SEA LICE PRESENCE AND PATHOGENICITY IN THE CAMPBELL RIVER AND SUNSHINE COAST SALMON FARMING REGIONS OF BRITISH COLUMBIA

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FOREWORD:

To date a cohesive document describing the status of sea lice and salmon farming in the Campbell River and Sunshine Coast areas was lacking. Presented here is a summary of the current scientific understanding of sea lice in British Columbia's Campbell River area (fish health monitoring zone 3.2 plus specific farm sites located in zone 3.3 - Althorpe, Hardwicke and Shaw Point) and on the Sunshine Coast. The majority of this information is directly from the book chapter "Sea Lice Management on Salmon Farms in British Columbia, Canada" written by Drs. S. Saksida, D. Morrison, M. Sheppard, and I. Keith (with permission of the first author, book in progress), with added summaries of motile lice abundance reported from March through July 2004-2010 in these farming areas which was compiled from data provided by the BC Salmon Farmers Association.

TABLE OF CONTENTS

INDEX OF TABLES

1 SEA LICE AFFECTING SALMON IN BRITISH COLUMBIA

1.1 *Lepeophtheirus salmonis*

1.1.1 The species of sea louse most commonly reported on wild (Beamish *et al.* 2000) and farmed salmonids (Saksida *et al.* 2007a) in coastal BC are *Lepeophtheirus salmonis* (*L. salmonis*).

1.1.2 Morphologically, *L. salmonis* appear identical between the North Pacific and the North Atlantic regions.

1.1.3 Genetically, however, *L. salmonis* are **distinct** between the North Pacific and the North Atlantic regions (Yazawa *et al.* 2008). That is, there is enough genetic evidence to confidently state that the louse species of the same scientific name on both coasts is actually two distinct louse species (one species on each coast).

1.1.4 *L. salmonis* are commonly found in high numbers on native Pacific salmon species adults.

1.1.5 Pink (*Onchorynchus gorbaschu*) and chum (*Onchorynchus keta*) salmon are considered the 'natural' hosts for the parasite (Nagasawa 2001).

1.1.6 However, Jones *et al.* (2006 a, b) describe significant naturally occurring *L. salmonis* infestations on three-spined stickleback (*Gasterosteus aculeatus*) in the wild as well as infestations resulting from controlled laboratory studies.

1.1.7 Three-spined stickleback were one of the four most common wild non-salmonid species netted or hooked in a survey of fish near salmon farms (Kent *et al.* 1999).

1.1.8 Pert *et al.* (2006, 2009) suggested successful settlement and feeding on non-salmonids allowed *L. salmonis* to use other species as peripatetic (or pratemic / transport hosts) to improve survival and to aid dispersion until a salmonid host is encountered.

1.1.9 Due to their preference for salmonids, *L. salmonis* infections tend to be more chronic and persistent (Integrated Pest Management Report 2003).

1.1.10 There are major reports describing large infestations of *L. salmonis* on adult Pacific salmon in coastal waters and high seas (Nagasawa *et al.* 1993; Johnson *et al.* 1996; Nagasawa 2001; Beamish *et al.* 2005; Trudel *et al.* 2007).

1.2 *Caligus clemensi*

1.2.1 The sea louse, *Caligus clemensi* (*C. clemensi*), is common as well, but to a lesser degree than *L. salmonis* (Johnson *et al.* 2004).

1.2.2 *C. clemensi* has a broad range of hosts including pink, coho, Chinook, sockeye and Atlantic salmon as well as rainbow trout, non-salmonid fishes (e.g. sticklebacks) and elasmobranchs.

1.2.3 Highly motile preadult and adult *Caligus* species often infect farmed salmon as preadults or adults (instead of attachment during earlier developmental stages).

1.2.4 The prevalence of *C. clemensi* may be underestimated by sampling due to the high motility of these animals.

1.2.5 Infections by *Caligus* species tend towards acute and transient (Integrated Pest Management Report 2003).

1.2.6 Spawning herring (*Clupea pallasii*) are possibly a major source of *C. clemensi* for juvenile salmon in coastal BC (Beamish *et al.* 2009).

1.3 *Lepeophtheirus cuneifer*

1.3.1 *Lepeophtheirus cuneifer* (*L. cuneifer*) is much less common than *L. salmonis* and *C. clemensi.*

1.3.2 12 known hosts including: rainbow trout and Atlantic salmon (Nanaimo and Quadra Island).

1.3.3 *L. cuneifer* are relatively rare (and possibly not recognized).

1.3.4 Adults and pre-adults are highly motile.

2 FISH HEALTH EFFECTS OF LEPEOPHTHEIRUS SALMONIS IN BRITISH COLUMBIA

2.1 Serious health issues associated with *L. salmonis* infestations on farmed salmon are frequently reported by salmon farming regions located in Europe and Eastern North America, but not in Japan or on the BC coast.

2.2 Heavy infections and damage as a result of infections with *L. salmonis* were rare and aquaculture veterinarians did not consider sea lice a serious health concern (Saksida *et al.* 2007a).

2.3 This discrepancy in pathology and epidemiology was difficult to explain when the identical-looking Atlantic and Pacific varieties of *L. salmonis* were believed to be the same species.

2.4 However, genetic and physiological differences between North Atlantic and Pacific Canadian *L. salmonis* indicate they are likely distinct varieties:

2.4.1 Fast *et al.* (2003) reported considerable differences in physiological reaction (higher protease activity) in coho and Atlantic salmon as well as rainbow trout mucous when exposed to *L. salmonis* collected from BC compared to *L. salmonis* collected from New Brunswick.

2.4.2 Todd *et al.* (2004) reported low but significant differentiation in the variation of six microsatellite loci between North Pacific and North Atlantic *L. salmonis*.

2.4.3 There are significant differences in the nuclear DNA sequences and the mitochondrial genome from *L. salmonis* collected from the North Pacific versus the North Atlantic (Yazawa *et al.* 2008).

2.4.4 Cumulatively, these studies suggest that the North Pacific *L. salmonis* is distinct from the North Atlantic variety thereby explaining why there is such a disparity in pathogenicity and virulence between the two groups.

3 SEA LICE ON SALMON FARMS IN BRITISH COLUMBIA

3.1 Sea lice infestations were not considered a significant fish health issue on salmon farms in BC since pathogenic lesions as described in the literature (Finstad *et al.* 2000) and observed in Europe were rarely observed in BC.

3.2 Consequently, prior to 2003, enumeration of sea lice only occurred if there were health and/or welfare concerns at a farm site. Thus treatments for sea lice infestation were rare and limited data was recorded.

3.3 An unexpectedly low return of pink salmon in 2002 led to reports in scientific journals (Morton and Williams 2003) and in the popular press suggesting that sea lice from Atlantic salmon farms were negatively impacting juvenile wild pink salmon and, in turn, affecting wild salmon returns.

