A visit to Norway—and the sea lice follies in BC

Professor Neil Frazer
School of Ocean and Earth Science and Technology
University of Hawaii at Manoa, Honolulu, HI 96822
neil@hawaii.edu

May 29, 2010

On May 20, 2010, the Norwegian corporation Cermaq held its Annual General Meeting in Oslo Norway. Cermaq does business in Canada through its subsidiary Mainstream, which owns 3 hatcheries and 28 sea cage sites on the coast of British Columbia, and through its subsidiary EWOS, which manufactures feed for farmed fish at its plant in Surrey. According to its 2010 annual report, Cermaq has 350 employees in Canada. Perhaps one third of those employees work for EWOS. The government of Norway owns 40% of Cermaq, and the Norwegian people are very conscious of the environment. As the trade commissioner at the Canadian embassy in Oslo phrased it, "Norwegians strive to be greener than any other country in the world." A small group from North America attended the Annual General Meeting to request that Cermaq/Mainstream remove its sea-cage sites from the migration routes of wild Pacific salmon in British Columbia.

The group consisted of Bart Naylor and Don Staniford, of the Pure Salmon Campaign, Darren Blaney of the Homalco First Nation, Nicole Mackay of Mackay Whale Watching, and me. Prior to the meeting, Bart, Don, Darren, Nicole and I met privately with the CEO and Directors of Cermaq to discuss events in BC. (Full disclosure: my travel expenses from Victoria were partly paid by the Wilderness Tourism Association of BC and the Pure Salmon Campaign.)

The private meeting with the CEO and Board was constructive. The Board appeared to know it had trouble—Cermaq lost a lot of money in Chile in 2008—and it was open to understanding events in BC. The meeting began with a promotional video by Cermaq that used the word sustainable at least ten times, and mentioned 'coordinated area management' (simultaneous fallowing and/or simultaneous treatment for lice) as though it was a new development instead of something that independent scientists have been urging salmon farmers to do for many years. The corporate director for public relations also mentioned it with some pride, as though all of the problems of the past were now solved.

Don Staniford showed the Board Damien Gillis' video of the "Get-Out Migration" that had culminated in Victoria on May 8. Darren Blaney spoke movingly about the effects of the Church House salmon farm on the local clams (gone within a few years), and Nicole Mackay spoke eloquently about the effects of salmon scarcity on orcas in the Broughton Archipelago (with reduced numbers of salmon, orcas must now spend so much time foraging that there is little time left to socialize and mate). I pointed out that the Victoria rally shown in the video had been attended by four to five thousand people, a Victoria policeman's estimate. I also pointed out that The Pure Salmon Campaign's goal of removing two farms from Okisollo Channel was regrettably modest. In my opinion

nearly all of them should be removed, not only for the safety of the Fraser sockeye, but also to let that area recover from the obvious eutrophication.

Shortly before the Annual General Meeting, we took part in a demonstration in front of the building where the meeting was to take place. Several other environmental organizations from Norway were present, along with a few Norwegian businessmen concerned for wild salmon. I held a sign written in Norwegian that said "Closed containment now," and stood with the others next to a large Norwegian flag with a few sea lice painted on it. Those lice might as reasonably have been painted on a Canadian flag, but we did not have a Canadian flag with us.

At the Annual General Meeting, Bart Naylor's shareholder resolution that the Board of Directors be elected every year, rather than every two years, was approved by a majority of independent shareholders, but it failed to pass because the manager of the Norwegian government's 40% share of Cermaq voted against it. Bart, Darren, Nicole and I each spoke for about three minutes, and Don showed a minute or two of the video from Victoria. An employee of Mainstream Canada smirked and snorted during our presentations, in glaring contrast to the ever-courteous Norwegians. I suppose she was present in Oslo because she had escorted to Norway an Ahousat chief that had recently allowed salmon farms into his nation. That Ahousat man didn't speak at the meeting other than to verbally attack Nicole afterward. I missed his harangue because an elderly shareholder, one of the founders of NorskData, wanted to tell me about his own scientific days.

