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Sea Lice: The Science Behind the Hype

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Contents

Summary Points / 2

Introduction / 3

What Are Sea Lice and Where Are They Found? / 3

Life Cycle / 5

Factors that Influence Sea Lice Development / 6

Differences Between Sea Lice Populations in the North Pacific and Atlantic Oceans / 7

The Impact of Sea Lice on Salmon Health / 9

Sea Lice Epizootics / 11

The Interaction Between Wild and Farmed Salmon / 12

Current Research Focus / 13

Conclusions / 13

References / 15

About the Authors / 20

About this Publication / 22

About The Fraser Institute / 23

Summary Points

1. What are sea lice?

    - In BC, two often-confused species of small parasitic crustaceans, *Lepeophtheirus salmonis* and *Caligus clemensi* are commonly referred to as sea lice

2. Sea lice life cycle

    - Sea lice have both free-swimming and parasitic stages in their life cycle

3. Factors that influence sea lice development

    - Development rate increases with temperature; an increase from 7°C to 14°C can halve the time needed for development
    - Free swimming sea lice larval stages are intolerant of low salinities such as those found in BC's inshore waters.

4. Differences between sea lice populations in the north Pacific and Atlantic Oceans

    - In the Atlantic Ocean, farmed Atlantic salmon often outnumber wild Atlantic salmon, potentially providing a reservoir in which sea lice can survive over winter. In BC there is evidence that wild fish and sticklebacks provide a potential host reservoir for sea lice to over-winter.
    - Salinities are lower in the northern Pacific than in the Atlantic, a factor likely to decrease sea lice occurrence and development

5. The impact of sea lice on salmon health

    - Much of the information currently available on the impact of sea lice on salmon health is from Atlantic salmon, not Pacific salmon.
    - It is not known at this time what intensity (concentration) of sea lice has an effect on the health of Pacific salmon, nor what level would cause mortality

6. Sea lice epizootics[1]

    - Sea lice are native and prevalent (endemic) in the North Pacific ocean and are found on around 90 percent of Pacific salmon
    - As a result of their prevalence, it is likely that severe outbreaks will occur given the correct combination of environmental factors

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1 Affecting a large number of animals at the same time within a particular region or geographic area.

Introduction

Sea lice infestations are one of the most widely publicized issues regarding farmed fish in British Columbia. These small invertebrates have starred in documentaries (Bissell, 2005; Slinger, 2003), an advertising campaign (CAAR, 2005), and even a popular US television show (Boston Legal, 2005). But do these small parasites warrant all this attention? Current research reveals that Pacific salmon are less susceptible and more resilient to sea lice than Atlantic salmon. Furthermore, research into the actual effect of sea lice on Pacific salmon is, as yet, inconclusive.

What Are Sea Lice and Where Are They Found?

The term "sea lice" is a generic name, often with unpleasant connotations, used to describe a range of marine invertebrates that are generally small, and which have, for some reason, become part of popular culture. In southern Africa, "sea lice" is the common name for mole crabs, from the genus *Emerita*, which are innocuous burrowing crabs found on sandy, high energy shores and used as fishing bait. In the southern US, sea lice are planktonic organisms related to jellyfish and sea anemones. In this incarnation they pose a serious threat to human health because they sting thousands of swimmers every year. (There is a burgeoning industry providing suntan creams that negate the stings of these little jellyfish.)

In BC and other regions around the world where salmon are indigenous, the term sea lice (also called salmon lice) refers to the parasitic copepods often found on wild and farmed salmon. But even within the communities that encounter these copepods, there is an obvious problem of sea lice identification as there is frequently some confusion as to what they really are. Amongst some sport salmon fisherman and even salmon farm workers, harmless Cumacean shrimps (closely related to copepods) have been confidently identified to the authors as sea lice. The sea lice identification problem is exacerbated by conflicting reports in both the media and scientific publications on the impact of these lice on salmon health and even wild salmon returns (Morton *et al.*, 2004; Krkosek *et al.*, 2005; and Colcleugh, 2006).

The sea lice that naturally affect salmon and trout in the marine environment belong to the family *Caligidae* and to the genera, *Caligus* and *Lepeophtheirus*. In British Columbia, 14 species (2 species of *Caligus* and 12 species of *Lepeophtheirus*) of sea lice parasitize many different species of marine fish (Kabata, 1973). These 14 species of sea lice have a similar body shape. Differences within species of each of these two genera are small, and difficult to identify without the assistance of a magnifying glass and some taxonomic training. However, only two species, *Lepeoptheirus salmonis* and *Caligus clemensi*, pose a potential threat to both farmed and wild salmon.