3.4 Salmon farms in the Broughton Archipelago were singled out (farms in this area constituted 35-39% of total farmed Atlantic salmon production in BC between 2000-2006).

3.5 In response to these accusations, the provincial government instituted stringent sea lice monitoring systems and control measures on salmon farms (described in Saksida *et al.* 2007a).

3.6 In March 2003, routine sea lice monitoring began on Atlantic salmon farms in the Broughton Archipelago (originally as part of the Broughton Archipelago Sea Lice Action Plan) (Saksida *et al.* 2007a).

4 BRITISH COLUMBIA SEA LICE MANAGEMENT STRATEGY

4.1 For fish health reporting and surveillance the provincial coast line is divided into zones:

4.1.1 Boundaries follow major drainages or watersheds

4.1.2 Entire BC coastline (including Vancouver Island) is divided into 10 zones

4.1.3 Farms are contained in 7 of these zones

4.2 In October 2003, the monitoring program in the Broughton Archipelago was expanded to include all British Columbia salmon farms as part of a provincial management plan known as the Sea Lice Management Strategy.

4.3 The Sea Lice Management Strategy stipulates that during the period of juvenile pink salmon migration out of the nearshore (March to July), *L. salmonis* are to be below 3 motile lice per fish (including all preadult and adult males and female *L. salmonis* stages).

4.4 If *L. salmonis* levels exceed this threshold during March to July, the farmed fish must be treated with medicant or be harvested.

4.5 This threshold was lower than that prescribed in Norway at that time (0.5 adult females *L. salmonis* or 6 motile *L. salmonis*) (Heusch *et al.* 2005).

4.6 Management options during the rest of the year remain at the discretion of the farmer and attending veterinarian.

4.7 The threshold of 3 motile *L. salmonis* was not based on scientific evidence:

4.7.1 It was determined by government and industry as a level that would allow precautionary management while more scientific data were gathered to better inform the issue.

4.7.2 It acknowledged both: the lack of serious sea lice disease occurring in BC farmed salmon compared to other global jurisdictions with *L. salmonis*, and the large populations of wild salmon in BC that are known to carry sea lice and thus greatly influence the sea lice abundance on farmed salmon, particularly during the summer to fall return migration season.

4.8 As part of the monitoring program implemented in October 2003, farms growing Atlantic salmon in British Columbia have been required to report sea lice data into a database:

4.8.1 This involves compulsory reporting of the abundance of chalimus and motile stages (preadult and adult stages) of *C. clemensi* and *L. salmonis* on a monthly basis.

4.8.2 Monitoring and reporting of sea lice data on a farm begins as soon as one month has passed following the entry of the third pen of smolts; reporting ends when less than three pens remain during harvest.

4.8.3 The mandatory reporting may be interrupted in the event of sea lice treatment, fish health events, or environmental problems, such as low dissolved oxygen.

4.8.4 The protocol for monitoring sea lice on salmon farms requires that three pens (twenty fish per pen) be assessed.

4.8.5 Sampled pens include one index pen, that is the first pen populated in the system, and two randomly selected pens per sample period.

4.8.6 Farms growing Pacific salmon are required to monitor and report sea lice information less frequently: thirty fish per farm on a quarterly basis.

4.9 For assessment, fish are most often sedated in totes and examined for sea lice (totes are examined for lice as well).

4.10 Motile stages of *L. salmonis* and *C. clemensi* are identified and counted.

4.11 Attached stages (copepodid and chalimus stages) are counted also, but species determination is not required.

4.12 The farms report counts to a central database owned by the British Columbia Salmon Farmers Association, and monthly reports summarizing sea lice abundance for motile *L. salmonis*, adult female *L. salmonis* and motile *C. clemensi* by zone are provided to the British Columbia Ministry of Agriculture and Lands.

4.13 These monthly sea lice abundance data summaries are made available to the public through the government website.

5 GOVERNMENT AUDITING OF INDUSTRY SEA LICE MONITORING IN BRITISH COLUMBIA

5.1 In January 2004, the British Columbia Ministry of Agriculture and Lands initiated random sea lice audits on Atlantic salmon farms to assess:

5.1.1 The capacity of the farm staff to properly identify and enumerate sea lice, particularly motile *L. salmonis.*

5.1.2 The validity of the data reported by the salmon farm industry.

5.2 Audited farms are selected at random by sub-zone. Subzones with more farms, have more audits.

5.2.1 Audits are conducted on a quarterly basis with 50% of the salmon farms audited between April to July (quarter 2) and 25% of farms audited in each of the other quarters.

5.2.2 For the majority of sub-zones, more than one farm is audited during the sampling period (quarter)(range 1-9).

5.3 Sea Lice Audit protocol:

5.3.1 Sample 20 fish per pen, split such that Ministry technicians (auditors) evaluate lice on ten of the fish and the farm personnel evaluate the other ten.

5.3.2 This audit process is repeated for all three pens.

5.3.3 The counts obtained by the auditor from the thirty fish assessed for the farm are statistically compared to the assessment made by the farm personnel using a standard two-sample T-test analysis.

5.3.4 This enables the auditor to assess the sea lice identification proficiency of the farm personnel.

6 RESULTS OF BRITISH COLUMBIA MINISTRY OF AGRICULTURE AND LANDS SEAL LICE MONITORING AUDITING PROGRAM

6.1 Audits conducted between 2004 and 2009 found that in 93% of the assessments (approximately 250 of 271) there was no statistical difference (at 5% error) in the assessment for motile *L. salmonis* and adult female *L. salmonis* between the farm personnel and the government auditors (BC MAL 2003-2005, 2006, 2007, 2008) indicating that lice were properly identified and enumerated by farm personnel.

6.2 More importantly, the audit program is used to verify the accuracy of the sea lice data that industry provides to the provincial government on a monthly basis.

6.3 Since the government audits are conducted quarterly while industry collects and submits data on a monthly basis, the verification of accuracy is based on whether or not the mean abundance values obtained during the quarter from the audited farms fall within the 95% confidence levels calculated from data collected from all the farms in the same sub-zone during that quarter.

6.4 Saksida *et al.* (2006) reported that, for the 2004-2005 period, the audit data was not significantly different than the industry reported data most (75%) of the time.

6.5 In 2004 and 2005, in instances where significant difference between the audit findings and the *L. salmonis* abundance levels reported by the salmon farms were observed, these differences were equally split (six and six respectively) between the two parties –auditor and farmer. Saksida *et al.* (2006) in presenting the verification method described the potential source of differences between the audit and industry data stating that audit abundance estimates were single measures versus industry abundance estimates from monthly measures that captured the dynamic nature of lice abundance.

6.6 A similar comparison for data collected to 2009 showed a parallel trend with data collected during a quarter not being significantly different than the industry reported information (average 72% of the time). This provides confidence that the data reported by the industry during this period is a true representation of lice levels on the farms (BC MAL 2006, 2007, 2008, unpublished data for 2009).

