STATE OF MAINE
BOARD OF ENVIRONMENTAL PROTECTION

IN THE MATTER OF

NORDIC AQUAFARMS, INC. Belfast and Northport Waldo County, Maine A-1146-71-A-N L-28319-26-A-N L-28319-TG-B-N L-28319-4E-C-N L-28319-L6-D-N L-28319-TW-E-N W-009200-6F-A-N	)))))))))))	INTERVENORS NORTHPORT VILLAGE CORPORATION AND UPSTREAM WATCH'S COMMENT REGARDING FEBRUARY 5, 2020 MEMO FROM DAVID RUSSELL AND MARCY NELSON (DMR) TO GREGG WOOD (DEP)

Intervenors Northport Village Corporation ("NVC") and Upstream Watch ("Upstream"), pursuant to the Board of Environmental Protection Eleventh Procedural Order dated February 19, 2020, at Paragraph 6.D(1), submit this written comment in response to a memo dated February 5, 2020 from David Russell and Marcy Nelson (Maine Department of Marine Resources or "DMR") to Gregg Wood (Maine Department of Environmental Protection or "DEP").

NVC and Upstream enclose their response and comment as attached in **Exhibits A** and **B,** a memorandum from Upstream's expert witness Mr. William Bryden and Upstream's consultant Dr. Dixon, respectively. While these gentlemen largely agree with DMR's memorandum, NVC and Upstream note that DMR's conclusions predated the February 11-14, 2020 hearing which took place in this matter, during much useful testimony was adduced.

Therefore, NVC and Upstream respectfully request that DMR's comments will be considered in light of the attached and the information provided during the course of the hearing, and will result in an updated recommendation.

INTERVENORS
NORTHPORT VILLAGE CORPORATION
AND UPSTREAM WATCH

By________________________________
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CERTIFICATION

I hereby certify that a copy of the foregoing was electronically mailed this 21st day of February, 2020 to those indicated on the attached Service List.

David J. Perkins, Esq.

EXHIBIT A

My review is based on more than a decade of real-world experience monitoring the environmental impacts of RAS facilities globally with an emphasis on Atlantic Canada.

The underlying premise of my arguments stems from the simple facts that:

a) Mortality will occur in Nordic's tanks at an alarming rate and involving extreme numbers of fish. This is evidenced by the numerous RAS facilities in existence in the NW Atlantic area that use aquifer only water, ozone as a water clarifier, and UVc at 250-300 mJ/sec/cm2. Mortalities of 20-35% are common for the egg to smolt stage with added mortality as the fish age and approach market size of 3.5-4.5 kilos. The older the fish the more likely it is to be amplifying and shedding contagions. Mortality rates of 50% from egg to market size fish is common.
b) That these mortalities are primarily from: 1) local external known contagions entering the facility, 2) contagions entering the tanks via the eggs, 3) unknown causes at least in part due to pathogens presently unknown to science.

Some Nordic Math

Nordic will likely stock similar numbers of fish that the Canadian company, Grieg NL, is planning to stock: 8 million eggs every 12 month with eggs added continually to allow for about a 22% mortality (See table below from NL EA Reg of Greig NL).

Table 2.10. Egg importation schedule during ramp up (Years 2–5) and steady phase (Year 6 onward). Shipments in February will be used for seasonal productions.

Year	Order Month	Planned No. of Smolt to Sea	Extra to allow for mortality (%)	No. of Eggs Received
2	September	1,000,000	22	1,220,000
2	October	1,000,000	22	1,220,000
Total		2,000,000		2,440,000
3	June	1,000,000	22	1,220,000
3	August	1,000,000	22	1,220,000
3	October	1,000,000	22	1,220,000
Total		3,000,000		3,660,000
4	February	1,000,000	22	1,220,000
4	June	1,000,000	22	1,220,000
4	August	1,000,000	22	1,220,000
4	November	1,000,000	22	1,220,000
Total		4,000,000		4,880,000
5	February	1,000,000	22	1,220,000
5	June	2,000,000	22	2,440,000
5	August	2,000,000	22	2,440,000
5	November	1,000,000	22	1,220,000
Total		6,000,000		7,320,000
6	February	1,000,000	22	1,220,000
6	June	2,000,000	22	2,440,000
6	August	1,000,000	22	1,220,000
6	October	2,000,000	22	2,440,000
6	November	1,000,000	22	1,220,000
Total		7,000,000		8,540,000

