Lousy Choices

Drug-resistant Sea Lice in Clayoquot Sound

LIVING OCEANS

RAINCOAST RESEARCH

Lousy Choices: Drug Resistant Sea Lice in Clayoquot Sound

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- and -

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Executive Summary

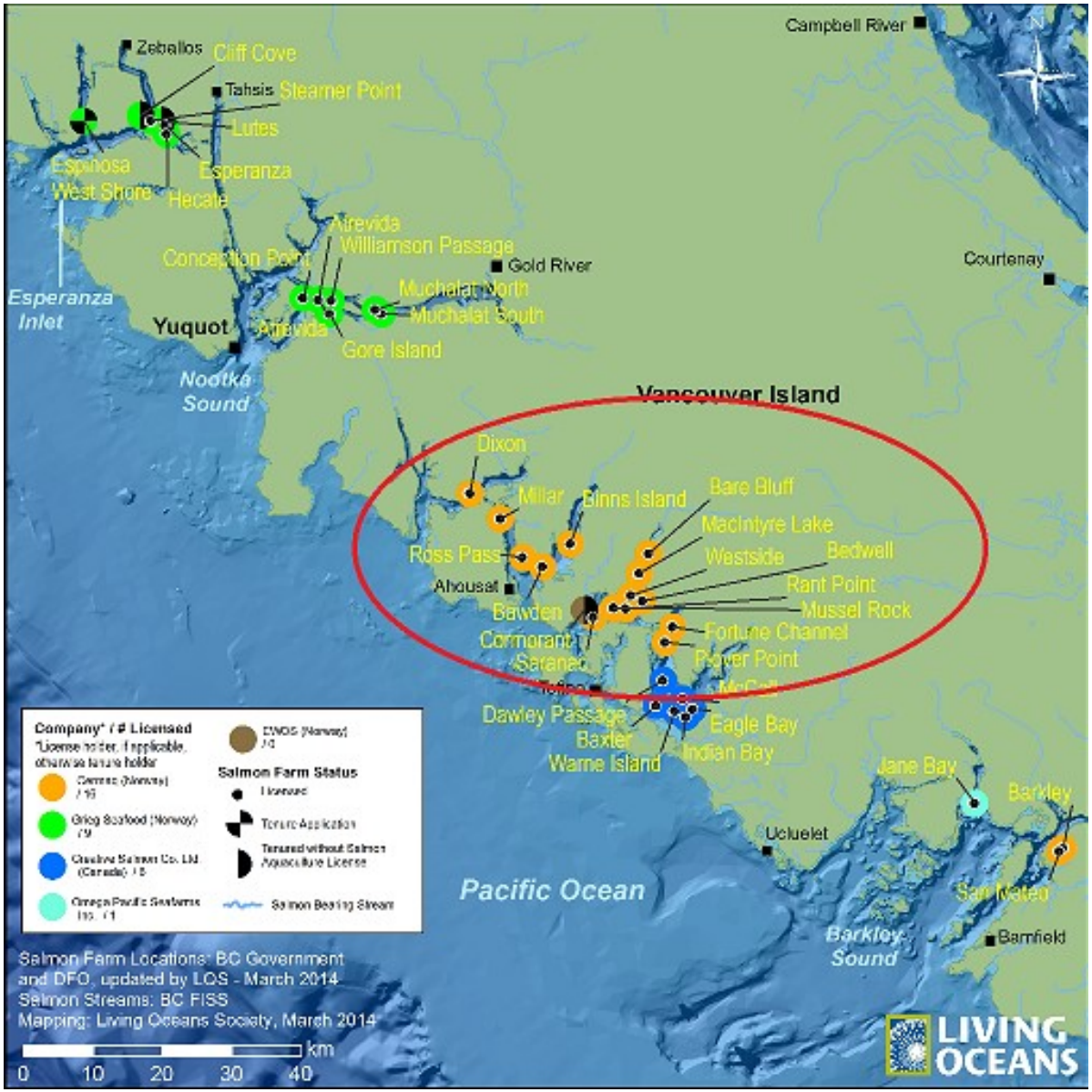
The spring of 2018 saw parasitic sea lice on both farmed and wild juvenile salmon in Clayoquot Sound reach levels never before seen in the Province of B.C. Forty to ninety-six percent of the wild fish sampled were infested, many at levels that would ensure death.

Sea lice are normally kept in check with the use of a drug called SLICE™. This report sets out the evidence that the parasite has become resistant to this drug; and that regulators and industry knew resistance was developing as early as 2014, but have publicly and repeatedly denied the fact.

Worse yet, despite the approval of alternate treatments that might have been effective if used before lice levels soared as high as eighteen times the management threshold, industry failed to have alternate treatments available in time to prevent lethal levels of infestation on outmigrating juvenile wild salmon.

Clayoquot Sound used to support healthy populations of sockeye, chinook, coho, chum and pink salmon. Monitoring of wild juvenile fish during the spring 2018 outmigration, conducted by the salmon farming company Cermaq whose farms were responsible for the outbreak, captured a single pink salmon and no sockeye. A few juvenile Chinook were captured but released without examination.

Forty percent of the coho and chum that were examined in their study were infested with sea lice, with one chum reported as having 43 sea lice on it. One to three sea lice can kill a juvenile salmon.



Sixty percent of the infested chum carried more than two lice.

Independent monitoring found 96 percent of wild juveniles carried lice, with an average of 8.04 per fish. Lice counts ranged as high as 50 per fish.

So far as the public record discloses, nothing that Cermaq did, or failed to do, broke any laws or violated its licence to use public waters.

It was a certainty that, over time, sea lice in the North Pacific would develop resistance to SLICE™. That has happened everywhere the product has been used, including eastern Canada. Even knowing that such an event would occur with the use of only one chemical treatment, government regulators responded slowly to approve alternate treatments. They did so in 2016 and 2017; but by that time the records show that it was too late. By 2017, Fisheries and Oceans Canada (DFO) unquestionably knew that resistance to SLICE™ had developed in west coast Vancouver Island farms, even as they denied it.

Why alternate treatments were not immediately made obligatory remains a mystery, but the fact is that SLICE™ continued to be used, and used in repeat treatments, at farms where the lice were clearly resistant to it. This may in fact have accelerated the development of resistance during the several months that its use was continued.

A juvenile herring covered with Caligus sea lice, Hot Springs Cove, 2018

The evidence suggests that sea louse resistance to SLICE™ is being observed in Broughton area farms as well; and concerns have been expressed by DFO veterinarians that resistance could be transferred into the Discovery Islands in bloodwater emanating from the Browns Bay fish processing plant, which has processed fish infested with drug-resistant lice.

Regardless where the SLICE™ resistant lice may be today, it will soon be the case that sea lice cannot be controlled with SLICE™ at any B.C. open netpen salmon farm. For wild salmon, this means increasing risk of exposure to lethal parasite levels at a time when stocks are already critically depressed in many regions. For the marine ecosystem as a whole, it means increasing exposure to a cocktail of new drugs and chemicals whose impacts, whether alone or in combination, have been at best poorly studied in marine environments.

The sea lice management policy of Fisheries and Oceans Canada has long been criticized for lack of scientific underpinning and a failure to come to grips with impacts on wild juvenile salmon at the most sensitive period in their life cycle. It has brought us to a place where we are left with lousy choices, simply put: increasingly toxic chemicals being dumped directly into the marine environment, or escalating impacts on wild juvenile salmon--or both.

This has grave implications for both the salmon farming industry and wild salmon: failure to control the abundance of lice in the vicinity of farms has led to lethal levels of infestation on wild juvenile salmon as they pass by these farms on their seaward migration. Sea lice have been identified as a cause of population level declines in pink salmon in the Broughton Archipelago, the only region in which long-term study of the parasite's impact on wild salmon has taken place. This year, sea lice are responsible for considerable losses to wild salmon in Clayoquot Sound and at least one salmon farming company, Cermaq.

Why are sea lice of concern?

Sea lice occur naturally in Pacific waters: it is not uncommon to find them on a wild-caught salmon. In the natural cycle, lice die as the wild salmon enters fresh water to spawn in the summer/fall; so when the juvenile salmon begin emerging in spring, there are few if any lice in coastal waters. Wild salmon operating in the natural cycle would not normally encounter lice in any significant numbers until they have fully developed scales and are large enough to withstand the wounding and blood loss caused by the lice[1].

In the confines of an ocean netpen, however, farmed salmon present ideal hosts for the parasite. Farms act as lice incubators, increasing lice abundance dramatically over natural levels. "Sea lice also have a high reproductive capacity and their abundance can increase rapidly. Once mature, a female may survive for about 200 days and produce about 10 pairs of egg strings during that period depending on temperature. At 10°C, the time to egg hatching is only eight to nine days (for *Lepeophtheirus salmonis*) and it takes about one month for a louse to mature on a host at this temperature[2]."

A single farm harbouring lice at an average of 3 females per fish is capable of shedding billions of larval lice that can travel 30 km on marine currents[3]. As the majority of B.C.'s fish farms are located in wild salmon nursery areas, wild juvenile salmon may be exposed at the critical moment when they begin their spring out-migration to the open ocean. Their small size and (in some species) lack of scales make them so vulnerable that they may be simply eaten to death.