6.7 In addition to the sea lice data aggregated by zone, individual farm sea lice counts are made available by two of the largest salmon producing companies in the region, Marine Harvest Canada and Mainstream Canada, through their respective company websites.

6.8 This level of data sharing is unique and provides the public with access to information not available in other salmon farming regions.

7 EPIDEMIOLOGY OF SEA LICE ON FARMED SALMON IN BRITISH COLUMBIA

7.1 Sea lice information has been routinely collected and reported by the salmon farms in British Columbia since 2003/04.

7.2 Prior to that period, examinations were intermittent and, as a consequence, data was not readily available. Evaluation of the lice levels collected showed the data was positively skewed.

7.3 Consequently, it was suggested that median abundance values should be reported in addition to mean abundance levels (Saksida *et al.* 2007a), but this practice was not adopted.

8 SEA LICE ON FARMED PACIFIC SALMON IN BRITISH COLUMBIA

8.1 Sea lice assessment and reporting on farmed Pacific salmon (Chinook and coho salmon) are less stringent than those for farmed Atlantic salmon.

8.1.1 Assessments are less frequent and done with fewer fish.

8.2 Saksida *et al.* (2006) examined the sea lice data collected from farmed Pacific salmon in 2004.

8.2.1 Regional differences were reported with Pacific salmon farmed on the East side of Vancouver Island having higher mean abundance of motile *L. salmonis* than those farmed on the West side of the Island.

8.2.2 However, even during the autumn when higher lice levels would be expected, the mean level of motile *L. salmonis* was 3.7 for the farms located on the East side of Vancouver Island.

8.2.3 During the spring, when lice on the salmon farms were to be maintained below three motile *L. salmonis,* the mean abundance reported on farms with Pacific salmon was 0.7.

8.2.4 Even without treatment, lice levels on farmed Pacific salmon were maintained at equal to or below those observed on farmed Atlantic salmon.

8.2.5 Similarly, Ho & Nagasawa (2001) reported that coho salmon farmed in Japan had substantially lower sea lice levels than farmed rainbow trout.

8.2.6 Fast *et al.* (2002) found that *L. salmonis* matured more slowly on coho salmon than on rainbow trout or Atlantic salmon and concluded that coho salmon had a relatively high innate immunity to *L. salmonis*.

8.2.7 *Caligus clemensi* levels on farmed Chinook and coho salmon in British Columbia were even lower than those reported for *L. salmonis* with mean levels ranging between 0 and 0.03 (Saksida, unpublished data).

8.3 As a consequence of the low levels of sea lice on farmed Pacific salmon in British Columbia, and due to the handling stress experienced by Pacific salmon, by the end of 2004, the provincial government stopped the required quarterly monitoring and reporting of sea lice abundance for these species.

8.4 Continued monitoring was limited to opportunistic counts during routine handling events, and details of this monitoring were subject to audit.

9 CALIGUS CLEMENSI ON ATLANTIC SALMON IN BRITISH COLUMBIA

9.1 *Caligus clemensi* infects a wide variety of fish species that are residents of British Columbia's coastal waters (Parker & Margolis 1964; Beamish *et al.* 2005).

9.2 Parker and Margolis (1964) suggested that this ecto-parasite is "specific to environment rather than host" –most likely a reflection of its wide host specificity.

9.3 *Caligus clemensi* tends to be the less common (often by many numerical factors) sea louse species occurring on farmed Atlantic salmon.

9.4 However, in 2003, *C. clemensi* made up 42% of the motile sea lice observed on farmed Atlantic salmon (Saksida *et al.* 2007a), and Beamish *et al.* (2006) reported a similar proportion (40.6% between February and July) from their study in the same area (the Broughton Archipelago).

9.5 Unlike *L. salmonis* levels, which tended to be higher on farmed populations with longer ocean residency times, motile *C. clemensi* abundance levels did not appear to have a predilection to any year-class (Saksida *et al.* 2007a,b).

9.6 Additionally, it was reported that *C. clemensi* levels do show inter-annual variation though there did not appear to be consistent inter-seasonal variation (Saksida *et al.* 2007a).

9.7 However, a more recent assessment using a more extensive dataset (2004-2009) from random British Columbia Ministry of Agriculture and Lands sea lice audits (utilizing the methods of Saksida *et al.* (2006 & 2007a)) indicated a higher abundance in younger farmed salmon populations when the combined data was assessed ($p<0.001$).

9.8 In contrast, when the data was assessed by year, *C. clemensi* abundance levels on younger farmed salmon populations were significantly higher than those seen in older farmed salmon populations in only 3 of the 6 years examined (2004, 2005 and 2008) (I. Keith, unpublished data, 2010).

9.9 These findings are similar to reports of infestation with *C. elongatus* in Scotland where higher abundance levels were seen in younger salmon populations but differ in that the authors noted consistent levels from year to year (Revie *et al.* 2002a; McKenzie *et al.* 2004).

9.10 From highest to lowest the significant seasonal differences in mean abundance for *C. clemensi* were: autumn, winter, summer, and spring respectively.

9.11 In addition, there exists significant differences in abundance levels of *C. clemensi* between zones: the highest levels in the Campbell River and Port Hardy regions and the lowest levels in the Sunshine Coast (I. Keith (unpublished data).

9.12 This new evidence of year class, seasonal and regional pattern differences likely reflects the greater statistical power achieved through examination of a more extensive dataset and may result from the higher frequency (75%) for sea lice treatments that occur in older populations (Saksida *et al.* 2007a) influenced by the treatment timing (to achieve fewer than three motile *L. salmonis* from March to July) (Saksida *et al.* 2007a).

10 LEPEOPHTHEIRUS SALMONIS ON ATLANTIC SALMON IN BRITISH COLUMBIA

10.1 *Lepeophtheirus salmonis* levels on farmed Atlantic salmon tend to fluctuate both temporally and spatially.

10.1.1 Levels generally rise as time spent in seawater increases.

10.1.2 This trend was reported in both wild and cultured salmon and is likely attributable to increased length of exposure (Nagasawa 1985; Bron *et al.* 1991; Tully and Nolan 2002; Revie *et al.* 2002b; Heuch *et al.* 2003; Trudel *et al.* 2007).

10.1.3 Saksida *et al.* (2006) reported that levels of *L. salmonis* on Atlantic salmon more than one year in sea water were 2.5 times higher than on salmon less than one year in sea water.

10.1.4 The rate of increase of motile *L. salmonis* on farmed salmon in British Columbia was calculated at 2% per month (Saksida *et al.* 2007b)

10.2 VARIATION IN SEA LICE ABUNDANCES BETWEEN SEASONS

10.2.1 With very few exceptions, *L. salmonis* levels increase in the autumn on farmed Atlantic salmon in British Columbia (Saksida *et al.* 2006, 2007a, 2007b).