[2] One degree-day is the mean temperature, above 0°C, experienced for a period of 24 h. For example, a salmon egg incubated at an average daily temperature of 10°C for 62 days, from fertilization to hatching, is said to have hatched in 620 degree-days.

EXHIBIT A

See also the government response to a freedom of information request in NL Canada (FLR 2020-1) The table of mortalities is mainly from two 3.2 million fish hatchery that use only aquifer water and UVc at 250-300mJ/sec/cm2 in NL owned by Cooke and Marine Harvest. Note mortalities of up to 45% from egg to smolt.

Species	# Introduced	Developmental Stage	Mortalities Developmental Stag	Number of Morts
Atlantic Salmon	1948855	Fry	Fry	78616
Atlantic Salmon	2500000	Eyed Eggs	Fry	173282
Atlantic Salmon	1500000	Eyed Eggs	Fingerlings	357387
Atlantic Salmon	10397086	Eyed Eggs	Fingerlings	6298102
Atlantic Salmon	10123830	Eyed Eggs	Fingerlings	1500000
			Eyed Eggs	3000000
			Fry	500000
Atlantic Salmon	2200920	Fry	Fry	165281
Atlantic Salmon	235520			
Atlantic Salmon	2800000	Eyed Eggs	Fingerlings	620470
Atlantic Salmon	700000	Eyed Eggs	Eggs	654040
Eel	33000	Fingerlings	Fingerlings	8426
Tilapia	4250	Fingerlings	Fingerlings	12
Lumpfish	29262			
Lumpfish	5000			
Atlantic Salmon	11665959	Eyed Eggs	Fry	490000
			Fingerlings	2100000
			Eyed Eggs	3000000
Eel	374880	Fingerlings	Fingerlings	11246
Eel	4881	Adult		
Atlantic Salmon	3256358	Fry	Fry	1026164
Atlantic Salmon	2610000	Eyed Eggs	Eggs	550000
Atlantic Salmon	1930000	Eyed Eggs	Fingerlings	730000
Tilapia	3400	Fry	Adult	0
Atlantic Salmon	2310638	Fry	Smolt	10990
			Fry	28587
Atlantic Salmon	2140000	Eyed Eggs	Fingerlings	490000
Atlantic Salmon	1620000	Eyed Eggs	Eggs	960000
Atlantic Salmon	10231025	Eyed Eggs	Fry	1400000

A target of about 7 million smolt will be required by Nordic, at least, to produce 33,000mt in phase II. A 12-month time frame from egg to smolt is required and a further 12 months for market sized fish is typical. So, a 24-month cycle will require 14 million fish (7m egg to smolt, and 7m smolt to market size) plus additions for mortality. 7 million market ready fish times 4.5 kilos per fish equals 31,500mt while Nordic is aiming for 33,000mt. For argument's sake, let me assume that 14 million fish will be held in the tanks at any one time with daily mortalities removed and augmented by additional fish/eggs being added.

A recent study in British Columbia highlighted a Canadian Federal agency's sworn testimony during the Cohen Commission hearings on the diminution of salmon in the Fraser River. The federal Department of Fisheries and Oceans calculated a single net pen site's viral shedding load at 65 billion viral particles per hour for a single virus that has a high prevalence (>80%), in this case PRv. Please see: https://clayoquotaction.org/wp-content/uploads/2020/02/GoingViral-Report_FINAL.pdf
A typical net pen site has 500,000 fish in BC and as many as 850,000. An average of about 750,000 would likely be on the high side for numbers.

