White Paper on Industrial Finfish Aquaculture

Sierra Club, Maine Chapter

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NOTE: *This white paper is not establishing Sierra Club policy, rather, it is providing guidance to activists working on these issues in the state and around the world. The conclusions of this white are consistent with current Sierra Club policy. As a working draft, challenges or additions to the content are welcome. Send to jimimerkel@gmail.com.*

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Definitions

There are several types of aquaculture systems used for raising finfish:

- **Fully Closed** land-based Recirculating Aquaculture Systems or **RAS** are technologies that discharge **zero effluent** and require little to no additional "make-up" water once the tanks are full.
    - These systems are engineered as monocultures or polycultures.
    - Zero-discharge is considered the **"best practicable technology"** that can **"eliminate the discharge of pollutants into navigable waters,"** two requirements of the Clean Water Act and many state laws.[1]
    - These systems are operational and economically competitive.

- **Open** land-based RAS that release continuous effluent into the environment and depend on continuous new sea and /or fresh water. These systems are not recommended.

[1] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_41a395272c3349fc943a4db99c7100f6.pdf

- **Nearshore and offshore net-pen** systems. These 'open' systems are the least costly, however, due to a history of escapes, entanglements, pollution and spread of disease, these systems are not recommended and should be phased out.

- **Floating** RAS that replaces net-pens with a fabric or hard shell for containment. These systems typically release large amounts of effluent and have extensive polluting at-sea infrastructure. These systems are not recommended.

Executive Summary

- The Sierra Club has adopted a precautionary principle on Feb. 17, 2001, which states:
    - When an activity potentially threatens human health or the environment, the proponent of the activity, rather than the public, should bear the burden of proof as to the harmlessness of the activity. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation.

- Finfish aquaculture projects must be fully closed, as they are often near natural water resources. Whether near marine or fresh water, they must not degrade the environment or impact wild fisheries in any measurable way, having zero chemical and biological effluent into aquifers, rivers, bays and estuaries.
    - Fully closed systems should be required as "best practicable treatment" called for in the Clean Water Act. Systems are available that do not require regular pumping of ground water or sea water and do not discharge into aquifers, rivers, bays or estuaries.

- Industrial-scale RAS are typically extremely energy intensive and would make meeting current government approved climate targets difficult. Legislators should consider requiring new developments including aquaculture projects to demonstrate carbon neutrality in operations and construction.
    - RAS can use wind and solar energy and rely on generators only for back-up during power outages. Simply resorting to carbon trade schemes is insufficient.
    - Generators should not be used regularly for peak shaving to reduce costs. Adding large CO2 emitters during a climate crisis will place an unfair curtailment burden on existing businesses and residents to meet climate targets.

- Projects should make use of brownfield sites (if they can be utilized without further negative impact on the environment) or previously cleared or industrialized lands (with stable soils, and not prime agricultural lands, wetlands or forests).

- Smaller-scale closed finfish systems that use polycultures are preferred. These systems incorporate several species with different trophic and spatial niches that increase species health and minimize wastes. Monocultures typically require chemical intervention[2] while violating compassionate animal welfare.[3] [4] [5]

- Communities are wise to consider the restoration of wild stocks by ensuring fish passage, habitat protection and preventing overfishing as an alternative to aquaculture. By restoring fisheries and rebuilding a sustainable working waterfront the benefits will be long lasting for many small holders and businesses through a circular sustainable-yield economy[6] [7] that exports neither profits nor a region's ecosystem services.

- A community's clean fresh water, seawater, air and soil are public resources to be shared by natural ecosystems and human activity. One large fish factory can use disproportionate amounts of a region's fresh water, energy, carbon budgets, or assimilative capacity at the expense of smaller businesses and nature.

THE SIERRA CLUB POLICY[8]

The following states the Sierra Club National Policy on **Industrial Finfish Aquaculture**.

Farming of fish and other aquatic organisms

1. Cultivation of aquatic organisms in a manner that has a high potential to impact natural ecosystems, such as net-pen fish farming in coastal waters, should be discouraged.
2. Aquaculture systems should include components that recycle wastes internal to the system.
3. Multi-trophic aquaculture systems that integrate fish and plant ecosystems to process waste and optimize use of resources should be encouraged. (Sustainable Marine Fisheries Policy)[9]

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[2] Reverter, M., Sarter, S., Caruso, D. *et al.* Aquaculture at the crossroads of global warming and antimicrobial resistance. *Nat Commun* **11,** 1870 (2020). https://doi.org/10.1038/s41467-020-15735-6

[3] Sneddon LU. Pain perception in fish: indicators and endpoints. ILAR J. 2009;50(4):338-42. doi: 10.1093/ilar.50.4.338. PMID: 19949250.

[4] https://www.ciwf.com/shop-with-compassion/fish/fish-certification-labels/

[5] https://awionline.org/content/fish-farming

[6] https://archive.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail

[7] https://webgate.ec.europa.eu/fpfis/cms/farnet2/sites/default/files/publication/en_farnetguide17.pdf

[8] *https://www.sierraclub.org/policy/agriculture/food*:

[9] https://www.sierraclub.org/policy/policy-sustainable-marine-fisheries

1. Introduction

This white paper is intended to inform decision-makers, citizens and the many stakeholders who rely on a sustainable working waterfront and marine ecosystem as to the risks and benefits of industrial-scale finfish RAS and discuss the opportunity costs in terms of wild fish recovery.

With some of the most historically productive fishing or lobstering grounds now being promoted as locations for industrial fish farms, members of the fishing community[10] are questioning whether these operations will deliver on their promises of low impact or, instead, add to the problems fisheries already face, further complicating recovery efforts with novel diseases and pollutants. The fishing communities also know that the large capture of forage fish as feed for aquaculture, agriculture and pet food is in part contributing to a declining wild catch. Some 14 species at the base of the food chain are used in fish pellets. Scientists link cod's disappearance to alewife demise.[11] Further, poorer countries catch and eat forage fish directly which is more efficient than feeding these forage species to higher trophic species such as salmon in captivity. Research suggests that finfish aquaculture is creating the very problem they claim to solve. [12]

The real alternative to finfish aquaculture is the recovery of marine systems through ensuring fish passage (with dam removals or functioning ladders) and enforcing sustainable catch regulations. The fecundity of properly managed wild fisheries is astonishing and wherever given the chance, the comeback has been impressive.[13] This generation decides whether our children will be able to catch and eat a wild fish, abundant just a generation ago.

Small-scale aquaculture and sustainable wild fisheries have a long history around the world of providing mollusks, seaweed, crustaceans and fish.[14] These modest operations utilizing ponds, rivers, oceans, estuaries, and even land-based facilities, for the most part, have coexisted with native fisheries,[15] at times beneficial or having little negative impact on surrounding ecosystems.[16] [17]

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[10] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/d7341b_c47f99aa826c48969e323216bd92563c.pdf

[11] Edward P. Ames, John Lichter, Gadids and Alewives: Structure within complexity in the Gulf of Maine, Fisheries Research, Volume 141, 2013, Pages 70-78, ISSN 0165-7836, https://doi.org/10.1016/j.fishres.2012.09.011.

