Journal of Fish Diseases 2010, 33, 913–917 doi:10.1111/j.1365-2761.2010.01192.x

Short Communication

The efficacy of emamectin benzoate against infestations of sea lice, *Lepeophtheirus salmonis*, on farmed Atlantic salmon, *Salmo salar* L., in British Columbia

S M Saksida[1], D Morrison[2] and C W Revie[3]

1 British Columbia Centre for Aquatic Health Sciences, Campbell River, BC, Canada
2 Marine Harvest Canada, Campbell River, BC, Canada
3 University of Prince Edward Island, Charlottetown, PEI, Canada

Keywords: British Columbia, efficacy, emamectin benzoate, *Lepeophtheirus salmonis*, treatment.

Sea lice are a naturally occurring ectoparasite of wild salmon (Nagasawa 2001; Beamish, Neville, Sweeting & Ambers 2005). There is also clear evidence that these parasites are seldom a production or fish health concern on farms in British Columbia (Saksida, Constantine, Karreman & Donald 2007), in direct contrast to most other salmon-producing regions (Heuch, Revie & Gettinby 2003; O'Donohoe, Kane, Kelly, Nixon, Power, Naughton & Jackson 2008; Lees, Gettinby & Revie 2008a). Nevertheless, owing to concerns regarding the potential impact of sea lice originating from farmed Atlantic salmon, *Salmo salar* L., on wild Pacific salmon species, *Oncorhynchus* spp., in BC, their effective control continues to be a subject of considerable interest (Morton, Routledge, Peet & Ladwig 2004; Krkošek, Ford, Morton, Lele, Myers & Lewis 2007). Indeed, it has been suggested that the recent reductions in sea lice infestations on wild salmonids in the Broughton Archipelago (an area of major research focus over the past 5 years) are a consequence of improved lice management actions on salmon farms (Harvey 2009). While a number of management practices, such as single year-class production and between-cycle fallowing, can have a positive effect on lice control within farms, the most direct effects are associated with the use of medicines to control sea lice. This is particularly the case if a goal is to minimize lice numbers at a specific point in the production cycle, for example during the period when wild smolts are most likely to be migrating past farms.

In 2003, BC regulatory authorities established requirements that farms maintain lice abundance below a threshold of three motile stage *Lepeophtheirus salmonis* between March and June (Saksida *et al.* 2007). In 2004, these same authorities commenced a sea lice surveillance programme where between 25% and 50% of active Atlantic salmon farms were assessed by government biologists for sea lice during each quarter to verify reported levels (Saksida *et al.* 2007). These regulations have not changed. In BC, the only product that is currently available to treat sea lice on salmon farms is SLICE® (Intervet Schering-Plough Animal Health). SLICE® is an oral formulation of emamectin benzoate, which is added to fish feed and delivered at a dosage of 0.5 μg kg^{-1} fish for 7 days. There have been a number of reports indicating reduced efficacy of emamectin benzoate when used on farmed fish in a range of other salmon-producing countries. These include Chile (Bravo, Sevatdal & Horsberg 2008) and Scotland (Lees, Baillie, Gettinby & Revie 2008b), with less well-documented reports in Ireland (O'Donohoe *et al.* 2008 – non-specific report of 'reduced sensitivities',

Correspondence *S M Saksida, British Columbia Centre for Aquatic Health Sciences, PO Box 277 Island Highway, Campbell River, BC, Canada V9W 2P0*
(e-mail: sonja.saksida@cahs-bc.ca)

Journal of Fish Diseases

p.19) and Norway (personal communication – T. Horsberg, 7/1/2010). In the summer of 2009, the relevant authorities issued licences for the use of two alternative sea lice medicines in eastern Canada owing to growing evidence that SLICE® was becoming ineffective on farms in the Bay of Fundy (AVC-CAHS 2009). Given these developments, it is important to ascertain the situation with respect to treatment efficacy on farms in British Columbia and that is the main purpose of this communication.

The most commonly occurring species of sea lice on farmed Atlantic salmon in BC is *L. salmonis* (Beamish, Jones, Neville, Sweeting, Karreman, Saksida & Gordon 2006; Saksida *et al.* 2007). While *Caligus clemensi* can also occur, infestations with this species tend to be at a lower level and are more sporadic. In addition, the evidence of tolerance in sea lice to emamectin benzoate from other regions has been associated with *L. salmonis* (the exception being Chile where this species does not occur and the tolerance has been observed in populations of *Caligus rogercresseyi*). For these reasons, the study reported here focuses on *L. salmonis* and compares treatments using SLICE® on farms in BC to examine evidence for changes in efficacy since the implementation of mandatory monitoring and the establishment of recommended treatment thresholds in 2003.

