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SLICE® THE LICE: The chemical of choice on BC salmon farms

SALMON FARMING HISTORY

You don't have to look very hard to find evidence of salmon farms on British Columbia's wild and rugged coastline—they are common in sheltered bays and inlets along the coast. Salmon farms grow hatchery origin salmon in large, floating, open net-cages, which allow chemicals and waste to pass freely into the marine environment. The industry got its start in the 1960s in Norway and Scotland, where aquaculturists discovered that Atlantic salmon could be grown in pens close to shore where they could be easily harvested and quickly shipped to demanding markets. The Canadian salmon farming industry began in British Columbia's Sunshine coast in the 1970s as small, locally owned farms. Through the 1980s most farm tenures were bought by a few European companies and the industry rapidly expanded. Today, farm-raised salmon is one of British Columbia's largest agricultural exports, but with significant environmental costs.

Many salmon farms can have upwards of a million fish contained in several pens at any one time. Numerous environmental impacts have been associated with farming such as organic pollution from fish waste and excess feed, escaped non-local Atlantic salmon, and the spread of disease and parasites to local wild fish.

Most salmon farms in British Columbia rely on antibiotics and pesticides to keep their farm stock "healthy". Pest management in the salmon aquaculture industry isn't much different from other non-organic agricultural activities in the country—the only striking difference is that it happens in the open ocean. As with most forms of agriculture, it is often necessary to treat crops or livestock with chemicals to reduce the impacts of pests. The same holds true for salmon farming.

PROBLEMS WITH SEA LICE, FARMED SALMON AND WILD SALMON

Salmon are cultural icons in many countries including Canada. Wild salmon have been a reliable and accessible food resource for aboriginal people for millennia. Recently, the health of these stocks has been threatened by the spread of sea lice—a parasitic crustacean that commonly flourishes in the cramped conditions of open net-cage salmon farms. Sea lice occur naturally on many different species of wild fish; however, the unusual conditions created by salmon farms produce prodigious numbers of sea lice, which spread to wild juvenile salmon nursery areas with devastating effects. Sea lice attach to the surface of fish and feed on tissue and mucous[1-2]. There are two species in particular that primarily affect commercial and wild salmon stocks in British Columbia. Both species share a similar lifecycle and have a planktonic larval stage that later matures into juvenile and adult stages when a host fish is found. One species is a specialist and requires a salmon host to complete its lifecycle, while the other is a generalist and can survive to reproduce on other fishes as well.

Recent science shows that open net-cage salmon farms "harbour" disease and parasites that can harm individual wild fish and impact their populations[3-8]. A recent study has predicted the extinction of certain local wild salmon populations in just a few years due to sea lice from salmon farms[7]. Another recent study indicates that wild salmon sea lice infestations are occurring in several salmon farming areas in British Columbia[9]. In addition, infestations are not limited to chum and pink salmon—juvenile Pacific herring and sockeye salmon have been found infested with lice within the vicinity of farms. It is clear; the industry has a serious pest problem that harms its own product, as well as wild fish.

WHAT IS SLICE®?

Due to sea lice outbreaks, farmed fish (just like crops and livestock) often require treatment with pesticides to reduce pests. A number of different chemicals have been used to treat for lice in the past[10]. At present, the preferred treatment has the trademark name—Slice® and contains the chemical emamectin benzoate (EB). EB was first globally registered in Japan in 1998 to help control caterpillar pests on leafy vegetable crops. In the USA emamectin benzoate was used primarily in agriculture to control pests on lettuce, celery, and other vegetables and was eventually co-opted by the fin fish industry to treat for sea lice.

Slice® is derived from a group of compounds know as avermectins, which are produced from a fungus. The pesticide inhibits nerve transmission and leads to death by binding to specific high-affinity sites in the target organism's nervous system. Slice® is applied to fish feed, which is then eaten by salmon and absorbed through the gut. The chemical is subsequently circulated to the fish's tissues. At this point, sea lice that are feeding on tissue (skin, fins and/or gills) ingest the toxin. Slice® binds to ion channels of louse nerve cells and disrupts transmission of nerve impulses, resulting in paralysis and death.