10.2.2 The lowest levels are most frequently reported in the summer. Beamish *et al.* (2006) reported that, in one region, prevalence of sea lice infected Atlantic salmon ranged from 85% in February to 46% in August and the intensity of all lice stages on fish was highest in February (21 lice per fish) and lowest in July (3.3 lice per fish).

10.2.3 Orr (2007) looked at gravid female lice levels to estimate egg production from selected farms located in the Broughton Archipelago. He estimated that maximum egg production occurred during November and December 2003 and that by January/February egg production was down by 50%. By March/April, egg production was down to 6% of the maximum estimated levels.

10.3 The increase in lice abundance on farmed salmon in the autumn may be associated with the return of adult Pacific salmon to their natal rivers (Saksida *et al.* 2006, 2007a; Beamish *et al.* 2005).

10.4 The British Columbia coast has many more wild salmon than other salmon farming regions. Beamish *et al.* (2005) reported 100% prevalence with abundance ranging between ten and twenty mobile *L. salmonis* on all five species of adult Pacific salmon returning to spawn along the coast of British Columbia. These authors suggested that in some years there could be between ten and forty million Pacific salmon in the Queen Charlotte Strait (a region adjacent to zones 3.3-Broughton and 3.4-Port Hardy).

10.5 Direct transfer of motile stages has been reported to occur in situations where host densities are high such as: within salmon farms in Europe (Ritchie 1997; Tully & Nolan 2002) and from wild to farmed salmonids in Japan (Ho & Nagasawa 2001).

10.6 For the period between March and the end of June, when thresholds levels were in effect, the majority of farms were in compliance with the maximum threshold of 3 motile *L. salmonis* . All zones were in compliance in 2007-2009.

10.7 Of the years when there were zones not in compliance, 2004 was the worst with 3 zones reporting levels greater than 3 lice between 1 and 3 months of the 4 month period.

10.8 Compliance was higher for farms with younger salmon than older farmed salmon populations.

10.9 For populations in seawater less than a year, compliance ranged from 85% (2004 and 2006) to 100% (2005, 2007-2009) of the zones and between 66% (2004 and 2006) and 100% (2007-2009) for salmon populations in seawater for more than one year.

10.10 Saksida *et al.* (2007a, b) summarized sea lice levels in the Broughton Archipelago between 2003 and 2005 and found mean motile lice levels were four times higher in 2004 than in either 2003 or 2005.

11 VARIATION IN SEA LICE ABUNDANCES BETWEEN FARMING REGIONS

11.1 There is considerable variation in abundance between the fish health zones assigned by the provincial government.

11.1.1 Saksida *et al.* (2006) reported that *L. salmonis* levels ranged from 0.47 to 3.29 for 2004.

11.1.2 Saksida *et al.* (2007a) noted large standard deviation (SD) associated with the mean abundance levels. For example, in October 2004 a SD of 6 was associated with a mean of 2.5.

11.1.3 Saksida *et al.* (2007b) showed significant inter-zone variation for farms operating in the Broughton Archipelago.

11.2 It has been suggested that the variation in lice abundance between the different farming regions may be partly related both to the species of wild salmon found in a zone and to their respective abundances (Saksida *et al.* 2006; Jones *et al.* 2006).

11.3 Another source of variation in lice abundance between the different farming regions may be *L. salmonis* in the Pacific Ocean have been reported on non-salmonid hosts such as the three-spined stickleback (*Gasterosteus aculeatus*) (Jones *et al.* 2006). The role that these alternate species may play in the natural infestation patterns of sea lice on wild and farmed salmon has not been determined as yet.

11.4 Observed regional differences may be linked to environmental factors including differences in temperature and salinity, or to local hydrography (Jones *et al.* 2006). For example, regions with the highest salinity reported the highest sea lice abundance levels (Saksida *et al. 2006, 2007a*).

11.5 Laboratory studies have confirmed associations of environmental factors and lice abundance, and in British Columbia there are differences in environment factors between salmon farming regions or zones.

11.5.1 Changes in salinity and temperature have been reported to affect *L. salmonis* survival and growth rates. Johnson and Albright (1991b) reported that at salinities of 20 and 25mg/l, the majority of active nauplii died at the copepodid moult stage. Active copepodids were only obtained at 30mg/l.

11.5.2 Salinity patterns vary considerably among the different BC regions: for instance, both the west coast regions as well as the Broughton region show annual variation in surface (0-1 m) salinity with the seasons of lowest salinity being reverse to one another.

11.5.3 Farms on the west coast of Vancouver Island report lowest levels of salinity in the winter and highest in the summer with a mean difference of 4mg/L (23-27mg/l) (Saksida *et al.* 2006).

11.5.4 It has been proposed that the variation may be associated with precipitation, which is especially high during the fall and winter. Conversely, farms situated in the Broughton Archipelago report highest salinity levels in the winter and lowest in the summer with mean differences of almost 6mg/L reported (range 29-23mg/L)(Saksida *et al. 2006*).

11.5.5 The freshwater run-off from snowmelt which occurs in the summer reduces surface salinity (Foreman *et al.* 2006; Saksida *et al.* 2006, 2007a, b; Beamish *et al.* 2006).

11.5.6 Saksida *et al.* (2007b) used a generalized linear model to assess factors associated with *L. salmonis* abundance in the Broughton Archipelago. Several factors such as salmon age, farm location and time of year were found to be significantly associated with abundance - salinity was not. However, this dataset was relatively small containing information collected over 3 years (2003-2005).

11.6 There is less inter-annual variation in the other farming regions even though there are differences in the average salinity values between regions.

11.6.1 For instance, the Sunshine Coast farms report annual salinity of about 23 mg/L, while the other regions report about 30 mg/L (Saksida *et al.* 2006).

11.6.2 The Sunshine Coast (zone 3.1), which is the southernmost farming region, reported the lowest sea lice level on a consistent basis with mean monthly motile levels frequently below one *L. salmonis* per fish without the use of therapeutants.

11.6.3 Consequently, the requirement for monthly reporting was discontinued in 2006. Even so, the government continued to include these farms in the audit program (Saksida *et al.* 2006). The farms in the zone voluntarily started reporting into the database in 2010.

11.7 There were few differences observed in the water temperature profiles of the different BC regions. Sea temperatures (at 5 m) were higher in the summer than the winter months for each region.

11.8 Saksida *et al.* (2006) observed that water temperature did not appear to influence sea lice levels in salmon farming areas of British Columbia. This may be because the reported temperatures are within the tolerance levels of *L. salmonis* (Johnson & Albright 1991b).

11.9 During the summer when water temperatures were the warmest and the development of *L. salmonis* would be expected to be greatest, the abundance levels of lice in all zones was lower than in the winter (Saksida *et al.* 2006).

12 HYDROGRAPHIC EFFECTS ON ABUNDANCE

12.1 Other environmental factors such as current speed and flushing time were found to be significant in Scotland according to Revie *et al.* (2003).