Controlling the abundance of lice is critical for the salmon farming industry, because the quality and even survival of farmed fish may be sharply reduced by heavy lice infestation. Lice feed on the mucus, skin and blood of the fish, often leaving large lesions that lower the value of the farmed salmon product and open the door to infections from other pathogens in the water.

World-wide, the industry's attempt to control sea lice is one of the largest and most rapidly

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1. Effects of host migration, diversity and aquaculture on sea lice threats to Pacific salmon populations Krkošek, M. et al (2007) DOI: 10.1098/rspb.2007.1122
2. Minister of Agriculture's Advisory Council on Finfish Aquaculture Final Report and Recommendations at p. 77
3. Mustafa, A., et al (2001). Life-span and reproductive capacity of sea lice, Lepeophtheirus salmonis, under laboratory conditions. *Special Publication Aquaculture Association Of Canada*, (4), 113-114.

growing costs associated with salmon farming, particularly because this parasite has an uncanny ability to develop resistance to virtually every method of treatment employed to combat them (both chemical and non-chemical). As a consequence, more new land-based salmon farm capacity, which eliminates marine parasites from the equation, is being developed nearly everywhere that salmon are farmed and marketed--except Canada.

What happened in Clayoquot Sound in 2018?

Earlier this spring, researchers in Clayoquot Sound discovered juvenile wild salmon were heavily infected with sea lice. Living Oceans discovered that lice levels on the farms had soared above the management trigger of 3 motile lice (lice capable of moving from one host to another) per fish in Cermaq's Clayoquot Sound farms. This occurred just as the tiny wild salmon were trying to migrate past the farms.

A close examination of the lice counts made on those farms and of the limited publicly available information on treatment revealed that lice levels had begun to rise dramatically as early as January 2018.

Salmon farmers are legally obliged to take some form of management action—either treatment or removing the fish from the water—when lice levels reach 3 per fish during the spring outmigration (established as March 1- June 30). The Conditions of Licence read:

"within 15 calendar days of the discovery, implement a plan which will reduce the absolute sea lice inventory within the [netpen]."

Neither Cermaq nor DFO publicly releases records of the drug treatments applied to farmed salmon. However, the only drug approved until recently is emmamectin benzoate, sold as SLICE™, which is administered as a feed additive for seven consecutive days following which, according to the manufacturer, lice levels should drop dramatically and remain suppressed for 8-10 weeks. The manufacturer also cautions that, should treatment not prove as effective as desired, it should be followed immediately with a bath treatment using a different chemical agent —literally, a chemical bath designed to cause the remaining lice exhibiting drug resistance to detach from the fish.

Bath treatments using hydrogen peroxide, sold as Paramove 50™, were approved for use by the Provincial government for Cermaq's farms in March, 2018, but according to the records made public by DFO,[4, 5] it was not until June that the company treated its first three farms (Plover Point, Bawden, Bare Bluff). In July, Fortune Channel and Bedwell were treated.

Fortune Channel, where lice began rising in early April, reported publicly that it was taking 'health management action" in May, 2018, and would not continue their bi-weekly lice counts. We believe that this treatment involved the use of SLICE™, as at this time there was no other drug approved for use. There is a gap in sampling from May 28 until July 8, with no evidence that the treatment had any effect on lice levels. By July 10, the average levels on the farm had reached 11.32 motile lice—approximately 3 times the level at which management action is required—and a hydrogen

4. https://open.canada.ca/data/en/dataset/3cafbe89-c98b-4b44-88f1-594e8d28838d

5. For clarity, SLICE™ is a 'drug', orally administered. Paramove 50™ and SALMOSAN VET™ are referred to as 'chemicals' in this report. Drug use is not publicly reported by DFO, while chemical use is. Thus, when the public reports refer to 'management action' on the farms but do not mention the use of a chemical, we infer that a drug is being used. While SLICE™ is the only approved drug, we cannot rule out the possibility that another drug was approved on an emergency basis and that fact is not yet publicly disclosed.

peroxide bath was used. Eleven days later, levels had increased again, returning to the management threshold of 3 motile lice. Levels were allowed to rise again to 7.78 before the company decided, according to news reports, to harvest the fish for processing into fertilizer "because of their strict animal welfare policy".

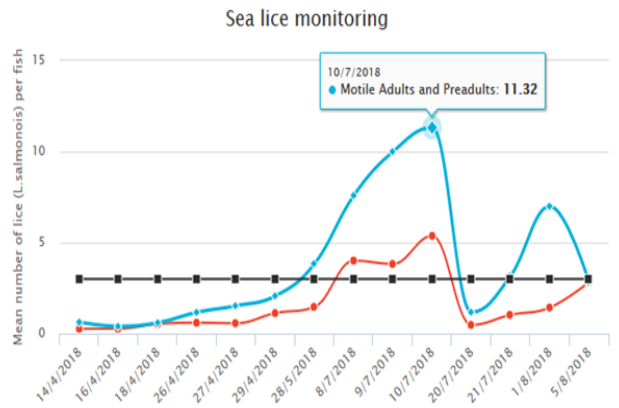
Elsewhere in Clayoquot Sound, Cermaq's concern for animal welfare was not evident. At their Bawden farm, lice levels rose above the management threshold in January. A management action was taken in February but showed little evidence of efficacy. Lice counts rose out of control, to an unprecedented 54.7 motile lice per fish. Female lice were recorded as reaching an average of nearly 30 per fish, which would mean that the farm at these points harboured some 26,000,000 lice, each capable of producing 250 to 1000 eggs in a single reproductive cycle[6].

Bawden exceeded the management threshold for sea lice throughout the entire sensitive period for wild salmon outmigration (March 1 – June 30).

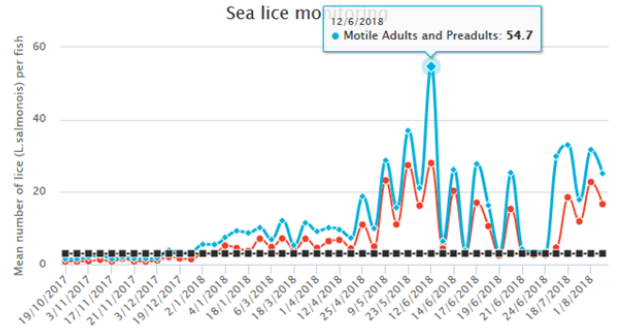
A hydrogen peroxide bath administered at Bawden in mid-June failed to reduce lice levels sufficiently and they peaked again less than 3 weeks later, reaching over 33 per fish before harvesting began in July. The farm was reporting average lice levels of over 25 per fish when reporting ceased in August.

Of greater concern is the pattern of peaking and troughing of lice numbers that is seen on this farm and all others in Clayoquot Sound in 2018. Sea lice numbers do not spontaneously reduce: absent some form of

Fortune Channel



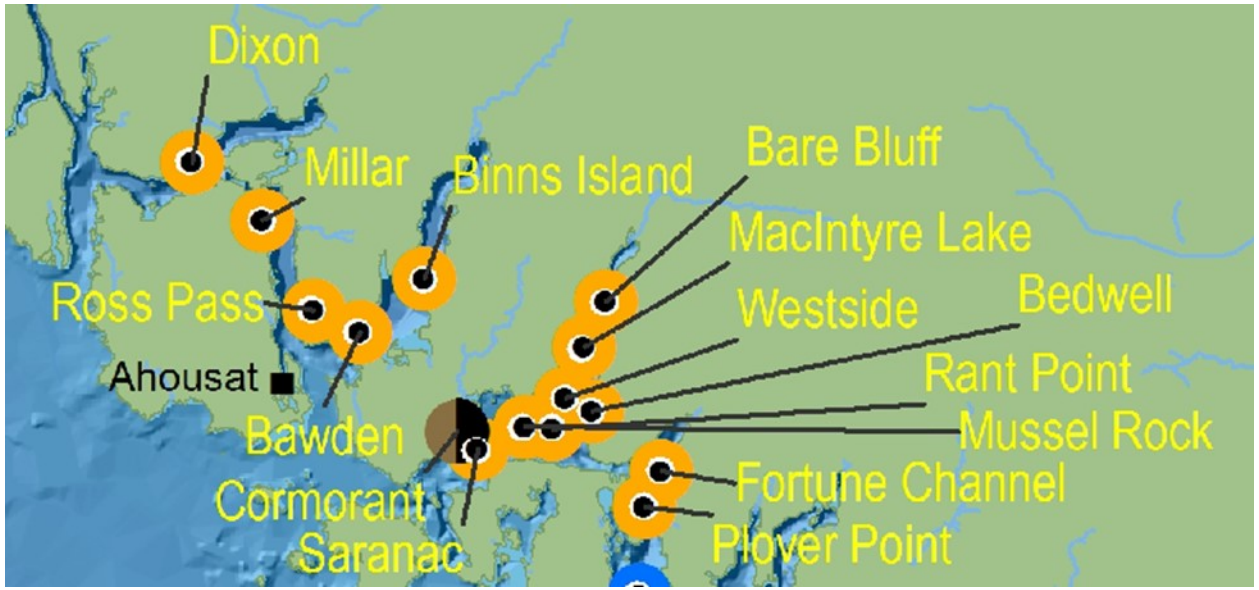
Bawden



treatment, lice numbers just continue to go up. The pattern of peaking and troughing is strongly suggestive of repeated, ineffective treatments. This kind of repeated, ineffective treatment actually promotes the development of drug resistant lice: lice that survive treatment and reproduce pass on the resistance; and if the next generation is also exposed to the drug, there is potential for even greater resistance developing[7].