It is worth bearing in mind that there are difficulties in distinguishing between *Lepeophtheirus* and *Caligus* species (Butterworth *et al*., 2005). These difficulties can contribute significantly to the public perception of the impact of sea lice on both wild and farmed salmon. If these species are not correctly identified, the inferences that fishermen and the general public make about the origin of the sea lice on juvenile Pacific salmon can be incorrect.

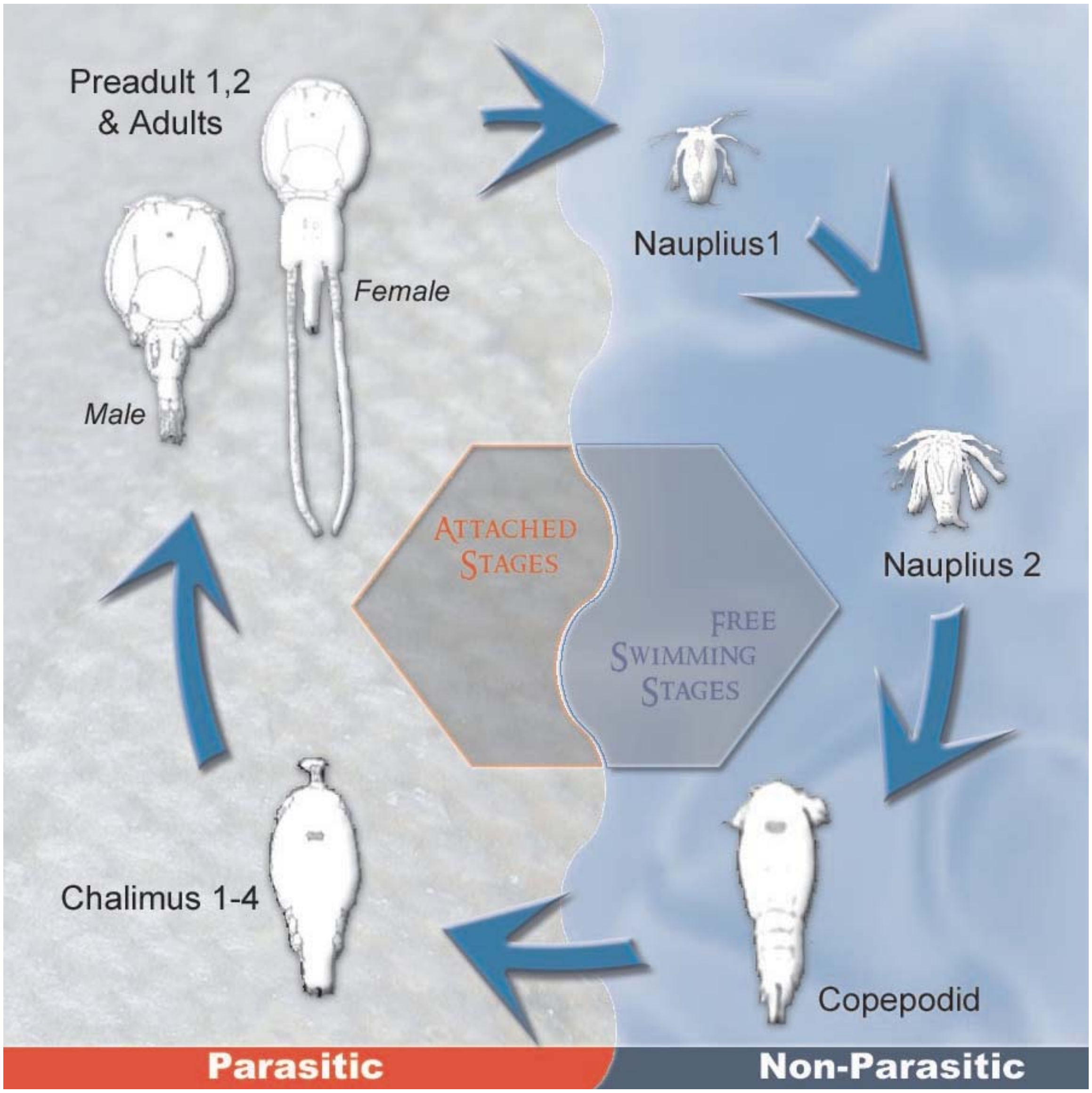
Caligus clemensi are found not just on one species of fish, but on a wide range of fish (for a detailed description, see Kabata, 1988). They are most commonly found in large numbers on herring, hence the common name, herring louse. *C. clemensi* can be found on farmed and wild salmon, often after they have had close encounters with herring. In other regions of the world, other *Caligus* species are more important to farmed salmon fisheries, specifically, *Caligus rogercresseyi* in Chile, and *Caligus elongatus* in Europe and eastern Canada. These are very mobile parasites that abandon their host very quickly if they are handled. Hence, there is some evidence that the abundance of these species of *Caligus* on wild salmon has been severely underestimated (Chris Todd, 2004, personal communication).

