the Gulf are environmentally sound, sustainable, and provide maximum benefits to the nation. The current permitting process for offshore aquaculture is of limited duration and is not intended for the large-scale production of fish, making commercial aquaculture in federal waters impracticable at this time. The plan will allow fish farms to be installed only after careful application review and, once installed; the facilities will be under strict regulatory supervision by three Federal agencies. Under the plan, the growing of species native to the Gulf of Mexico that are managed by the Council, except shrimp and corals, would be allowed. Examples of allowable species include: snappers, groupers, cobia, and red drum. If approved by the Secretary, the Aquaculture fishery management plan will be implemented and enforced by NOAA Fisheries. For further information including the draft "Fishery Management Plan for Regulating Offshore Marine Aquaculture in the Gulf of Mexico" go to: http://sero.nmfs.noaa.gov/sf/AquacultureHomepage.htm

On June 4, 2009 NOAA announced it is seeking public comment on the FMP for Regulating Offshore Marine Aquaculture in the Gulf of Mexico. For further information go to: http://sero.nmfs.noaa.gov/bulletins/pdfs/2009/FB09-035%20NOA%20Aquaculture.pdf

On June 12, 2009 citing environmental concerns and regulatory issues, 37 members of Congress asked the Department of Commerce to reject the plan to allow fish farms in the Gulf of Mexico (Newsom 2009). According to the letter, "The potential impacts of this industry and the many unknown factors necessitate precaution, not hasty development. Therefore, we urge you to disapprove the council's offshore aquaculture plan and work with Congress to develop a comprehensive regulatory program that will address these concerns."

2. NOAA OFFSHORE AQUACULTURE REPORT: In July 2008, NOAA released the report "Offshore Aquaculture in the United States: Economic Considerations, Implications & Opportunities" (NOAA 2008). The report, written by some of the leading natural resource and fisheries economists and aquaculture business experts in the United States says that "aquaculture shows significant economic potential and good prospects for success in the United States." The authors call for clear rules to guide the development of an offshore aquaculture industry. Other key findings of the report include:

A. Over time, the economic potential for offshore aquaculture is likely to grow because seafood demand and prices will increase, there will be more competition for sites closer to shore, and costs will be lower due to improved technology, experience, and economies of scale;

B. A range of technologies would likely develop to address logistical and environmental challenges;

C. The limited supply of fish meal and fish oil is not likely to be a constraint on the expansion of U.S. aquaculture as alternative feed ingredients from soybeans and other plants, algaes, yeasts, fish processing waste, and other products are being developed; and

D. Offshore aquaculture would create job opportunities for U.S. fishermen, especially jobs that involve vessel operations and maintenance of offshore operations.

3. GAO MARINE AQUACULTURE REPORT: In May 2008, the GAO released the report "Offshore Marine Aquaculture Multiple Administrative and Environmental Issues Need to Be Addressed in Establishing a U.S. Regulatory Framework." The GAO undertook this study to identify key issues that should be addressed to develop an effective regulatory framework for U.S. offshore aquaculture. The report's findings were grouped into four main areas: Program Administration, Environmental Management, Permitting and Site Selection, and Research. The summary of the Environmental Management section is as follows:

> A process to assess and mitigate the environmental impacts of offshore operations is another important aspect of a regulatory framework. For example, many stakeholders told GAO of the value of reviewing the potential cumulative environmental impacts of offshore operations over a broad ocean area before any facilities are sited. About half of them said that a facility-by-facility environmental review should also be required. Two states currently require facility-level reviews for operations in state waters. In addition, stakeholders, key studies, and state regulators generally supported an adaptive monitoring approach to ensure flexibility in monitoring changing environmental conditions. Other important areas to address include policies to mitigate the potential impacts of escaped fish and to remediate environmental damage.

4. OIL RIGS AND OFFSHORE AQUACULTURE: A controversial plan was proposed in July 2008 by the Bush Administration (Department of Interior, Minerals Management Service {MMS}) to allow use of existing oil and gas platforms from three to 200 miles offshore for fish farming (See **Figure 5** for a map of oil platforms off Southern California). This plan is contained in the draft Environmental Assessment (EA) for the proposed rule on “Alternative Energy and Alternate Uses of Existing Facilities on the Outer Continental Shelf.” According to the draft EA:

