

# Evaluation of Sea Lice, *Lepeophtheirus salmonis*, abundance levels on farmed Salmon in British Columbia, Canada.

## AUTHORS

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## ABSTRACT

Mobile *L. salmonis* levels and treatment data collected from Atlantic salmon farms located in seven zones in British Columbia were evaluated. Regional and annual differences were observed with mean annual abundance levels ranging from 0.30 to 3.29 per fish. The number of treatments ranged from 0 to 3 per production cycle, with the majority of treatments occurring in the winter and spring. Reasons for the differences are suggested. Farmed Pacific salmon data is also discussed.

## INTRODUCTION

Unlike what has been seen in many of the other regions where Atlantic salmon (*Salmo salar*) farming occurs, sea lice *Lepeophtheirus salmonis* (*L. salmonis*) have not been considered a serious health concern for salmon farms located in north western North America: British Columbia (BC), Canada and Washington State, USA. As a result of the perceived low risk of impact on farmed fish health, sea lice levels were rarely evaluated unless treatment was being considered.

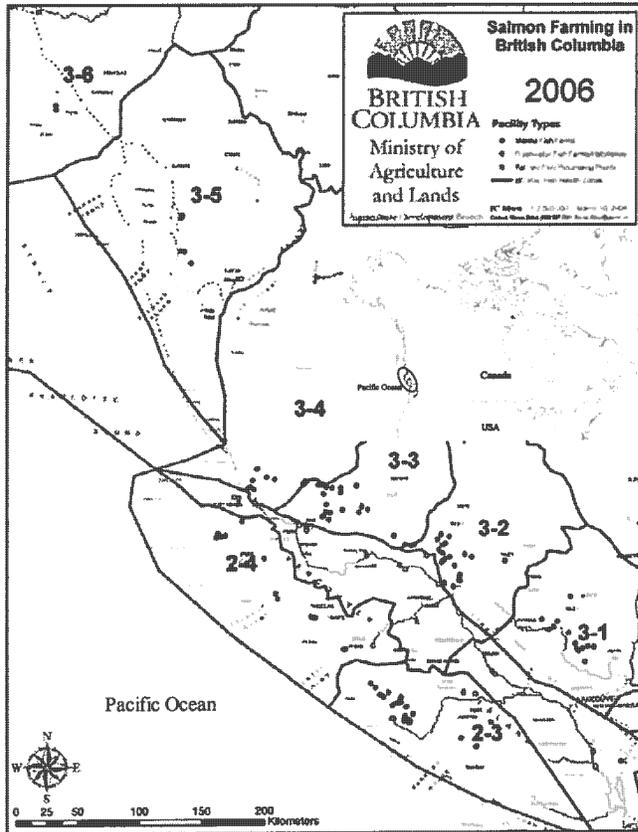
In 2003, however, the Provincial government of British Columbia instituted stringent sea lice monitoring and control measures in response to the public's concerns in 2002 of potential negative impacts that sea lice from Atlantic salmon farms were having on juvenile wild pink salmon (*Onchorynchus gorbachu*) (Saksida et al. 2006). As a result, Atlantic salmon farms commenced monthly monitoring and reporting for attached stages (chalimus) and mobile stages of *Caligus clemensi* (*C. clemensi*) and *L. salmonis* levels. To confirm the validity of the data reported by industry, the BC Ministry of Agriculture and Lands (BCMAL) initiated random sea lice audits on Atlantic salmon farms in 2004. Farmers of Pacific salmon, Chinook and Coho (*O. kisutch* and *O. tshawytscha* respectively), were also required to monitor and report quarterly sea lice abundance levels. After one year, based on the low levels of sea lice and the health implications from sampling stress, routine monitoring of Pacific salmon ceased.

This report provides a summary of the mobile *L. salmonis* abundance data collected from October 2003 to December 2005 in British Columbia on all farmed Atlantic salmon and one year of data from all farmed Pacific salmon. The data was examined for regional and annual differences. Treatment records and environmental data were also examined to provide some insight into differences observed between regions. The Atlantic salmon farm data was compared with data collected during Provincial government audits.