In the context of salmon aquaculture and wild salmon in British Columbia, *Lepeophtheirus salmonis* is the important species. Also commonly known as the salmon louse, *L. salmonis* is a parasitic caligid copepod (Johnson and Albright, 1991; Butterworth *et al*., 2004). Ubiquitous in the North Pacific and Atlantic Oceans (Kabata, 1973), it is a parasite on both farmed (Pike, 1989) and wild (Johnson *et al*., 1996) salmon as well as on sea-run trout. High infection intensities[2] on salmon through either primary lesions or secondary infections (Pike and Wadsworth, 1999), lead to stress, impaired performance, reduced physiological ability (Bjørn and Finstad, 1997; Bowers *et al*., 2000; Finstad *et al*. 2000; and Wagner *et al*., 2003), and in extreme cases, death (Kevin Butterworth, 2005, personal communication).

Because *L. salmonis* is the species associated with both wild salmon and farmed salmon in BC, it is to this species that we refer in the rest of this document when we use the name "sea lice." The success of this parasite is demonstrated by the cost of sea lice outbreaks to the aquaculture industry worldwide, which is estimated to be between Can $38 million and Can $95 million in Norway (Boxaspen and Næss, 2000). An updated review of the salmon lice situation in Norway is given in Heuch *et al*., 2005.

2 Infection intensity is the number of lice infesting a single salmon.

Figure 1: Life Cycle of *Lepeophtheirus salmonis*



Source: Catherina Murphy, AquaNet Canada *(www.aquanet.ca)*. Reprinted with permission.

Life Cycle

Overall, *L. salmonis* has 11 life stages, from the egg through to the adult stage (see figure 1). The first three stages are free-swimming and non-parasitic. The larval sea lice then finds a host and progresses through 7 parasitic life stages before the next generation of eggs are produced (Johnson and Albright, 1991).

Factors that Influence Sea Lice Development

Environmental factors that have the most impact on the development and success of the infective larval stage (the copepodid stage) in settling onto a new salmon host are temperature and salinity. Depending on the combination, these two factors can either promote swift growth and survival of sea lice, or retard their development and severely reduce their survival.

Temperature

Research has shown that at lower temperatures (below 7°C), sea lice in the free swimming copepodid stage are less able to take the next step and settle onto a host than when the water temperature is warmer (Tucker *et al*., 2000). The speed with which the sea lice develop from an egg to the copepodid stage is also temperature dependant. It takes approximately 10 to 14 days to develop from the egg to the copepodid stage when the water is between 7 and 8°C. However, as with most crustaceans, elevated temperatures not only increase activity, but also growth. Hence, at higher temperatures, such as those found in late summer in British Columbia (±14°C), the copepodid stage will develop much faster, and be better able to settle on passing salmon. In fact, the development time can be halved (Butterworth, 2005, personal observation). The impact of temperature on the overall generation times[3] for sea lice is equally pronounced. At 7.5°C, the generation time is 106 days, but at 14°C, the generation time is 36 days (Tully, 1992). Such temperature-dependant growth rates can potentially have a significant impact on population densities of the copepodid life stage (settlement stage) of *L. salmonis* in shallow coastal waters, which are prone to warming.

Salinity

Salinity plays a very important part in the life cycle of *L. salmonis*. Successful development of the copepodid stage has been reported in the literature to only occur at salinities above 30‰[4] (Pike and Wadsworth, 1999), like those found in the North Atlantic, which averages 37.9‰, and the North Sea at ±35‰ (Swensen, 2004). However, in British Columbia, successful development to the copepodid stage and subsequent settlement onto a host has been achieved at salinities as low as 28‰ (Butterworth, 2005, personal obser-

3 The time taken to complete one full generation. Hence, the time taken for the sea lice to grow from a egg through to adult until it produces the next generation of eggs.