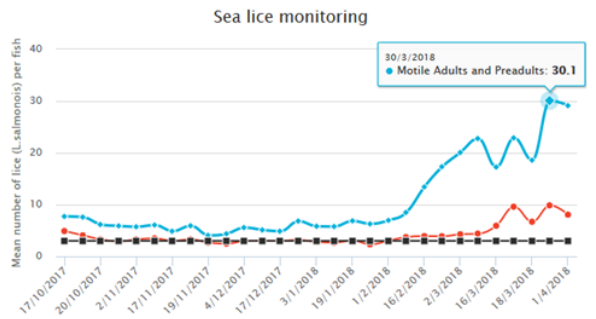
6. Mustafa, A., et al (2001). Life-span and reproductive capacity of sea lice, Lepeophtheirus salmonis, under laboratory conditions. *Special Publication Aquaculture Association Of Canada*, (4), 113-114.
7. http://www.nasco.int/pdf/2016%20papers/CNL_16_42_TBSS_Sturm.pdf

What these data suggest is that Cermaq's attempt to manage sea lice on their salmon farms was just making matters worse.

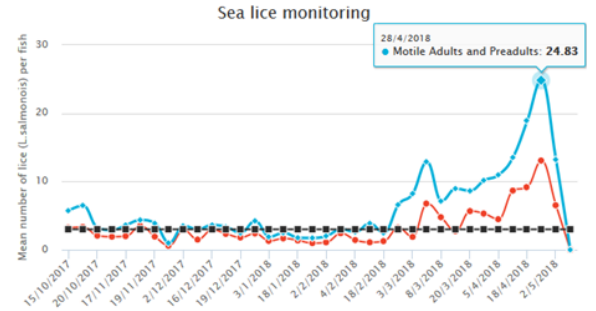


Millar, Ross Pass and Dixon were all harvested before June, but exceeded 3 motile lice per fish from March onward. Plover Point and all operating farms between Saranac and Bare Bluff showed the pattern of rapid peaks and troughs in lice and exceeded 3 motiles per fish during some or all of the sensitive period for wild juveniles. No fish were stocked at Westside, MacIntyre, Cormorant or Binns between March and June, 2018.

Millar Channel

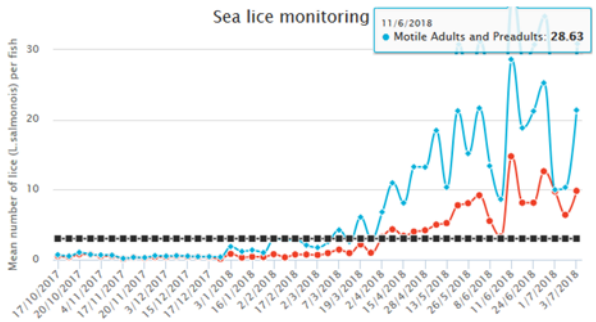


Dixon Bay

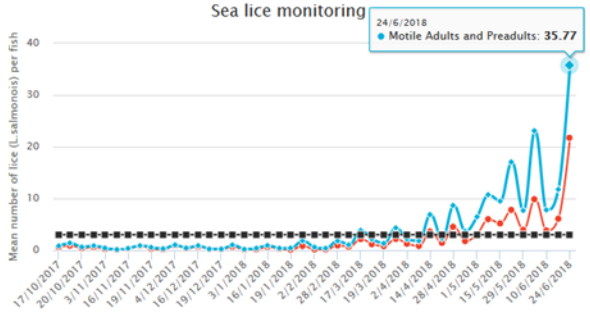


Adult Females Motile Adults and Preadults Required Treatment Level

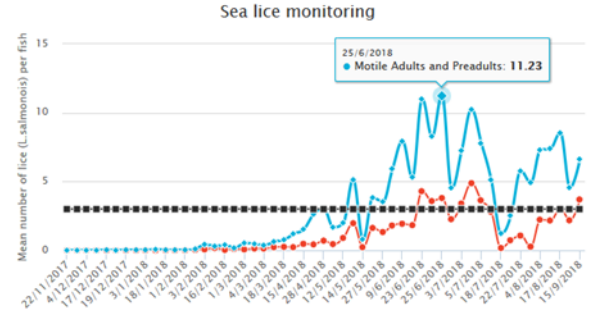
Saranac

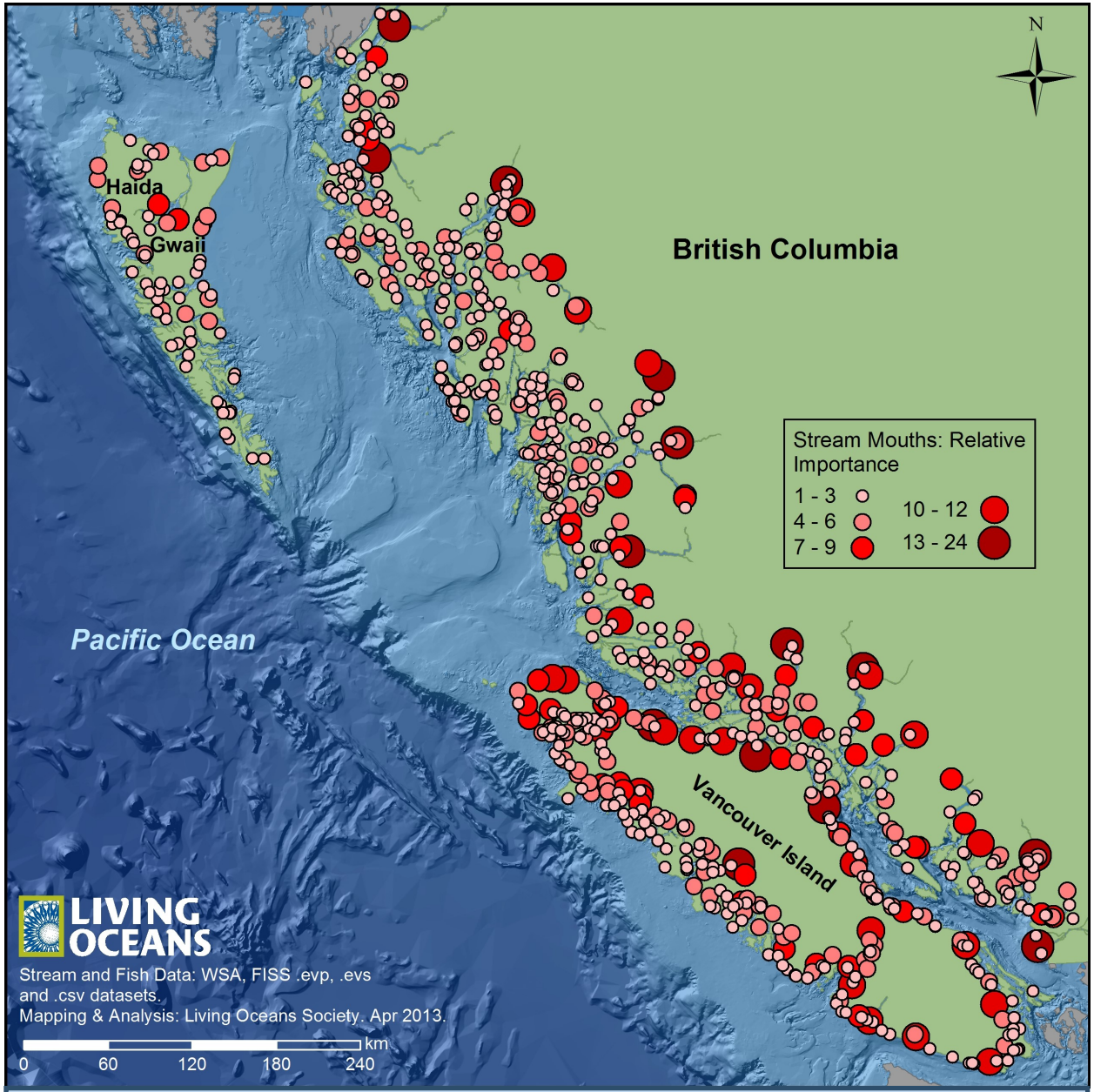


Mussel Rock



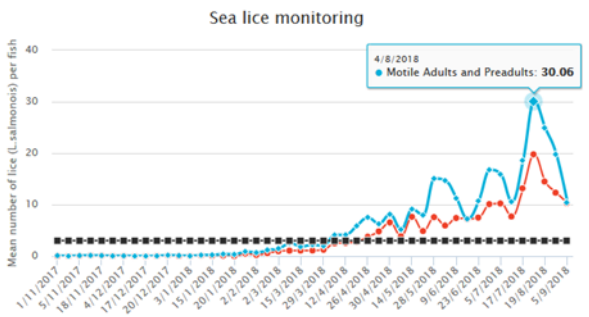
Bedwell



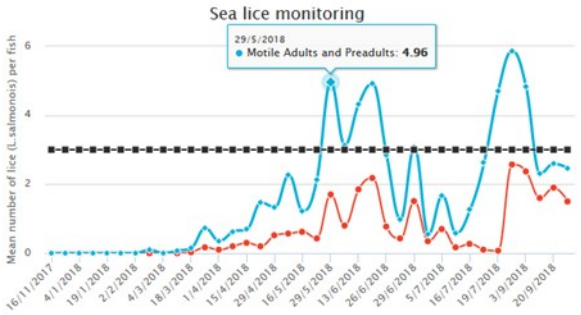


Salmon streams on the WCVI are—or were—major contributors to the salmon fisheries of both Canada and the U.S. as shown in this map ranking the relative importance of streams. In 2018, the outlook for all stocks on the WCVI was poor, with no data reported for pink salmon and all other species stocks depressed below 'target levels' for fisheries purposes.