[12] https://www.sciencedaily.com/releases/2018/06/180614213822.htm

[13] https://www.nature.org/en-us/about-us/where-we-work/united-states/maine/stories-in-maine/the-comeback-alewives-return-to-maine-rivers/

[14] https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/polyculture

[15] Ridler, Neil & Wowchuk, M. & Robinson, Bryn & Barrington, K. & Chopin, Thierry & Robinson, Shawn & Page, F. & Reid, G.K. & Szemerda, Michael & Sewuster, J. & Boyne-Travis, S.. (2007). Integrated Multi-Trophic Aquaculture (IMTA): a potential strategic choice for farmers. Aquaculture Economics & Management. 11. 99-110. 10.1080/13657300701202767.

[16] Morton A, Routledge R, Hrushowy S, Kibenge M, Kibenge F (2017) The effect of exposure to farmed salmon on piscine orthoreovirus infection and fitness in wild Pacific salmon in British Columbia, Canada. PLOS ONE 12(12): e0188793. https://doi.org/10.1371/journal.pone.0188793

[17] https://www.facetsjournal.com/doi/10.1139/facets-2018-0008#pill-view-options

2. Background

Over the last 30 years, net pen aquaculture systems have made their way into shallow sensitive marine ecosystems, often with anticipated detrimental impacts.[18] These systems replicate many of the problems of Concentrated Animal Feeding Operations (CAFOs), allowing pollution, pathogens and parasites to flush through containment nets or over containment structures into surrounding waters.
Though they benefited from sunlight and the increased biodiversity of the sea, escapes, sea lice infestations, diseases and mass die-offs have occurred.[19] [20] [21] Most net pens were sited in sensitive shallow estuaries, rivers and bays or in critical off-shore habitats.

Local fishermen and women who have lived through the impacts of net-pen aquaculture have voiced opposition to industrial aquaculture. Pollution, spread of sea-lice and reduced lobster catch[22] [23] have led some regions to ban salmon farming, as in Argentina (June 30, 2021)[24] and the state of Washington[25]. As opposition to **near-shore net-pen** aquaculture[26]intensifies, **off-shore net pens** are being proposed as a way to dilute pollutants into a larger volume of sea. These systems are exposed to harsh off-shore weather conditions, and escapes,

[18]University of British Columbia. "Salmon virus originally from the Atlantic, spread to wild Pacific salmon from farms: Study finds Piscine orthoreovirus (PRV) is now almost ubiquitous in salmon farms in British Columbia, Canada.." ScienceDaily. www.sciencedaily.com/releases/2021/05/210526150216.htm (accessed August 9, 2021).
[19] https://www.newyorker.com/tech/annals-of-technology/washington-states-great-salmon-spill-and-the-environmental-perils-of-fish-farming
[20] https://www.theguardian.com/news/2020/sep/15/net-loss-the-high-price-of-salmon-farming
[21] https://animaloutlook.org/investigations/aquaculture/
[22] http://www.friendsofportmoutonbay.ca/docs/sea-cage-aquaculture-impacts-market-and-berried-lobster.pdf
[23] Inka Milewski, Ruth E. Smith, Heike K. Lotze, Interactions between finfish aquaculture and American lobster in Atlantic Canada, Ocean & Coastal Management,
Volume 210, 2021, 105664, ISSN 0964-5691,
https://doi.org/10.1016/j.ocecoaman.2021.105664.
[24] https://www.patagoniaworks.com/press/2021/6/30/historic-announcement-argentina-becomes-first-country-to-reject-salmon-farming
[25] https://foe.org/news/washington-state-governor-approves-industrial-ocean-fish-farm-ban/
[26]https://vimeo.com/555901886?fbclid=IwAR0ZWJghxRVK-kdf3Ld-IyE3pnCuLjO7_HJsT6BIdhmySZc_8d4_jO9jBVs

diseases and the efficacy of "dilution as a solution" remain as unsolved issues.[27]

In an attempt to solve the issues with near-shore and off-shore net pens, RAS or Recirculating Aquaculture Systems have been developed. Some of these systems are fully contained and once charged with water, have zero discharge into the marine environment. [28] As they do not require a regular draw of fresh or seawater, biosecurity risks of infecting wild species are better controlled. Long-standing methods such as polycultures utilize several complementary species and are more self-sustaining having fewer negative impact on the surrounding land and sea. However, many industrial 'fully open' or 'partially open' RAS systems are now being proposed and permitted that are called "recirculating" yet require large daily quantities of water and discharge millions of gallons of effluent per day into the same waters that wild fish, shellfish, seaweeds and lobsters rely on.

The sizable infrastructures needed for open RAS facilities lead to broad environmental concerns. The systems include containment structures, diesel generators, pumps and pipes for fresh and saltwater, filters, control systems, fuel, chemical and sludge storage and feed systems. Large trucks deliver needed "inputs" and haul away "outputs." Back-up generators need to be large enough to power the operations continuously during extended power outages. Their carbon footprints are so large that meeting state or municipal climate targets become difficult.[29]

Floating sea-based RAS can pump billions of gallons a day of partially filtered effluent into sensitive bays. They require the continuous running of large generators at sea, emitting noise which travels long distances and effect marine life.[30] Combusting diesel fuels generate sizable quantities of air pollutants and carbon emissions. Other risks include toxic algae blooms, spills of fuels and toxic substances and fish escapes during hurricanes and storms, more frequent due to climate change.

Both land-based and floating "open" RAS pump clean water in and typically output significant quantities of dissolved nitrogen, phosphorous, odors, feed, and medication residues, at times requiring exemptions from pollution laws.[31] [32] [33] [34]

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[27] https://clf.jhsph.edu/sites/default/files/2019-09/ecosystem-and-public-health-risks-from-nearshore-and-offshore-finfish-aquaculture.pdf
[28] https://www.sustainableblue.com
[29] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_325649afaad2439c8316a864d2f24979.pdf?index=true
[30] Peng, C., Zhao, X., & Liu, G. (2015). Noise in the Sea and Its Impacts on Marine Organisms. *International journal of environmental research and public health*, *12*(10), 12304–12323. https://doi.org/10.3390/ijerph121012304
[31] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_6ffbd30418014db19236f5b01dae6e9d.pdf
[32] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_a33201b6f2dc4d899f726b124fb6da42.pdf
[33] https://npr.brightspotcdn.com/4a/49/f643354c42faa06c4c443922bd01/maine-pollutant-discharge-elimination-system-permit.pdf
[34] https://www.maine.gov/dep/ftp/projects/nordic/procedural-orders/2020-05-28%20Nordic%20Seventeenth%20Procedural%20Order.pdf

These systems are complex but in terms of pollutants, they have inputs and outputs similar to CAFOs,[35] such as poultry, pig or beef operations, except the dissolved wastes go into marine waters, out of sight, while the concentrated sludge is trucked offsite to sacrifice lands[36] or experimentally used as biofuels or fertilizers.[37]

Open land-based and floating RAS systems have been used as hatcheries for growing young fish. However, for growing fish to several pounds for market, they have had serious problems.[38] [39] Several start-up operations have experienced mass die-offs, such as the Norwegian-owned Atlantic Sapphire. On July 9, 2021 their Denmark facility lost 17 percent of the harvest – over 360,000 fish, a loss of $3 million after expected insurance proceeds. Earlier in 2021, two mass-die offs occurred at their 160-acre Florida facility totaling 800,000 fish.[40] Insurers and financiers have elaborated on these risks.[41] [42]Multiple law suits and stiff local opposition have challenged Nordic Aquafarms in Belfast.[43] [44] [45] Then in September 2021, a fire and release of corrosive chemicals occurred at the Danish RAS facility with police and armed forces warning residents with burning, itching, rash or acute shortness of breath to seek medical attention and ordering any caught fish be destroyed.[46] The waters turned red with toxic Iron Sulfide.

