Available online at www.sciencedirect.com
ScienceDirect
Fisheries Research 91 (2008) 35–41
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

The prevalence, density and impact of *Lepeophtheirus salmonis* (Krøyer) infestation on juvenile pink salmon (*Oncorhynchus gorbuscha*) from the central coast of British Columbia, Canada

Kevin G. Butterworth [a,*], K. Fiona Cubitt [b], R. Scott McKinley [b]

[a] *BC Centre for Aquatic Health Sciences, 621 Island Highway, P.O. Box 277, Campbell River, British Columbia, Canada V9W5B1*
[b] *Centre for Aquaculture and Environmental Research, University of British Columbia, 4160 Marine Drive, West Vancouver, British Columbia, Canada V7V1N6*

Received 5 January 2007; received in revised form 1 November 2007; accepted 5 November 2007

Abstract

Juvenile Pacific pink salmon (*Oncorhynchus gorbuscha*) were captured by beach seine in two adjacent channels leading from headwaters to coastal marine areas in 2004 and examined for sea lice. The sample sites represented the key areas of potential wild/farmed interaction by sea lice (*Lepeophtheirus salmonis* and *Caligus clemensi*) in the Finlayson and Mathieson Channels. The mean prevalence of infestation was 18.4% with a mean density of 0.28–0.64 lice g^{-1}. The ratio of *L. salmonis* life stages was 26%:35%:39% for copepodid/chalimus:pre-adult:adult life stages respectively. There was no significant effect of sample site on sea lice prevalence. There was a significant increase in sea lice density between headwater and seaward sample sites. Significantly higher condition indices were recorded for pink salmon from the Finlayson Channel compared to the Mathieson Channel. There was no significant effect of sample site on condition indices within each channel between sample sites towards the headwaters, adjacent to and seaward from commercial salmon farms. There was no effect of sea lice density on the condition indices of juvenile pink salmon sampled at each site.

Keywords: Sea lice; *Lepeophtheirus salmonis*; *Oncorhynchus gorbuscha*; Pink salmon; Condition index

1. Introduction

The alleged role of commercial net-pen salmon farms as a possible source of *Lepeophtheirus salmonis* (Krøyer) infestations on passing wild Pacific salmon, has received much attention from both the scientific community and the popular press. Hence, this study has been focused on *L. salmonis* and not *Caligus clemensi*.

Given dispersal rates of the larval stages (O'Donoghue et al., 1998) by dynamic flow fields, caused by changing tides, currents and local shifts in wind direction, there is a huge potential for larval dispersal (Asplin et al., 1999, 2004). Therefore, more conclusive evidence is needed before a cause and effect relationship can be demonstrated between sea lice on salmon farms, and infection levels on wild Pacific salmon. The debate in British Columbia has focused around possible impacts of *L. salmonis* on pink salmon (*Oncorhynchus gorbuscha*) stocks in the Broughton Archipelago (Brooks, 2005). The controversy is based on correlatory evidence which link changes in sea lice infestation intensities on juvenile pacific salmon in near-shore habitats with proximity to commercial net-pen salmon farms (Morton et al., 2004, 2005; Morton and Routledge, 2006). This correlatory evidence adds to that previously reported in the Atlantic Ocean (Costelloe et al., 1996, 1998; Bjørn et al., 2001; Penston et al., 2002; McKibben and Hay, 2002).

There have been attempts by researchers to use alternative methods in a bid to ascertain the risks posed by sea lice from salmon farms to juvenile wild Pacific salmon. Successful mathematical models have been developed to examine populations of sea lice on farmed Atlantic salmon (Revie et al., 2005). Additionally, quantitative analysis (Krkosek et al., 2005, 2006) has been used to extrapolate the potential for sea lice to transfer between farmed salmon and wild juvenile Pacific salmon. The models do not allow for differences in sea lice development

* Corresponding author. Tel.: +1 250 286 6102; fax: +1 250 286 6103.
E-mail address: kevin.butterworth@cahs-bc.ca (K.G. Butterworth).

0165-7836/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.fishres.2007.11.018

rates due to salinity and temperature fluctuations, arguably the most important environmental factors affecting *L. salmonis* larval stage development (Butterworth et al., 2006). Additionally, current research suggests that pink salmon possess a mechanism that facilitates the rejection of attached larval stages of *L. salmonis* (Jones et al., 2006), a difficult factor to incorporate into a model as the nature of the mechanism is unknown.

The Finlayson and Mathieson Channels on the central coast of British Columbia, Canada support a range of fishery and aquaculture activities. There are conflicting reports and interpretations on the impacts of *L. salmonis* on juvenile wild Pacific salmon (Jones and Nemec, 2004; Morton et al., 2004, 2005; Krkosek et al., 2005, 2006; Beamish et al., 2005, 2006; Jones et al., 2006). Hence there is the potential for net-pen salmon farms in this region to impact the levels of *L. salmonis* on adjacent wild salmon stocks.