## MATERIAL AND METHODS

Atlantic salmon farms were monitored a minimum of once per month with a total of 60 fish examined; 20 fish from each of three pens. In 2003-04, Pacific salmon farms were required to monitor 30 fish per site quarterly. Farms are divided into seven provincial fish health zones with five located along the coast of mainland BC (region 3) and the remaining two located on the west coast of Vancouver Island (region 2) (Figure 1). Atlantic salmon sea lice data is summarized based on these seven zones. Due to the small number of Pacific salmon farms, the data collected and analyzed from these farms was reported on a regional basis.

The analysis focused on providing simple descriptive summary statistics. Abundance—the average number of sea lice per fish—was calculated for each farm and used to calculate means for the respective zones or regions. The distribution of the lice data was skewed to the right and contained outliers, therefore the logarithm of each value (value +0.001) was computed. Log transformed values were used in ANOVA followed by multiple comparisons using Tukey HSD test. All two-sample statistical comparisons were done using Student t-test on untransformed data.



All analyses were done using STATISTIX for Windows® (Analytical Software). The level of significance was set at 5% ( $p \leq 0.05$ ). All figures presented in the report were prepared using Excel 2000® (Microsoft). The BCMAL audit and farm data comparisons were made for each zone and quarter by comparing the confidence intervals for each.

Figure 1 – shows the location of the BCMAL Fish Health Zones

## RESULTS

There were 73 Atlantic salmon farms in operation between October 2003 and December 2005 in the seven zones, with the number of active farms within a zone ranging from two to twenty (Table 1). There were a total of 26 Pacific salmon farms operating; 10 in region 2 and 16 region 3.

Significant differences were observed in the mean mobile *L. salmonis* abundance levels on Atlantic salmon located in the different

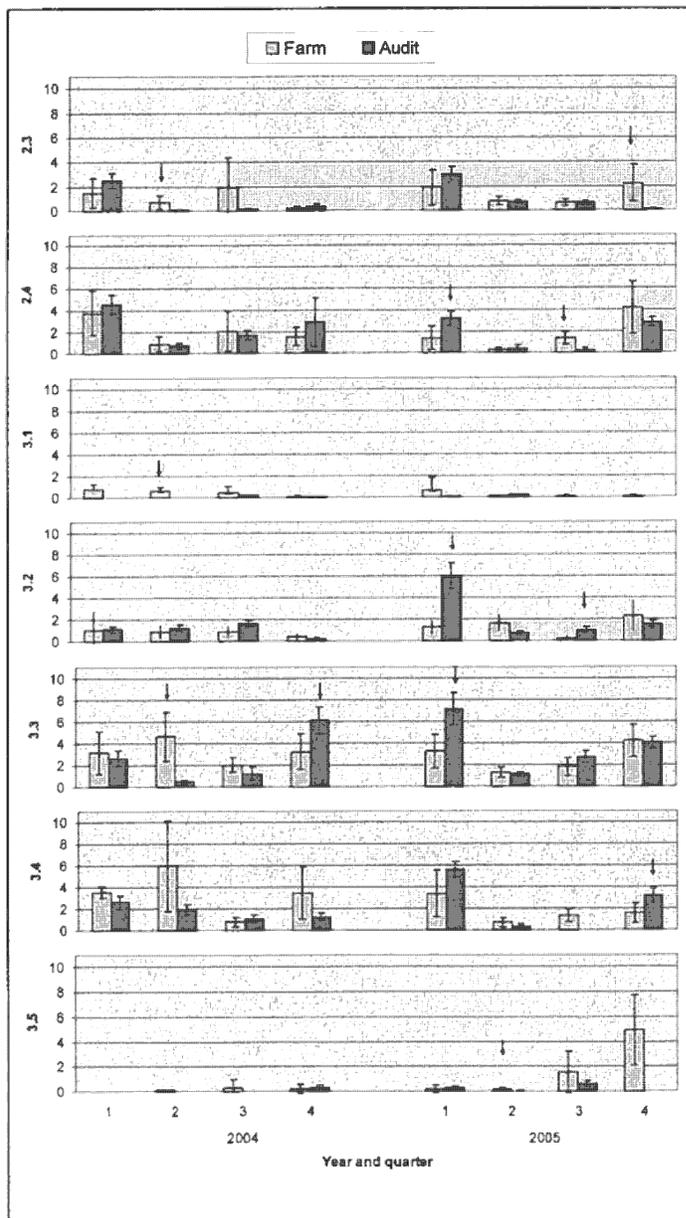
zones ( $p < 0.001$ ). The mean abundance levels for all the zones for each year are displayed in Table 1. The lowest reported levels occurred in zone 3.1 with less than 0.50 mobiles for both 2004 and 2005. Zones 3.3 and 3.4 reported the highest mean abundance levels in 2004 (3.3 and 3.0 respectively).