12.2 The primary hydrographic transport mechanisms in the Broughton Archipelago are estuarine flows resulting from considerable river and glacier melt runoff (Foreman *et al.* 2006).

12.3 These influences were particularly strong in the inlets of the region especially during the summer months when river flow was at its maximum. Wind driven circulation likely plays a significant role in sea lice dispersion (Asplin *et al.* 1999; Murray & Gillibrand 2005).

12.4 The significance of these factors around the salmon farms in British Columbia is still not understood.

13 TREATMENTS FOR SEA LICE IN BRITISH COLUMBIA

13.1 Treatment for sea lice prior to the establishment of threshold levels in 2003 was rare.

13.2 Past treatment option 1: Ivermectin

13.2.1 Available by veterinary prescription only, ivermectin was the only therapeutant used with any frequency for the treatment of sea lice on farmed salmon in British Columbia prior to the year 2000.

13.2.2 The product was administered via medicated feed (four day treatment at 0.05 mg/kg per fish/day).

13.2.3 Ivermectin was reported to be quite toxic to Atlantic salmon (Johnson *et al.* 1993; Palmer *et al.* 1996) and, in attempt to minimize toxicity, veterinarians often instructed that the medicated feed be provided every other day or every third day until the full four day treatment regime was completed or until signs of potential toxicity were noted.

13.3 Past treatment option 2: Fish pump

13.3.1 The other tool used in the management of sea lice was to move the salmon through a fish pump (i.e SILKSTREAM™, ETI, Washington USA) in order to dislodge the motile lice from the fish.

13.3.2 The discharge water would sometimes be filtered to collect the detached lice. This method was very labour intensive and resulted in stress and physical injury to the fish.

13.4 Current treatment option: SLICE®

13.5 In 2000, SLICE® (emamectin benzoate, Intervet-Schering Plough Animal Health) became available to veterinarians under special permit, called an emergency drug release or EDR, obtained from Health Canada a ministry of Canada's federal government.

13.5.1 Soon after, it became the only therapeutant used for sea lice treatment in British Columbia.

13.5.2 Another in-feed product, Calicide® (teflubenzuron supplied by Nutreco), did achieve registration in Canada for use in salmon; however, the product has not been used in British Columbia due to difficulties with availability and to the product's limited effectiveness on adult lice.

13.5.3 The option of bath treatments has yet to be implemented in British Columbia.

13.5.4 SLICE® is an approved drug in most major salmon aquaculture countries including Norway, Scotland, Ireland and Chile.

13.5.5 The treatment regime for SLICE® is the same as that used in other regions (seven day treatment at 0.05 micrograms emamectin benzoate per kg of fish/day).

13.5.6 In Canada, the withdrawal period - the amount of time following treatment that the fish must be held before they can be harvested – has been amended several times since the drug has been available under the special permit (Emergency Drug Release).

13.5.7 Initially, it was set at 25 days when used at water temperatures above 5C with maximum residue limit (MRL) set at 100 parts per billion (ppb). In 2005, Health Canada amended its policy on permitted SLICE® residues after completing a reassessment of available data and modified the MRL down to 42 ppb and increased the withdrawal level to 68 days when used at temperatures above 5C.

13.5.8 In 2008, Health Canada revised the EDR conditions for SLICE® that permitted the harvest of fish prior to the 68 day withdrawal period if the farm demonstrated that the populations to be harvested were equal to or less than the MRL of 42ppb based on the results of three tissues from ten fish in each harvest pen.

13.5.9 SLICE® finally gained full registration approval in July 2009 with a recommended withdrawal period of zero days.

13.6 Frequency of SLICE® usage in British Columbia

13.6.1 There has been an increase in use of SLICE® after the introduction of the threshold limits with quantities in 2005 over 2.5 times greater than levels that existed prior to implementation of the BC Sea Lice Management Strategy in October 2003.

13.6.2 According to data supplied by BC MAL, the peak use of SLICE occurred in 2005 (~0.25 g/ metric ton (MT) of salmon produced) and usage since has been at or below 0.2 g/ MT.

13.6.3 Saksida *et al.* (2006) examined sea lice treatment data collected from all farms during the first two years of the regular monitoring program (2004, 2005) and reported that the total number of SLICE® treatments for Atlantic salmon ranged from zero to three per production cycle (i.e. smolt entry to harvest).

13.6.4 In another report, the average number of treatments per production cycle was estimated to be 1.6 in the Broughton Archipelago with the average farmed salmon residing in the ocean almost nine months before receiving its first treatment (Saksida *et al.* 2007a).

13.6.5 Additional data reported in Saksida *et al.* (2010) suggest that frequency of treatment has not changed over the five years since the establishment of the maximum threshold levels. This same dataset shows that every year there are farms that do not need to treat for sea lice.

13.7 Comparison of SLICE® usage in British Columbia verses other jurisdictions

13.7.1 The level of treatment frequency [in BC] is lower than levels reported in any other national and international salmon farming jurisdictions (Johnson *et al.* 2004).

13.7.2 Sea lice levels were reported to remain lower than pre-treatment levels for 3-5 months following a SLICE® treatment (Saksida *et al.* 2007a, Saksida *et al.* 2010).

13.7.3 This is a substantially longer efficacy than in Europe and Eastern North America where reported duration of efficacy ranged from 43 days to 14 weeks (Armstrong *et al.* 2000; Stone *et al.* 2000a, b; Treasurer *et al.* 2002).

13.7.4 The length of the "lice-free" period in British Columbia and the generation time for lice reproduction at ambient water temperatures in British Columbia indicate that re-infestation from within a farm following a site-wide treatment is unlikely.

13.8 Almost 75% of SLICE® treatments occurred in populations of Atlantic salmon during their second year in seawater between October and March (Saksida *et al.* 2007a, Saksida *et al.* 2010).

13.8.1 This differs from the reported situation in Norway and Scotland where the majority of treatments occur in the summer and fall months (Heuch *et al.* 2003).

13.8.2 The difference is likely the result of: trying to reduce the mean motile *L. salmonis* abundance levels to below three for the start of the spring wild juvenile Pacific salmon migration out of the near shore in March; and to adherence to required SLICE® treatment withdrawal periods prior to scheduled harvest dates.

13.8.3 There is very little evidence to suggest that any of the treatments were being provided in response to health concerns in the farmed salmon.

13.9 An immediate concern for the BC salmon farming industry continues to be the inherent limitation of having only one sea lice treatment product available for use.

13.9.1 Compared to other agricultural industries which utilize integrated pest management, (a rotation of treatments) to prevent or delay development of resistance in a pathogen.

14 SLICE® TREATMENT EFFICACY

14.1 Concerns regarding emamectin benzoate treatment failures, reduced sensitivity and/or potential resistance have been voiced in and, in instances, confirmed in Scotland, Ireland, Chile and Norway (Lees *et al.* 2008a,b; O'Donohoe *et al.* 2008; Bravo *et al.* 2008; pers comm. - T.Horsberg).