The aim of this study was to examine the prevalence, infestation density, life history and impact of *L. salmonis* on juvenile pink salmon in the Finlayson and Mathieson Channels on the central coast of British Columbia, Canada. To achieve this aim, Aboriginal Ecological Knowledge (AEK) was utilised to identify sampling sites on the main routes of progression for juvenile pink salmon through these channels, from headwaters, past existing commercial net-pen salmon farms, to the Milbanke Sound. As with the sampling sites AEK was used to identify the main routes of progression of the juvenile pink salmon through the Finlayson and Mathieson Channels. The calculation of estimates of ordinary least-squares regression parameters, as discussed by Cone (1989), was used as a measure of condition index and indicator of fish health.

2. Methodology

2.1. Study area

Aboriginal Ecological Knowledge of routes used by juvenile pink salmon progressing through these channels was provided by the Kitasoo Fisheries Management and was used to determine the most effective sampling sites. The names and grid references of the sample sites are recorded in Table 1 which corresponds to those used on the map in Fig. 1. The sampling sites were located up-channel from commercial salmon farm tenures towards the headwaters of the channels, adjacent to commercial salmon farm tenures and seaward from commercial salmon farm tenures. Dashed arrows in Fig. 1 represent the net surface flow of water down the inlets into the coastal marine areas. Wild juvenile pink salmon were sampled from each of these areas over the period of the 4th–11th of June 2004.

At each site, juvenile pink salmon were captured using a 15.24 m beach seine with a 1.83 m drop. The bunt had a mesh size of 6.35 mm, and the end panels 12.7 mm. To negate possible loss of sea lice due to handling, the salmon were crowded as little a possible in the bunt. Due to the small size of the fish it was possible to backfill a plastic bucket (15 l) with water from the bunt by slow immersion which simultaneously carried salmon into the bucket without handling the salmon. This had the additional benefit of not crowding the fish which would potentially cause abrasion between the salmon and between the salmon and the bucket. The salmon were swiftly removed from the bucket by dip-net and individually examined for sea lice using a jeweler's loop. Individuals with sea lice ($n = 50$), and control sample ($n = 10$) were swiftly sacrificed with a blow to the head. The number of uninfected individuals examined whilst looking for infected pink salmon was recorded. The sea lice were identified, quantified and removed. The length of the pink salmon was recorded and species visually identified by a consensus of the researchers and the Kitasoo Fisheries Management staff involved in the sampling process. The sea lice were stored in 1.5 ml centrifuge tubes of 95% EtOH and placed on ice. For ease of comparison, the life stages of *L. salmonis* were separated into three groups, non-mobile (copepodid and chalimus), pre-adult (pre-adult 1 and 2) and adult (adult ♀ and ♂). The pink salmon carcasses were individually sealed in a plastic bag which were individually labeled and placed on ice.

Upon return to the laboratory the weight of the salmon was recorded (Acculab VI-200). To ensure quality control, the individual pink salmon carcasses were examined in the laboratory for any sea lice that may have been overlooked. All sea lice (*L. salmonis* and *C. clemensi*) were cataloged against the original capture records, examined for a second time and identified to species and life stage (Galbraith, 2005), using a dissecting microscope.

2.2. Condition index

The relative condition of each fish was evaluated by regressing ln W (weight) vs. ln L (length) as described by Cone (1989). The regression line was calculated using the length (mm) and weight (g) data from the control (uninfected) pink salmon. The

Table 1
The location names, sampling dates, grid references, catch data, sea lice prevalence, mean infestation intensities and mean infestation densities from each sample site

Site and sampling date	Grid reference	Site no.	No. of pink salmon	Prevalence (%)	Mean intensity ± σ (lice salmon^{-1})	Mean density ± σ (lice g^{-1})
Mary's Cove 11/06/04	N52°36′45.6″ W128°26′37.6″	1	428	11.7	1.58 ± 0.76	0.46 ± 0.38
McPherson/HPC 07/06/04	N52°34′16.2″ W128°14′25.3″	2	191	26.2	1.68 ± 1.06	0.62 ± 0.70
Jackson Passage* 11/06/04	N52°32′48.7″ W128°26′04.5″	3	200	25	2.26 ± 1.63	0.47 ± 0.39
Arthur Island* 10/06/04	N52°26′30.0″ W128°16′57.7″	4	262	19.1	2.58 ± 1.71	0.37 ± 0.30
Dowager 04/06/04	N52°26′29.9″ W128°24′44.0″	5	302	16.6	1.62 ± 0.88	0.65 ± 0.6
Tom Bay 08/06/04	N52°23′47.9″ W128°16′02.5″	6	250	20	1.5 ± 0.91	0.28 ± 0.18

Sample sites adjacent to commercial net-pen salmon farms are marked with an asterisk (*).