At Atlantic Sapphire's Florida facility, three workers were hospitalized in April 2021 after being overcome by fumes from an unknown gas, according to Seafood Source.[47] Several months later in Maine, an industry backed bill, LD-1473, was introduced to exempt the entire aquaculture industry from the Uniform Building and Energy Codes. The bill failed in committee, but forecasts the risks to workers, animal welfare and the ecosystem when an industry unduly influences public processes.

Such problems are not rare. For example, a RAS startup, VeroBlue in Webster City, Iowa went bankrupt in 2018 leaving over 70 companies unpaid, totaling $100 Million.[48]

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[35] https://www.sierraclub.org/michigan/why-are-cafos-bad
[36] https://www.ucsusa.org/sites/default/files/2019-10/cafos-uncovered-executive-summary.pdf
[37] https://www.sciencedirect.com/science/article/pii/S2211339819300334
[38] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_51f4e5795dab47298dd485a357325471.pdf?index=true
[39] https://www.sciencedirect.com/science/article/pii/S001671852100124X
[40] https://www.miaminewtimes.com/news/activists-accuse-atlantic-sapphire-salmon-farm-of-animal-cruelty-12210072
[41] https://salmonbusiness.com/banks-skeptical-about-financing-land-based-fish-farms-must-have-a-better-overview-of-the-overall-risks/
[42] https://salmonbusiness.com/aquaculture-insurer-on-ras-less-than-2-premium-but-over-5-of-the-losses/
[43] https://www.csmonitor.com/Environment/2019/0313/Aquaculture-wars-The-perils-and-promise-of-Big-Fish
[44] https://www.upstreamwatch.org/current-appeals
[45] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_d07a559d15754ff19a2207986334c37f.pdf
[46] https://nord.news/2021/09/16/large-fire-at-salmon-factory-has-created-corrosive-chemical-emissions-2/
[47] https://www.seafoodsource.com/news/aquaculture/three-atlantic-sapphire-workers-overcome-by-fumes-hospitalized
[48] https://www.messengernews.net/news/local-news/2018/11/awash-in-100m-debt-veroblue-files-for-chapter-11-sues-top-management/

Creditors included Webster City itself and Hamilton County. Promised tax relief and jobs never materialized.

Maine Proposals:

Company	Location	QTY/yr. Mil lbs.* MT	Effluent Mgd**	Nitrogen Lbs/day	CO2 MT/yr.***	Tech.
Nordic Aquafarms[49]	Belfast	66 33,000	7.7	1,484	594,000	RAS
Whole Oceans[50]	Bucksport	44 20,000	18.6	7,460	360,000	RAS
American Aquafarms[51]	Frenchman Bay	66 33,000	4,000	2,338	594,000	FLOAT RAS
Kingfish Maine[52]	Jonesport	13 6,000	28.7	1,580	144,000	RAS
Aquabanq**	Millinocket	22 10,000	N/A	N/A	180,000	RAS
Totals		211 102,000	4,055	13,082	1,870,000	

*Mil lbs. = Million pounds of fish produced per year, MT = metric tons produced per year.
**Mgd = million gallons of effluent per day to be discharged directly into coastal waters
*** MT/yr. = metric ton (MT) CO2e generated per year calculated using life-cycle assessment methods and scientific studies that includes construction and operational carbon emissions. Carbon emissions for RAS varies between 16.7 and 23 MT CO2e/MT fish produced.[53] CO2e is estimated using a conservative 18 MT CO2e/MT fish for each of the 5 projects.
**** Aquabanq decided to shift to zero effluent[54]

The cumulative impacts of five proposed facilities in Maine would release over 4 billion gallons of effluent per day, with nitrogen equivalent to 19 Portland sewers[55] (500-750 Pounds per day) into waters that Maine's lobster industry rely on to be clean. They would add 1,870,000 metric tons of carbon to the atmosphere, equivalent to adding 406,500 cars to Maine's roads. These carbon emissions represent 15.7 percent of Maine's 2030 GHG target (11.91 (MMTCO2e). **The opportunity costs of investing $1.3 billion dollars to grow 102,000 metric tons of fish in confinement must be evaluated in terms of a similar investment into dam removal and the restoration of abused fisheries.**

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[49] https://www.maine.gov/dep/ftp/projects/nordic/applications/MEPDES%20Permit%20Application_Final_Oct%2019,%202018.pdf

[50] https://www.epa.gov/sites/default/files/2018-10/documents/draftme0037478permit.pdf

[51] https://www.maine.gov/dep/ftp/projects/american-aquafarms/applications/mepdes/FB01%20Long%20Porcupine%20General%20Application%20for%20Waste%20Discharge%20Permit%20with%20Attachments.pdf

[52] https://www3.epa.gov/region1/npdes/permits/2021/finalme0037559permit.pdf

[53] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_325649afaad2439c8316a864d2f24979.pdf?index=true

[54] https://www.intrafish.com/shrimp/norwegian-land-based-salmon-operators-have-poisoned-the-well-executive-says-rivals-mistakes-forced-strategic-shift/2-1-1057096

[55] https://www.pressherald.com/2018/06/07/odor-complaints-drop-after-12-million-portland-wastewater-plant-upgrade/

Due to the unlikely feasibility of solving the above-mentioned challenges of "open" systems, "fully closed" RAS have become the preferred technology as they have zero effluent and recycle wastes internal to their system.[56] A Wyoming based firm who were proposing to grow open RAS salmon at an old mill site in Millinocket, Maine announced on 8/25/2021 that they decided to shift from salmon to zero effluent shrimp stating "Norwegian land-based salmon operators have poisoned the well" stating that their rivals mistakes forced their strategic shift.[57] The town of Gouldsboro, Maine is now considering a moratorium on large-scale aquaculture projects.[58] Government regulators should also make this shift and enforce the Clean Water Act requirements for "best practicable treatment" and require these zero discharge systems be used.

3. KEY FINDINGS

The following key findings detail opportunities and risks regarding finfish.