"Facts" about Slice® (emamectin benzoate) in Canada

- Slice® is not registered for use in Canada but has become the preferred chemotherapeutant for treating sea lice outbreaks on salmon farms.
- The chemical is pending approval and registration from Health Canada but is available for limited use through Health Canada's Emergency Drug Release program, in which a licensed veterinarian administers and oversees its application to sea lice infected farmed salmon.
- Warning labels on other plant pesticides that contain emamectin benzoate recommend that the product not be applied directly to water, areas where surface water is present or to intertidal areas below the mean high tide mark- Slice® is applied to salmon feed and dumped directly into the ocean.
- Data on the quantity of Slice® used are not publicly reported but are available through the provincial Ministry of Environment.
- Slice® data provided by the provincial Ministry of Environment are inaccurate and unverified by the farm companies.

- Slice® is so toxic that it takes only a few grams of the chemical to treat tonnes of salmon feed.

CONCERNS ABOUT SLICE®

There are many unanswered questions about Slice® use in BC that highlight the need to exercise the precautionary principle. A detailed eco-toxicity study is merited for coastal British Columbia, as other areas in the world where Slice® is used may have different ecosystems.

Unanswered questions regarding Slice® use in Canada

- Can repeated applications be made without detrimental effects to non-target organisms?
- Are the risks to non-target marine organisms based on a one-time application known?
- What is the potential for cumulative environmental loading and effects based on repeated use? This has not been formally assessed in Canada or any other country.
- There are no data on Slice® or its metabolites in waters surrounding Canadian fish farms after application.
- The effects of Slice® on larval crustaceans has not been examined in detail and there is no information on the effect this toxin has on microbes.

TOXICITY AND PERSISTENCE IN THE ENVIRONMENT

Human health effects?

Emamectin benzoate (main ingredient of Slice®) is known to cause moderate eye irritation in humans and if swallowed can result in central nervous system effects such as muscle tremors, decreased activity, ataxia (unsteadiness or incoordination) and dilated pupils. If inhaled, EB can cause irritation to the respiratory tract and can result in chemical pneumontis if aspirated. Emamectin benzoate is harmful if absorbed through the skin and prolonged or frequent repeated exposure can cause allergic skin reactions.

Effects on non-target species?

Slice® has been shown to have toxic effects on many marine species and its effects on a number of other marine organisms such as starfish and snails are unknown. Most of the testing was done in Europe or eastern North America. In Scotland the most sensitive species tested for exposure to EB was a marine lugworm. Hazard warnings for another pesticide called Proclaim™ that contains 5% emamectin benzoate note that EB is toxic to aquatic invertebrate organisms, birds and mammals. The warning also recommends that the product is not applied directly to water, areas where surface water is present or to intertidal areas below the mean high tide mark. High doses of Slice® have also been shown to induce moulting in Atlantic lobsters and it is suspected that EB also has endocrine disrupting effects in other crustaceans.

There is a major knowledge gap and limited information about the effects of Slice® use in Canada's and other countries' maritime environments. Many of the organisms that showed toxic effects to EB testing, exhibited these effects (i.e., death) at concentrations higher than the EB concentration currently used to medicate feed. However, it has been suggested to obtain maximum efficacy farm companies should coordinate the use of Slice® at multiple farms in a given geographical area. This mass coordinated usage may result in higher concentrations of Slice® in all mediums (e.g., water column or sediment) that would exceed concentration expectations based on a single 7-day application at one farm. The effects of coordinated Slice® usage over a large geographic area on ecologically important zooplankton and bottom dwelling animals (e.g., round worms and small crustaceans) has not been formally assessed.