14.1.1 Lees *et al.* (2008a,b) analyzed abundance data from Atlantic salmon farms in Scotland between 2002 and 2006 and found that not all treatments were effective – evidence of reduced efficacy over time.

14.1.2 Conversely, Saksida *et al.* (2010) conducted a similar analysis with data collected from farms in British Columbia from 2003 when mandatory monitoring and lice thresholds were implemented to 2008 and found that where has been no change in the efficacy of the emamectin benzoate's apparent duration of effect. The study found by one month (26-34 days) post-treatment lice levels had fallen to below 20% of pre-treatment levels and remained at or below 10% of pre-treatment levels for at least month - the time-period assessed.

14.1.3 Lees *et al.* (2008a) defined an "effective" treatment in Scotland, as a treatment where the abundance of motile *L. salmonis* fell to less than 40% of their pre-treatment level at some point in the 13 weeks post-treatment.

14.1.4 Based on this definition, all of the treatments evaluated in British Columbia clearly fulfilled the criterion of being effective, with levels by 13 weeks post-treatment remaining at or below 10% of pre-treatment levels.

14.1.5 Review of 2009 data shows this same pattern (D. Morrison, unpublished data).

14.1.6 All of this suggests that, unlike most other salmon farming regions in the world, a decline in efficacy of SLICE® is not evident on salmon farms in British Columbia.

15 ASSESSMENT OF SEA LICE DATA FROM FARMS OPERATING IN THE CAMPBELL RIVER AND SUNSHINE COAST REGIONS

15.1 Sea lice levels and production on farmed salmon in the Campbell River area (fish health zone 3.2, and Althorpe, Shaw Point and Hardwicke from zone 3.3) during March-July (emphasis on 2007 and 2008) includes all farms with the exception of Yellow Island Aquaculture.

15.1.1 Campbell River region is a high salinity area (>27ppt) with little variability.

15.1.2 Number of farms operating in this region has not changed substantially in the period between 2004-2010 (14-16 farms).

15.1.3 In 2004, 50% of farms operating in the areas were stocked with Atlantic salmon; the other with Pacific salmon (primarily Chinook salmon)

15.1.4 Subsequently, there was a switch to more Atlantic salmon such that by 2007 all farms in this area were rearing Atlantic salmon

15.1.5 Between 2004-2010, Atlantic salmon populations were highest in 2008 (8.7M) followed by 2007 (7.3M)

TABLE 1. Number of Fish (millions) and Farms Stocked

		March	April	May	June	July
2004 #Fish	Chinook	5.0	5.6	4.6	4.2	3.9
	Atlantic	**2.7**	**2.3**	**3.7**	**3.7**	**4.1**
#Farms	Chinook	7	7	7	7	9
	Atlantic	**6**	**6**	**7**	**7**	**7**
2005 #Fish	Chinook	2.6	2.6	2.5	2.5	2.2
	Atlantic	**5.0**	**5.6**	**6.3**	**7.2**	**5.9**
#Farms	Chinook	3	3	3	3	3
	Atlantic	**9**	**10**	**10**	**12**	**12**
2006 #Fish	Chinook	0.8	0.8	0.8	0.8	0.8
	Atlantic	**5.1**	**5.5**	**6.3**	**7.2**	**7.0**
#Farms	Chinook	1	1	1	1	1
	Atlantic	**11**	**12**	**13**	**13**	**12**
2007 #Fish	Chinook	0	0	0	0	0
	Atlantic	**6.6**	**6.6**	**7.8**	**7.5**	**7.8**
#Farms	Chinook	0	0	0	0	0
	Atlantic	**11**	**12**	**13**	**13**	**12**
2008 #Fish	Chinook	0	0	0	0	0
	Atlantic	**8.7**	**9.0**	**8.8**	**8.6**	**8.3**
#Farms	Chinook	0	0	0	0	0
	Atlantic	**15**	**15**	**16**	**16**	**17**
2009 #Fish	Chinook	0	0	0	0	0
	Atlantic	**7.0**	**6.5**	**7.0**	**6.9**	**7.4**
#Farms	Chinook	0	0	0	0	0
	Atlantic	**15**	**15**	**15**	**14**	**11**
2010 #Fish	Chinook	0	0	0	0	0
	Atlantic	**6.7**	**7.2**	**7.3**	**7.2**	**n.a.**
#Farms	Chinook	0	0	0	0	0
	Atlantic	**14**	**14**	**14**	**14**	**n.a.**

TABLE 2. Average number of motile (adult and pre-adult, males and females) lice per fish on farmed Atlantic salmon reported in the Campbell River area March through July 2004-2010. Mean values are shown in bold, and range of values (lowest and highest) are also shown. BC Ministry Agriculture and Lands (BCMAL) audit results for quarter 2 (April-June) are provided –in cases where 2 values are provided, the first is for populations in seawater for less than one year and the second is for populations in sea for greater than one year. Average abundance of motile (adult and pre-adult, males and females) lice per fish on Pacific salmon farmed in 2004 are provided as well. After 2004, reporting was not required as levels were low and there was no need to treat.

Lepeophtherius salmonis

	March	April	May	June	July
2004 avgs:	**0.60**	**0.85**	**0.74**	**0.90**	**0.63**
low	0	0.05	0	0.05	0.1
high	1.7	1.78	1.15	2.05	2.4
BCMAL			1.23		
2005 avgs:	**1.99**	**2.92**	**1.21**	**0.81**	**0.28**
low	0.68	0.37	0.08	0.02	0
high	4.25	7.87	4.33	4.27	0.73
BCMAL			0.74		
2006 avgs:	**1.69**	**1.19**	**1.07**	**1.17**	**0.89**
low	0	0.04	0.03	0.05	0.2
high	6.05	6.3	5.43	5.03	3.72
BCMAL			1.3		
2007 avgs:	**0.35**	**0.75**	**0.83**	**0.63**	**0.38**
low	0	0	0.07	0.02	0.03
high	1.18	0.1	4.6	1.73	0.95
BCMAL			0.03/0.8		
2008 avgs:	**1.58**	**2.22**	**1.49**	**0.86**	**0.78**
low	0.20	0.00	0.00	0.12	0.07
high	5.22	10.72	6.32	3.66	3.68
BCMAL			0.54/1.59		
2009 avgs:	**1.65**	**0.38**	**0.47**	**0.56**	**0.97**
low	0.00	0	0.08	0.08	0.37
high	7.28	1.72	1.90	1.70	2.37
BCMAL			0.28/0.45		
2010 avgs:	**0.34**	**0.61**	**0.57**	**0.53**	**0.93**
low	0.03	0.04	0.08	0.05	0.02
high	1.00	2.68	3.07	1.22	1.95
BCMAL			No data		