So, 14,000,000 / 750,000 = 18.66.

So, 18.66 x 65,000,000,000 = 1.213 trillion viral particles in the tanks being shed *per hour*. This is for a virus that weakens salmon, causes an immunological response in the fish, but may not always cause a mass mortality event. The fish are most often simply, sick.

Sick fish in a protective tank, spoon fed, and treated with antibiotics for secondary infections, can, and will most often be, sent to market. A sick wild fish, having been exposed to the effluent is less likely to survive and reproduce.

Even if we allow a 99.999% reduction for Nordic's sanitation system, we can quickly see that the sheer number of viral particles renders the treatment virtually ineffective. Taking a 3-log or even a 6-log reduction from 1.213 trillion leaves a huge number.

But our example, and the story, obviously does not end with one single virus that Maine does not even test for i.e. PRv, but the Board needs to consider two points. 1) there are many viruses that harm salmon for which the U.S. and Maine government do not test on a regular basis, even during vet examinations nor egg importations including: Eg, PCMv, EMv, etc. The main viruses tested for are the 5 World Organization on Animal Health (OIE) reportable viruses for which they are required to test by international treaty. The bar for testing to protect the public from fish disease is set very low, and the public is quite unaware. Consider that from a site containing 500,000 to 850,000 fish, only 3 to 5 fish are tested for ISAv, and then only once every 30-45 days, and a maximum of 10 fish are tested every 2 months. This worrisome omission can and should be remedied by the Nordic permit and the bar thus set high for future land-based fish farms. Note that Maine has not detected ISAv since 2013 but it's been there. In the same time period, and in the same ocean, Atlantic Canada has found it 115 times. America, and Maine must do better to protect the public.

The math results in the following self-evident statements: statistically:

virtually all viral contagions will enter the tanks sooner or later,
once inside the tanks they will amplify quickly, and
once amplified they will leave the facility in staggering numbers *per hour*.

EXHIBIT A

While the 0.04-micron filtration offered by Nordic is excellent, it is rated on a small percentage of particles passing through imperfections in the filters. We see a rating of 99.9% blocked at 0.04 microns, but this simply means that 0.1% will get through. This number once again is relative to the numbers of contagions in the water being filtered. Please be assured that the bacteria that 14 million salmon will produce in 15C to 18C water is tremendous (trillions per species of contagion and quadrillions when all species are counted).

Now, one has to ask one's self, if more than a MILLION salmon will die every year in Nordic's tanks, how many endangered wild salmon could their effluent kill. We have about 1100 wild salmon left in the Penobscot. Listed as "endangered". These wild salmon, like tanked salmon, school and thus one sick fish can quickly pass along contagions to those swimming downstream of it and rubbing against it.
Recommended mitigations: 1) reduce water use to aquifer only water, 2) use only local salmon genetics as per the Williamsburg Treaty recommendations, 3) require third party testing of effluent samples taken off Nordic's land such that chain of custody is maintained for legal purposes.

Where exactly is the bar set?

