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RAINCOAST CONSERVATION SOCIETY

Science Bulletin
Fish Farm Link to Sea Lice Infections on B.C. Wild Salmon Confirmed

Transmission Dynamics of Parasitic Sea Lice from Farm to Wild Salmon

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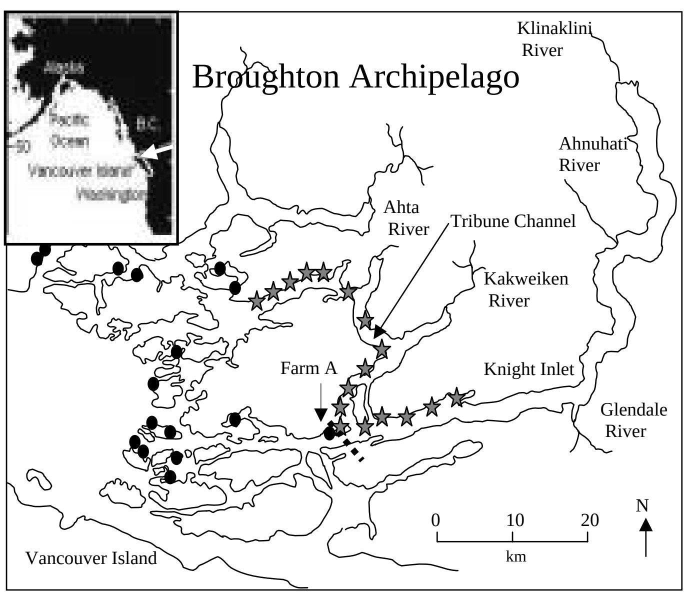
Salmon farming has been associated with sea lice infestations of wild juvenile salmon and wild salmon population declines in B.C.'s Broughton Archipelago. Despite a strong weight of evidence, the causal nature of these relationships has been highly contentious. A scientific consensus has been limited, in part, by an inability to adequately track the movement of these parasites between farmed and wild salmon.

Infection pressure near the farm was approximately 70 times greater than natural levels & exceeded ambient levels for 30 km.

Research Summary This peer-reviewed report looks at lice infestations on wild juvenile pink and chum salmon as they migrated past an isolated salmon farm down a long and narrow migration corridor in the Broughton Archipelago, BC (see Box 1). Mathematical models were used to analyze these data (see Box 2) and revealed juvenile salmon were initially infected with sea lice originating from two host populations: farm salmon and naturally occurring hosts. The calculations suggest the infection pressure near the farm was approximately 70 times greater than natural ambient levels and exceeded ambient levels for 30 km of migration route (see Box 3). This amounts to a total direct contribution of sea lice from the farm that was approximately 30,000 times greater than the natural production of sea lice in the length of habitat occupied by the salmon farm.



Box 1. Study Area

- ★ **Sample sites**,
- • **Active salmon farms**

Salmon Migration Juvenile pink and chum salmon originate in freshwater streams in Knight Inlet. They must then travel south and west down the inlet toward Tribune channel and either continue down Knight Inlet or travel through Tribune Channel on their way to sea.

Sample Sites Farm A is the first salmon farm juvenile salmon would encounter along their migration and is the focus of this analysis presented here.

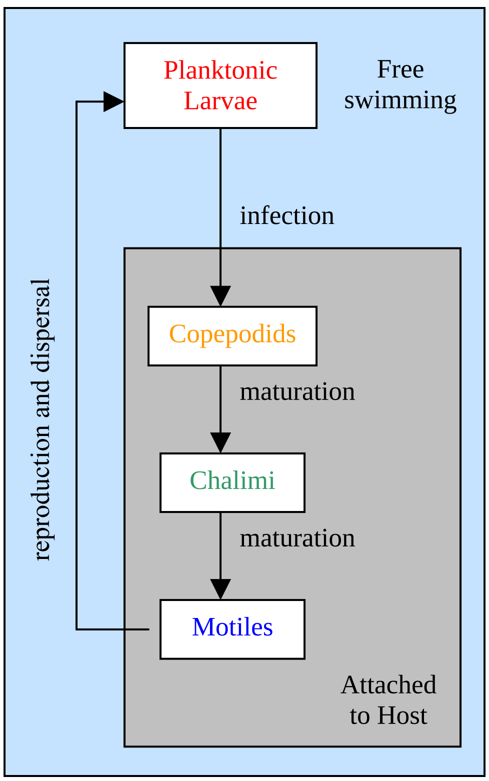
Data All sites were sampled within a 14-day period in May 2003 resulting in a high-resolution dataset of sea lice infection levels on juvenile pink and chum salmon as they passed an isolated salmon farm (Farm A). The non-lethal sampling of approximately 5500 fish far surpasses the sampling intensity other B.C. studies. Please refer to the source paper[iv] and Krkošek et al 2005b[v] for the full methodology and analysis.