Caligus clemensi

Caligus clemensi

	March	April	May	June	July
2004 avgs:	**0.20**	**0.13**	**0.88**	**0.64**	**0.20**
low		0	0	0	0
high		0.52	4.4	3.4	0.9
BCMAL			0.03		
2005 avgs:	**0.55**	**1.09**	**0.83**	**0.25**	**0.03**
low	0	0	0	0	0
high	3.42	6.25	5.36	1.05	0.23
BCMAL			0.36		
2006 avgs:	**0.06**	**0.06**	**0.11**	**0.43**	**0.16**
low	0	0	0	0	0
high	0.13	0.24	0.41	3.12	1.03
BCMAL			0.12/0.11		
2007 avgs:	**0.28**	**0.64**	**0.71**	**0.65**	**0.35**
low	0	0	0	0	0
high	1.33	3.48	5.82	2.72	1.7
BCMAL			0.017/0.05		
2008 avgs:	**0.21**	**0.24**	**0.18**	**0.23**	**0.37**
low	0	0.00	0.00	0.00	0.00
high	0.83	1.01	0.95	1.46	2.95
BCMAL			0.02/0.05		
2009 avgs:	**0.68**	**0.28**	**0.56**	**0.33**	**2.11**
low	0	0	0	0	0.02
high	3.53	2.40	3.37	1.87	14.38
BCMAL			0.32/0.07		
2010 avgs:	**1.02**	**1.40**	**0.62**	**0.66**	**0.80**
low	0	0	0	0	0
high	3.82	6.58	1.6	1.74	2.94
BCMAL			No data		

Lepeophtheirus salmonis on Farmed Pacific salmon

	March	April	May	June	July
2004 avgs:	**1.1**	**0.22**	**0.02**	**0.74**	**0.6**
low	0.5	0.22	0.02	0.09	0.6
high	2.1	0.22	0.02	2.0	0.6

Caligus clemensi

	March	April	May	June	July
2004 avgs:	**0**	**0**	**0**	**0**	**0**

low	0	0	0	0	0
high	0.1	0	0	0	0

15.1.6 The average number of farms stocked with Atlantic salmon that reported sea lice data was 90.5% (range 68.8-100%) The lowest reporting occurred in March 2007 (68.8%). Reporting in 2007 was 78%. Reporting in 2008 was at 86%.

15.1.7 The government audit values were higher than *L. salmonis* levels reported by area in 2004 and 2005. However audit levels were at or below levels reported by farms in all other years.

15.1.8 Average motile *L. salmonis* for period during which the threshold (<3motile) is in effect (March –June) was adhered to for area but not necessarily by individual farms in every month.

15.1.8.1 In 2007, 2 farms were above threshold: South Thurlow in April and Cyrus Rocks in May.

15.1.8.2 In 2008, 6 farms were above threshold: North Campbell River farms Lee's Bay in April, Hardwick in March, Althorpe in May and June. Farms in Okisollo: Sonora Island in May and Sonora Point in June. Mid Campbell River area farm - Phillips Arm was above threshold in May.

15.1.8.3 Lowest mean abundance *L. salmonis* levels was seen in 2007 and 2010 followed by 2004. Highest mean abundance *L. salmonis* levels occurred in 2005 followed by 2008.

15.1.9* With the exception of 2010, *C. clemensi* levels on farmed salmon have been lower than *L. salmonis

15.1.1 BCMAL audit levels lower/similar to levels reported for area in all years for *C. clemensi.*

15.1.2 Lowest mean abundance of *C. clemensi* levels in 2006 followed by 2008. Highest mean abundance of *C.clemensi* levels in 2010 followed by 2009.

15.2 Sea lice levels and production on farmed salmon in the Sunshine Coast (zone 3.1) during March to July

15.2.1 Sunshine region is a moderate salinity area (20-26ppt).

15.2.2 This is one of the original salmon farming regions in BC.

15.2.3 Overall number of farms operating in this region has not changed substantially in the period between 2004 and 2010 (about 5-10 farms).

15.2.4 Pacific salmon (Chinook and coho) as well as Atlantic salmon are grown on the farms

15.2.5 In 2007 (March to July) 3-4 farms (range indicates farms were newly stocked or harvested during the period) were stocked with Atlantic salmon (total number fish was 0.35M). In 2008 (March to July) there were a similar number of farms stocked with 25% more Atlantic salmon (0.56M).

TABLE 3. Number of Fish (millions) and Farms Stocked on the Sunshine coast

		March	April	May	June	July
2004 #Fish	Pacific	0.86	0.78	0.73	0.85	0.52
	Atlantic	**0.86**	**1.09**	**1.10**	**0.96**	**1.03**
#Farms	Pacific	3	3	3	4	3
	Atlantic	**5**	**5**	**5**	**5**	**5**
2005 #Fish	Pacific	0.50	0.47	0.53	0.98	1.14
	Atlantic	**0.87**	**0.82**	**0.71**	**0.62**	**0.52**
#Farms	Pacific	3	4	4	4	4
	Atlantic	**5**	**6**	**6**	**6**	**6**
2006 #Fish	Pacific	0.15	0.15	0.32	0.47	0.48
	Atlantic	**0.50**	**0.38**	**0.37**	**0.31**	**0.28**
#Farms	Pacific	3	4	4	4	4
	Atlantic	**5**	**5**	**5**	**4**	**4**
2007 #Fish	Pacific	0.40	0.39	0.39	0.39	0.33
	Atlantic	**0.39**	**0.39**	**0.36**	**0.31**	**0.31**
#Farms	Pacific	2	2	2	2	2
	Atlantic	**3**	**3**	**4**	**3**	**3**
2008 #Fish	Pacific	0.27	0.22	0.19	0.17	0.12
	Atlantic	**0.63**	**0.63**	**0.63**	**0.48**	**0.46**
#Farms	Pacific	2	2	2	2	2
	Atlantic	**3**	**3**	**3**	**3**	**4**
2009 #Fish	Pacific	0.07	0.07	0.48	0.48	0.47
	Atlantic	**0.52**	**0.51**	**0.51**	**0.49**	**0.48**

#Farms	Pacific	1	1	2	2	2
	Atlantic	**4**	**4**	**4**	**3**	**3**
2010 #Fish	Pacific	0.60	0.58	0.53	0.62	
	Atlantic	**0.93**	**0.92**	**1.19**	**1.19**	
#Farms	Pacific	3	3	3	4	
	Atlantic	**5**	**4**	**4**	**4**	

TABLE 4. Average number of motile (adult and pre-adult, males and females) lice per fish on farmed Atlantic salmon reported in the Sunshine Coast area March through July 2004-2010. Mean values are shown in bold, and range of values (lowest and highest) are also shown. BC Ministry Agriculture and Lands (BCMAL) audit results for quarter 2 (April-June) are provided as well –in cases where 2 values are given, the first number is for populations in seawater for less than one year and the second number is for populations in seawater for greater than one year. Additionally, average abundance of motile (adult and pre-adult, males and females) lice per fish on Pacific salmon farmed are provided for 2004. After 2004, reporting was not required as levels were low and there was no need to treat.