Fish health in Maine's RAS facilities is inextricably linked to effluent impacts. Fish are not levitated from the tank upon their immune system being triggered. The sheer volume of water moved, numbers of fish in the tanks, and thus, number of contagions in the effluent water, also means that this needs full public scrutiny using the best available technology. The bar for fish health monitoring in Maine and the USA is set while looking through the lens of what will impact food supplies and thus profits of the companies involved, ie the extremes of worst case scenarios. The contagions monitored are mainly those required by international agreements (eg OIE) due to their ability to collapse salmon aquaculture production - a handful of viruses and bacteria. As long as the fish can grow, they can be sold, with a very few exceptions. A sick wild fish is a dead fish or a fish that has a reduced capacity to breed. Should we not be monitoring the effluent based on how healthy the fish are in the tanks? Should we not demand that the fish are healthy? Where is the limit for antimicrobials? The Salmon Health Initiative in BC, run in part by the DFO's Dr Kristi Miller-Saunders, uses genetic techniques to monitor the fish's immune system. She, in essence, checks to see if the fish is in a diseased state. The techniques used do not rely on subjective physical symptoms that may or may not be present or obvious. This approach is leaning toward what the W.H.O. calls One Health. If we don't want literally tons of antibiotics dumped in Belfast bay, if we don't want wild fish exposed to the effluent from sick fish, then we need to truly monitor the health of the fish in the tanks. This is best done using genetic techniques pioneered into the field of salmon health in BC, while screening for the full panel of known contagions. Please learn more by talking with Dr Miller-Saunders.
https://www.pac.dfo-mpo.gc.ca/science/facilities-installations/pbs-sbp/mgl-lgm/staff-personnel/miller/Kristi_Miller_CV_July2011.pdf (250) 756-7155

EXHIBIT A

Mitigation: Screen tanked fish using genetic techniques that monitor the immune system of the fish. Screen for all known pathogens on a very regular basis. Require corrective actions when fish health is compromised after identifying the cause. Have enforcement ramifications.

Monitoring and contingency

DMR suggests few if any monitoring requirements for effluent or influent. DMR mentions the good contingency plans, however few if any contingency plans have been provided in the application. Perhaps the most significant lack of a contingency plan would be the response to a large die off.

As a sign of approval of Nordic's pathogen removal process DMR offers the fact that DMR's own facilities do not use anything near as complete/good. Granted, DMR has been doing this work for years with century knowledge and tradition. I believe that it is now reasonable for Upstream to seek a review of DEP monitoring data below each of DMR's hatcheries. If our state is to develop standards and criteria to permit land-based salmon, and in fact support a corporate permit, is it not reasonable that we set the standard? This may be a good time to fully analyze DMR facilities for pollutants, with a full spectrum of viruses and bacteria and pharmaceuticals. We may all learn from this and owe it to the industry to evaluate our own facilities.

In addition, Nordic offers no contingency plan. Suppose disease strikes? Are there holding tanks? What happens to all the contaminated water? Will it be discharged t thee Bay? Will it be cleaned by the proposed treatment system or will that system be overwhelmed?

Chlorine

One process in the Nordic application that DMR provided comments on is the Onsite Seafood Processing. On page 7, is written:
"Chlorination of processing waste streams is highly effective for neutralizing many pathogen threats. As chlorine-based disinfection systems are subject to human error and equipment failure, it is insufficient to serve as the only means of preventing the release of exotic pathogens of high consequence should such be present in the fish to be processed . However, when effluent streams are subsequently sent to the robust secondary treatment process , such a Nordic's effluent treatment plant with filtration to 0.4 microns and UV at 330 mJ/cm3, the risk is inconsequential compared to other avenues for pathogen introduction."
This is a concern, since this is the first we have heard that potentially errant amounts of chlorine may be entering the MBR treatment facility. MBR works because of beneficial bacteria reducing nutrient loads. High levels of chlorine can drastically reduce the capability of a MBR system. The fact that there is a single, central MBR system raises additional concerns. If individual tanks develop a viral load or failure all their waste will go to this central facility for discharge

“Bird Feeder Effect” due to Temperature

As every salmon angler that fishes with a thermometer can attest, salmon enjoy water at a certain temperature, Ideally, 12-18C. Thus, the alleged 0.3C increase in water temperature over

a 100m wide plume will, at times of below ideal ambient water temperatures (e.g. 6C during the smolt migration) result in the fish being attracted to the warmer water that will be full of contagions. The same will happen during times of extremely warm water of 19C and above. A 0.3C difference, as any angler will attest, will affect a salmon's behavior. This, combined with the ever present contagions in the effluent, is a serious weakness for the project.
An additional effect was suggested by Dr Pettigrew: Secondary characteristics, e.g. coves with eddies, points that create eddies, and other features that can concentrate effluent particles i.e. contagions.
Recommended mitigation: reduce temperature difference by cooling the water before discharge. Reduce pathogen creation by only allowing aquifer water to be used.