> Siting, construction, operation, and decommissioning of oil and gas platforms and other structures on the OCS are regulated by the MMS under the OCSLA, as amended (43 U.S.C. 1331 et seq.). Current regulations (30 Code of Federal Regulations [CFR] Part 250 Subpart Q) require that an oil and gas structure be removed and the site cleared to predevelopment conditions within one year after cessation of all production on the lease. Under the proposed action, the MMS would establish a program that would permit, on a discretionary basis, alternate uses for these platforms during and after production, subject to the requirements of subsection 8(p) of the OCSLA. Under the proposed action, the MMS would issue proposed regulations that would describe the means by which MMS would process any applications for such alternate uses of existing OCS structures. An overview of potential alternate uses for these facilities is given in Chapter 6 of the Programmatic EIS. These uses include alternative energy production, offshore aquaculture, and research and monitoring. The MMS will evaluate and conduct an appropriate NEPA review of individual proposals to modify or convert the existing facilities for alternate use activities. (http://www.mms.gov/offshore/PDFs/DraftEA-AEAU_ProposedRule-070308.pdf)

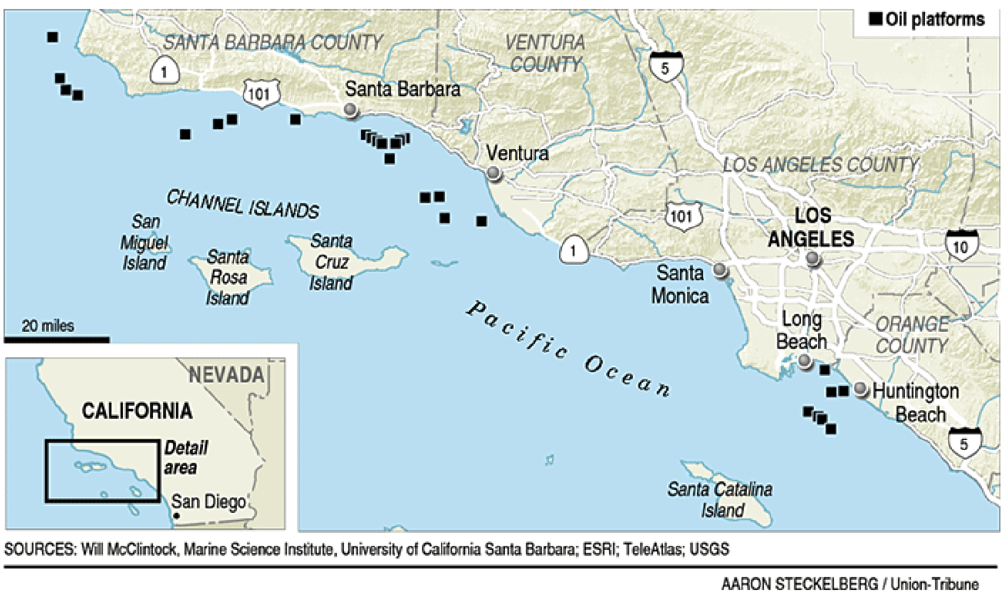

Figure 5: Oil platforms located off the Southern California Coast.

Reaction to the proposed rule was polarized. Pro-aquaculture interests such as the Ocean Stewards Institute, a trade organization advocating for the emerging open ocean aquaculture industry, supported the proposal "provided there is adequate environmental monitoring and operational oversight by other relevant federal agencies"(IntraFish 2008). Environmental and fishing groups cited concerns about the negative environmental impacts of offshore aquaculture (e.g., disease transfer, pollution from net-pen facilities, impacts from escaped fish, and cumulative ecosystem impacts) and the ability of MMS to effectively regulate fish farms. The Pacific Coast Federation of Fishermen's Associations (2008) said: "The Bush Administration took an end-run around Congress with a proposal that, for the first time ever, would set up a federal program to allow industrial fish farming in U.S. federal waters" and "By going through a federal agency rulemaking instead of going through Congress, the Administration is seeking to permit fish farming in federal waters without waiting until Congress passes the Administration's controversial fish-farming bill unveiled earlier this spring."

In April 2009, the Obama Administration released the final regulations for "Renewable [formerly called "Alternative"] Energy and Alternate Uses of Existing Facilities on the Outer Continental Shelf." The MMS stated that they had received numerous comments on the proposed rule pertaining to the use of OCS facilities for aquaculture purposes and, in a reversal from the Bush Administration; they now do not intend to authorize aquaculture projects at OCS facilities. The new rule also recognizes NOAA as having oversight of Federal aquaculture activities. According to MMS:
(http://www.mms.gov/offshore/AlternativeEnergy/PDFs/AD30RenewableEnergy04-22-09.pdf)

> The MMS does not intend to implement an OCS aquaculture program involving the use of existing OCS facilities. The statutory language in section 388 of the Energy Policy Act, amending section 8 of the OCS Lands Act was intended to provide the Department broad discretion in considering activities that involve the alternate use of an OCS facility. If MMS were to receive an application for an alternate use right of use and easement (RUE) for aquaculture activity, we *may* consider that application in light of engineering, environmental, adjudication, and other issues relating to MMS responsibility over the OCS facilities proposed for this use, but a different agency would be responsible for permitting and managing actual aquaculture activity under any RUE that is granted. The aforementioned notwithstanding, the DOI has supported legislation previously proposed in Congress that would grant the Department of Commerce regulatory authority for evaluating and authorizing aquaculture activities, including aquaculture activities that would involve use of existing OCS platforms and facilities. Should this or similar legislation become law, the DOI would reconsider whether aquaculture activities are appropriately regulated under this subpart.