Lepeophtheirus salmonis - Atlantic Salmon

	March	April	May	June	July
2004 avgs:	**0.60**	**0.85**	**0.74**	**0.90**	**0.63**
low	0.3	0.03	0	0.1	0
high	0.3	1.35	0.80	1.4	1.8
BCMAL			0.03		
2005 avgs:	**1.99**	**2.92**	**1.21**	**0.81**	**0.28**
low	0.02	0.07	0.08	0.07	0.03
high	0.15	0.18	0.25	0.23	0.15
BCMAL			0.23		
2006 avgs:	**1.69**	**1.19**	**1.07**	**1.17**	**0.89**
low	0.08	0.07	0.05	0.05	0
high	0.20	0.78	0.20	0.22	1.03
BCMAL			No audit		
2007 avgs:			**No data**		
low					
high					
BCMAL			0/0		
2008 avgs:			**No data**		
low					
high					
BCMAL			0/0.10		
2009 avgs:	**0.08**	**0.37**	**0.02**	**0.33**	

low	0.00	0.37	0.02	0.00	
high	0.15	0.37	0.02	0.65	
BCMAL			0.67		
2010 avgs:	**0.18**	**0.12**	**0.33**	**0.42**	**0.00**
low	0.00	0.00	0.18	0.02	0.00
high	0.70	0.31	0.55	1.34	0.00
BCMAL			No data		

Caligus clemensi

	March	April	May	June	July
2004 avgs:	**0.00**	**0.01**	**0.05**	**0.00**	**0.00**
low	0	0	0	0	0
high	0	0.02	0.10	0	0
BCMAL			0.00		
2005 avgs:	**0.00**	**0.03**	**0.00**	**0.01**	**0.00**
low	0	0	0	0	0
high	0	0.05	0	0.02	0
BCMAL			0.00		
2006 avgs:	**0.01**	**0.00**	**0.01**	**0.02**	**0.00**
low	0	0	0	0	0
high	0.02	0	0.02	0.03	0
BCMAL			No audit		
2007 avgs:			**No data**		
low					
high					
BCMAL			0.10/0.00		
2008 avgs:			**No data**		
low					
high					
BCMAL			0/0.21		
2009 avgs:	**0.05**	**0.00**	**0.00**	**0.00**	
low	0	0	0	0	
high	0.09	0	0	0	
BCMAL			0.00		
2010 avgs:	**0.00**	**0.01**	**0.00**	**0.24**	**0.05**
Low	0	0	0	0	0.05
High	0	0.05	0	0.60	0.05
BCMAL			No data		

Lepeophtheirus salmonis on Farmed Pacific Salmon

	March	April	May	June	July
2004 avgs:		**0.83**		**1.53**	
low		0		0.07	
high		1.67		3	

Caligus clemensi on Farmed Pacific Salmon

	March	April	May	June	July
2004 avgs:		**0**		**0**	
low		0		0	
high		0		0	

15.2.6 No data was reported by salmon farms operating in 2006 and 2007 in the Sunshine Coast region, however a portion of the farms were audited by BC MAL.

15.2.7 BCMAL audit values were higher than the *L. salmonis* levels reported by area in 2009. Audit levels were at or below levels reported by farms in 2004 and 2005. In 2006 and 2007, audits assessed *L. salmonis* at or close to 0.

15.2.7.1 Average motile *L. salmonis* for period when threshold (<3 motile lice) is in effect (March –June) was adhered to for area as well as all farms in every month reported. Mean abundance for area <1 in all years reported.

15.2.7.2 According the BC MAL farm audit results, for all years *C. clemensi* levels were lower on farmed salmon than *L. salmonis*.

15.2.8 BC MAL audit levels were similar to or lower than levels reported for the area in all years for *C. clemensi (*where comparisons can be made).

15.2.8.1 *C. clemensi* levels were very low in all years (mostly 0).

16 INTERPRETATION OF SEA LICE ON ATLANTIC SALMON FARMS

16.1.1 Overall, there does not seem to be higher numbers of farmed Atlantic salmon or sea lice levels on farms that would provide evidence to suggest that lice contributed to the record low returns in 2007 and record high returns in 2008.

16.1.2 The number of salmon farms operating in both areas has not changed significantly between 2004 and 2010. The total number of salmon grown in the Campbell River region remained constant. However, there was an increase in the number of farms raising Atlantic salmon in the Campbell River area to the point where, as of 2007, 100% of the farms operating in the area were rearing Atlantic salmon. On the Sunshine Coast, the number of Atlantic salmon raised surpassed the number of Pacific salmon in 2008-2010. Overall however, numbers have not changed over this period.

16.1.3 Sea lice overall are at higher abundance levels in the Campbell River area compared to the Sunshine coast farms.

16.1.4 These 2 farming areas have very different environments. Campbell River farms have higher salinity than the Sunshine Coast farms. Higher salinity is better for sea lice production and survival. However, environment characteristics are only relevant if there are a source of sea lice in the area. The apparently very low sea lice levels on Sunshine Coast farms didn't require treatment and this suggests that there are few sources of lice (i.e fish with sea lice)

16.1.5 Comparison of the 2007 and 2008 outmigration periods of the sockeye salmon shows that in 2009 returns were very low and in 2010 returns were very high.

16.1.6 Rationale -- farmed Atlantic salmon are a primary sources for *L. salmonis* lice particularly when other important sources (i.e. wild salmon) are not in the vicinity. If one accepts this assertion, then one needs to also accept that while farmed salmon may be an important source of *L. salmonis* to juvenile salmon in March-May, that in May and June when adult wild salmon begin to return to the coast carrying large loads of sea lice that these wild salmon present an equal capacity to transfer louse infection to juvenile salmon.

16.1.6.1 The number of Atlantic salmon in both the Campbell River areas and the Sunshine Coast in 2008 was higher than in 2007 (this is reverse to what would be expected if there was an effect correlation).

16.1.6.2 The abundance of sea lice (*L. salmonis*) was higher in 2008 than 2007 in the Campbell River area. In fact, there were more farms that reported lice out of compliance to the 3 motile stages in 2008 than in 2007 on farms operating in the Campbell River area. It must be pointed out, however, that overall *L. salmonis* levels were low. There was no difference (based on audit) in the Sunshine Coast farms. These observations are the reverse to what would be expected if there was an effect.

16.1.7 *C. clemensi* is a species of louse with a very broad host range including species of fish found in high number in the near shore environment (i.e. herring). Farmed salmon cannot be considered the only source and probably not the primary source of this louse during the spring (or any time of the year).

16.1.7.1 The data suggests that *C. clemensi* on farmed salmon is very low. Abundance in 2007 was similar to that of *L. salmonis* in the Campbell River area. Levels in 2008 were higher than 2007 in the Campbell River area. Levels were low in both years in the Sunshine Coast area.

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