4 Parts per thousand (denoted by the premille symbol). This measure is used to record the salinity of seawater and is denoted as 1 part in 10^3.

vation). Once at this stage, copepodids actively avoid sea water with a salinity below 20‰ (Heuch, 1995); their optimal survival is at 30‰ (Johnson and Albright, 1991). Hence, lower salinities of around 27 to 30‰, such as those commonly recorded in BC inshore waters, could have a significant damping effect on *L. salmonis* distribution and population sizes.

As fresh water is less dense than salt water, lower salinities tend to be found in the ocean's surface layers. There is a theory that sea lice copepodids actively avoid lower salinities by migrating to lower depths at higher salinities. Hence, the vertical migration patterns of salmon smolts[5] may affect their risk of infestation.

Differences Between Sea Lice Populations in the North Pacific and Atlantic Oceans

Species and population differences

In the North Atlantic, *L. salmonis* has been a severe problem for both farmed and wild salmonids (Fast *et al.*, 2002; Stone *et al.*, 2002; Glover *et al.*, 2003, 2004; Heuch *et al.*, 2003; Wagner *et al.*, 2003, 2004). Atlantic salmon make up the bulk of finfish aquaculture in the North Atlantic and *L. salmonis* have had a large impact on wild Atlantic salmon and the sea-run brown trout (*Salmo trutta*). After years of pollution, over fishing (Berry, 2000), and destruction of natural stream habitat, the population of wild salmon stocks in the North Atlantic have decreased (Hiscock *et al.*, 2005). That decrease and the poor ability of Atlantic salmon to re-establish populations in traditional spawning streams (Cubitt *et al.*, 2006) have led to farmed Atlantic salmon outnumbering wild Atlantic salmon in some locations.

However, the situation in the North Pacific along British Columbia's coast is rather different. First, instead of one species of migrating salmon, there are five that undertake long migrations. To complicate the picture further, *L. salmonis* shows differential levels of prevalence on different species of Pacific salmon. In the Pacific Ocean, the highest levels of infection have been reported on Pink salmon (*Oncorhynchus gorbuscha*) and rainbow trout (*O. mykiss*) (Nagasawa, 2001). Lower infection levels were found on Coho salmon (*O. kisutch*), Chum salmon (*O. keta*) and Chinook salmon (*O. tshawytscha*). The Sockeye salmon (*O. nerka*) had the lowest infection levels (Nagasawa, 2001). However, this rela-

5 The salmon life stage between a parr (fresh water juvenile) and an adult, when the juvenile is at least one year old and has adapted to the marine environment.

tionship is poorly understood and subsequent surveys have shown high levels of sea lice on sockeye salmon in excess of those found on pink salmon (Beamish *et al.*, 2005).

In BC, wild salmon vastly outnumber farmed salmon. There are 128 salmon farm tenures[6] in BC, compared to more than 9,600 distinct stocks of wild Pacific salmon identified on the BC coast. All of these distinct stocks are considered to be separate populations, subject to unique environmental and anthropogenic[7] pressures. Additionally, over-wintering wild coho and chinook salmon (Healey, 1991; Sandercock, 1992) and schools of wild sticklebacks (Jones *et al.*, 2006) in coastal waters provide an ideal stock of potential hosts upon which the sea lice can over-winter, ready to infect out-migrating wild smolts in the spring. Hence, there is a large potential reservoir of sea lice associated with wild fish, not farmed salmon. This is the opposite of the North Atlantic, where due to the severe depletion of wild fish stocks, it is primarily the salmon farms that contain the largest pool of potential hosts upon which sea lice can over-winter.

Hydrographical differences

Due to the sensitivity of sea lice to salinity, local hydrographical[8] differences can have a direct effect on sea lice lifecycle viability. Inshore waters of the North Atlantic, such as those along the Norwegian Coast, have an average salinity of 33-34‰ at 10 meters depth (Heuch *et al.*, 2005). The Broughton Archipelago of British Columbia, has an average salinity of 29-30‰ at 10 meters depth (Brooks, 2005). This difference between Norway and British Columbia reflects the overall differences between the North Atlantic and North Pacific Oceans (of the major oceans, the North Atlantic has the highest salinity at an average of 37.9 ‰). However, the salinity in the upper layers varies according to the fresh water run-off in the area. Hence, the surface salinity and vertical gradient of mixing can vary significantly from area to area.