KEY FINDING #1: CUT THE EFFLUENT PIPE -- RIVERS, ESTUARIES, BAYS
The sites chosen for industrial finfish aquaculture are typically the most productive fresh and salt water systems, serving many ecosystem functions. Because wild fish use these same waters throughout their lifecycle, recovery efforts are severely threatened by chemicals, diseases and viruses. 'Open and partially open' land-based aquaculture operations flush biological pollutants into fresh and salt waters via effluent pipes. Although much of the solids are filtered out, the dissolved pollutants include nitrogen and phosphorus. Because large coastal areas already suffer shellfish closures linked to excessive nitrogen, these discharges will increase eutrophication and red tides.

Note: The Penobscot Estuary is among the most productive marine ecosystems on the east coast. The proposed Bucksport facility at the river's mouth has recovering populations of Atlantic Salmon and alewives.

[56] Jani T. Pulkkinen, Anna-Kaisa Ronkanen, Antti Pasanen, Sepideh Kiani, Tapio Kiuru, Juha Koskela, Petra Lindholm-Lehto, Antti-Jussi Lindroos, Muhammad Muniruzzaman, Lauri Solismaa, Björn Klöve, Jouni Vielma, Start-up of a "zero-discharge" recirculating aquaculture system using woodchip denitrification, constructed wetland, and sand infiltration, Aquacultural Engineering, Volume 93, 2021, 102161, ISSN 0144-8609, https://doi.org/10.1016/j.aquaeng.2021.102161.
[57] https://www.intrafish.com/shrimp/norwegian-land-based-salmon-operators-have-poisoned-the-well-executive-says-rivals-mistakes-forced-strategic-shift/2-1-1057096
[58] https://www.mdislander.com/maine-news/waterfront/large-scale-aquaculture-moratorium-explored-in-gouldsboro

As an example of industrial scale, a proposed facility in Belfast, Maine, would release a 7.7 million gallon/day waste water plume, containing 11-times more nitrogen than the Belfast City Sewer,[59] to yield 33,000 metric tons/year of fish.[60] This plume will move in and out with tides and winds, all within shallow waters important for eelgrass and salmon and cod recovery. Sea life including lice will be attracted to the odors of the plume while any viruses and diseases discharged could threaten endangered salmon recovery.[61]

The water bodies receiving the effluents have currents that flow in complex paths, at various depths, around islands, and are affected by winds, river outflows, tides and seasonal salinity changes from rivers. To predict the impact and dispersal of an effluent plume requires a multiyear study to understand the site-specific behavior.[62] The thermal pollution of open RAS is a concern as discharges of millions of gallons of water per day will warm receiving waters. Studies reveal that warmer brackish water effect the heart rate, appetite, digestion, growth rate and disease in marine organisms including increases in the risk of algae blooms [63]and can kill or drive away cold-water fish.[64] More research is needed to know how this would affect salmon recovery, local lobster catches or mussel and kelp farms.

Many government agencies require adherence to the Clean Water Act and have requirements that the best available technology be used.[65] 'Closed' RAS, similar to Sustainable Blue,[66] Aquamaof[67] and Superior Fresh[68] should be explored as "best available" technology. Combined with successful restoration efforts,[69] locally-based regenerative aquaculture systems[70] could meet Maine's economic needs and ecological imperatives including sequestering carbon.[71]

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[59] https://www.maine.gov/dep/ftp/projects/nordic/public-comments/Merkel,%20Jim%203.pdf
[60] https://www.epa.gov/sites/default/files/2018-10/documents/draftme0037478permit.pdf
[61] Núñez-Acuña, G., Gallardo-Escárate, C., Fields, D. M., Shema, S., Skiftesvik, A. B., Ormazábal, I., & Browman, H. I. (2018). The Atlantic salmon (Salmo salar) antimicrobial peptide cathelicidin-2 is a molecular host-associated cue for the salmon louse (Lepeophtheirus salmonis). *Scientific reports*, *8*(1), 13738. https://doi.org/10.1038/s41598-018-31885-6
[62]https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_646c0a57836240afbb8b1c2bcb3bfc3c.pdf?index=true
[63]https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_54e257b464c54d55af8231b22a324840.pdf
[64] https://www.jstor.org/stable/44547838
[65] tps://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_41a395272c3349fc943a4db99c7100f6.pdf
[66] https://www.sustainableblue.com
[67] https://salmonbusiness.com/aquamaof-reveal-600-ton-atlantic-salmon-rd-facility-in-poland/
[68] https://www.fishfarmingexpert.com/article/superior-fresh-outlines-big-salmon-leap-forward/
[69] https://estuaries.org/bluecarbon/
[70] http://www.seagreensfarms.com
[71] https://www.youtube.com/watch?v=Vzn5XO_GYL0&t=75s

KEY FINDING #2: Restore a Sustainable Working Waterfront

Studies show that the benefits of restoring wild fisheries outweigh the costs.[72] According to NOAA over 2 million dams and other barriers block fish from migrating upstream in the US. "Atlantic salmon used to be found in every river north of the Hudson River. Due to dams and other threats, less than half of 1 percent of the historic population remains. The last remnant populations of Atlantic Salmon in U.S. waters exist in just a few rivers and streams in central and eastern Maine. They are an endangered species."[73]

The Penobscot Nation had explicitly claimed the Penobscot River (now with two RAS aquaculture proposals) as theirs before signing a 1796 treaty that secured vital sustenance fishing rights.[74] "Restoration of the river's migratory fish stocks is necessary to comply with sustenance fishery rights guaranteed by the 1980 Maine Indian Land Claims Settlement Act and treaties between the Penobscot Nation, Massachusetts, and Maine. Penobscot tribal members have used the watershed and its abundant natural resources for physical and spiritual sustenance for 10,000-12,000 years."[75]

Where properly functioning fish ladders have been built or dams removed, massive alewife runs have returned, even on small rivers. Recovery of the historical abundance of diverse fish species is linked to recovery of forage pelagic fish; these are primary feeders near the base of the food chain that feed on plankton and are food for larger fish, seabirds and marine mammals.[76]

By restoring damaged fisheries, a sustainably managed wild catch of diverse species can return a thriving economy and ecology to communities, once again employing many smallholders. This working waterfront has historically included many value-added and support businesses that serve the local and regional economy. Communities are advised to:

- support dam removal or ensure fish ladders actually work,
- eliminate overfishing and using forage fish as feed for other animals and fish,
- regulate toxic industries and
- enact sustainable-yield laws that protect wild populations[77] and stop offshore industrial fishing.[78]

KEY FINDING #3: FINFISH EFFLUENT WILL AFFECT LOBSTER'S ABILITY TO FIND FOOD

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[72] Sumaila UR, Cheung W, Dyck A, Gueye K, Huang L, Lam V, et al. (2012) Benefits of Rebuilding Global Marine Fisheries Outweigh Costs. PLoS ONE 7(7): e40542. https://doi.org/10.1371/journal.pone.0040542