Sherring Plough Animal Health reports that EB has been detected in the tissues of invertebrates caught near net cages up to one month after treatment indicating that bottom dwelling scavengers may have ingested excreted materials as well as uneaten feed [11]. Limited research into the uptake of EB into commercially important species such as Dungeness crabs and prawns has been conducted[12], but the toxicity thresholds for these species have not been experimentally derived.

Data on EB effects on a number of different organisms are limited to studies on acute toxicity rather than chronic, sub-chronic effects on mortality, fecundity, reproductive success, or growth, which would occur in areas where Slice® is used repeatedly.

What are the exposure pathways for Slice® into the environment?

- Slice® can enter the water column as a metabolite excreted from fish that have ingested medicated feed, especially in high current areas where waste excretion is not accompanied by rapid settling to the seabed.
- Slice® can directly enter the water column from the un-eaten medicated feed.
- Slice® is introduced directly to the seabed as un-eaten food falling through the net-pens and/or as a metabolite in fecal matter.

Slice® is delivered to lice infected salmon as a coating on feed. Once ingested the toxin is metabolized and circulated throughout the fish before being excreted. The predicted environmental concentrations (PEC) of Slice® in the water downstream can and have been derived from mathematical model predictions. However, these estimates do not account for the recommended synchronized use of Slice® medicated feed over a large geographical area and these models do not account for the possibility of benthic-pelagic exchange from sediments under net pens where Slice® has been used repeatedly.

Persistence in the environment?

Slice® can remain in the environment for many days depending on conditions. Environmental risks associated with Slice® deposition can depend on factors such as the sensitivity of the receiving environment, which to date are largely unknown. Slice® has low solubility, which suggests once in the marine environment and settled to the bottom, the toxin could become tightly bound to soil/sediment/organic matter on the seabed. The Scottish environmental protection agency assumes that it takes seven and a half months for half of the original amount of the toxin used in treatment to degrade[13]. A Scottish study found trace amounts of Slice® in the sediments twelve months after treatment [14]. This is ample time for sensitive organisms to come into contact with the chemical.

WHAT ARE THE ACTIONS TAKEN TO REDUCE LICE ON FARMS AND ARE THEY EFFECTIVE?

The BC provincial government has set protocols for monitoring sea lice levels on salmon farms. Atlantic salmon farms are required to monitor sea lice levels on their fish a minimum of once a month and report the findings to the Ministry of Agriculture and Lands. When lice levels on average at the farm reach three motile lice (mature lice) per fish at any time of year, fish must be checked twice a month. If lice levels reach three motiles during the juvenile wild salmon out-migration period (March to July), then one of two actions is usually taken to reduce lice production on the farm: harvesting or treatment with Slice®.

When harvesting is taken as the action to reduce sea lice numbers at the farm, it is usually because harvesting was previously scheduled to occur at that time period by the company as part of their management schedule. Reducing the number of fish at the farm may reduce the total numbers of lice if the majority of fish are harvested quickly; however, it frequently takes more than a month to empty a farm, during which time the average motile level may continue to increase well beyond the 3 motile trigger with hundreds of thousands of fish still at the farm.

When Slice® is the action taken, salmon farms in BC generally apply medicated feed coated with the chemical when the 3 motile lice/fish trigger is reached. This trigger has no scientific basis[15]. The recommended dosage of emamectin benzoate is 50 µg/kg of fish biomass per day and treatments last for 7 days. It is very difficult to predict the efficacy of Slice® against sea lice on farmed salmon. Factors such as water temperature affect the rate of drug clearance from the skin and muscle and fish size, maturity, health and condition may also have influence[16]. A minimum withdrawal time of 68 days is set by Health Canada after administering Slice®, which is based on allowable levels of the drug in harvested fish tissue.