In the Atlantic Ocean, there has been extensive anthropogenic impact on the rivers and streams by farming activity, the creation of dams for irrigation and hydroelectric power generation, or major changes to the course of rivers for navigable purposes. All of this impact has not only decreased the available area of natural salmon habitat, but has also limited the influx of fresh water into inshore waters.

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6 Tenures convey property rights to marine resources from the crown to private firms within defined parameters, in this instance for the establishment of salmon net-pen farms.

7 Caused either directly or indirectly by human activities.

8 Hydrography is the measurement, description, and mapping of surface waters.

On Canada's west coast, the vegetation is predominately temperate rain forest.[9] Locally known as the Raincoast, these forests are some of the rarest intact inland and island ecosystems and receive an average of 1.8m (74"), of precipitation annually. Precipitation is heaviest in the winter and drops off during the spring to a low in the summer, before increasing swiftly in the fall. Additionally, Washington State's Puget Sound ranges in salinity from 21 to 27‰, in part due to the average of about 4.1 billion gallons of water per day discharged into the sound by surrounding rivers and streams (Swensen, 2004).

High precipitation causes a large influx of fresh water into the marine environment from rivers, via the inlets, and into coastal waters. As fresh water is less dense than salt water, it sits on top of the sea water and a strong, vertical salinity gradient (a halocline) forms between the two bodies of water. Large influxes of fresh water can dramatically affect the surface salinities found in coastal waters. This effect is exacerbated by the addition of glacial melt in the spring, when the new fry first start their migration to the sea. As discussed previously, sea lice are very sensitive to changes in salinity.

Areas of high precipitation, such as coastal British Columbia, are characterized by a low salinity layer on the surface of near-shore marine waters, which is detrimental to the development and survival of sea lice larvae. Heuch *et al.* (2002) have argued that such lower salinities are of paramount importance in restraining the growth of sea lice populations. However, it is possible that the sea lice larvae simply avoid this layer by moving below it in the water column (Heuch *et al.*, 2002). Therefore, the less saline layer on top of the water may slow the development of viable settlement stages of the sea lice, and additionally provide a "safe corridor" for the migrating smolts moving through inshore waters. Sea lice are only able to develop to the copepodids stage at salinities greater than 30‰ (Pike and Wadsworth, 1999). Hence, we would hypothesize that it is the difference in salinity in near-shore coastal waters in BC that prevents the high infection intensities of sea lice on salmon in the North Atlantic that has been reported by the popular press. However, at this time, we do now know whether the migrating Pacific salmon favour the low salinity surface waters or the deeper waters with higher salinities.

The Impact of Sea Lice on Salmon Health

To date, the bulk of research has focussed on the impact of sea lice infestations on Atlantic species of salmonid (Stone *et al.*, 2002; Glover *et al.*, 2003, 2004; Heuch *et al.*, 2003; and Wagner *et al.*, 2003, 2004) and not on Pacific salmon. Research on Atlantic salmon is very useful to scientists studying Pacific salmon, as it provides insights on some of the

9 A temperate rain forest is any forest in the mid-latitudes that receives more than 50 to 60 inches of rainfall a year.

Table 1: Average Skin Damage in Wild Pacific Salmon Species, 2003 and 2004

Species	2003		2004	
	Sample Number	Average Skin Damage	Sample Number	Average Skin Damage
Pink salmon	217	1.4	132	0.4-0.9
Chum salmon	30	0.1	62	0
Sockeye salmon	60	0.5	124	0.4-1.5
Coho salmon	52	0.4	208	0.2
Chinook salmon	21	0.3	140	0.3
Total average	380	1	666	0.42

Skin damage category and criteria:
0: No skin damage and no red discoloration of skin surface from haemorrhaging.
1: Minor red discoloration from haemorrhaging, but reduced in intensity and in area; no scale abrasion but pin hole penetrations may be present.
2: Moderate haemorrhaging resulting in more red color over an area about one half the size of the anal fin; minor scale abrasion may be present.
3: Severe haemorrhaging, area of haemorrhaging approximately the size of the anal fin or larger and almost uniformly red; no lesions; scale abrasion common, but skin intact.
4: Lesions present, skin removed and muscle exposed or skin partially removed exposing necrotic tissue; haemorrhaging at margins of lesions.