[73] https://www.fisheries.noaa.gov/insight/barriers-fish-migration

[74] https://medium.com/indigenously/penobscot-million-b5e8d02bf290

[75] https://atlanticsalmonrestoration.org/partners/penobscot-indian-nation

[76] Dias, B. S., Frisk, M. G., & Jordaan, A. (2019). Opening the tap: Increased riverine connectivity strengthens marine food web pathways. *PloS one*, *14*(5), e0217008. https://doi.org/10.1371/journal.pone.0217008

[77] Sumaila UR, Cheung W, Dyck A, Gueye K, Huang L, Lam V, et al. (2012) Benefits of Rebuilding Global Marine Fisheries Outweigh Costs. PLoS ONE 7(7): e40542. https://doi.org/10.1371/journal.pone.0040542

[78] https://doi.org/10.1525/elementa.346

An 11-year study in Port Mouton Bay, Atlantic Canada, released June 28, 2018, in *Marine Ecology*,[79] measured the impacts to lobster in proximity to net pen salmon aquaculture. Although this study was focused on net pens, the odor plume of an open RAS system will create the same effect as it pertains to lobsters.

Inka Milewski, a marine biologist who managed the study in its last four years, stated, "What we found was during periods when the fish farm was actively raising fish, market catch across all regions, dropped by 42 per cent." "The egg-bearing lobster counts also dropped by an average of 52 per cent when the farm was active," she said. Milewski believes an odor plume from the farm may be affecting lobster's ability to detect food; thus, and they are "not finding their way into the traps."

The study reported:

- Lobster "sniff" the odor seascape with antennules and chemoreceptors on their legs.
- Odors are used to locate food, find mates, detect predators and avoid stresses.
- Sulphides and ammonium have toxic and behavioral effects on adults and other lobster life stages.
- In laboratory studies, 50% of lobster die within 3.3 days in low oxygen, low sulphides (5.5 μM) and ammonium (17 μM) conditions (Draxler et al. 2005)
- Berried lobster (female lobster with fertilized eggs attached) are highly sensitive to odors and temperature.
- Berried lobster show retreat behavior at 50 μM sulphide (Butterworth et al. 2004); at 500 μM and regular oxygen conditions, 50% of lobster died in 22.5 hr.
- Further, the study said the effects of nitrogen pollution include the following:
    - Decrease in water quality.
    - Increase in epiphyte growth on eelgrass.
    - Increase in benthic algae
    - Increase in nuisance or "slime" algae.

Independent-reviewed studies should take place before RAS finfish operations affect the lobster industry, to determine potential impacts.

KEY FINDING #4: LARGE CARBON FOOTPRINTS WILL MAKE MEETING CLIMATE GOALS UNLIKELY

[79] Inka Milewski, Ruth E. Smith, Heike K. Lotze, Interactions between finfish aquaculture and American lobster in Atlantic Canada, Ocean & Coastal Management, Volume 210, 2021, 105664, ISSN 0964-5691, https://doi.org/10.1016/j.ocecoaman.2021.105664.

Note: The resources needed to construct and operate land-based systems make them among the most carbon-intensive seafood choices.

Several research studies have been done on "open" RAS salmon citing it among the highest carbon footprint seafood a person could eat, generating up to 23 kg CO2e/kg.[80] The large footprints result from the extensive materials and energy used in construction, energy for pumping and conditioning water, oxygen, chemicals and feed. Although RAS companies claim their fish saves carbon over airfreight, as mentioned earlier, only 5% of seafood is shipped by air and wild local fish have dramatically lower carbon intensity. Researchers at the University in Halifax, calculate the carbon intensity of wild caught salmon at 1.9kg CO2e/kg,[81] twelve times lower than RAS salmon. Haddock is 2.4 kg CO2e/kg or 9.6 times less than RAS salmon.

And if one decides to eat wild small pelagic fish such as sardines or any one of 14 species now ground up for farmed fish feed, the carbon intensity would be 115 times lower than RAS salmon (0.2 kg CO2e/kg).[82]

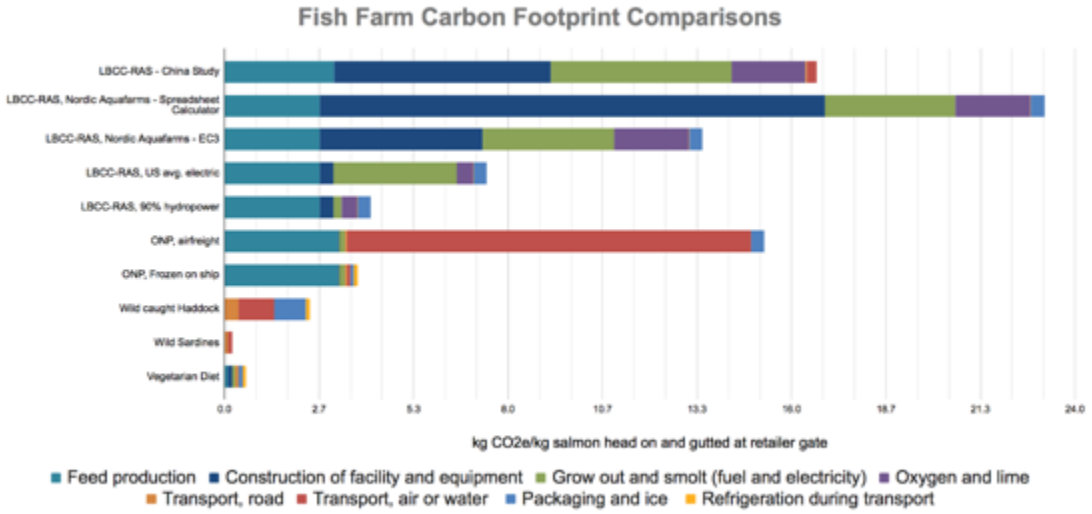
Another potential climate impact of aquaculture facilities is the loss of carbon sequestration if land is cleared for construction. Forests and wetlands both sequester and store carbon with equal amounts stored above and below ground level.[83] Brownfield sites should be used providing the sites are stable and won't release buried toxins.