Williamsburg Treaty

This treaty requires fish rearing facilities to use only local genetics The rationale behind the requirement is that:

1) screening of any imported eggs is not 100% and only tiny samples of each shipment are tested/screened. Thus, all pathogens eventually get past the screening process.

2) Non-native salmon e.g. Norwegian strain salmon proposed to be used in Maine are likely to carry known non-native viruses and/or virus strains in the eggs.

3) Not all viruses nor viral interactions are known. See Mordecia et al 2019 and Ferguson et al 2019 as examples of ones discovered within the last 12 months that have been harming wild and aquaculture fish for decades or more.

ARTICLE 5

Measures to Minimise Impacts of Aquaculture and Introductions and Transfers

Each Party shall take measures, in accordance with Annexes 2, 3 and 4 to this Resolution, to:

- minimise escapes of farmed salmon to a level that is as close as practicable to zero through the development and implementation of action plans as envisaged under the Guidelines on Containment of Farm Salmon (CNL(01)53);
- minimise impacts of ranched salmon by utilizing local stocks and developing and applying appropriate release and harvest strategies;
- minimise the adverse genetic and other biological interactions from salmon enhancement activities, including introductions and transfers;
- minimise the risk of disease and parasite transmission between all aquaculture activities, introductions and transfers, and wild salmon stocks.

Movements into a Commission area of reproductively viable Atlantic salmon or their gametes that have originated from outside that Commission area should not be permitted.

EXHIBIT A

Recommended mitigation: Require Nordic to only use native genetics and rapidly develop its own broodstock. This is what all aquaculture facilities in the NW Atlantic currently are doing. The Treaty has not yet been broken in nearly 40 years despite serious expansionist pressure by industry to do so. It is currently under its biggest threat ever due to the amounts of money pouring into Maine's proposed RAS industry that appears to be developing ahead of an adequate broodstock source. Sanity and logic dictate the industry growing at a pace that matches the development of a broodstock using local genetics.
There is currently a lack of sufficient production of the typical endemic St. John River eggs used by all aquaculture facilities in the NW Atlantic. Rather than violate the treaty, Nordic can and should quickly develop the broodstock fish required and purchase eggs from NS in the meantime.

The State of Washington recently (2019) caught Nordic's chosen supplier (Stofnfiske) shipping *norwegian strain* PRv infected eggs. The company was fined $800,000 and the fish destroyed. The egg supplier admitted that PRv free eggs are available but are in short supply and cost more. Similarly, Chile banned Stofnfiske from shipping eggs to them due to Stofnfiske having been caught with a super deadly, non-species-specific virus VHSv 4a (pacific strain!) in their hatchery in 2015. I can give MANY more examples, but this should suffice. Stofnfiske in Iceland is using/offering only Norwegian salmon eggs to Nordic.

What Must Nordic Prevent from Entering the Tanks?

The intake water will be filtered at 10 microns. But 250 gallons *per hour,* 24/7 will be surface water (Little River or Bay). In fact, *about 20% of the total volume of ALL THE TANKS* will be replaced every day, or 7.7 million gallons. This acts like a moderate sized flow through design BUT with the added risk of recycling the water thus capturing and employing the worst aspects of both designs when considering disease. Obviously 10 micron filters and 250mJ/sec/cm2 light with some ozone clarifying the turbidity will not stop bacteria, fungi, and viruses from entering *including both finfish and human pathogens transmitted and amplified by fish (human pathogens called zoonotics, see google for a list of 6 bacteria that salmon amplify that cause pathology in HUMANS)*. Nordic is relying primarily on UVc as sanitation, which we know is only a percent effective. Moreover this percentage is variable based on turbidity (which can be extreme in the river and bay used as a water source).
No surveying nor modeling was done for what Dr Russell in a 2015 article in The FishSite suggested is the number one reason RAS facilities go bankrupt: Disease. There has been a complete lack of contagion surveys in Little River, and Belfast Bay near Little River where surface water is proposed to be used. It is unfortunate that Nordic's aquifer wells show issues with seawater ingress and are not able to supply enough pure clean fresh water for Nordic's proposed operation. However, this should not be allowed to trigger surface water use resulting in dramatic increases in antibiotics and harm to marine fish stocks. This use of surface water is now not allowed in NS, China, and frowned upon globally in the aquaculture industry for obvious reasons.