Prospering Cermaq

There is no need to feel sorry for Cermaq/Mainstream shareholders, or for those of Marine Harvest and Grieg. Removal of salmon farms from the migration routes of wild Pacific salmon will reduce North American farmed salmon production, but will only temporarily reduce the profits of those three large Norwegian companies that control over 91% of farmed salmon production in British Columbia. To see this, consider events following the recent disease crisis in Chile. When Chilean production dropped, farmed salmon suddenly became a luxury instead of a commodity in the markets served by Chile. Prices jumped, and salmon farmers not directly affected by the epidemic enjoyed greatly increased profits.

Cermaq aside, it is quite possible that the economy of BC would also be improved by making farmed salmon a luxury rather than a commodity. Recall that Cermaq employs only 350 people in BC, less than 12% of its global workforce. If farmed salmon were a luxury rather than a commodity, the industry would more closely resemble the wine industry, which contributes many jobs to the BC economy; and the 21,000 direct jobs in BC's wilderness tourist industry would be safe. For reference, the BC Salmon Farmers Association claims 2,800 direct jobs in salmon farming.

Intelligent companies always seek to increase profit rather than revenue, provided that a reduction in revenue does not cause the size of the company to shrink relative to that of

its competitors. If the removal of farms from migration routes in British Columbia does not penalize one company more than another—in other words, if the percentage decrease in production of each company is the same—the companies will accept the necessary changes after only perfunctory protest. Deciding which farms to remove is not difficult science, and the farms can be shut down within six months with relatively little financial hardship to the companies concerned. Remember we are talking about large multinational companies. Cermaq's 2009 cash flow from operations was C$180 million. Only 33% of its revenue comes from Mainstream, its fish-farming subsidiary, and only 25% of Mainstream's revenue comes from its sea-cage sites and hatcheries in BC.

Why eminent scientists are angry

Peer-reviewed studies show that farm-fostered sea lice reduce the productivity of wild salmon populations. Each autumn, larvae from lice on in-migrating wild adult salmon infect farm salmon. Six months later, larvae from lice on the farm salmon infect out-migrating juvenile wild salmon. Pink and chum salmon fry are especially vulnerable because they enter the ocean weighing about a quarter of a gram and they do not have scales. In areas without salmon farms, infection rates of pink salmon fry are negligible compared to rates in areas with farms. Sea lice are classified as parasites because they increase the mortality rates of their hosts in well-understood ways.

Despite the simplicity of the mechanism, and the many peer-review studies that support it, there is confusion in Canada because of a small group of scientists in Canada's Department of Fisheries and Oceans (DFO). Those scientists have an explicit duty to support government policy, and the current Minister of Fisheries and Oceans favors salmon farming. This is not a recipe for good science. Judging from their papers, this group lacks basic training in the population dynamics of host-parasite systems, and their intention is to mislead their readers. In plain English, their papers appear to have been written mainly for propaganda purposes. In Norway, by contrast, government scientists now accept that sea lice from salmon farms are responsible for declines of wild salmon and sea trout.

Dr. Larry Dill, a world-renowned Canadian ecologist, has described DFO's Minister and senior bureaucrats thus: "They are either extremely ignorant, misinformed, or they are lying to us." Dr. Daniel Pauly, easily the world's most eminent fisheries scientist, agrees with Dr. Dill. As Dr. Dill noted in his testimony to the Parliament of Canada's Standing Committee on Fisheries and Oceans, the science supporting declines of wild salmon due to salmon farms is about as certain as science can ever be, and it is wrong for decision makers to delay or deny by seizing on the fact that nothing in science is ever 100% certain. Scientists who have studied the situation, and are not compromised by being on the payroll of the salmon farming industry or a captive government agency, agree that farms must be removed from the migration routes of juvenile Pacific salmon in British Columbia if those salmon are to be preserved.