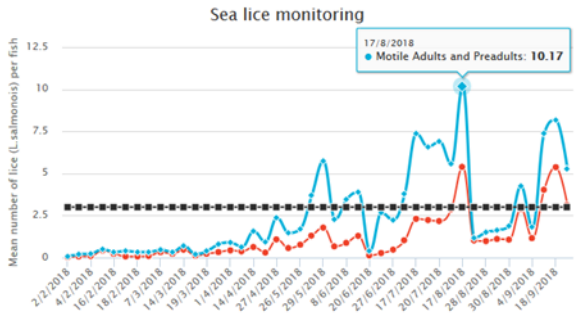
Rant Point



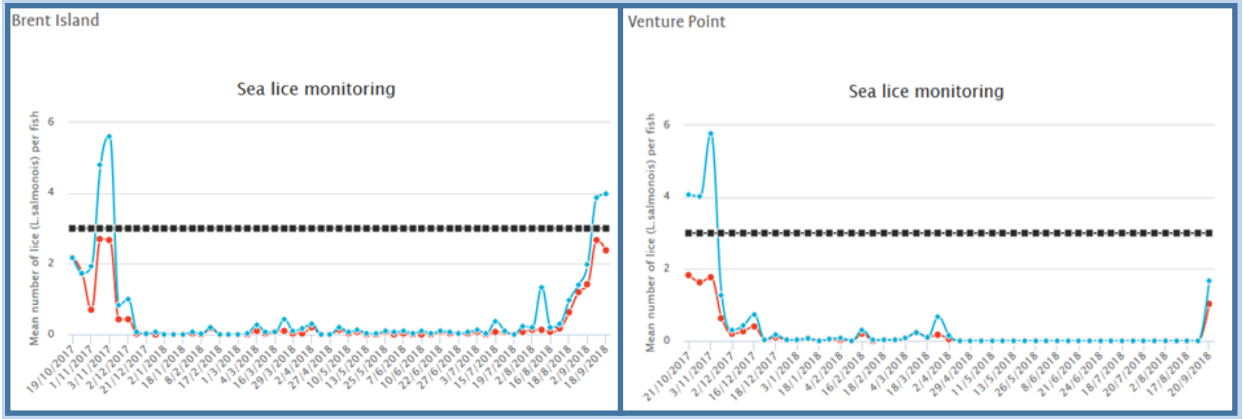
Bare Bluff



Plover Point



The pattern of sea lice levels following effective treatment with SLICE™ looks more like the following, from farms in the Discovery Islands. SLICE™, according to its manufacturer, attains maximum efficacy within one week and continues to be effective for up to 8 -10 weeks. It is perhaps important to mention here that we do not know that these farms were, in fact, treated with SLICE™; other drugs or chemicals could have been used with emergency approval or a veterinarian's prescription of an off-label use of another approved drug.



An August 15, 2018, Area 24 Roundtable meeting in Tofino laid to rest any doubt as to whether or not sea lice in BC have developed drug resistance. The meeting received an update from Cermaq's Regional Production Manager, Eric Jensen.

Jensen advised that, while they were still using SLICE™, they were definitely seeing SLICE™ resistance in the sea lice on their farms. He further reported that they had noticed the spread of SLICE™-resistant lice to sites other than Fortune Channel and that there was a progression of resistance to the drug along the whole coast of Vancouver Island. Early harvesting and Paramove treatments had not yet lowered lice levels below the threshold[8].

Jensen referenced bioassay work undertaken in support of a Provincial permit to use Paramove 50™, which apparently attests to the SLICE™ resistance; but that information does not appear to be publicly available.

The meeting was also advised that treatments with Paramove 50™ had resulted in as much as 15 percent mortality of the stock and did not bring lice levels below the 3 motile threshold. Jensen said that the company would try repeat bathing in future.[8]

It should be noted that DFO's policy for managing sea lice (and a condition of salmon farmers' licences) requires them to take management action "that will reduce the absolute sea lice inventory within the [netpen]" within 15 days of reaching the 3 lice per fish threshold. On a literal reading of the policy, no breach of licence conditions occurred because lice inventories did decrease, even if only for a period of days, only to reach even higher levels at the next count.

There is no information to suggest that Cermaq was fined for delays in implementing effective treatment. DFO farm audit information has not been published since November, 2017, so it is not possible to say to what oversight these farms were subject.

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8. Clayoquot Sound Roundtable Aug 15 2018 Minutes accessed at https://www.dropbox.com/sh/yifi3x1qz9pmsz1/AAAdjEN0uJt4uD7DYU0dVJdqa/2018/Aug%2015%202018?dl=0&preview=Clayoquot+Sound+Roundtable+Aug+15+2018+Minutes.pdf&subfolder_nav_tracking=1

How long has this been going on?

The development of drug and chemical resistance in sea lice is a problem that industry, government and conservationists have known about for many years and it has been long argued that it would affect salmon farming on this coast; as it has in every other salmon farming region in the world where lice are present, including the east coast of Canada.

SLICE™ use on salmon farms began in Canada in 1999, when it was approved on an emergency basis only. It wasn't fully approved until 2009, but as use continued the trend toward resistance became apparent.

A Canadian Science Advice Secretariat (CSAS) review of pesticide use in salmon farming in Canada observes, "Poor efficacy of SLICE® resulted in a crisis situation in the salmon aquaculture industry in southwest New Brunswick in 2009 and 2010 and emergency registration was granted by PMRA for Salmosan®, Paramove® 50 and AlphaMax®. In the fall of 2010 Environment Canada issued a directive regarding the use of AlphaMax® and that product was no longer applied. Currently Salmosan® and Paramove® 50 are used in New Brunswick, Nova Scotia, and Newfoundland."[9]. The PMRA granted full registration for Paramove 50™ in 2016 and SALMOSAN VET™, another type of bath treatment, in 2017.

It was clearly to be expected that the same resistance to SLICE™ that has been experienced elsewhere would eventually develop here in British Columbia. Kreitzman et al. (2017)[10]. theorized that the only reason we were not seeing resistance here as quickly as it has developed elsewhere is that each year, returning wild salmon bring an influx of 'new' sea lice that have never been exposed to the drug. According to this theory, the 'new' lice infused the farm lice populations with fresh genetics, resetting drug resistance towards zero. This theory should have been ground-truthed by tracking the response of lice to SLICE™ in a systematic way.

The Coverup

DFO has been aware of developing drug resistance in sea lice on B.C. salmon farms since 2014, despite public denials.

A June 2014, email obtained through the *Access to Information and Protection of Privacy Act* (ATIP) from DFO senior aquaculture biologist Kerra Shaw reports:

"there is some indication from Broughton Archipelago bio-assay work that sea lice tolerance to* [SLICE™] *emmamectin benzoate may be developing".

"It is recommended that Cermaq have a site specific condition added to their licence requiring laboratory bioassay work to be conducted on sea lice from this farm [Sir Edmund] *to continue to learn more about treatment efficacy. This data will be used by Cermaq and DFO to appropriately manage sea lice and treatments in the future"*[11].

However, this recommendation was not made a condition of licence, thus inhibiting DFO's capacity to track and respond to this known

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9. Research Document 2014/002, A review of potential environmental risks associated with the use of pesticides to treat Atlantic salmon against infestations of sea lice in Canada
10. https://onlinelibrary.wiley.com/doi/full/10.1111/conl.12395
11. 11.ATIP (A- 2015-00587) The Broughton Archipelago is Dzawada'enuxw First Nations traditional territory, located off the northeast shores of Vancouver Island.

threat to wild salmon. In the following excerpt from an ATIP[12], we see that the language recommended above was been struck out by the author, on the advice of Gary Taccogna, then Regional Manager of Aquaculture Environmental Operations for DFO.

"Integrated strategies for managing sea lice is important to the sustainability of the industry and the environment in which it operates" (Roth et al., 2003). One component of those strategies is a plan that provides options for multiple treatments of sea lice, which helps ensure that treatments continue to be effective and to decrease the chance of drug resistance developing. The challenge in BC is that emamectin benzoate (EMB; aka SLICE) has been the only approved treatment available for managing sea lice for over a decade. Work has occurred to enable the registration of hydrogen peroxide (Paramove 50), and it is now available as an additional treatment. Now that two treatments are available, DFO will be working with industry fish health staff to develop a pest management plan in the Broughton Archipelago that will include: an updated treatment strategy, a multi-company approach for coordinated treatments, as well as field and laboratory efficacy assessments. Fish Health Management Plans will be updated to reflect current Best Management principles of pest management. ~~Companies should now be proactively developing integrated management strategies using all treatments.~~

~~The sensitivity of sea lice to EMB in BC appears to be stable, but routine monitoring using both field and laboratory efficacy data should occur to continue to ensure this. Currently, there is a field monitoring program that demonstrates EMB remains an effective treatment. The lab test employs bioassays which expose sea lice to varying concentrations of EMB to determine effective lethal doses. If the lab test demonstrates drug effectiveness is decreasing, these data could predict decreased field effectiveness. There are baseline data now established from which trends of increasing tolerance could be assessed. In areas where we anticipate or observe sea lice management challenges, it is imperative that laboratory bioassays be undertaken.~~

~~We have some indications from Broughton Archipelago bioassay work that sea lice tolerance to EMB may be developing. There is no indication that Cermaq is monitoring EMB efficacy by bioassay in this area. Given the proposed production increase and the increased EMB tolerance in the area, it is recommended that a site specific licence condition require Cermaq to undertake laboratory bioassay monitoring.~~

Also in 2014, Dr. Simon Jones of DFO obtained public funding, in collaboration with salmon farming company Marine Harvest Canada, for a project to study sublethal effects of SLICE™ on sea lice. The text of the project description includes the following statement:

"However, recent treatment failures have been linked to resistance to SLICE® within sea lice populations. While in vitro data support the conclusion that sea lice in British Columbia remain sensitive to SLICE®, treatment efficacy is variable among sites"[13].