EXHIBIT A

Mitigation: Full year (all seasons and conditions) survey for contagions in source water before a permit is issued. Limit use to aquifer only water (City and Nordic wells). Monitor for ingress of surface water that can carry contagions.

Lack of Effluent Monitoring at the end of the pipe

Neither the State nor the U.S. will monitor for finfish contagions in the effluent. Thus, it behooves the DEP to require this in any permits it issues for effluent.
Mitigation: This should be sampled off Nordic's land, by an independent 3rd party approved by Maine DEP with no ties to aquaculture, while maintaining a transparent chain of custody for legal purposes.

Lack of Antimicrobial Limits

Currently the complete lack of antimicrobial (aka antibiotics) limits results in over-use, poor design, etc. and poor decisions by investors and operators. This industry is addicted to drugs, E.g. the Cooke RAS aquifer-only hatchery in NL used 183 million milligrams in 2016 to produce less than 3 million smolt of ~100 grams each.
Mitigation: Cap antibiotics with serious fines as a deterrent; allow only aquifer water to be used; require public reporting of amounts used on a weekly basis.

Lack of Public Transparency

Maine and the U.S. in general would benefit from significantly improved public reporting for issues that impact the environment, e.g. mortality numbers, disease events/diagnoses, antibiotic usage rates, and mass mortality events. Increasingly large regions of the globe require this information to be announced on a website and/or press releases issued by the government.
Mitigation: Require weekly public disclosure of mortalities, disease events, diagnoses, antibiotic usage, and mass mortalities.

Potential Impacts on Sturgeon

The same issues discussed above for salmon exist for the endangered Sturgeon, but we know even less about Sturgeon epidemiology (i.e. disease ecology). They too will be attracted to slightly warmer water full of contagions when the bay is cold. They will feed on the many fish and shellfish species that can act as reservoirs and amplifiers of what Nordic's effluent is streaming 24/7. This is part of what Dr Podolsky suggested is a "permanent impact".
Mitigation: Long term monitoring of sturgeon for contagion loads. Challenge Sturgeon with salmon RAS contagions in a lab setting to determine transmissible contagions and required numbers of contagions per litre of water to facilitate infection.

EXHIBIT A

Dams and Migration of Anadromous Fish

The Inland Fish and Wildlife has already expressed written concerns about installing a fish passage around dams due to increased impacts on hatcheries from marine viruses being carried by anadromous fish such as salmon. This could become an issue for Nordic if the dams need work and thus have to have a fishway installed.
Mitigation: Require dam removal or that any permit be conditioned on installation of a fishway if either of the dams need any alterations or stabilization.

Lack of Antimicrobial Resistance (aka AMRs) Baseline Data and Testing of Effluent by U.S. and Maine.

There is an admitted serious lack of AMR surveillance at both the state and federal level. This is a very serious issue for water management and treatment. McIntosh et al (2008) showed that AMRs from fish pathogens can jump to human pathogens in an RAS setting in as little as 6 weeks. AMRs are a huge issue globally and a serious concern for the WHO.
Mitigation: Gather the required baseline data of AMR for fish fungus and bacteria before the project starts as well as zoonotics. This is required to monitor for effects from the project after start-up.

Lack of Mitigation and Remedy Bonds

Both the U.S. and Maine suffer from a lack of effective deterrents to breaking environmental laws and causing unregulated damages. As such, Nordic should have to have a bond available for environmental damages and breaking permit conditions.
Mitigation: Mandate effective clean-up, and deterrent bonds in all permits.