I share the feelings and concerns of Dr. Dill and Dr. Pauly. Moreover, the same lies that were used to deceive the people of BC are now being used to deceive countries that

haven't yet given their coasts over to sea cages. The propaganda generated by that small group of scientists at DFO has not only created confusion in Canada; it has created confusion around the world.

One of the ways in which the bureaucrats at DFO have controlled this issue is by tasking unqualified people to deal with it. The sea lice group at DFO would not be bad scientists if they stuck to what they know, but they haven't had the courage to admit that they don't have the necessary mathematical training. To fish pathologists and old-school fisheries scientists, the sea lice issue is a mystery, but to anyone with training in mathematical ecology, it is easy. Remember there are only two important questions: (1) Does adding farm fish to the ocean cause sea lice levels to rise? (2) Do increased levels of sea lice cause wild fish to decline? Both questions can be answered with a Yes, using basic ecology or basic physics, without ever putting a farm fish in the water. Anything other than a decline of wild fish would be a miracle.

Unfortunately basic ecology doesn't tell us how much the wild fish will decline. For that, one can do a type of mathematical calculation that fewer than a hundred biologists in the world would understand—or one can perform experiments by actually farming fish in sea-cages. Since most fisheries biologists prefer experiments to mathematics, it is no surprise that the experiment has now been done. Every sea-cage in Norway, Scotland, Western Ireland, British Columbia is part of that huge experiment, and we now have the answer to the question: How much do wild fish decline?

Not surprisingly, the answer is this: If you put just a few farm fish in the water (a few mom-and-pop farms) wild fish decline hardly at all, but if you put a lot of farm fish in the water, wild fish decline a lot. For technical reasons that are difficult to explain here, wild fish decline at an accelerating rate as more farm fish are added. In other words the loss of wild fish caused by the second farm in an area is more than the loss of wild fish caused by the first farm in that area. Similarly the loss of wild fish caused by the third farm is greater than the loss of wild fish caused by the second farm, and so forth, until the wild fish are completely gone.

The decline of local wild fish caused by the farms doesn't happen overnight. The way it happens is that every year, on average, there are fewer wild fish. Unfortunately, wild populations are difficult to census, and they are so variable from year to year that a decline can be hard to discern until decades of data have accumulated. The parties responsible for the decline inevitably use the delay in the decline to point the finger elsewhere, as tobacco scientists used to do with lung cancer.

DFO's distraction science

Salmon sea cages in coastal areas provide a dramatic example of the effect discussed above because transfers of parasites between farm and wild are synchronized in time. As noted earlier, when adult wild salmon migrate past salmon farms toward their rivers each fall, they give whatever diseases they have to the farm fish. The farm fish unintentionally culture those diseases over the winter. When the juvenile wild salmon swim past the

farms in the spring they get the diseases of their parents back from the farm fish—several months earlier than would happen under natural conditions. The infection pressure on the wild juvenile salmon is very great because the farm salmon are large in number and size. Sea lice are a well-studied example of this because they are easy to see on a fish.

That disease transfer mechanism isn't difficult to understand, but the sea lice group at DFO tries hard not to understand it, and the natural human propensity for wishful thinking has made their work popular with the salmon farming industry and with governments that want to have both farmed and wild fish. The DFO group has tried to discredit the disease transfer mechanism in three main ways: (a) by promoting unlikely alternative sources of the sea lice on juvenile wild salmon: (b) by attempting to show that lice don't lower the life expectancy of their juvenile hosts: and (c) by distracting the public from well-established population-level effects. I'll consider the alternative source hypothesis first.

By trawling a large area of ocean, one DFO scientist managed to find 35 wild salmon in April–May, then hinted that this very small population could be the source of the lice on the juvenile wild salmon, ignoring the many millions of farm salmon located just a few miles from the wild salmon rivers. In another paper, he suggested that returning adult wild salmon are the source of the lice on the juvenile wild salmon, a proposition that could only make sense if the adult wild salmon returned several months earlier than they actually return.