The question remains: is the 3 motile lice/fish trigger for the application of Slice® good enough to protect wild out-migrating salmon stocks? Orr (2007) highlights conservative estimates on lice production as it may relate to salmon farms. Each gravid female louse can produce at least 250 eggs[17], during a reproductive cycle. A conservative estimate suggests that before the 3 motile lice/fish trigger is reached and thus before Slice is applied, each farmed salmon may be producing more than 100 planktonic lice at each farm at any given time (based on egg to plankton survival rate of 0.268[18]). Each salmon farm is usually stocked with over a ½ million fish producing hundreds of millions of lice during the time when juvenile salmon are migrating to sea[17] (Figure 1). A recent report in the top journal *Science*, indicates that sea lice from salmon farms may be driving populations of pink salmon towards localized extinction[7].

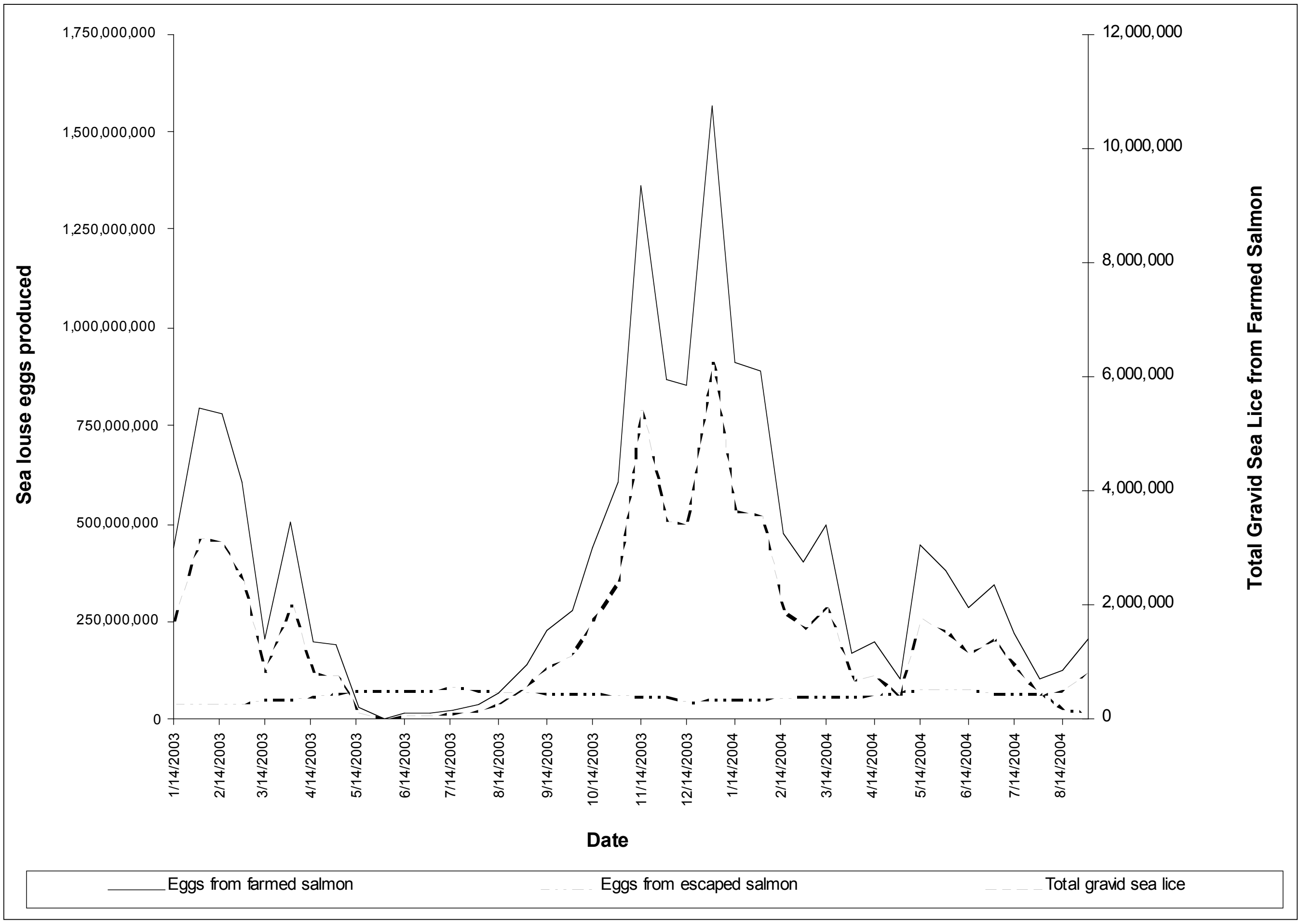

Figure 1. Total number of gravid sea lice from farmed salmon and sea louse eggs produced from farmed salmon and from escaped farmed salmon from Marine Harvest farms in the Broughton Archipelago in 2003 and 2004 (Orr, 2007). Slice® application evident on figure where egg production and total gravid female counts approach zero.

Potential for Slice® resistance development

As in other forms of agriculture, pests develop resistance to pesticides. The salmon farming industry continues to use Slice® to combat sea lice outbreaks on salmon farms, and as a result there are concerns being raised about lice developing resistance. Sherring-Plough[19] states, "the question is not if resistance will occur, the question is when will resistance occur and then what can be done to prevent or delay the onset and to reduce the impact of resistance development." A recent study conducted in Chile indicates that the sea louse, *Caligus rogercresseyi*, has lost sensitivity to Slice® at all the localities analyzed[20].

Heavy reliance on use of Slice® on salmon farms in the Bay of Fundy raised concerns about sea lice developing resistance[21]. A recent study indicates that treating hatchery reared smolts with Slice® prior to release yields a lower degree and shorter period of protection against sea lice infection[22]. Environment Canada and Health Canada suggest that farm managers should strategically "rotate" Slice® with different pesticides and management actions, which reaffirms the real potential for resistance development. It is recommended that at least two or more pesticides should be routinely used as part of an integrated pest management program.