On April 23, 2009 Commerce Secretary Gary Locke, addressing a Senate hearing, said the National Oceanic and Atmospheric Administration will oversee the preparation of the Obama Administration's fish-farming guidelines. He also said that the administration is not giving up on efforts to advance aquaculture that started under the Bush administration, although his department (Commerce) may take a different course (Winter 2009).

5. NOAA - USDA ALTERNATIVE FEEDS INITIATIVE: Aquaculturally-raised fin fish are primarily fed fish meal composed of "bait fish" such as anchovy (*Engraulis sp., Anchoa sp.*), anchoveta **(***Cetengraulis sp.),* herring **(***Clupea sp.*), menhaden (*Brevoortia tyrannus*), capelin (*Mallotus villosus*), and sand eel/sand lance ***(****Ammodytes sp)*. These small pelagic species are important to the marine ecosystem, as they are prey for fish, birds and mammals. The largest single use of fish meal is as a constituent of poultry feeds. Fish meal use is concentrated in a small proportion of global aquaculture production; nearly 70% of global use is in salmon, trout and shrimp feeds (Hardy and Tacon 2002). The total estimated amount of fishmeal and fish oil used within compound aquafeeds has grown over three-fold from 963 to 2,936 thousand tonnes and from 234 to 802 thousand tonnes from 1994 to 2003, respectively (Tacon 2005). Technologies aimed at development of alternative sources of protein (e.g., plant-based) for fish meal and oil appear promising. Increased reliance on alternative sources of fish feed will be critical for continued global expansion of aquaculture, allaying concerns about both the overharvest of small pelagic species and contaminated farm-raised product.

The National Oceanic and Atmospheric Administration (NOAA), in partnership with the U.S. Department of Agriculture (USDA) launched the Alternative Feeds Initiative on November 15, 2007 to accelerate the development of alternative feeds for aquaculture. According to NOAA:

> The purpose of the NOAA-USDA Alternative Feeds Initiative is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the important human health benefits of farmed seafood. Ultimately, the initiative will lead to the commercialization of alternatives for some species which will result in reduced dependence on marine fish resources by feed manufacturers and seafood farmers worldwide. NOAA is partnering with the USDA's Agricultural Research Service and Cooperative State Research, Education, and Extension Service on the initiative, which will build on ongoing USDA and NOAA research to identify alternative protein and oil sources for aquaculture feeds.

In April 2008, NOAA's Aquaculture Program hosted the NOAA-USDA National Stakeholder Meeting on Alternative Feeds for Aquaculture in Silver Spring, Maryland. Over 60 participants representing aquaculture producers, the aquaculture feeds industry, private research consortiums, other federal agencies, academia, and non-government organizations focused on research priorities for promising alternatives to fish meal and oil in aquaculture diets. The presentations from the meeting have been posted at http://aquaculture.noaa.gov/news/feeds.html.

6. NOAA's 10-YEAR PLAN FOR AQUACULTURE: On October 30, 2007, the National Oceanic and Atmospheric Administration (NOAA) finalized and adopted the 10-Year Plan for Marine Aquaculture as an agency-wide policy document. The plan (http://aquaculture.noaa.gov/pdf/finalnoaa10yrrweb.pdf) is intended to guide the agency as it works toward establishing marine aquaculture as an integral part of the U.S. seafood industry and as a viable technology for replenishing important commercial and recreational fisheries. The plan provides specific goals for the NOAA Aquaculture Program and an assessment of the challenges the agency will face in its effort to reach its goals. The goals in the 10-Year Plan are: 1) A comprehensive regulatory program for marine aquaculture, 2) Development of commercial marine aquaculture and replenishment of wild stocks, 3) Public understanding of marine aquaculture, and 4) Increased collaboration and cooperation with international partners.

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Appendix 1: List of all Washington State rivers and streams that have been surveyed for Atlantic salmon juvenile and adults as of December 12, 2008. Those with an asterisk (*) have been surveyed more than once and those with a pound (#) have not had any snorkel surveys conducted, only foot, backpack electrofishing, hook and line, or float boat surveys (Washington Department of Fish and Wildlife 2008).