[80] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_325649afaad2439c8316a864d2f24979.pdf?index=true

[81] Parker, R.W.R., Blanchard, J.L., Gardner, C. *et al.* Fuel use and greenhouse gas emissions of world fisheries. *Nature Clim Change* **8,** 333–337 (2018). https://doi.org/10.1038/s41558-018-0117-x

[82] Fuel use and greenhouse gas emissions of world fisheries
Robert W. R. Parker 1,2*, Julia L. Blanchard 1,3, Caleb Gardner1, Bridget S. Green1, Klaas Hartmann1, Peter H. Tyedmers 4 and Reg A. Watson 1,3

[83] https://www.frontiersin.org/articles/10.3389/ffgc.2019.00027/full



Notes:

1. In the above chart, the first bar is an operational RAS in China.[84]
2. Bars 2 and 3 are based upon detailed LCA assessment from documents submitted by Nordic Aquafarms in Belfast. Bar two used a more detailed calculator that allowed for more construction details: foundations, buildings, tanks, motors, filters, pumps, etc. The Bar 3 calculator allowed for fewer data inputs.[85]
3. Bars 4, 5, 6 and 7[86] are results from a 2016 study.[87]
4. Bars 8, 9 and 10 evaluate the carbon footprint of wild caught seafood, or production of plant proteins.[88]

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[84] This Life Cycle Assessment or LCA paper was published in 2019, based upon actual data from growing out 29,000 salmon in northern China from 100 g smolts to 4 KG fish.[84] The results of this study were that to grow one tonne of live-weight salmon required 7,509 KWh of electricity and generated 16.7 tonnes of Co2e, 106 kg of SO2 e, 2.4 kg of P e and 108kg of N e (cradle to farm gate). The study cited electricity and feed as the larger components of the overall impact. This more recent study from an actual operation reported roughly double the tonnes of CO2e/tonne of fish compared to the 2016 FreshWater Institute Study (Bars 4, 5, 6 and 7 counting from the top) (7.4 vs. 16.7).[84] The power per tonne of fish produced was 5,460 kWh in the 2016 study while the more recent China study was 7,509 kWh. Many factors can account for the differences such as power grid composition, fish food sources and makeup, different inventories and assumptions, however, the data are close enough to offer some confidence in their similar methodologies and findings.

[85] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_325649afaad2439c8316a864d2f24979.pdf?index=true

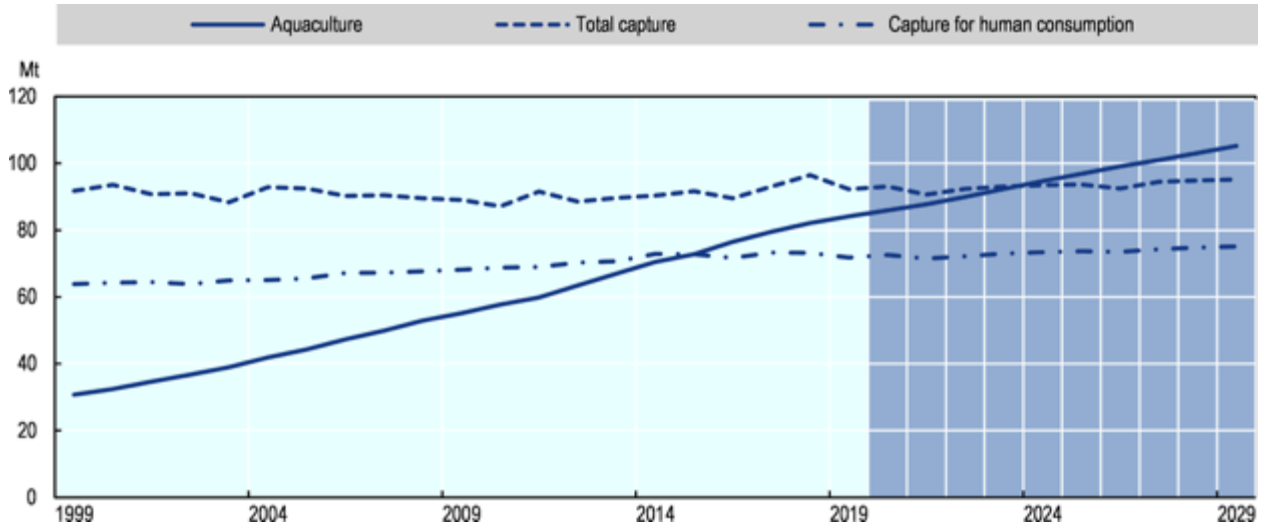
[86] Yajie Liua, Trond W. Rostena, Kristian Henriksena, Erik Skontorp Hognesa,Steve Summerfeltb, Brian Vincib, Comparative economic performance and carbon footprint of two farming models for producing Atlantic salmon (Salmo salar):Land-based closed containment system in freshwater and open net pen in seawater, in Aquacultural Engineering 71, (2016) 1-12. https://doi.org/10.1016/j.aquaeng.2016.01.001

[87] This study compared producing Atlantic salmon in open pens in seawater to a hypothetical land-based closed containment recirculating aquaculture system (LBCC-RAS) based upon the Conservation Fund's Freshwater Institute grow out trials of Atlantic salmon.[87] This is the study that is often cited to argue that salmon grown in a LBCC-RAS system has a lower carbon footprint than shipping open net pen (ONP) salmon by airfreight from Norway to Seattle, Washington: 7.4kg CO2e/kg (RAS) vs. 15.2 kg CO2e/kg (airfreight from Norway to Seattle). Electricity to produce 1 tonne of salmon in RAS is cited as 5,460 kWh. However, shipping frozen net-pen salmon by container ship from Norway to the US was the lowest footprint option in this study at 3.75kg CO2e/kg.

[88] For example, wild caught Demersal fish (eg. Haddock) species have a life-cycle CO2e intensity of *2.4 kg CO2e/kg*. Small Pelagic fish (eg. Sardines) have a lifecycle CO2e of 0.2 kg CO2e/kg.[88] Vegetarian diets including legumes have CO2e in the range of 0.6 kg CO2e.[88]

KEY FINDING #5: MARKETING CLAIMS REQUIRE A DEEPER LOOK

The aquaculture industry commonly cites statistics that suggest industrial aquaculture



will lower imports, take pressure off wild fisheries, save carbon, create jobs and cut taxes. These claims require a deeper look. 1. Claim: 90 percent of seafood is imported. Analysis: A 2019 article in the Proceedings of the National Academy of Sciences of the United States of America or PNAS states[89] that this number doesn't account properly for seafood that is exported for processing where labor is less expensive and then reimported. According to the latest statistics 35-38% of seafood consumed in the U.S. is produced domestically, meaning 62-65% is imported.[90] The United States is the world's 4th largest exporter of seafood.[91] The misleading 90% number is used to suggest the USA needs to produce more fish domestically with aquaculture. Sustainable alternatives include processing fish locally or consuming local wild catch; these would reduce the carbon footprint of exporting seafood only to reimport it, just to pay lower wages. This would also create more jobs, tax revenue, support historic working waterfronts and indigenous coastal fishing communities, and further reduce seafood imports. The SLOWFISH movement advocates less frequent and smaller harvests of locally caught fish, within sustainable yields, ensuring an enduring sector of the economy and food system.

Note: The graph above from the Food and Agriculture Organization (FAO) is used to justify expansion of aquaculture. Source: OECD-FAO Agricultural Outlook 2020-2029[92]

2. Claim: Population growth and human demand for fish will outpace what the sea can supply; suggesting aquaculture must make up for demand.