Zone	Total # Atlantic Salmon Farms	Mean Abundance <i>L. salmonis</i> 2004 (SD) [# farms, n]	Mean Abundance <i>L. salmonis</i> 2005 (SD) [#farms, n]	Total # treatments in zone (28 months)	Average # treatments per cycle
2.3	12	1.02 (2.15) [7, 48]	1.29 (1.98) [12,73]	9	0.75
2.4	13	2.19 (3.40) [12,73]	1.57 (2.46) [10,64]	13	1.50
3.1	7	0.47 (0.58) [6,38]	0.30 (1.22) [7,34]	2	0
3.2	10	0.74 (0.88) [6,46]	1.37 (2.19) [10,101]	15	1.50
3.3	20	3.29 (5.63) [18,160]	2.61 (3.83) [20,163]	36	1.75
3.4	9	3.00 (4.15) [6,45]	1.62 (1.93) [8,53]	14	2.40
3.5	2	0.22 (0.22) [2,9]	1.70 (2.45) [2,24]	3	3.00

Table 1 - provides a summary of the total number of active Atlantic salmon farms within each zone in 2004 and 2005, and the mean *L. salmonis* abundance level with standard deviation (SD) for each year. The table also indicates the total number of treatments given in the zone from October 2003 to December 2005, as well as the average number of treatments per cycle (smolt entry to harvest).

These abundance levels were significantly higher than levels reported in other zones (3.5, 3.1, 2.3 and 3.2 respectively) ( $p < 0.001$ ). Zone 3.3 also reported the highest levels in 2005 (2.61). Significant inter-annual variation in *L. salmonis* levels were observed in only two zones; zone 3.2 ( $p = 0.013$ ) where the mean abundance in 2005 was greater than in 2004 (1.37 and 0.74 respectively) and zone 3.4 ( $p = 0.046$ ) where the mean abundance in 2004 was greater than in 2005 (3.00 and 1.62 respectively). Overall, Atlantic salmon farms containing populations greater than one year in seawater (Y2) reported 2.5 times higher *L. salmonis* levels than farms with populations less than one year in seawater (Y1) (mean values 2.95 and 1.18 respectively,  $p < 0.001$ ).

Treatment data for each zone was also examined. The only sea lice treatment available in BC is SLICE® (emamectin benzoate). The average number of treatments per production cycle (i.e. smolt entry to harvest) ranged from 0 to 3 (Table 1). The fewest treatments per production cycle were reported in zone 3.1 (0), although there were two treatments reported in the zone, one in each of 2004 and 2005, that occurred on a broodstock farm; not a production farm. The highest average number of treatments per production cycle was recorded in zones 3.4 and 3.5 (2.40 and 3.00 respectively), with the majority of treatments (60%) occurring in the winter and spring.