That project concluded in early 2015, yet no published paper appears to report the results.

In 2015 sea lice levels in the Broughton Archipelago returned to levels recognized as damaging to young wild salmon[14].

In meetings in March 2016, the DFO denied that any evidence of drug resistance had been detected, describing the 2014 memo above as having been 'in error'[15]. Aquaculture branch scientists ascribed the high lice levels, already being repeated in 2016, to warm water temperatures. However, the manufacturers of SLICE™ claim that it works in all seawater temperatures and that it kills all life-stages of lice[16]. With effective and timely treatment, water temperature alone would not account for uncontrollable lice levels.

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12. ATIP A- 2015-00587 (p. 1617)
13. Project description accessed at http://www.dfo-mpo.gc.ca/aquaculture/sci-res/rd2015/lice-eng.html
14. Bateman et al 2016, Recent failure to control sea louse outbreaks on salmon in the Broughton Archipelago, British Columbia. Can J Fish Can. J. Fish. Aquat. Sci. **73**: 1–9.
15. Personal communication, Brenda McCorquodale to Karen Wristen, March, 2016
16. MSD Animal Health SLICE Technical Monograph accessed at https://www.msd-animal-health.no/binaries/Slice-SSP-Monograph.tom84-151889.pdf

B.C. Minister's Advisory Council Misled

The B.C. Minister of Agriculture's Advisory Council on Finfish Aquaculture (MAACFA) was established under Terms of Reference published in May, 2016 and held meetings between July, 2016 and November, 2017. Members of the Council included:

- Dr. Don Noakes, Dean, Faculty of Science and Technology, Vancouver Island University, who has been actively involved in research on Pacific salmon and interactions between wild and farmed salmon for 30 years. His career includes 19 years working for Fisheries and Oceans Canada;
- Rebecca Reid, Regional Director General, Fisheries and Oceans Canada; and
- Jeremy Dunn, then Executive Director of the BC Salmon Farmers Association

as well as representatives from First Nations, non-profit associations, business and academia.

The Council was charged with making recommendations to the Minister of Agriculture concerning provincial policy on the granting of Crown land tenures to salmon farming companies. It was permitted to scope its own investigations and recommendations. At its meetings, it heard presentations from several scientists, including Dr. Stewart C. Johnson of DFO and Dr. Gary Marty, a fish pathologist with the Province of B.C.

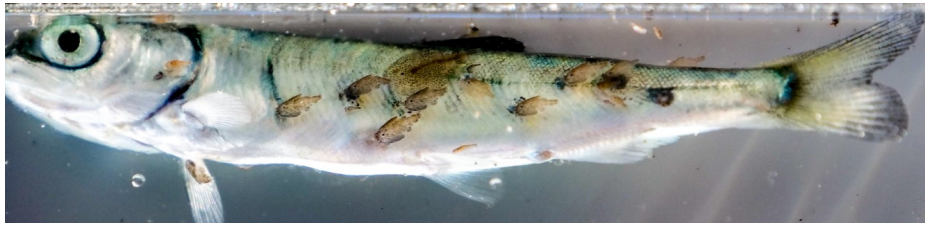
Dr. Johnson describes the focus of his research in the following manner on the Government of Canada website:

> Disease research focuses on determining the nature of the relationship between fish and three different pathogens: nodavirus (Atlantic cod, turbot), Aeromonas salmonicida (Atlantic salmon) and the **sea louse Lepeophtheirus salmonis (Atlantic and Pacific salmon)**[17] [emphasis added]

Dr. Johnson's written presentation contains no reference to sea lice resistance to SLICE™.

Dr. Gary Marty advised the Council that sea lice in B.C. are still "effectively controlled" by current management measures[18]:

- **Sea lice** (some juvenile Pacific salmon ARE more susceptible than farmed Atlantic salmon)
  - Effectively controlled by current adaptive management



17. https://profils-profiles.science.gc.ca/en/profile/stewart-johnson

18. accessed at https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/fisheries-and-aquaculture/minister-or-agriculture-s-advisory-council-on-finfish-aquaculture/maacfa-2017-docs/dr_gary_marty_-_province_of_bc.pdf

The final report by MAACFA, published in January, 2018 contains several references to the "fact" that there is no evidence of drug resistance in sea lice in B.C.:

> "The council also heard that there is no evidence of resistance to the particular sea lice therapeutant called SLICE although evidence exists in Europe[19].
>
> [Recommendation] *4.3. Continue monitoring sea lice levels on B.C. salmon farms and on juvenile wild salmon; monitor populations of wild salmon in proximity to salmon farms; and, test on a regular basis the effectiveness of treatments in controlling sea lice levels and for resistance to sea lice therapeutants*[20].
>
> Resistance in sea lice has been documented in Europe but not to-date in B.C.[21].

Yet it was clearly within the knowledge of the DFO Veterinarians, at the same time the Council was meeting, that drug resistant lice were a problem on the west coast of Vancouver Island. On August 2, 2017, Zac Waddington, Lead Veterinarian-Pacific Region, wrote an email[22] expressing concern that the farmed salmon coming from the west coast of Vancouver Island that are processed at the Browns Bay facility near Campbell River in the Discovery Islands could be transferring drug resistant sea lice from the western waters into the inside waters, in the bloodwater flowing untreated into Discovery Passage This is a significant concern as Price et al (2013)[23] report that viable sea louse eggs and larvae can be released in bloodwater by farmed salmon processing plants.

From: Waddington, Zac <Zac.Waddington@dfo-mpo.gc.ca>
Sent: August 2, 2017 4:07 PM
To: [redacted]
Subject: Referral from [redacted]

Hello. I am brand new to DFO, and I work [redacted] in the Aquaculture Management Division. A few weeks back I was chatting with Ian Keith (the other DFO vet) about sea lice resistance and the possible spread of those genetics via waste water at the processing plant, especially the one in Brown's Bay. I understand that Marine Harvest has installed some fancy effluent treatment at their facility, but I am told that the effluent treatment at Brown's Bay is not nearly at that level. I would be keen to chat with you about the nuances of waste water treatment and what DFO may/should do about trying to ensure that any resistant sea lice aren't being transferred to the opposite side of the island. Let me know when/if this would work. Thanks very much,

The recipient of the pictured email, the name of the person referring the author and the name of his colleague in the Aquaculture Management Division were redacted from the ATIP response, citing s. 19(1) of the *Access to Information and Protection of Privacy Act*. The usual procedure, where personal information is contained in a potential ATIP response, is to circulate the request to the individuals named and seek consent. Section 19(2) of the Act permits disclosure with consent, which was apparently not forthcoming.

19. MAACFA Report, Ibid, p. 14
20. Ibid, p. 15
21. Ibid, p. 79
22. ATIP A-2017-00981, pg. 15
23. Price MHH, Morton A, Eriksson JG, Volpe JP. 2013 Fish Processing Facilities: New Challenge to Marine Biosecurity in Canada. J Aquatic Animal Health, 25:4, 290-294.

It is difficult to imagine that the subject of SLICE™ resistance was of sufficiently common knowledge that two DFO veterinarians might "chat" about it, yet it was unknown to the DFO Regional Director General, Rebecca Reid; to Drs. Stewart Johnson and Don Noakes, both of whom specialize in diseases and parasites of wild and farmed fish; to Dr. Gary Marty, a vocal proponent of salmon farming and to the Executive Director of the B.C. Salmon Farmers' Association, whose members would have first-hand knowledge and a considerable financial stake in the subject.

All of these individuals (except Dr. Marty) had the opportunity to review drafts of the MAACFA report long before its finalization in January of 2018 and participated in meetings for the purpose, without ever alerting the Council to the clearly extant evidence of drug resistance.

The evidence points plainly to one of two things: an attempt to mislead the Minister's Advisory Council and concerned members of the public; or an inexcusable failure to communicate critical information about drug resistance to senior officials within the DFO.

The question why the Department might seek to mislead the public or the Council on this issue is not hard to fathom: uncontrolled sea lice and the cocktail of drugs and chemicals that have been used to combat them pose risks to wild salmon and marine ecosystems that many of us find unacceptable. The advent of drug-resistant sea lice takes B.C. into an entirely new regime of lice management, in which chemicals toxic to aquatic life will be dumped into the ocean multiple times in the course of each farm growout cycle, with unknown implications for wild salmon ecoystems.