A second DFO scientist has worked very hard to create an impression that three-spine stickleback are the source of the lice on juvenile wild salmon. He's very careful not to say exactly that—it's enough that his work create confusion about the issue. None of the 21,000 lice he found on 1,300 sticklebacks were egg-bearing females, and almost all of the lice were juvenile lice stages. Since he sampled the stickleback for lice in spring, and lice only survive a few months, the lice on the stickleback couldn't possibly have originated with adult wild salmon the previous autumn. The lice almost certainly originated with the millions of farm salmon near where he sampled the sticklebacks. Later he attempted to have salmon lice reproduce on stickleback in his laboratory, without success.

Any responsible scientist would have done a spatial analysis of the lice on sticklebacks to see whether lice burdens on the sticklebacks were greater near farms than distant from farms, as they were on the juvenile wild salmon sampled by Marty Krkošek and Alexandra Morton. This DFO scientist has not analyzed the spatial pattern of lice infection on stickleback, nor has he done so with his samples of juvenile wild salmon. In his 2006 paper on stickleback there were no salmon farms on his map of the Broughton Archipelago. The paper was published in a journal whose editor is unlikely to know that the Broughton Archipelago has over 20 salmon farms.

Now let's look at the notion that lice do not lower the life expectancy of juvenile wild salmon. It is well established in the scientific literature that lice feed on the exterior mucus layer and skin of fish, consuming metabolic resources and providing a point of

entry for secondary infections, and that they cause fish to act in ways that make them more visible to predators and thus more likely to be eaten. All three mechanisms are guaranteed to lower life expectancy. That is why sea lice are classified as parasites.

The DFO stickleback scientist has also confused the life expectancy issue by doing laboratory experiments in which juvenile pink salmon were exposed to lice larvae. What happened is that most of the lice fell off his fish. The lack of mortality of the pink salmon might have been related to the duration of exposure being very short compared to the exposure duration of juvenile pink salmon out-migrating through the Broughton Archipelago, and it might have had something to do with the fact that the fish weren't infected under natural conditions. When independent scientists did a similar experiment using naturally infected fish, keeping the fish in the same waters in which they were caught, the naturally infected fish died at a much higher rate than the uninfected fish even when they were protected from predators.

Now let's look at the population level question. In plain English, the suggestion is that maybe the little fish that died from sea lice would have died anyway, so the number of returning adult wild salmon isn't reduced by their deaths. It's not an absurd proposition, because if there is a shortage of food, having too many young salmon competing for it could cause many of them to starve. However, a strong population-level effect from lice had already been established in the scientific literature, both generally and for pink salmon stocks in the Broughton Archipelago. Unable to confront the issue head on, and without the mathematical training necessary to even try, the senior DFO sea-lice scientist wrote a paper entitled "Exceptional marine survival of pink salmon that entered the marine environment in 2003 suggests that farmed Atlantic salmon and Pacific salmon can coexist successfully in a marine ecosystem on the Pacific coast of Canada." I'm convinced that title was changed after review—I can't imagine any serious reviewer passing on it—but as a propaganda instrument it is perfect. The paper is fundamentally unscientific in a number of ways.

First of all, survival wasn't exceptional. (Here I use the word survival to mean inter-generational survival, the ratio of returning adults in the daughter generation to the escapement of the parent generation. Escapement is the number of fish in the parent generation that entered the stream to spawn.) All population models for pink salmon have the feature that survival increases with decreasing parent population, and the parent generation (the pinks that returned in 2002) of the pinks that went to sea in 2003 and returned in 2004 was the smallest it had been since 1960, so one would expect high survival. For example, the pinks that went to sea in spring of 1961 and returned in 1962 had even higher survival than the pinks that went to sea in spring of 2003.

The second unscientific thing about the paper is that marine survival is unknown. To estimate marine survival, you must divide survival by several other numbers, including eggs-per-spawner and egg-to-fry survival. Values for egg-to-fry survival are as low as 5% for streams without spawning channels and as high as 57% for streams with spawning channels. If you want a high estimate of marine survival, you pick an egg-to-fry survival of a few percent, and if you want a low estimate of marine survival, you pick an egg-to-

fry survival appropriate for a stream with a spawning channel. At least 40% of the pink salmon in the Broughton Archipelago come from streams with spawning channels, so it would have been appropriate to use a high egg-to-fry survival or at least some kind of average egg-to-fry survival. Instead, the author picked 5.6%, which is only 1.3% more than the lowest egg-to-fry survival in the source he cited. The effect was to inflate his estimate of marine survival by a factor of at least 4.