Second Generation of Farm-Origin Lice Causes Additional Infection The results also show that lice, once transmitted to wild juvenile salmon, were transported down the migration route where they reproduced and re-infected the wild juvenile salmon. Inclusion of this second generation of lice raises the farm-origin infection pressure above natural levels for approximately 75 km of migration route resulting in a total direct and indirect contribution of sea lice that was 200,000 times greater than the natural production of sea lice in the length of habitat occupied by the salmon farm. This transport and reproduction of farm-origin lice raises the possibility for disease growth and spread to other wild salmon populations up and down the coast.

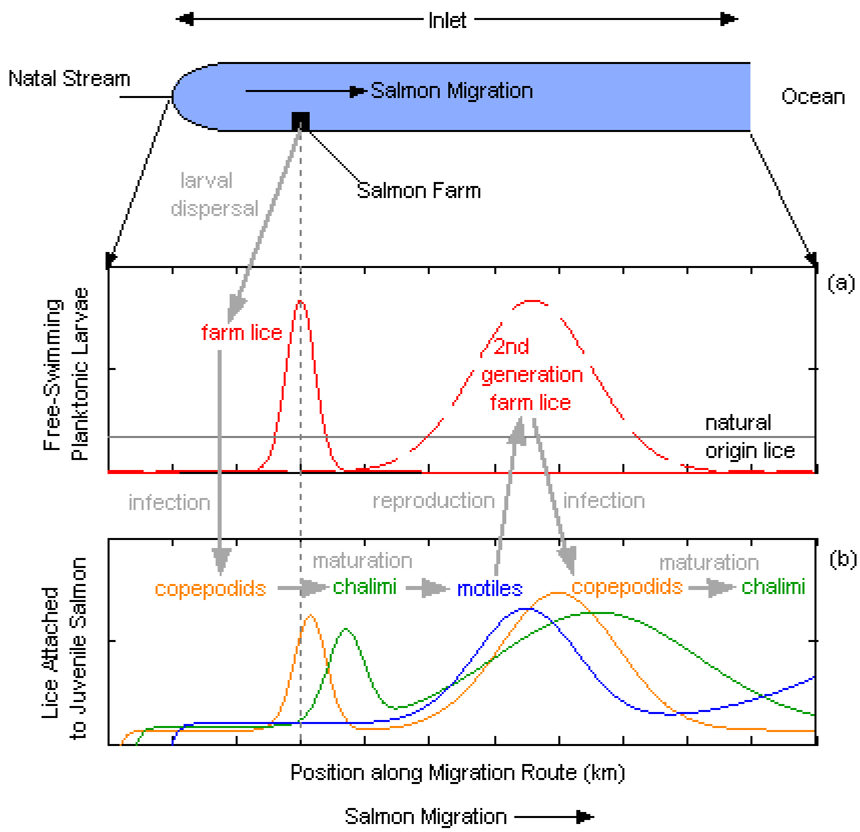
These data satisfy even the most conservative benchmark for proof - this is the definitive work on the issue.

Box 2. Louse Lifecycle and Transmission Dynamics

Louse Lifecycle



Transmission Dynamics Model



Life Cycle The two main stages are free-swimming planktonic larvae and attached parasites. Free-swimming larvae must attach to a host fish and the first attached stage is the copepodid (orange), which then develops through chalimus (green) and motile (blue) stages. Motile lice include sexually reproductive adults, whose progeny are released into the water column as planktonic larvae, completing the lifecycle.

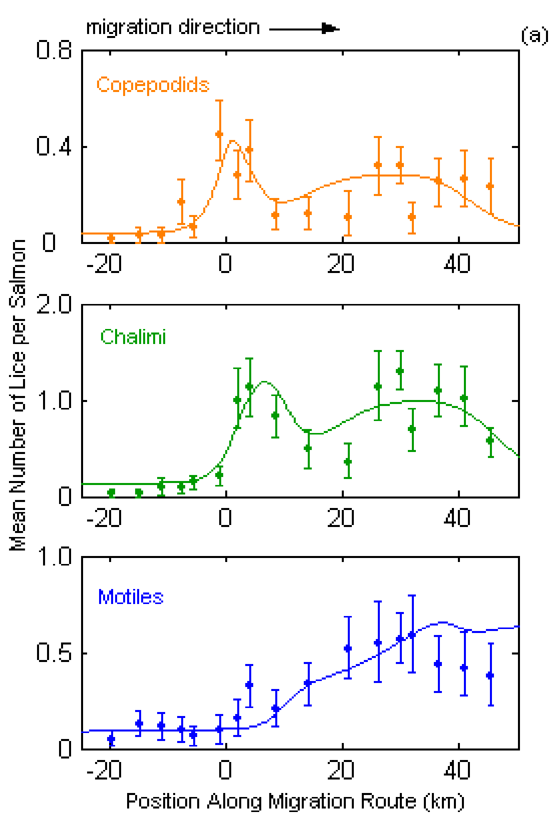
Transmission Dynamics The model combines the sea lice lifecycle with interactions among farmed salmon, alternate natural hosts, and wild out-migrating juvenile salmon. The graphs illustrate how juvenile salmon, which enter the marine environment free of lice, migrate past salmon farms and are infected with sea lice. The second spike in lice is from reproduction by the farm-origin lice on the wild fish, after the wild fish have moved on past the farm.