Analysis: Seafood demand is partially created through marketing – advertising products that businesses hope to profit from. Seafood prices fluctuate widely for complicated

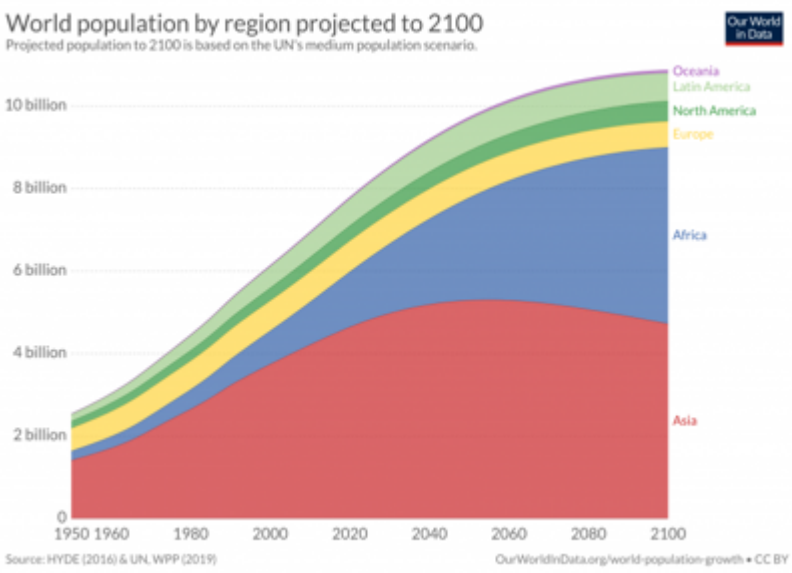
[89] Jessica A. Gephart[a],[1], https://www.pnas.org/content/116/19/9142/tab-article-info

[90] https://www.pnas.org/content/pnas/suppl/2019/05/02/1905650116.DCSupplemental/pnas.1905650116.sapp.pdf

[91] https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_198073.pdf

[92] https://www.oecd-ilibrary.org/sites/4dd9b3d0-en/index.html?itemId=/content/component/4dd9b3d0-en

reasons. A linear growth line is a projection, not science, possibly drawn as a marketing tool. There are several nuances to this widely used projection. First, nearly 120 nations are at or below replacement fertility with the human population of these nations projected to peak and then slowly decline over the next few decades. This means demand for expensive RAS fish could decline.



Second, the large catches of pelagic forage fish used to feed higher trophic farmed fish such as salmon, are typically captured in Asian, African or South American waters, depriving small-scale indigenous fishing communities of their traditional source of protein.[93] This demand also disrupts generations of self-reliant economies. Nearly all population growth projected for the planet is in Africa.[94] This population will be far more secure by being able to go to sea in small boats catching a sustainable yield of their forage fish for human consumption. It is misleading to suggest aquaculture will "feed the hungry."

3. Claim: Carbon Emissions are reduced by locating RAS systems near consumers. Analysis: A frequently sited study by the Freshwater Institute compares transporting net-pen salmon by plane from Norway to Seattle and compares that total carbon footprint to a hypothetical land-based RAS, presumably close to markets.[95] The claim is that eating RAS fish produced regionally spares the carbon emitted when flying fish from distant lands. The problem with this claim is that only 5% of annual world seafood production is transported by plane.[96] These airfreighted products tend to be luxury foods, never intended to feed burgeoning populations. The rest is shipped by sea or ground at far lower carbon footprints. "Depending on the prevailing conditions, air transport causes around 170 to 200 times more emissions than the transport of the same quantity of goods by

[93] https://thefishsite.com/articles/african-fishmeal-factories-under-fire
[94] https://ourworldindata.org/region-population-2100
[95] Yajie Liua, Trond W. Rostena, Kristian Henriksena, Erik Skontorp Hognesa,Steve Summerfeltb, Brian Vincib, Comparative economic performance and carbon footprint of two farming models for producing Atlantic salmon (Salmo salar):Land-based closed containment system in freshwater and open net pen in seawater, in Aquacultural Engineering 71, (2016) 1-12. https://doi.org/10.1016/j.aquaeng.2016.01.001
[96] https://www.eurofishmagazine.com/sections/trade-and-markets/item/173-freshness-and-quality-versus-environmental-and-climate-impact

ship."[97] With the United States being the world's fourth largest exporter of seafood; consumers have the option of eating un-caged fish caught locally. Just as cage-free eggs and fair-trade enter today's consumer choices, the slow fish and community supported fisheries movement advocates for smaller, less frequent portions of low trophic level fish harvested at sustainable levels by small-scale fishermen and women.[98]

4. Claim: Create jobs and cut taxes
Analysis: Many rural communities in Maine are in need of good paying jobs and ironically, at the same time, many employers struggle to find qualified employees. Because industrial aquaculture is highly mechanized and the jobs require unique qualifications, for the short term, few employees will be from the local area. More employment could be attained through support for many smaller sustainable businesses. Boom-bust economics are correlated to too-big-to-fail projects.[99]

Industrial developments can struggle to net tax benefits to residents as their facilities create additional strain on public infrastructures such as roadways, water and sewer systems and electrical grids. For example, a municipality may agree to pay costs for dechlorinating water, running sewer pipes, or upgrading treatment facilities. Rate-payers might not know they will shoulder the costs of new powerlines or secure debts.

Large businesses can access state-level funds that might otherwise be directed toward municipalities, again reducing any net benefit to residents. Towns may assume financial risks or be asked to relieve taxes during a financial emergency, a drop in commodity prices or in the case of aquaculture, a mass mortality of finfish. Diverse smaller businesses can yield similar tax benefits and employment while creating fewer demands on, and risks to, the surrounding environments and infrastructures.

KEY FINDING #6: ENERGY USE AND POLLUTION
The welfare of fish in RAS is dependent upon power grids to continually circulate, filter and replace water. Facilities must plan for a week or more of power interruption from ice storms or grid failures. Generators capable of running the entire operation are necessary. To demonstrate the scale of the power needed, consider the Belfast facility with a proposed demand of 28 MW, power sufficient for a 38,000-home subdivision.[100] Eight 2-megawatt back-up diesel generators each with a 65-foot smoke stack, plan to be operated daily in a residential area to shave peak demand. Noise and air pollution concerns neighbors as permits are sought to store and burn 900,000 gallons of fuel annually.
By comparison, the 2019 peak demand for the entire mid coast of Maine was 145 MW (megawatts). This power demand requires a $63 million upgrade to a power corridor, with costs passed on to ratepayers.

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[97] https://www.eurofishmagazine.com/sections/trade-and-markets/item/173-freshness-and-quality-versus-environmental-and-climate-impact
[98] Liao Y-Y, Chang C-C. Impact of the Slow Fish Movement Curriculum on Students' Awareness of Marine Environment Conservation and Marine Resource Sustainability. *Sustainability*. 2021; 13(5):2880. https://doi.org/10.3390/su13052880
[99] https://michaelhshuman.com/7-ways-to-grow-your-economy-now/
[100] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/2a8a91_2c1b43c743994bcf8cd08d71c95bef94.pdf

As another example, a sea-based RAS system proposed next to Maine's iconic Acadia National Park in Frenchman's Bay would include 10 diesel generators burning four million gallons of fuel annually.[101] On land or sea, the electricity required to grow Maine's proposed 100 MT of aquaculture fish a year is estimated at 75 MW.