The third unscientific thing about the paper is that the title-as-conclusion fails to warn the reader that conditions in the Broughton in the spring of 2003 were nearly ideal. The BC government had mandated a fallow of farms along the migration route. Other farms held only smolts. Several farms in the Broughton had been emptied of farm salmon because of an epidemic of IHN virus. Sea lice infection pressure in the Broughton was thus about as low as it could be without totally shutting down salmon farming. Is this mentioned in the paper? The fallow is mentioned, even in the abstract, but not in a way that conveys its true extent.

You can see why this paper and his other papers on sea lice make entertaining reading. The language is impeccably scholarly, there are no lies, and every base is covered. But unless you are a scientist reading the paper carefully you would be tempted to conclude from it that salmon farming isn't having much of an effect on pink salmon. If you read only the title, you might think that everything is very fine indeed. It's an exquisite piece of misdirection.

Effects on BC universities

The propaganda generated by that small group of scientists at DFO has also had a pernicious effect on university science. If you look carefully at BC's three largest universities you will find at each of them at least one major scientist with a minimal understanding of ecology and a large grant for research in aquaculture. Aquaculture is a full-employment program for disease specialists with PhDs, and those who do not understand ecology have difficulty understanding the difference between salmon farming and other types of aquaculture. That is one reason why BC is about to lose Martin Krkošek, one of its finest scientists, to New Zealand. Marty, as he is called, is the young ecologist who greatly expanded the sea-lice sampling program begun by Alexandra Morton in the Broughton Archipelago. By all measures of scientific worth (scholarly publication, teaching, presentations at meetings and demonstrated ability to secure funding) Marty is head and shoulders above anyone else at his career stage. In both sea lice science, and ecology generally, he towers above the sea lice scientists of every country in the world—yet neither UVic nor UBC nor SFU hired him when they had faculty positions for which he was more than qualified.

A few weeks ago I attended Sea Lice 2010, a biennial scientific meeting about sea lice, which this year was held in Victoria. A UVic biology professor, the director of a research centre there, gave a presentation in which he cheerfully confessed to not understanding ecology. During the discussion period he wondered out loud whether sea lice really cause mortality rates of fish to increase. Robert Poulin, the eminent parasite ecologist and

evolutionist, responded dryly, "That is why we call them parasites," and the discussion moved on. As you might have guessed, this UVic professor has a large grant for research in aquaculture that is irrelevant to the important questions mentioned above. The real purpose of his grant, although he may not realize it, is to distract attention from the important issues. He is doing 'distraction science.'

Are neurotoxins the answer?

In BC's Broughton Archipelago the salmon farmers have temporarily arrested the decline of pink salmon by using the neurotoxin emamectin benzoate to reduce sea lice levels on their fish, but this is not a desirable long-term solution because neurotoxins can have unintended effects in the environment, and one of the hard lessons of the 20th century is that very small concentrations of xenobiotic chemicals can have important effects that aren't immediately obvious. Also, sea lice could develop resistance to emamectin benzoate, as has happened in Norway. That is thought to be less likely in BC than in Norway, because every autumn the gene pool of lice on BC farm salmon is refreshed by lice from in-migrating wild salmon, but there is recent anecdotal evidence for resistance at some BC farms. Finally, there are other diseases lurking in wait. Nature has a large supply of them, and many of them make sea lice look benign by comparison. In a farm-free environment those diseases are controlled by predators like seals and porpoises that eat sick fish before they have a chance to spread their disease, but a farm system has no such preemptive controls—it is like a bomb with a delicate fuse.