Whether the Council was deliberately misled or not, the fact that information concerning attempts to control the spread of sea lice to wild salmon is not being effectively communicated to the general public and must be extracted through the laborious ATIP process only enhances suspicions that attempts by the industry and by DFO to control sea lice are going badly.

What are these lice levels doing to the wild fish?

After 30 years of salmon farming in B.C., we still cannot point to a definitive body of published, peer-reviewed literature that tells us what level of lice infestation each species of juvenile salmon can withstand.[24] There is no direct linkage between levels of infestation on wild juveniles and management measures required to be taken on farms, despite clear evidence that farms are increasing the local abundance of sea lice in wild salmon habitat. This is a signal failure of the DFO's aquaculture management.

Chum salmon smolt, Vargas Island, May 1, 2018

Papers published independently of DFO do provide guidance on the impacts of sea lice on wild salmonids. This literature shows that sea lice can kill juvenile salmon outright or, where they survive, have adverse impacts on their ability to compete for food and avoid predators that may lead to their failure to return to spawn[25]. In one study, exposure to salmon farms increased sea lice infection on migrating wild salmon for 80 km, killing 9-95% of young wild pink salmon on migration routes in the Broughton Archipelago[26]. The youngest stages of wild salmon in the Broughton Archipelago were killed by just 1-3 lice per fish[27]. Heavily infected juvenile Fraser River sockeye salmon were 20% less successful at consuming food than lightly infected fish[28].

Building on this guidance, the $5million Pacific Salmon Forum was established by the Premier of BC in December 2014 to protect wild salmon and increase public confidence in aquaculture. Their recommendation #8 advised that ***"No more than 3% of juvenile wild pink and chum salmon of less than 0.5 grams should have more than one pre-adult or later stage L. salmonis [sea louse] between March 1 - May 31"*** [29].

Sea louse infection of juvenile herring in BC was unreported in the scientific literature until the arrival of salmon farms and has now been reported in the Discovery Islands (Morton et al 2008). However the sea louse infections photographed on herring in Hot Springs Cove, Clayoquot Sound, are unprecedentedly high and a serious concern for the viability of herring in this region.

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24. While at least one project has been undertaken with a combination of industry and government funding to investigate exactly this question, there appears to be no published paper as a result of the project. Drs. Simon Jones and Stewart Johnson of DFO obtained funding from the Program for Aquaculture Regulatory Research in 2010 for a 4-year study entitled, "The effects of single and repeat *Lepeophtheirus salmonis* (sea lice) infections on the health of juvenile Pacific salmon". The project description states, "This multi-year project is examining the susceptibility and lethal infection level of juvenile sockeye, coho, and chum salmon to *L. salmonis*. In addition, the effects of previous exposure to *L. salmonis* on susceptibility to infection and the physiological and immunological responses will be determined for these species". No report of the findings could be located on the DFO website or internet searches for that title. Project description accessed at http://dfo-mpo.gc.ca/aquaculture/rp-pr/parr-prra/projects-projets/2010-P-01-eng.html

25. Morton A, Routledge R. 2006 Mortality Rates for Juvenile Pink *Oncorhynchus gorbuscha* and Chum *O. keta* Salmon Infested with Sea Lice *Lepeophtheirus salmonis* in the Broughton Archipelago. Alaska Fishery Research Bulletin 11(2):146 –152; Krkosek, M., Ford, J. S., Morton, A.B., Lele, S., Myers, R.A., & Lewis, M.A., 2007. Declining wild salmon populations in relation to parasites from farm salmon. Science. 318, 1772-1775.

26. Krkosek M, Lewis M, Morton, Frazer LN, Volpe JP. 2006 Epizootics of wild fish induced by farm fish. PNAS 103 (42) 15506-155 http://www.pnas.org/content/103/42/1550610

27. Morton A, Routledge R. 2006 Mortality Rates for Juvenile Pink *Oncorhynchus gorbuscha* and Chum *O. keta* Salmon Infested with Sea Lice *Lepeophtheirus salmonis* in the Broughton Archipelago. Alaska Fishery Research Bulletin 11(2):146 –152

28. Godwin S,Dill L, Reynolds J, Krkosek M, Sea lice, sockeye salmon, and foraging competition: lousy fish are lousy competitors, *Can. J. Fish. Aquat. Sci.* (2015) 72: 1113-1120

29. Pacific Salmon Forum PDF - http://johnreynolds.org/wp-content/uploads/2012/07/bc-psf-final-report-2009.pdf

Despite the advice of the Pacific Salmon Forum, DFO sets no limits on absolute lice abundance in any given area. It manages lice solely through the conditions of licence, requiring "management action" within 15 days of lice exceeding 3 motiles per fish, but with no target for overall abundance or levels per fish that must be attained. In other words, so long as the farm is being treated, lice levels can soar as they did in Clayoquot this year, with no breach of licence conditions, environmental laws or policies of the Canadian government.

The conditions of salmon farm licences also require salmon farmers to undertake monitoring of juvenile salmon during the prescribed outmigration period, which is March 1 – June 30. Some farming companies make this information public; Cermaq is one of them[30].

Table 4: Results of analysis for sea lice infestation on the sample population collected by beach seine in Clayoquot Sound, BC in 2018.

Species	Sample size (n)	Total number of lice observed	Total number of fish infested	Prevalence (%)	Abundance	Average Intensity
chum	696	1254	284	40.8	1.80	4.4
coho	45	61	18	40.0	1.36	3.4
pink	1	0	0	0	0	0
threespine stickleback	3	6	3	100.0	2.00	2.0
Total	**745**	**1321**	**305**	**40.9**	**1.77**	**4.3**

The reports of average abundance and intensity mask the specific data*:* ***lice counts on wild juvenile chum in Clayoquot Sound in the spring of 2018 ranged from 0 to 43 per fish. Forty percent of these relatively small samples were found to be infected.***

It is sadly noteworthy that only a single pink salmon was captured; and no sockeye, although local rivers support these species. Chinook were captured but were released without observation of their infestation: population numbers for these fish are too low to permit taking samples for laboratory analysis.

For chum salmon, 60 percent of infected fish were infected with 2 or more lice. Weights are not given for each fish sampled, but the range of weights was given, at 0.3 g to 7.1 g, making it likely that chum were impacted at a far greater rate and intensity than recommended by the Pacific Salmon Forum, above.

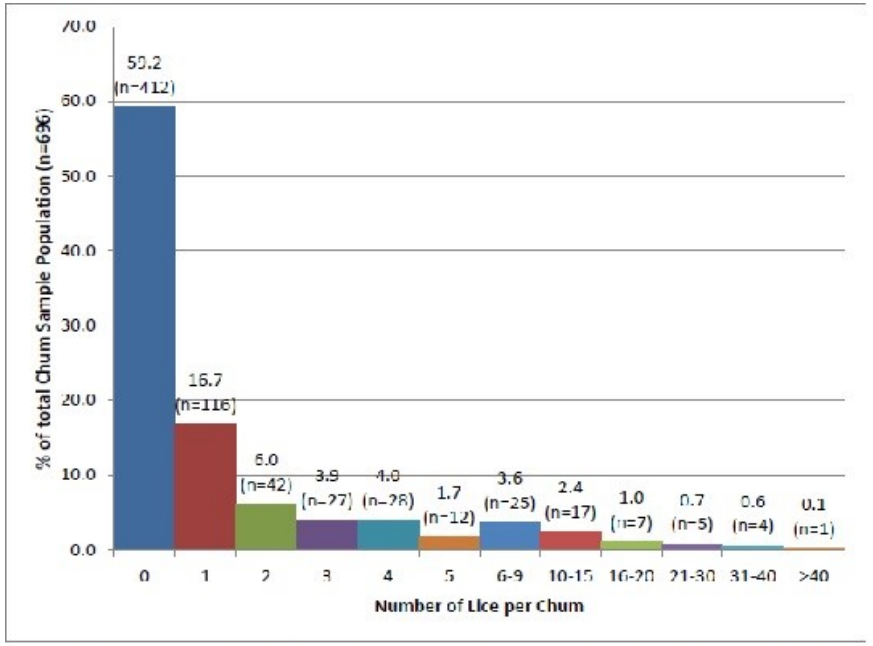

Figure 5: The number of sea lice per chum salmon graphed as a percentage of the total chum sample population collected in Clayoquot Sound in 2018.