Societies Must be Judged on How the Treat Their Most Vulnerable

Belfast Bay is a class SB Bay that allows "no harm" - especially to endangered species we have already mismanaged into near extinction. This is the most alarming form of public resource mismanagement and in fact threatens our very existence. We once had enough salmon to feed the U.S. Will we now allow the farming of this species to destroy the very fish that it owes its existence too? If this SB Classification is meaningful, and the DEP is committed to protecting the remaining 1100 salmon in the Penobscot River, then the Precautionary Principle must be used when examining “best practices" for RAS such as “zero effluent” designs e.g. Sustainable Blue, Superior Fresh, etc. which can be scaled to 10s of 1000s of mt. **If** effluent is to be allowed then ***all precautions*** must be taken, such as those outlined above, to reduce impacts on this endangered stock and the other struggling marine fish stocks exposed to any effluent.

EXHIBIT A

Mitigation: Require all the above recommendations as conditions on any DEP permit issued to Nordic.

References:

Ferguson,H; Emiliano Di Cicco, Carlos Sandoval, Daniel D. MacPhee, Kristina M. Miller, 2019. Haemorrhagic kidney syndrome may not be a variation of infectious salmon anaemia, Aquaculture, Volume 516 (note error in paper as it says publication is Feb 2020)

McIntosh, D., Cunningham, M., Ji, B., Fekete, F., Parry, E., Clark, S., . . . Ritchie, R. (2008). Transferable, multiple antibiotic and mercury resistance in Atlantic Canadian isolates of Aeromonas salmonicida subsp. salmonicida is associated with carriage of an IncA/C plasmid similar to the Salmonella enterica plasmid pSN254. Journal of Antimicrobial Chemotherapy, 61(6), 1221-1228.

Mordecai, Miller, Di Cicco, Schulze, Kaukinen, Ming, . . . Mordecai, Gideon J. (2019). Endangered wild salmon infected by newly discovered viruses. ELife, 8, ELife, September 3, 2019, Vol.8.

EXHIBIT B

UNIVERSITY OF WATERLOO
FACULTY OF SCIENCE
Department of Biology

December 9, 19

Fish Disease and Aquaculture Facility Implications

Brian Dixon, PhD
Professor of Biology
Canada Research Chair in Fish and Environmental Immunology

Fish disease is a serious problem for the aquaculture industry and some estimates suggest that facilities at Maine latitudes can lose up to 34% of their stock to disease over the whole life cycle[1]. There are measures that can be taken to mitigate the effect of disease, but the installation of a facility which grows salmon through both their fresh and salt water life phases would have difficulty implementing some of those measures and thus could potentially become a point source for fish diseases from their outflow pipes.
Firstly, there are numerous bacteria and viruses that are ubiquitous in the ocean water of the North Atlantic and many are opportunistic pathogens. Examples would be infectious salmon anaemia virus and the bacterium *Aeromonas salmonicida*. In order to filter pathogenic bacteria from ocean water, one would need to filter that water through a 0.22 micrometer (um) filter, which would slow the pumping of the water and would likely clog easily. No filter is stringent enough to filter out viral particles. A 0.1 um filter would not filter viruses, which are nanometers in diameter and would clog even more frequently. Once a pathogen entered a larger recirculating system, it would be extremely difficult to clear it out and would probably involve euthanizing all the animals and bleaching the system at a minimum.
Below is information regarding specific viruses and bacteria that should be of concern.