Adapted from Beamish *et al*., 2004, 2005.

physiological mechanisms that are affected by sea lice infestation. This is called the August Krogh principle, and is the underlying ethos behind the field of comparative physiology and biochemistry. However, although the mechanisms may be the same, the levels of susceptibility and response vary between species. Hence, the number of sea lice that cause mortality in Atlantic salmon should not be assumed to cause mortality in Pacific salmon. Each species needs to be examined individually.

Research has shown that while Atlantic salmon have little resistance to sea lice infestation, this resistance can be strengthened by selective breeding (Kolstad *et al*., 2005). Atlantic salmon and sea trout develop lesions when infected with sea lice, and appear to have very little defence against the infestation apart from turning away from the sea and heading back into fresh water streams. This causes the sea lice, which are intolerant to low salinities, to drop off the afflicted salmon.

Interestingly enough, unlike Atlantic salmon and sea trout, Pacific salmon species artificially infected with sea lice in a laboratory setting only exhibit attachment marks from the sea lice. There appears to be no visible surface lesions, even at adult *L. salmonis* intensity levels lethal to these salmon (Butterworth, 2005, personal observation). In July and August of 2003 and 2004, DFO conducted a study of skin damage caused by sea lice to returning wild Pacific salmon (Beamish *et al*., 2004, 2005). Of the 1,046 wild Pacific salmon infected with sea lice (table 1), the authors reported that there were a small number of sockeye and pink salmon with category 4 damage (Beamish *et al.*, 2004, 2005). However, the authors stressed that this was a rare occurrence.

Most of the pink salmon and some of the sockeye salmon had subcutaneous haemorrhaging ranging from mild red discolouration to moderate over the area only half the size of the anal fin (category 2 damage). In contrast, Wootten *et al*. (1982) reported epidermal damage on Atlantic salmon as a result of sea lice infestation of sufficient severity to qualify as category 4 skin damage. Although these data would suggest that the Pacific salmon appear to be more resistant to skin damage from sea lice than their Atlantic counterparts, there are reported cases where pink salmon have had severe lesions from sea lice infestation (Kabata, 1970).

Perceived differences in the severity of skin damage between Pacific and Atlantic species may be in part due to the lack of epithelial hyperplasias[10] and the inflammatory response of Altantic salmon to an infestation of sea lice (Johnson and Albright, 1992; Johnson, 1993). It is important to note that even though the Pacific salmon species appear to be more resistant to sea lice infestation, there is as yet no scientific assessment of the impact of infestation intensity on the general health of these salmon.

Sea Lice Epizootics

L. salmonis is native and prevalent (endemic) to the North Pacific and Atlantic oceans. In the Pacific, sea lice monitoring programs have reported the occurrence of sea lice on 91 to 92 percent of fish sampled, with a mean intensity of between 5.83 and 11.9 lice per fish (Nagasawa, 2001; Beamish *et al*., 2004, 2005) on Pacific salmon. A prevalence[11] of 90 percent sea lice on pink and chum juvenile salmon was reported by Morton *et al*. (2004) for the Broughton Archipelago. With such a high prevalence of sea lice in areas with and without salmon farms, it is to be expected that the combination of currents, temperature, and salinity necessary for a sea lice epizootic [12] will on occasion occur. Such epizootics have been well documented for a century, well before salmon farming was introduced (Calderwood, 1906; White, 1940; Johnson *et al*., 1996).

10 Epithelial hyperplasias is an abnormal increase in the cells in a tissue, whereby the bulk of the tissue is increased.

11 The number of fish infected with sea lice. Distinctly different to infection intensity which is the number of lice per fish.

12 Affecting a large number of animals at the same time within a particular region or geographic area.

The Interaction Between Wild and Farmed Salmon

The alleged role of commercial salmon farms as a possible source of sea lice infections in passing wild salmon has received much attention from both the scientific community and the popular press. The debate in British Columbia has focussed on pink salmon stocks in the Broughton Archipelago. For a comprehensive synopsis of this issue, see Brooks (2005). The controversy is based on evidence that correlates[13] higher sea lice infestation intensities in areas of BC with salmon farms, as opposed to areas without salmon farms (Morton *et al.*, 2004, 2005; Morton and Routledge, 2006). This 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). However, while higher sea lice infestations tend to occur in areas of BC with salmon farms, this correlation cannot be used to conclude that salmon farms are, in fact, the cause of the more intense infestations. More recent research suggests that it is possible for farmed and wild salmon to co-exist in a sustainable manner in the same habitat (Beamish *et al.*, 2006). In the Pacific, sea lice monitoring programs have reported the occurrence of sea lice on 91 to 100% of salmon sampled in areas with and without salmon farms (Nagasawa, 2001; Beamish *et al.*, 2004, 2005). Additionally, given the rates of dispersal of the lice in their 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 present on salmon farms, and infection levels among wild salmon.