BCMAL audited 25% of the active Atlantic salmon farms in 2004 and in Q1, Q3, and Q4 of 2005. During Q2 in 2005, 50% of the farms were audited. In 2004, no audits occurred in zone 3.1 in Q1 and zone 3.5 was only audited in Q4. In 2005, no audits were conducted in zone 3.4 in Q3, nor in zones 3.1 or 3.5 in Q4. The range of farms audited per quarter within an audited zone ranged between one and three except during Q2 in 2005, when the number of farms audited per zone ranged from one to eight. Figure 2, provides a summary of the mean *L. salmonis* abundance levels on Atlantic salmon for all zones comparing the BCMAL audit mean to the industry reported means. In general, the audit data mirrored the farm data with the highest values obtained in zones 3.3 and 3.4, and the lowest levels in zone 3.1. The lowest sea lice levels occurred in the summer. The audit levels and farm reported levels differed in 24% of the comparisons with audit levels significantly higher in 50% (6) and farm levels significantly higher in 50% (6). The highest number of these occurred in Q2 of 2004 and Q1 of 2005.

Figure 2 shows the mean abundance levels and confidence intervals calculated for Atlantic salmon farm data and audit data in each zone for each quarter in 2004 and 2005. The arrowheads indicate the zones and quarters where farm and audit data significantly differed.

Figure 3 shows the mean abundance of *L. salmonis* on Pacific salmon for each calendar quarter in each zone. Region 3 had significantly higher *L. salmonis* levels than region 2 ( $p=0.017$ ). The highest abundance was observed in the fall (Q4) and lowest in the spring (Q2) for farms in both areas. No Pacific salmon farms were treated for lice control.

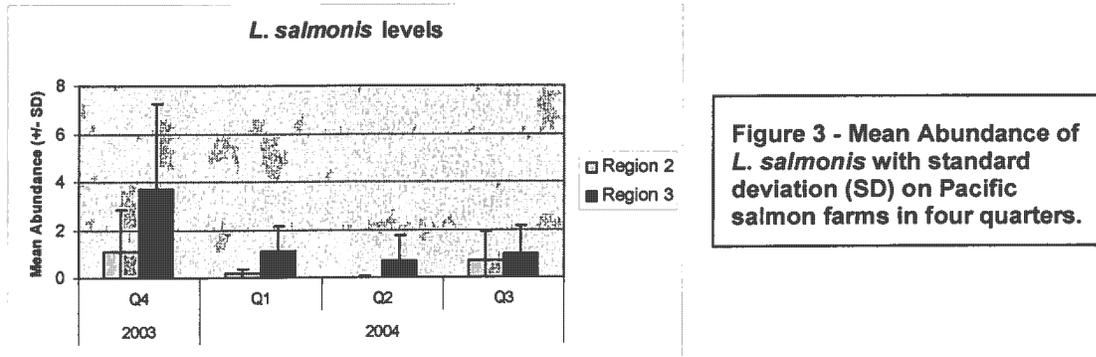


Figure 3 - Mean Abundance of *L. salmonis* with standard deviation (SD) on Pacific salmon farms in four quarters.

In addition to sea lice data, the farms submitted water salinity measured at the surface (0-1 m) and temperature measured at 5m. These are shown in Figure 4 in addition to mean precipitation from Environment Canada weather stations located within the zones. The highest year-round salinities were reported in zones 3.4 and 3.5 (~30 ppt), while the lowest salinities were found in zone 3.1 (~ 23 ppt). Zone 3.2 appeared to maintain moderately high salinity levels year-round (~28ppt). Distinct seasonal differences in salinity were observed in three of the seven zones 2.3, 2.4 and 3.3. Zones 2.3 and 2.4, both of which are located on the west coast of Vancouver Island and received the largest amount of rainfall of all the zones, particularly in the fall and winter, reported salinity levels to be lowest in the fall (Q4) and winter (Q1). This is the reverse to what was observed in zone 3.3, located on the east side of Vancouver Island, where the lowest salinity levels occur in the summer (Q3) and the highest levels in the fall and winter. Not surprisingly, cooler water temperatures were recorded on farms located on the northern reaches of Vancouver Island and the central coast compared to the western and southern coasts of Vancouver Island. Seasonal variations in temperature were observed in all zones with the highest levels occurring in the summer (Q3) and the largest variation in temperatures (~ 5C) between the warmest zone (3.1) and coolest zone (3.3) The winter (Q1) had the lowest temperatures and the smallest variation (1.5C) between the warmest (3.1) and coolest (3.5) zones.