30. Table 4 and Figure 5 were taken from "Wild Juvenile Salmonid Monitoring Program, Clayoquot Sound 2018" prepared by Mainstream Biological Consulting, July, 2018 accessed at https://www.cermaq.com/wps/wcm/connect/a08bb1f5-818a-4fc9-8fa5-c0cbc8fafb31/Clayoquot+Wild+Juvenile+Salmonid+Monitoring+2018.pdf?MOD=AJPERES

Sampling performed independently of Cermaq by the Cedar Coast Field Station between April 26 and June 23 found 96% of the wild fish sampled (mostly chum) were infested with sea lice at various stages of development, with an average of 8.04 lice per fish. The lice counts per fish varied from 0 to over 50. [31]

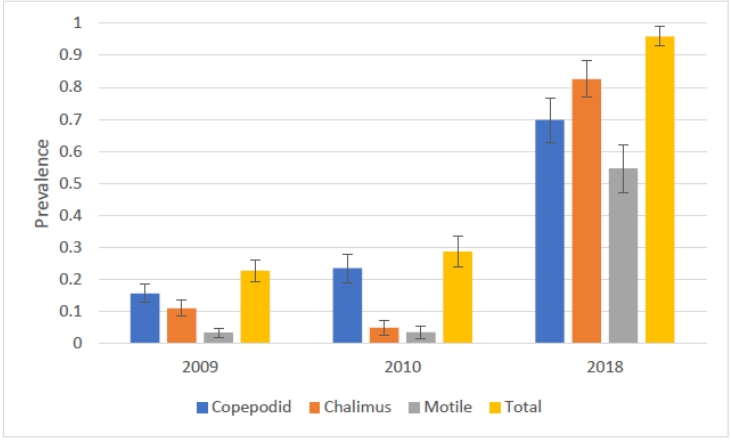

Figure 10 The proportion of the salmon examined that had at least one louse of either *L. salmonis*, or *C. clemensi* sea lice species, with 95% confidence intervals. Displayed are the values gathered in 2009 (n=620), 2010 (n=345), and 2018 (n=172) from Cypress Bay and Vargas Island from late April to June. Data from 2009 and 2010 was gathered by the Wild Fish Conservancy.

Figure 11 A Chum Salmon fry seined from Buckle Bay, Vargas Island in May 2018. Note the presence of sea lice in the chalimus and motile stages and lice induced chalimus scars.

The prevalence of infested fish reported by the Cedar Coast research team (at 96%) is significantly different from Cermaq's findings (40%), but a direct comparison of the two studies must be approached with caution. Sample sizes, methods, dates and locations differed. Cermaq's sampling included sites where juvenile salmon would have had less exposure (spatially and temporally) to farm effluent than the sites Cedar Coast sampled. Cedar Coast's sampling continued a full month beyond the last samples taken by Cermaq. The most biologically relevant data is the condition of the juvenile salmon as they leave Clayoquot Sound, i.e. after they have passed all the salmon farms, and this is data collected by the Cedar Coast team.

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31. Bartlett, M.C, Simmerling, J.S. Hunter D. 2018. Juvenile salmon and sea lice monitoring in Clayoquot Sound 2018. Cedar Coast Field Station report. Available from: http://www.cedarcoastfieldstation.org/archives/

Where do we go from here?

Drug-resistant sea lice management has a known trajectory, given the long experience in Norway and on Canada's east coast. Varying the drugs and chemicals used, using them in combination and experimenting with off-label uses are all approaches that have been tried, with sometimes devastating impacts on wild fisheries[32].

In Canada at present, the only approved alternatives to SLICE™ are Paramove 50™ and SALMOSAN VET™, both of which are bath treatments. Baths are more expensive than orally administered drugs, requiring more labour and equipment as well as having high potential to cause fatal stress to the fish being treated.

Reports of the effectiveness of Paramove 50™ vary from 70 to 95 percent. Repeated bathing is possible, but repeat treatments may stress the fish, lead to reduced growth and higher mortalities[33].

In August, 2017, Canada's Pest Management Regulatory Agency (PMRA) granted full approval for the drug azamethiphos (SALMOSAN VET™) for use against sea lice on salmon farms. It was approved without any study of the likely impacts on crustaceans or other marine organisms of the Pacific coast and with full knowledge of its lethal impacts on east coast lobster and shrimp.

Wild juvenile fish are often drawn into open netpens, presumably by food and / or light. The potential for exposure to drugs and chemicals used in the netpens is clear. **Photo credit George Quocksister Jr.**

Concerns were raised during the public consultation about the effect of azamethiphos on clam beds, oyster gathering areas and shrimp and prawn fisheries due to the close proximity of salmon farms in B.C. to many shellfish areas. The PRMA responded,

"As lobster larvae was determined to be the most sensitive non-target invertebrate, risk mitigation applied to mitigate the risks towards lobster larvae will inherently also mitigate the risks towards other less sensitive non-target invertebrate and vertebrate species… **The product label contains many use restrictions established to reduce the risk to both lobster larvae in the water column as well as adult lobster on the ocean floor. As these restrictions are mandatory no matter where the product is used, east coast or west coast, these restrictions will mitigate the risk**…"[34][emphasis added]

32. https://bangordailynews.com/2013/04/27/business/cooke-aquaculture-to-pay-490k-after-illegal-pesticides-kill-lobsters-in-canada/
33. Treasurer JW, Grant A, Davis P. 2000 Physical constraints of bath treatments of Atlantic salmon (*Salmo salar*) with a sea lice burden (Copepoda: Caligidae). Contributions to Zoology 69 (1/2).
34. Registration Decision Statement for Azamethiphos, accessed at https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/registration-decision/2017/azamethiphos-2017-13.html

However, the product label posted on Health Canada's website[35] contains only the warnings and restrictions pictured here:

ENVIRONMENTAL PRECAUTIONS:

TOXIC to aquatic organisms. Apply only to, tarped net pens or to dosing tanks in well boats.

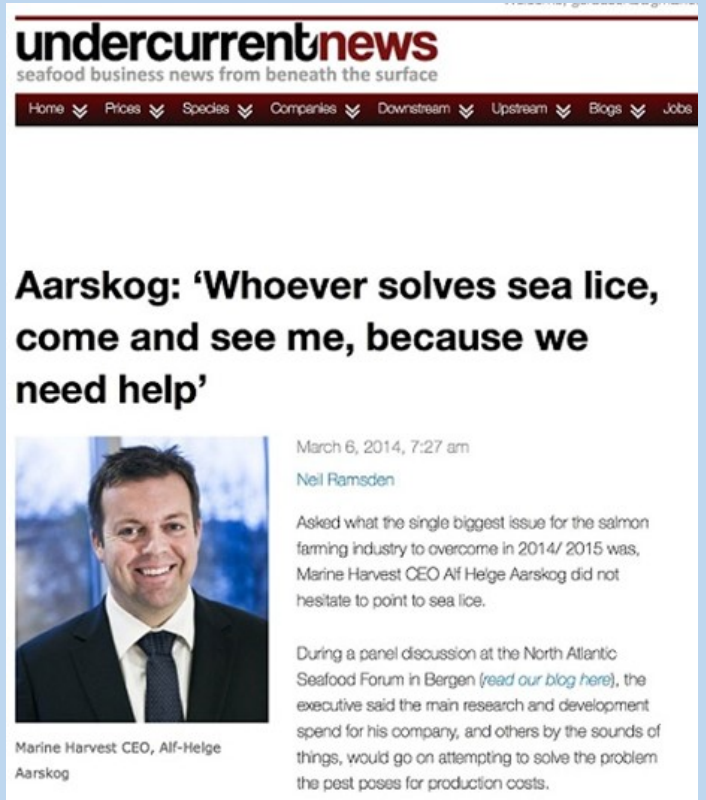
DO NOT discharge well boat treatment water within 1 km of any active lobster holding facilities which include active licensed lobster pounds and/or lobster tank houses as well as lobster cars/crates held within a designated harbour authority water lot, when the ebb or flow of the tide or the prevailing current is anticipated to be moving in the direction of a lobster holding facility within 2 hours from the start of the treatment.

When the treatment site is NOT within 1 km of an active lobster holding facility, which include active licensed lobster pounds and/or lobster tank houses as well as lobster cars/crates held within a designated harbour authority water lot, well boat discharge should be performed at outgoing tide or during periods with a local outgoing current.

As the nearest lobster holding facility—the nearest wild lobster, in fact—is some 6000 km distant from B.C. salmon farms, it is difficult to see how this restriction avails species in Pacific waters.

SALMOSAN VET™ is more toxic than hydrogen peroxide formulations and does not break down as quickly in the marine environment. It is effective only against the adult and pre-adult stages of sea lice and so repeat treatments are required as the lice mature. Like all pesticides, Canada has approved its use without disclosure of all chemicals contained in the formulation, so only the active ingredients are assessed[36].

With SLICE™ treatment, most of the drug could be presumed to be taken up by the farmed fish, with little drug residue consumed by non-target species or falling to the ocean floor. The alternative approved treatments involve bathing fish in chemical solutions that are effective only against the adult and pre-adult life stages of sea lice and may therefore lead to repeat treatments as lice mature on the fish. The bath chemicals are discharged directly to the ocean, relying on dilution to prevent toxic effects on the ecosystem.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Aarskog: 'Whoever solves sea lice, come and see me, because we need help'

March 6, 2014, 7:27 am
Neil Ramsden

Asked what the single biggest issue for the salmon farming industry to overcome in 2014/ 2015 was, Marine Harvest CEO Alf Helge Aarskog did not hesitate to point to sea lice.

During a panel discussion at the North Atlantic Seafood Forum in Bergen (*read our blog here*), the executive said the main research and development spend for his company, and others by the sounds of things, would go on attempting to solve the problem the pest poses for production costs.

Marine Harvest CEO, Alf-Helge Aarskog

The importance of sea louse control cannot be overstated and represents a global threat to wild salmonids and the industry. It is one of two main drivers of cost to the industry globally.

35. http://pr-rp.hc-sc.gc.ca/1_1/view_label?p_ukid=111789820

36. RD 2014/002, A review of potential environmental risks associated with the use of pesticides to treat Atlantic salmon against infestations of sea lice in Canada at p. 6

Sea lice can develop resistance to both approved bath treatments; manufacturers' warnings[37] indicate that care must be used to kill as many lice as possible in each treatment to slow the rate of development of resistance. As the chemicals are toxic to the fish being treated, this involves a tradeoff between farmed fish mortality rates and sea louse mortality rates.