Nearly all chemotherapeutants manufactured in the last hundred years have induced resistance in the target species[19]. Resistance of sea lice to pesticides was first documented in Scotland in 1990 when the effectivness of dichlorvos was reduced[23]. Resistance to avermectins (e.g., ivermectin and emamectin benzoate) has occurred among several target species. Ivermectin was used to control an intestinal flatworm of sheep and the first report of resistance occurred less than 3 years after its introduction in one location[24]. Similarly, within 5 years of the first commercial use of abamectin, resistance was observed among Colorado potato beetles and several species of mites[25].

Side resistance (also known as cross resistance) occurs when a pest or parasite species demonstrates resistance to similar compounds with the same or similar routes of action. Colorado potato beetles and houseflies that developed a tolerance to abamectin have also shown increased tolerance for emamectin benzoate, which suggests that side resistance should be expected among other species exposed to these types of compounds[19]. Side resistance to at least one type of chemotherapeutant has already been observed in sea lice. In Scotland, sea lice already resistant to dichlorvos were treated with azamethiphos (another similar type of chemical) and were less susceptible than the lice originally were to dichlorvos. Ivermectin has been widely used worldwide for control of sea lice on salmonids for at least 10 years, which presents the possibility for sea lice to develop side resistance to other pesticides in the avermectin group, particularly emamectin benzoate[19]. Therefore, the question is not if sea lice will develop resistance to Slice®, but rather when resistance will begin.

Summary

There are a number of concerns regarding Slice® (emamectin benzoate) which is used widely in British Columbia to control sea lice outbreaks on farmed salmon. Slice® is not registered for use in Canada and is only available through Health Canada's Emergency Drug Release program, in which a licensed veterinarian administers the toxin in the form of medicated feed to farm fish. Numerous government agencies and industry professionals recognize that there are many unanswered questions regarding Slice use in the province and its effects on the environment. Yet Slice® has become the preferred chemotherapeutant for treating sea lice outbreaks on salmon farms. There is a dire need to address these important issues before the province of British Columbia advocates Slice® as the solution to the sea lice epidemic that plagues our wild fish. Many of the problems associated with open net-pen salmon farming would be eliminated with closed containment fish farms. It is time for government and industry to move towards the development of closed containment technology.

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