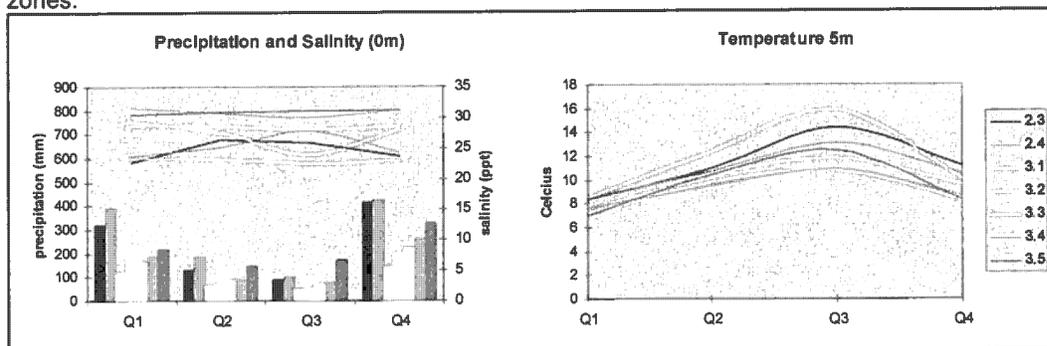


Figure 4 - The mean salinity (ppt) and temperature (C) for each quarter in each salmon farming zone, as well as the mean precipitation (mm) measured by Environment Canada at stations located in the zones.

## DISCUSSION

*Lepeophtheirus salmonis* data collected from both Pacific and Atlantic salmon farms was examined. The data collected from Pacific salmon farms indicates that both farmed Coho and Chinook are fairly resistant to sea lice. These findings are similar to those reported in Ho and Nagasawa (2001) who found that farmed Coho had substantially lower sea lice levels than farmed rainbow trout in Japan. In addition, Fast et al (2002) found that *L. salmonis* matured more slowly on Coho than on Rainbow trout or Atlantic salmon and concluded that Coho had an innate immunity to *L. salmonis*. These findings also support observations made

by BC farmers and veterinarians prior to the establishment of the regulated sea lice monitoring program (BCSFA, AAVBC pers.comm.). Therefore even though the data on Pacific salmon was collected for just one year, based on that single year of data of low abundance maintained without treatment, regulated monitoring of farmed Chinook and Coho salmon for sea lice is no longer required.

The Atlantic salmon farm data was compared to the data collected during the BCMAL audits. Given that the audits were a single sub-sample of the data collected from one or more farms within a zone in a three-month period, some differences between the means could be expected. Therefore, observing similarity in levels in over three-quarters of the data provides confidence that the industry-reported data is a true representation of mobile *L. salmonis* levels on the farms in BC. The data shows that the annual mean abundance of mobile *L. salmonis* levels was very low, ranging from 0.30 to 3.29. The number of treatments was also very low, ranging from 0 to 3 per production cycle with the majority of treatments occurring in the winter (Q1) and spring (Q2). Examination of the mean sea lice abundance levels in the various zones during those quarters showed many, if not all, of the treatments are related to meeting regulatory trigger levels rather than fish health concerns. Despite this, the number of treatments, as well as the mean abundance of sea lice reported on farms in BC, are substantially lower than the levels reported in Europe; particularly before government regulated triggers were mandated in Europe (Revie et al 2002, Heuch et al 2003). In BC, treatment effect using SLICE® appears to be longer than in Europe and as a result, there is little need for repeat treatments as is observed in Europe and Eastern Canada (Saksida et al 2006, Revie et al 2002). This would suggest that self re-infestation or cycling pressures are lower in BC than the other salmon farming regions.