For general information regarding viruses associated with aquaculture operations:

https://www2.gnb.ca/content/dam/gnb/Departments/10/pdf/Publications/Aqu/AquacultureGrowing.pdf

For information on Infectious salmon anemia (ISA) or ISAv. ("v" for virus), a virus that is endemic to the Atlantic, see: :

https://doi.org/10.1111/jfd.12670

For information on Infectious Pancreatic Necrosis (IPN) or IPNv, a virus that is endemic to Atlantic Canada and therefore probably to Maine as well, see the fact sheet at:

http://www.inspection.gc.ca/animals/aquatic-animals/diseases/ reportable/infectious-pancreatic-necrosis/fact-sheet/eng/1330099413455/1330099555496

For information on the bacterium, *Aeromonas salmonicida, that* is also common in the North Atlantic, see:

https://en.wikipedia.org/wiki/ Aeromonas_salmonicida

Ultraviolet (UV) systems can lose up to 40% of their initial efficiency in one year's time, therefore the UV light bulbs must be changed frequently for full effect[2]. Not all viral strains respond well to UV disinfection. For example, the infectious pancreatic necrosis (IPN) virus is hard to kill with UV. Additionally, the turbidity (i.e., lack of water clarity) in a waste stream negatively affects UV efficiency. One must have at least two of these systems in serial as backup in case one of them fail. Often a non-UV backup system is required that relies on treatment with ozone and chlorine, for example. Ozone can only be used as an effective treatment technique with fresh water as its use on saltwater produces hypobromous acid (bromine gas in water) from the bromides that naturally occur in seawater. The use of Chlorine as a treatment technique introduces the problem of trihalomethane production. That would be an undesirable outcome, from a water quality standpoint. However, backup treatment is still needed.

The RAS filters specified in the treatment system can get dirty quickly and if not kept properly can harbor pathogens. However, this question is not one that I, Brian Dixon, have the experience to answer conclusively. I would suggest that Nordic and the DEP consider the bio-security implications of the filtering system. It may be prudent to modify the treatment design such that each tank has its own bioreactor, knowing that even then some wastes will be discharged to the bay as the treatment systems adjust to changes in the mix of fresh and salt water in the effluent and it will be very difficult to maintain the microbiota in a system that mixes or switches between fresh and salt water as the microbes that thrive in those two conditions differ greatly.

If separate systems for fresh and saltwater are used, then ozone treatment can be used on the freshwater flows. If the fresh and saltwater will be mixed together, Nordic must assess and perhaps control the impact of antimicrobials on bioreactor efficiency. There is also a lot of concern about antimicrobials that are released into the environment causing an increase in antimicrobial resistance in pathogens of both animals and humans. A clear plan to ensure there is not excessive release of those compounds should be in place.

In a closed system, it is unlikely that disease will be spread by fish that might, through some unlikely scenario, actually escape into the Penobscot Bay. However, if the Nordic plant

receives salmon eggs from an outside source (thus requiring transportation) or sells smolts raised at the facility to another entity (also requiring transportation), it is possible that diseases could be introduced into the facility with the eggs or exported elsewhere with the smolts. One such incident involving salmon eggs occurred in Chile in 2007[3]. A Chilean facility – the 2nd largest producer of salmon in the world – was shut down due to infected imported eggs from Iceland. Pathogens are numerous. In Western Canada eggs cannot be imported from outside. While eggs can be tested randomly, this is not very accurate since each female salmon produces some 10,000 eggs. The incidence of disease in unvaccinated fish ranges between 50-60% of a population, while the range for vaccinated populations can be reduced to 20-30%. Parasites can also be an issue and are difficult to control. Parasites cannot be vaccinated against currently. The use of anti-parasite drugs (ivermectin is commonly used) is usually reserved for use after an outbreak is detected in a population.
Climate change will also be a concern. Warming ocean water will bring in new pathogens. Relevant to this concern, the regulators may need to evaluate the effect of temperature changes on the level of stress salmon undergo in the wild. Temperature changes in the bay caused by the effluent discharge from a large-scale salmon-raising facility could be a problem. Fish are very sensitive to temperature changes and stress caused by such changes can decrease their immune function and increase the possibility of disease outbreaks. Indeed, this has been one of the main focuses of my work for the past 30 years[4,5].

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