Researchers have attempted to use alternative methods to ascertain the risks posed by sea lice from salmon farms to migrating wild salmon. Successful mathematical models have been developed with which to examine populations of sea lice on farmed Atlantic salmon (Revie *et al.*, 2005). Additionally, quantitative analysis has been used to extrapolate some of the correlatory data discussed above. However, Krkosek *et al.* (2005, 2006) met with limited success, due in part to the complexity of the system under investigation, gaps in current scientific knowledge on the subject (Stein *et al.*, 2005), and a reliance on correlatory data for the model.

13 In this case, correlation refers to two variables (proximity to salmon farms and the number of sea lice on wild salmon) that are changing in a similar manner and appear to be linked. However, there is actually no evidence of a link (cause and effect) between the two variables. Hence, the variables may or may not be related.

Current Research Focus

It has not been possible to date to establish a direct causal link between the decline of wild salmon stocks and the expansion of the salmon aquaculture industry (Bjørn *et al.*, 2001; Tully and Nolan, 2002; Butterworth *et al.*, 2004). However, there are recorded differences in sea-lice infection intensities between areas with and without salmon farms, as discussed above. Hence it is important to establish whether salmon farms are actually significantly contributing to sea lice prevalence among wild salmon (Butterworth *et al.*, 2004). If the salmon farms are not contributing significantly to the problem, then sea lice on farmed salmon is a farm management problem, not a potential interaction issue between wild and farmed salmon. Were this separation to be proven, it would facilitate the development of more specific management policies for the effective control of sea lice on salmon farms.

If a direct link is established between sea lice on salmon farms and sea lice infestations on wild salmon, the question of effect arises. What is the impact of differing infection levels of sea lice on the health of the juvenile wild migrating salmon? Are there differences in the risks posed by sea lice to the different wild salmon species? If so, the impact of differing sea lice infection levels on the health and physiology of juvenile Pacific salmon needs to be ascertained. These data can subsequently be used as a benchmark when surveying sea lice intensities on wild salmon stocks.

The farming of Atlantic salmon in BC has introduced a new host that appears to be more susceptible to sea lice infestation than the naturally occurring wild Pacific salmon. Hence, there is the potential for Atlantic salmon to change the natural host-parasite balance between wild Pacific salmon and *L. salmonis*. Even though there is as yet no direct causal link established between sea lice on farmed salmon and sea lice on wild salmon, it remains important that sea lice infestation prevalence and intensities are monitored on farmed and wild salmon until the nature of the relationship between sea lice on wild Pacific salmon and farmed salmon in BC is better understood.

Conclusions

There are large gaps in our understanding of the impact of sea lice on Pacific salmon and the alleged role of salmon farms in exacerbating the problem. Even so, research to date indicates that Pacific salmon may be more resistant to sea lice infestation than their Atlantic counterparts. However, since farmed salmon production in British Columbia overwhelmingly consists of Atlantic species, it is in the best interests of salmon farmers to minimize sea lice on their fish, if for no other reason than to ensure quality control of their product.

There is no doubt that sea lice transfer from wild salmon to farmed salmon. There are no sea lice on farmed salmon when they are transferred from freshwater hatcheries to the sea farms to be grown through to market size. If sea lice can move into the net-pens and infect farmed salmon, they must be able to move out of the net-pens and infect wild salmon.

Therefore, there are two crucial questions that should be the focus of future research. First, are sufficient numbers of sea lice transferred from farmed salmon to wild Pacific stocks to have an impact on the endemic infestations on those wild stocks? And second, what is the minimum number of sea lice on individual Pacific salmon species at which the health of the salmon is compromised? Because there is as yet no answer to either question, it is currently not possible to conclude that sea lice on BC salmon farms are having a significant impact on the parasite loads of the wild Pacific salmon.

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