The Atlantic salmon farm data shows there are differences in sea lice abundance levels among the different farming zones in BC. It is apparent that zone 3.1 is unique in its low lice levels affecting farmed fish, while zones 3.3 and 3.4 consistently report higher levels than other areas. In fact, the levels in zone 3.3 were significantly higher than many of the other zones in either 2004 or 2005. Zone 3.5 also reported higher levels in 2005 (1.70), however, this result is difficult to interpret since there were so few active farms in that region (n=2). There is also evidence from data to suggest that some annual variation in abundance levels, particularly in some zones, may occur.

To understand the reasons for these regional differences requires consideration of the unique factors that affect lice levels in BC: environmental factors, abundance of wild hosts and effects of treatment need to be considered. The seasonal differences in the salinity patterns observed among the regions are quite interesting, with the two most southern zones and the two most northern zones located along the coast of the mainland showing very little annual variation, while the two zones located on the west coast of Vancouver Island (zones 2.3 and 2.4) and the middle area adjacent to the mainland (zone 3.3) showing considerable annual variation. It is quite likely that the seasonal differences observed in zones 2.3 and 2.4 are associated with precipitation, especially during the fall (Q4) and winter (Q1), while in zone 3.3 the low salinity levels seen in the summer (Q3) are likely associated with the substantial freshet (snowmelt) seen during the summer period (Foreman et al 2006). Salinity and temperature are parameters reported to affect *L. salmonis* abundance levels; the higher the salinity, the higher the settlement and the higher the temperature, the quicker the development of *L. salmonis* (Tucker 2000). It is evident in the results, as the zones with the higher salinity levels (3.3 and 3.4) had the most lice and the zones with the lowest salinity (3.1) had the lowest sea lice abundance levels. Interestingly, during the summer (Q3) when water temperatures were the warmest and the development of *L. salmonis* would be expected to be the fastest, the abundance levels of lice in all zones were lower than in the winter (Q1) when water temperatures were much cooler. Therefore, although there appears to be a link between water salinity and sea lice abundance levels, the importance of water temperature on sea lice levels in BC remains unclear. It is also interesting to note that in general, the Pacific Ocean is known to be less salty than the Atlantic Ocean (MBARI 2006). How subtle differences in water chemistry could affect *L. salmonis* infectivity and pathogenicity is yet to be explored.

Another influence on farm abundance and infestation patterns is the interaction with native fishes, especially the five species of wild adult Pacific salmon which carry *L. salmonis* in high levels when returning in the summer and fall to spawn. In the Pacific Ocean, both pink and chum salmon are considered the "natural" hosts of the sea louse (Nagasawa 2001). Beamish et al (2005) reported mobile *L. salmonis* levels on returning adult pink and chum salmon of 13 and 9 respectively. It is possible that the variation in lice abundance between the different zones may be in part related both to the species of wild salmon found in a zone and their respective run sizes. Furthermore, work by Jones and Nemeč (2004) has shown that *L. salmonis* are found on other species of fish, namely Three-Spined Sticklebacks (*Gasterosteus aculeatus*), previously unrecorded. The role that these alternate species may play in the natural infestation patterns of sea lice on wild and farmed salmon has not yet been determined.

Farmers and veterinarians in BC have stated that prior to public concerns raised in 2002 about juvenile pink salmon, the effects of sea lice on the health of farmed Atlantics in BC was less than that reported in other

farming jurisdictions. This report presents a summary of the data collected on sea lice abundance from all farming regions in British Columbia over a two-year period. The low number and frequency of treatment compared to that reported in other salmon farming areas, as well as the lower overall abundance of lice, indicates that sea lice are not a significant problem for farmed Atlantic and Pacific salmon in BC. However, it is evident that there are differences in sea lice abundance levels among the farming regions within BC. This fact is important from a lice control perspective, as the mitigation measures put into place have been focused on information generated from one primary area where concern has been expressed, the Broughton, which is located within zones 3.3 and 3.4. It is evident from the data presented that if enforced mitigation measures are required, then they should take into account these differences.