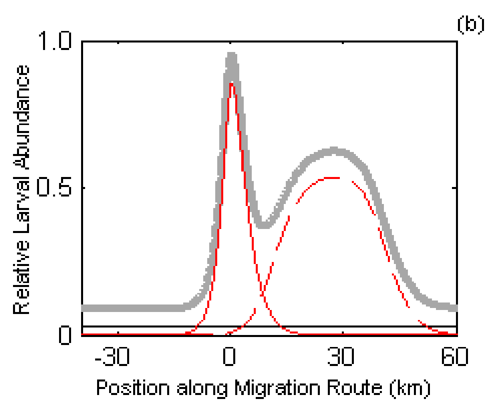
The transmission dynamics of lice between farmed and wild juvenile salmon follow the progression shown by the thick grey arrows. Larvae are produced by farmed salmon, disperse into the surrounding environment, infect juvenile salmon, and subsequently mature and reproduce on the wild fish.

Sea Lice (*Lepeophtheirus salmonis* and *Caligus clemensi*)
Sea lice have two distinct phases in their lifecycles – planktonic and parasitic. Planktonic larvae float freely in the water and allow lice to be transmitted between wild and farmed salmon. During the second, parasitic phase, lice attach themselves to a host salmon and feed on the surface of the fish – leading to increased disease and sometimes death in their infected hosts (See Box 2).

Links to Salmon Farms
Several European studies have correlated salmon farming with sea lice infestations of wild fish[i]. Several studies in B.C have examined this correlation and one study found that wild pink juvenile salmon were more heavily infected in salmon farming areas than in areas with no salmon farms[ii]. An additional study analyzed these relationships and discounted other non-salmon farm variables[iii]. The study described here is the first to quantify the spatial footprint of sea lice transmission from farm to wild salmon and track the subsequent farm-origin lineage of lice that infected wild salmon [iv].

These data, due to the massive sampling effort and the unequivocal nature of the conclusions, satisfy even the most conservative benchmark for proof - this is the definitive work on the issue. Sea lice counts released by Stolt Sea Farms confirm that study captures an average farm with sea lice numbers and stocking densities well within industry norms. Therefore the resultant transmission data are to be viewed as a conservative estimate of the impact of an "average" farm in the Broughton Archipelago.





Box 3. Model Agrees With Field Data

Graph (b) shows the model's inferred origins and spatial profiles of sea lice larvae that would be required to produce the patterns seen in the data (a). The red lines depict the location and relative abundances of planktonic larvae whose origin can be traced back to farmed salmon either directly or through one generation of lice.

Panels (a), above on the left, show actual louse abundances on juvenile pink and chum salmon as they passed Farm A, located at x=0. Points with 95% confidence bounds correspond to field data and the solid lines are the best fit of the model to the data.

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Implications

Given the increasing weight of evidence, including this research[iv], that salmon farms are a potentially lethal source of sea lice on wild salmon, there is ample evidence to compel precautionary action by regulators. The premise of industrial-scale open net aquaculture in wild salmon habitats needs to be reconsidered. The proposed expansion of the industry, including the introduction of new farmed species, throughout BC must be halted until the full ecological costs of this industry are understood. There is a clear potential for severe and irreversible damages to be inflicted upon wild salmon populations and their dependent cultures, ecosystems, and economies.

Research Published in Peer Reviewed Journal

The paper described here is published in the Proceedings of the Royal Society of London, Series B, March 2005 as, Krkošek, M., Lewis, M. A., & Volpe, J. P. *Transmission dynamics of parasitic sea lice from farm to wild salmon.*

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Salmon fry with sea lice
A. Morton photo

[i]McVicar, A. H. 2004 Management actions in relation to the controversy about salmon lice infections in fish farms as a hazard to wild salmonid populations. *Aquaculture Research*. 35, 751–758.
[ii] Morton, A., Routledge, R., Peet, C., & Ladwig, A. 2004 Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. Keta*) salmon in the near shore marine environment of British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences.* 61,147-157.
[iii] Williams, I., Groot, C., & Walthers, L. 2004. Possible Factors Contributing to the Low Productivity of the 2000 brood Year Pink Salmon *(Oncorhynchus gorbuscha). David Suzuki Foundation, 2004.*
[iv] Krkošek, M., Lewis, M. A., & Volpe, J. P. 2005a Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings of the Royal Society of London Series B, in press; on-line 30 March 2005.*
[v] Krkošek, M., Morton, A, & Volpe, J. P. 2005b Non-lethal assessment of juvenile pink and chum salmon for parasitic sea lice infections and fish health. *Transactions of the American Fisheries Society, in press.*

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