No cumulative effects analysis has been done for a scenario in which all of the farms clustered in an area like Clayoquot Sound require bath treatments at about the same time, as they did this year. Both Paramove 50™[38] and SALMOSAN VET™[39] are toxic to aquatic organisms. SALMOSAN VET™ is described as "very dangerous" to crustaceans[40].

There is no assessment of potential cumulative effects of the chemicals used in concert with other drugs or chemicals and no comprehensive monitoring program to obtain data on impacts to wild juvenile salmonids or other species. New drugs and chemicals may be approved on an emergency basis to control outbreaks when lice become resistant to currently approved chemicals.

This is the known trajectory of sea louse treatment: more toxic chemicals, used more frequently and often in combination, lasting longer in the environment and having unknown potential impacts on Pacific species.

Non-chemical treatment of sea lice

Two of the companies farming salmon in B.C. waters have announced that they have on order specialized equipment for non-chemical treatment of sea lice. Norwegian salmon farmers have been using warm water and fresh water baths to reduce sea lice since 2015. In 2016, Marine Harvest introduced its "Hydrolicer": a boat capable of producing fresh water from sea water and continually servicing its farms with fresh water bathing. The "Thermolicer" treatment system uses warm water to dislodge the lice.

Thermal de-licing was evaluated in 2016 by the Norwegian Veterinary Institute with positive early results:

The results show that thermal de-licing results in a significant reduction in the number of mobile and adult lice. Calculated reductions in lice burden vary between approximately 75 – 100%. Although not statistically significant, a reduction in number of attached lice stages was registered following treatment. Several participating farms recorded similar levels of lice three weeks post-treatment compared to pretreatment levels. It is considered likely that infection from other cages and neighbouring farms as well as development of attached stages to mobile stages will affect the situation.

The Institute concluded,

Thermal de-licing **should be used together with other measures** as part of an integrated anti-lice strategy. There is a considerable need for development of effective non-medicinal anti-lice treatments which maintain acceptable levels of fish welfare if aquaculture is to remain sustainable [emphasis added][41].

37. Ibid
38. Ibid
39. https://www.fishfarmingexpert.com/article/hydrolicer-unveiled/
40. https://www.steinsvik.no/en/products/e/seaculture/fish-health/thermolicer
41. https://www.vetinst.no/rapporter-og-publikasjoner/rapporter/2016/use-of-therapeutic-agents-against-salmon-lice-in-norwegian-aquaculture

But by 2018, the situation had changed. Extensive use of thermal de-licing in some geographic areas was leading, they suspected, to a developing tolerance for hot water:

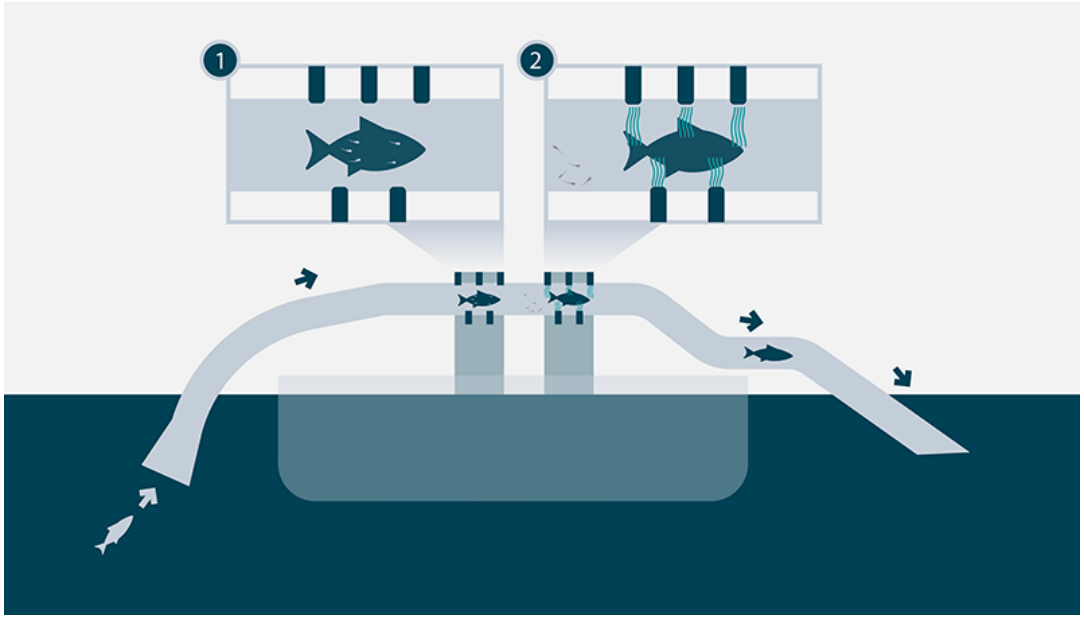
"The Veterinary Institute believes that repeated thermal delicings in the same geographic area are worrying in view of possible resistance " [42]

By the end of September, 2018, Barents Watch was reporting 8 percent of Norwegian farms with sea lice over legislated limits[43]. Undercurrent News reported "soaring" sea lice levels that affected Norwegian production levels significantly[44].

Few reports appear to be available on the efficacy of the Hydrolicer treatment. It was used on some Scottish salmon farms in 2017, where inspections by the Fish Health Inspectorate included the following observations[45]:

Rubha Stillaig was inspected on 15th February 2017, the FHI recording that the *"site has been using hydrolicer as lice treatment. Has been effective at reducing lice numbers, although numbers still slightly above suggested criteria for treatment.*

Furnace Quarry was inspected on 28th February 2017. The FHI recorded,"… *Treatments: Slice in April and June 2016, Alphamax June 2016, Salmosan 2 x August 2016 and end September/beginning October 2016, Hydrogen peroxide in October 2016, Hydrolicer x 2 beginning and end of November 2016. Levels coming down post treatment but re-settlement* [of lice on the fish] *was reported to have been quick.*



Schematic of the Hydrolizer, courtesy Marine Harvest Canada

Despite all the above treatment being deployed at this farm site, the FHI recorded that the farm was

"not below CoGP treatment thresholds from August 2016 through to harvest and at least one count of over 8 AF [adult female lice] was recorded every week from the implementation of the new sea lice policy in October 2016 until harvest" and that *"bioassays conducted in Loch Fyne showed high resistance to AMX and lowered sensitivity to Salmosan Vet. Reported that Salmosan and Hydrolicer achieved good initial clearance but resettlement was rapid."*

42. https://www.fishfarmingexpert.com/article/vets-fear-lice-may-develop-resistance-to-hot-water/
43. https://www.barentswatch.no/en/fishhealth/2018/18
44. https://www.undercurrentnews.com/2018/10/26/chile-salmon-producers-see-strong-prices-continuing-in-2019-as-norway-falters/
45. https://salmonaquaculturescotland.wordpress.com/2018/04/24/the-environmental-record-of-the-loch-fyne-salmon-farms-part-2/

The Hydrolicer has been used at some sites in New Brunswick since 2017. In its Annual Report for that year, the Atlantic Canada Fish Farmers' Association (ACFFA) has only this to say about non-chemical treatments:

A number of non-chemical control strategies including a hot water shower system was implemented in spring 2017 for certain sites and cleaner fish were introduced at more farms in 2017. As well a vessel equipped with a Hydro-Licer unit was used in some specific locations. This system mechanically removes the lice by passing the fish through a series of pumps. These new strategies will continue to be implemented and expanded as they become more effective[46].

ACCFA continues to stress the need for more chemical and drug therapies to be approved for use in Canada[47].

None of the non-chemical methods of louse control is fully effective at controlling sea lice on its own. Even combined with extensive and varied drug and chemical treatment, some Scottish and Norwegian farms using the non-chemical methods have been unable to control lice adequately.

Conclusion

As the globe continues to warm, we can expect that the rising seawater temperature and salinity that we have already experienced in B.C. coastal waters will continue. These are conditions that promote more rapid development of sea lice in open netpen aquaculture farms and they cannot be dismissed as a temporary aberration: they are the conditions in which sea lice will have to be managed.

There is no reason to expect that B.C. salmon farms will have any better luck managing the parasite than those same companies have had elsewhere in the world, now that sea lice have developed resistance to SLICE™.

Globally, the cost of sea lice management is an important driver of investment in land-based, contained facilities. There are nearly 300,000 metric tonnes of production planned or under construction worldwide, with a single U.S. facility designed to produce more that the total current output of all of B.C.'s salmon farms.

B.C. has many advantages to exploit in the development of this industry—a knowledgeable work force, markets and infrastructure, processing plants and a suitable land base among them. However, it will lose one important advantage, which is its established markets, if it does not move quickly to encourage this industry-wide shift. It is only a matter of time until land-based farms are established to serve the markets of the Pacific Northwest.

It is long past time for an open and honest approach to the regulation of aquaculture in Canada, that recognizes its impacts on wild salmon ecosystems and assists its transition to closed containment.

46. https://static1.squarespace.com/static/56e827cb22482efe36420c65/t/5ada031e1ae6cf6be3d702fe/

47. Ibid, at p. 4