## REFERENCES

Beamish R.J., Neville C.M., Sweeting R.M., Amber N.J. (2005) Sea lice on adult Pacific salmon in the coastal water of Central British Columbia, Canada. *Fisheries Research*, 76, 198-208.

Fast M.D., Ross N.W., Mustafa A., Sims D.E., Johnson S.D., Conboy G.A., Speare D.J., Johnson G., Burka J.F. (2002) Susceptibility of rainbow trout *Oncorhynchus mykiss*, Atlantic salmon *Salmo salar* and coho salmon *Oncorhynchus kisutch* to experimental infection with sea lice *Lepeophtheirus salmonis*. *Diseases of Aquatic Organisms*, 52, 57-68.

Forman M.G.G., Stucchi D.J., Zhang Y., Baptista A.M. (2006) Estuarine and tidal currents in the Broughton Archipelago. *Atmosphere-Ocean*, 44, 47-63.

Heuch P.A., Revie C.W., Gettinby G. (2003) A comparison of epidemiological patterns of salmon lice, *Lepeophtheirus salmonis* infections on farmed Atlantic salmon *Salmo salar* L. in Norway and Scotland. *Journal of Fish Diseases*, 26, 539-51.

Ho J., Nagasawa K. (2001) Why infestation by *Lepeophtheirus salmonis* (Copepoda:Caligidae) is not a problem in the Coho salmon farming industry in Japan. *Journal of Crustacean Biology*, 21, 954-960.

Jones S., Nemas A. (2004) Pink salmon action plan: Sea lice on juvenile salmon and on some non-salmonid species in the Broughton Archipelago in 2003. *Fisheries and Oceans Canada*, ISSN 1499-3848.

Monterey Bay Aquarium Research Institute (2006) Periodic table of elements in the ocean. <http://www.mbari.org/chemsensor/pteo.htm> (accessed April 2006)

Nagasawa K. (2001) Annual changes in the population size of the salmon louse *Lepeophtheirus salmonis*, (Copepoda: Caligidae) on high-seas Pacific Salmon (*Oncorhynchus spp.*), and relationship to host abundance. *Hydrobiologia*, 453/454, 411-416.

Revie C.W., Gattinby K., Treasurer J.W., Rae G.H., Clarke N. (2002) Temporal, environmental and management factors influencing the epidemiological patterns of sea lice, *Lepeophtheirus salmonis* infestations on farmed Atlantic salmon, *Salmo salar* L., in Scotland. *Pest Management Science*, 58, 576-584.

Saksida S, Constantine J., Karreman G.A, Donald A. (2006) Evaluation of sea lice abundance levels on farmed Atlantic salmon (*Salmo salar*) located in the Broughton area of British Columbia from 2003-2005. *Aquaculture Research* (submitted).

Tucker C.S., Sommerville S., Wooten R. (2000) The effect of temperature and salinity on the settlement and survival of *Lepeophtheirus salmonis* (Kroyer, 1837) on Atlantic salmon, *Salmo salar* L. *Journal of Fish Diseases*, 23, 309-320.

## ACKNOWLEDGMENTS

The authors would like to acknowledge the funding for this project provided by Aquaculture Collaborative Research and Development Program (ACRDP), Fisheries and Oceans Canada, the British Columbia Salmon Farmers Association BCSFA. The authors would like to thank all personal who collected and submitted the farm data, Chris Diamond and Maria Coombs who conducted the BCMAL audits, Darlene Hanson for her assistance in editing the manuscript and the Association of Aquaculture Veterinarian of BC (AAVBC) for their comments.