It is possible to imagine that an industry like sea cage farming would be repugnant to professionals who understand disease issues. It's not at all repugnant to pharmaceutical companies. Three out of the six sponsors of the scientific meeting referred to above were pharmaceutical companies: Intervet/Schering-Plough (a division of Merck), Novartis Animal Health, and PharmaQ. The University of Victoria Global Aquaculture Performance Project estimates that antibiotic usage by the marine finfish industry is about 5.5 million kg per year of active ingredient.

The Fraser sockeye

The surprising non-appearance of the Fraser sockeye in 2009 may be an example of the bomb effect. Scientists who are not on the payroll of the salmon farming industry or its captive government agencies agree that sea lice from the farms in the Discovery Islands area are a possible cause, but it is impossible to say how big a part lice played. The dark shadow over this picture is that salmon farming companies in BC seldom tell the public when they have disease outbreaks other than lice. If the farms in the Discovery Islands area had infectious haematopoietic necrosis (IHN) virus when the juvenile sockeye swam past on their way to the ocean, the sockeye could easily have been wiped out. IHN is the main reason sockeye are cultured only in fresh water, and it is a reasonable suspect because there were outbreaks of IHN on salmon farms in the Discovery Islands area in 1992–1996 and in the Broughton Archipelago during 2001–2003. IHN is endemic in BC, but as with sea lice, it is the magnitude of the infection pressure from farms that makes the difference for juvenile wild salmon.

A scientist from the sea lice group at DFO is now saying that the 2009 Fraser sockeye returned in low numbers because when they were juveniles migrating north in Georgia Strait they found little to eat. If the publications of this scientist regarding sea lice were less misleading, I might be inclined to believe him, but given his record, I reserve judgment. Don't expect the Cohen Commission to discover what caused the loss of the 2009 Fraser sockeye unless they subpoena all corporate records relating to diseases on salmon farms in the Discovery Islands. When I asked Dr. David Levy, the scientific manager of the Cohen Commission, about this he replied that it is easy for the Commission to extract information from DFO, because the Commission is also a federal agency, but that it is more difficult to extract information from the BC government or from the companies. In other words, don't hold your breath. But even if the Cohen Commission obtains those disease records there may still be no certain answer. Often records aren't kept. What is certain is that the farms in the Discovery Islands are like a 'time bomb' for the Fraser sockeye, and it should not take a Cohen Commission to remove them.

Alexandra Morton's credentials

DFO has tried hard to discredit her, even telling lies about her to sea lice scientists in Norway, but Alexandra Morton is a very competent scientist. The fact that she taught herself science instead of going through a conventional graduate studies program is a mark of genuine distinction. Some of the greatest scientists in history did not attend university: Michael Faraday, for example. As all research scientists know, it is not necessary to have even an undergraduate degree to be a scientist. All that is necessary is to do good research and publish it in peer-review journals. In fact, we have a saying in science: You are only as good as your last paper.

It isn't easy to combine science with actively caring about the place where one lives, but since 2001 Alexandra has spearheaded the scientific work that DFO would be doing if it were not a captive agency, the apparent puppet of a bureaucracy that is apparently itself a puppet of industry. There are other scientific heroes in this pantheon—Marty Krkošek, Mark Lewis and John Volpe come to mind—but they did not have to teach themselves science, as Alexandra did. Moreover, Alexandra is the only scientist who has consistently spoken out publicly, over and over, against the injustice and deceit that have been perpetrated on the people of BC by their own governments in regard to salmon farming.

Neil Frazer was born and raised on the coast of BC and has explored most of the coast of BC and southeast Alaska in his own boat. He is the author of over 100 peer-review scientific publications on the modeling of complex physical and biological systems, including several papers on sea lice. He has a bachelor's degree in engineering physics from the University of British Columbia and a PhD from Princeton University, and has been full professor at the University of Hawaii since 1989. He is the author of *Boat Camping Haida Gwaii* (Harbour Publishing, Madeira Park, BC). For a complete list of publications see http://www.soest.hawaii.edu/asp/GG/people/people.asp?ID=2215