Treatment efficacy was determined by comparing post-treatment motile (preadult and adult stages) *L. salmonis* abundance levels with those recorded prior to treatment. The methodology is similar to that outlined by Lees *et al.* (2008b) to evaluate changes in efficacy of emamectin benzoate used on Scottish salmon farms. Sea lice treatments on farms operated by Marine Harvest Canada between 2003 and 2008 are shown in Table 1. During this period, between 15 and 39 farms were operated by Marine Harvest Canada in BC. Over these years, the proportion of farms that did not treat for sea lice in a given year varied from around one-fifth to over a half (18% in 2004 to 58% in 2007), with the number of treatments on farms that did treat ranging from one to two. More treatments were administered during the second year of production, when compared to the number of treatments given in the first 12 months of post-seawater transfer. In the years for which efficacy assessments were carried out, there was a moderate preponderance of treatments in the autumn and winter (October–March) – 60%, 82% and 56% of all treatments took place in those seasons in 2003, 2007 and 2008, respectively.

Table 1 Number of farms stocked with salmon by Marine Harvest Canada, the total number and range of SLICE® treatments, and the number of farms that did not treat for sea lice in each year between 2003 and 2008

Year	Farms in operation	Total number of treatments (on all farms)	Treatments per farm (range)	Number of farms not treated
2003	15	7	1	8
2004	17	16	1–2	3
2005	24	19	1–2	6
2006	32	24	1–2	10
2007	38	18	1–2	22
2008	39	24	1–2	18

To assess changes in efficacy, sea lice abundance records from farms operated by Marine Harvest Canada that treated for sea lice in 2003, 2007 and 2008 were examined. Only records from farms on which all fish groups were treated with SLICE® simultaneously and for which adequate sea lice counts have been recorded pre- and post-treatment were considered. To establish meaningful pretreatment sea lice levels for comparison, at least one lice count had to be available for a farm in the period 3 weeks prior to the start of treatment. If sea lice counts were available more than once in that period, then the result from the evaluation closest to the start of treatment was used as the baseline. In practice, the precounts tended to be 1–2 weeks prior to treatment with the following mean [range] value for 2003, 2007 and 2008, respectively: 11.2 days [6, 23]; 8.5 days [1, 19]; and 11.3 days [3, 17]. To be able to evaluate efficacy, only treatments for which sea lice levels were monitored at least three times within a 13- week period post-treatment were included in the final data set. These restrictions reduced the number of records available for the analysis to five for 2003, 11 for 2007 and nine for 2008 (i.e. to 71%, 61% and 38%, respectively, of the total treatments administered in those years).

Treatment efficacy was evaluated in both absolute and percentage terms (Gustafson, Ellis, Robinson, Marenghi & Endris 2006). In the latter case, efficacy was estimated for each week in the period post-treatment according to the following calculation: Treatment Efficacy = [(mean motile count post-treatment/mean motile count pretreatment) × 100]. Simple statistical tests including Students *t*-test and analysis of variance (ANOVA) were used to examine for differences in sea lice levels following treatment. A Tukey HSD test was used for multiple comparisons for data found significant with ANOVA.

Figure 1a illustrates the mean motile *L. salmonis* levels pretreatment and for the 3 months following treatment. The data indicate that there does not appear to have been a change in motile levels that initiate a treatment; no significant differences in lice levels prior to treatment were found across the years ($P = 0.62$). The data also indicate that SLICE® remained effective in reducing motile sea lice levels, resulting in counts significantly below pretreatment levels for at least 3 months post-treatment ($P < 0.01$ for all comparisons). Furthermore, following treatment, sea lice levels were maintained at or below the three-motile *L. salmonis* threshold level for at least 3 months.

Figure 1b summarizes the efficacy of treatments on BC farms in terms of mean percentage reduction for each at 13 weeks post-treatment. In both 2003 and 2007, sea lice levels dropped below pretreatment levels in the week immediately subsequent to treatment (day 7–13), while in 2008, the drop appeared to be observed a little later. However, in all 3 years, by 1 month (26–34 days) after treatment, levels had fallen to below 20% of pretreatment levels. Thereafter, with