Abernathy Creek	Germany Creek *	Racehorse Creek
Admiralty Inlet	Goble Creek	Raging River
Alder Creek	Gorst Creek	Rock Creek (Cedar River Tributary) * #
Anderson Creek #	Grandy Creek	Rock Creek (Chehalis Tributary) #
Bacon Creek *	Green River (Puget Sound Tributary) *	Rocky Creek #
Beaver Creek	Green River (Columbia Tributary)	Salmon River * #
Beckler Creek	Greenwater River *	Salt Creek #
Bertrand Creek #	Hamm Creek * #	Samish River *
Big Hanford Creek #	Hamma Hamma River *	Sammamish River #
Bingham Creek*	Hill Creek #	Saratoga Passage * #
Black River *	Hoko River *	Satsop River *
Bogachiel River * #	Hood Canal #	Satsop River East Fork *
Boulder Creek	Humptulips River *	Satsop River Middle fork *
Breeze Creek	Humptulips River East Fork *	Satsop River West Fork *
Browns Slough	Humptulips River West Fork *	Sauk River *
Buck Creek	Hutchinson Creek	Sauk River North Fork
Burley Creek #	Independence Creek #	Scatter Creek *
Calawah River *	Issaquah Creek #	Seiku River *
Canyon Creek	Jackman Creek * #	Sherman Creek * #
Canyon Creek (Nooksack Tributary) #	Jones Creek #	Sherwood Creek #
Canyon River	Johns Creek *	Sibert Creek #
Carbon River *	Johns River *	Skagit River *
Cascade River *	Kalama River *	Skokomish River *
Cedar Creek *	Kapowsin Creek	Skookum River
Cedar Creek (Unnamed Tributary) *	Kennedy Creek *	Skookumchuck River *
Cedar River *	Klickitat River *	Skykomish River *
Chambers Creek *	Klickitat River (Little Klickitat River) #	Skykomish River North Fork *
Chehalis River *	Lewis River #	Snoqualmie River *
Chehalis River East Fork *	Lewis River (East Fork Wetland Site) *	Sol Duc River *
Chehalis River (Unknown Tributary)	Lewis River East Fork *	South Prairie Creek *
	Lewis River North Fork *	Spring Creek #
Chehalis River West Fork	Lilliwaup River *	Spurgeon Creek #
Cinnabar Creek *	Lincoln Creek #	Stavis Creek

Clark Creek #	Lummi River #	Stillaguamish River North Fork *
Clearwater River *	Lyre River *	
Cloquallum Creek * #	Mashell River *	Stillaguamish River South Fork *
Coal Mine Creek	McAllister Creek *	Sullivan Slough
Columbia River * #	McDonald Creek	Sultan River *
Copalis River	Mill Creek (Puget Sound Tributary) *	Summit Lake
Cornell Creek	Mill Creek (Columbia Tributary) *	Sund Creek #
Coulter Creek *	Mima Creek#	Swift Creek #
County Line Creek #	Minter Creek #	Tahuya River *
Coweeman River *	Morse Creek *	Taylor Creek
Cowlitz River *	Nemah River North Fork	Ten Mile Creek #
Cranberry Creek#	Newaukum Creek *	Thompson Creek #
Decker Creek *	Newaukum River *	Tilton River *
Deepwater Slough	Newaukum River South Fork *	Tokul Creek * #
Delezene Creek *	Newaukum River North Fork *	Tolt River *
Deschutes River *	Nisqually River *	Toutle River * #
Dewatto River *	Nooksack River #	Twanoh Creek#
Dosewallips River	Nooksack River Middle Fork *	Union River #
Dry Bed Creek	Nooksack River North Fork *	Unnamed Slough
Duckabush River *	Nooksack River South Fork #	Vance Creek
Dungeness River *	North River	Vesta Creek
Duwamish River	Ohop Creek *	Voights Creek
T105 Tributary #	Olequa Creek	Waddell Creek *
Elk Creek *	Perry Creek #	Wildcat Creek*
Elwha River *	Pilchuck River *	Wilkenson Creek
Fennel Creek #	Porter Creek *	Willapa River *
Finch Creek #	Prairie Creek #	Wiseman Creek*
Finney Creek *	Puget Sound (Hope Island) #	Wishkah River*
Fish Trap Creek #	Puyallup River *	Woods Creek #
Friday Creek #	Queets River * #	Workman Creek * #
Forks Creek	Quilicene River *	Wynoochee River *
Garrard Creek *	Quinault River #	Wynoochee River (Unnamed Tributary) *