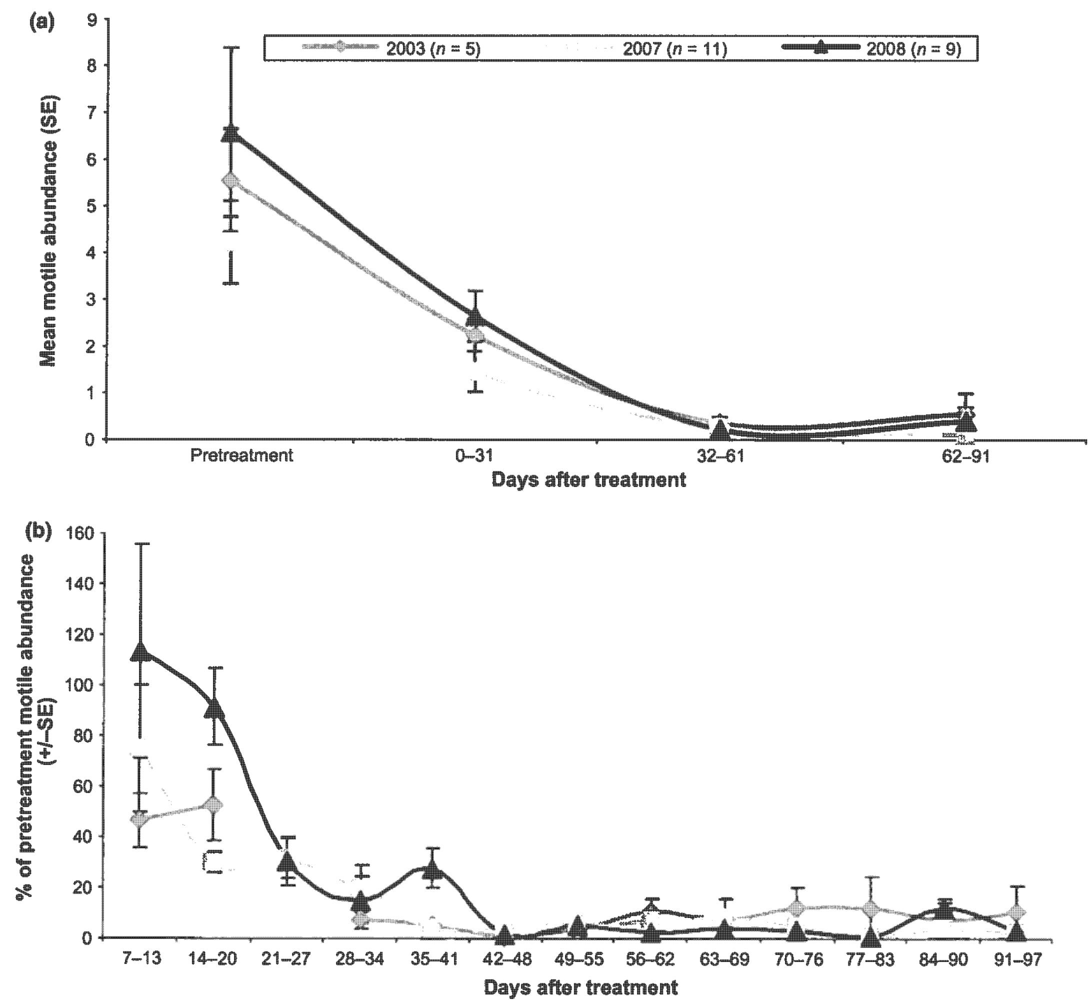

Figure 1 (a) Mean motile *Lepeophtheirus salmonis* abundance, pretreatment and from 0 to 91 days after commencement of treatment. (b) Post-treatment motile *L. salmonis* abundance as a percentage of pretreatment abundance, from 7 to 97 days after commencement of treatment.

the exception of one time period in 2008 (days 35–41), levels remained at or below 10% of pretreatment levels for the duration of the period examined. Lees *et al.* (2008c) defined an 'effective' treatment in Scotland as a treatment where the abundance of motile *L. salmonis* fell to < 40% of their pretreatment level at some point in the 13 weeks post-treatment. Based on this definition, all of the treatments evaluated in BC clearly fulfilled the criterion of being effective, with levels by 13 weeks post-treatment remaining at or below 10% of pretreatment levels. The data presented here suggest that, unlike most other salmon-farming regions, a decline in efficacy of SLICE® is not evident on salmon farms in British Columbia. This can be seen when comparing detailed efficacy profiles from 2003 to those of more recent years, but also from the simple fact that the number of annual treatments has remained constant between 2003 and 2009 (data not shown for this latest year).

The situation with respect to sea lice on BC salmon farms differs from other regions in a number of ways. There are significant numbers of wild salmon in the Pacific Ocean, and the presence of these large untreated populations may reduce the selection pressures that appear to be at work in regions where there are fewer wild hosts. In addition, there is evidence of a genetic difference between the Atlantic and Pacific *L. salmonis* (Yazawa, Yasuike, Leong, von Schalburg, Cooper, Beetz-Sargent, Robb, Davidson, Jones & Koop 2008), and the health implications associated with infection by the Pacific species appear to be more benign, leading to a significantly lower treatment requirement. It is unclear at this point whether these differences fully explain the continued effectiveness of SLICE® as a sea lice treatment in BC. Continued monitoring of lice levels and treatment efficacy, establishment of bioassay baselines and access to alternative sea lice treatments as part of an integrated pest management programme are all essential in ensuring that efficacy is not diminished in the future.

Acknowledgements

We acknowledge the support of the range of Marine Harvest Canada field staff for continued lice monitoring and in particular the efforts of Brad Boyce who provided access to the lice and treatment data.

References

AVC-CAHS (2009) *Sea Lice Tolerance to Emamectin Benzoate (SLICE®)*: Investigation and Standardization of Bioassays. Confidential report by the Centre for Aquatic Health Sciences (CAHS) to DFO Aquaculture Management Directorate.

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

Beamish R.J., Jones S., Neville C.M., Sweeting R., Karreman G., Saksida S. & Gordon E. (2006) Exceptional marine survival of pink salmon that entered the marine environment in 2003 suggests that farmed Atlantic salmon and Pacific salmon can coexist successfully in a marine ecosystem on the Pacific coast of Canada. *ICES Journal of Marine Science* **63**, 1326–1337.

Bravo S., Sevatdal S. & Horsberg T.E. (2008) Sensitivity assessment of *Caligus rogercresseyi* to emamectin benzoate in Chile. *Aquaculture* **282**, 7–12.

Gustafson L., Ellis S., Robinson T., Marenghi F. & Endris R. (2006) Efficacy of emamectin benzoate against sea lice infestations of Atlantic salmon, *Salmo salar* L.: evaluation in the absence of an untreated contemporary control. *Journal of Fish Diseases* **29**, 621–627.

Harvey B. (2009) Sea Lice and Salmon Farms: A Second Look. BC Pacific Salmon Forum report. Available at: http://www.pacificsalmonforum.ca/pdfs-all-docs/SeaLouseUpdate2009.pdf.

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**, 539–551.

Krkošek M., Ford J.S., Morton A., Lele S., Myers R.A. & Lewis M.A. (2007) Declining wild salmon populations in relation to parasites from farm salmon. *Science* **318**, 1772–1775.

Lees F., Gettinby G. & Revie C.W. (2008a) Changes in epidemiological patterns of sea lice infestation on farmed Atlantic salmon, *Salmo salar* L., in Scotland between 1996 and 2006. *Journal of Fish Diseases* **31**, 251–262.

Lees F., Baillie M., Gettinby G. & Revie C.W. (2008b) The efficacy of emamectin benzoate against infestations of *Lepeophtheirus salmonis* on farmed Atlantic salmon (*Salmo salar* L) in Scotland between 2002 and 2006. *PLoS ONE* **3**, e1549.F.

Lees F., Baillie M., Gettinby G. & Revie C.W. (2008c) Factors associated with changing efficacy of emamectin benzoate against infestations of *Lepeophtheirus salmonis* on Scottish salmon farms. *Journal of Fish Diseases* **31**, 947–951.

Morton A., Routledge R., Peet C. & Ladwig A. (2004) Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in the nearshore marine environment of British Columbia, Canada. *Canadian Journal of Fisheries & Aquatic Sciences* **61**, 147–157.

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**, 411–416.

O'Donohoe P., Kane F., Kelly S., Nixon P., Power A., Naughton O. & Jackson D. (2008) National Survey of Sea Lice

(*Lepeophtheirus salmonis* Krøyer and *Caligus elongatus* Nordmann) on Fish Farms on Ireland – 2007. Available at: http://www.marine.ie/home/publicationsdata/publications/Irish+Fisheries+Bulletin.htm.

Saksida S., Constantine J., Karreman G.A. & Donald A. (2007) Evaluation of sea lice abundance levels on farmed Atlantic salmon (*Salmo salar* L.) located in the Broughton Archipelago of British Columbia from 2003 to 2005. *Aquaculture Research* **38,** 219–231.

Yazawa R., Yasuike M., Leong J., von Schalburg K.R., Cooper G.A., Beetz-Sargent M., Robb A., Davidson W.S., Jones S.R.M. & Koop B.F. (2008) EST and mitochondrial DNA sequences support a distinct Pacific form of salmon louse, *Lepeophtheirus salmonis*. *Marine Biotechnology* **10,** 741–749.

Received: 20 February 2010
Revision received: 14 June 2010
Accepted: 17 June 2010