It is important to note that many technologies are available to dramatically lower carbon footprints. Some operators of fully closed RAS finfish operations are employing wind and solar energy and using recycled materials in construction.

KEY FINDING #7: BIOSECURITY, DISEASES AND VIRUSES

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.[102] The "extreme monoculture" environment of RAS (stressors, sanitation, density) often requires medications that can lead to resistant diseases as these wild creatures suffer in confinement.[103]

Note: Dead salmon dump on North Uist in September 2018. At least nine million fish have been killed by diseases, botched treatments, poor handling and other problems at salmon farms around Scotland since 2016, according to official returns.

1.) Fish farms can introduce diseases or viruses into wild fish stocks causing economic impacts. A scientific study found that piscine orthoreovirus or PRV was detected in: 95% of farmed Atlantic salmon, 37–45% of wild salmon from regions highly exposed to salmon farms and 5% of wild salmon from the regions furthest from salmon farms.[104] The problem is that once a virus begins spreading, vaccinations that might

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[101] https://www.maine.gov/dep/ftp/projects/american-aquafarms/applications/mepdes/FB01%20Long%20Porcupine%20General%20Application%20for%20Waste%20Discharge%20Permit%20with%20Attachments.pdf

[102] Leung, TLF and AE Bates (2013) Journal of Applied Ecology, 50:215–222

[103] Brown C. Fish intelligence, sentience and ethics. Anim Cogn. 2015 Jan;18(1):1-17. doi: 10.1007/s10071-014-0761-0. Epub 2014 Jun 19. PMID: 24942105.

[104] Morton A, Routledge R, Hrushowy S, Kibenge M, Kibenge F (2017) The effect of exposure to farmed salmon on piscine orthoreovirus infection and fitness in wild Pacific salmon in British Columbia, Canada. PLOS ONE 12(12): e0188793. https://doi.org/10.1371/journal.pone.0188793

protect caged fish, will not help wild fish. Biosecurity threats can be catastrophic when introducing viruses and diseases cultivated and mutated in aquaculture into bays and estuaries via outflow pipes.

2.) Poor practices by the industry can exacerbate these risks by shipping infected fish stock (as eggs, smolts, or food). According to Dr. Stephen Ellis, about 10% of caged salmon is sent to market early because it is infected with salmon anemia (ISA) virus. The aquaculture industry has developed markets for the smaller, diseased fish, unbeknownst to the consumer.[105] Sold fish and destroyed fish can spread viruses and diseases.

As Mark Hume reported in the *Globe and Mail*, updated May 11, 2018, "The action, filed with the Federal Court by Ecojustice on behalf of Alexandra Morton, alleges the Minister of Fisheries and Oceans (DFO) acted 'unlawfully' by issuing a license to Marine Harvest Canada Inc. (rebranded as MOWI, the owner of Ducktrap) to allow the farm to transfer fish carrying piscine reovirus (PRV)." The virus is deadly and causes heart and skeletal muscle inflammation in fish. "Morton said she first detected PRV last year when she tested samples of farmed salmon bought at Vancouver supermarkets. The Cohen Commission of Inquiry, which examined the collapse of sockeye stocks in the Fraser, warned that fish farms could be passing diseases to wild salmon. The Piscine reovirus began in Norway, home to massive aquaculture facilities.

3.) RAS can breed diseases resistant to anti-microbials. Viruses and diseases can be managed and reduced; however, risks are always present. Monocultures such as RAS tanks are the precise breeding grounds and bio-amplifiers for resistant forms of diseases. The use of antibiotics and medications has resulted in increased antimicrobial resistance. Additionally, recent trials have shown that the infectious pancreatic necrosis (IPN) virus has changed and that family lines of salmon genetically selected for resistance to the disease are no longer as protected as they once were.[106]

4.) Antimicrobials and disinfectants used to manage disease in aquaculture systems impact water quality. Antifoulants, fungicides, pesticides and other medications flush out the RAS discharge pipe beyond the footprint of the operation. Although some land-based operations claim they will not use antibiotics, recent permits applications include pages of medications and chemicals that include chlorine, [107] potassium monopersulfate, [108] and formaldehyde.[109] Open RAS that experiences mass die-offs need to use bleach or other chemicals to disinfect tanks, pumps and pipes and then dump millions of gallons of chemically laden water into the marine environment.

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[105]https://alexandramorton.typepad.com/alexandra_morton/2013/02/the-canadian-food-inspection-agency-cfia-has-declared-240000-isa-virus-contaminated-feedlot-salmon-are-fit-for-canadian-co.html

[106]h https://www.fishfarmingexpert.com/article/changes-in-ipn-virus-make-salmon-more-susceptible/

[107] da Costa JB, Rodgher S, Daniel LA, Espíndola EL. Toxicity on aquatic organisms exposed to secondary effluent disinfected with chlorine, peracetic acid, ozone and UV radiation. Ecotoxicology. 2014 Nov;23(9):1803-13. doi: 10.1007/s10646-014-1346-z. Epub 2014 Sep 12. PMID: 25213288.

[108] https://www.alfa.com/en/msds/?language=EN&subformat=AGHS&sku=89892

[109] http://www.npi.gov.au/system/files/resources/9c275e33-dcb4-6694-4995-24bd63aa09d6/files/factsheet-formaldehyde.pdf

5. Some systems employ UV light, ozone and bio-filters that do reduce pathogens and solids; however, UV treatment only works if viruses are not shielded by particles in the water. Because turbidity of water varies with runoff events, viruses can pass through.[110] Even with the addition of some ozone treatment this methodology will not address all virus and virions discharged. The combined levels of UV and ozone needed to fully sterilize, not merely partially disinfect a production tank is difficult given the sensitivity of the fish.

In fully closed land-based RAS facilities, the production water can be fully sterilized before introducing the fish. Then by implementing good bio-security measures, there is a better chance of reducing viruses and diseases.

KEY FINDING #8: SLUDGE

Finfish RAS generates large quantities of concentrated sludge. If dehydrated, considerable energy is needed and salts are further concentrated. In wintertime, with frozen soil and snow on the ground, trucking sludge out of state to warmer climates to spread on sacrifice zones would be problematic, as spring runoff would send the nitrogen-rich mix into streams, increasing nitrogen runoff. Work is ongoing in experimenting with generating biogas or fertilizers from aquaculture sludge.

Polyculture systems have been developed that recycle nutrients with "waste equals food" loops, where the manure grows algae or plants that are then feedstock components, possibly lowering the carbon intensity of feeds.[111]

KEY FINDING #9: FRESH WATER

Some land-based RAS systems require high daily rates of fresh, clean water from wells, aquifers or surface water. As an example, the Belfast facility in Maine would require more than 1.8 million gallons of fresh water/day,[112] similar to four Nestle bottled water operations in Maine. As climate change advances, so have extended droughts, putting wells used by municipalities, residents and farmers are at risk.[113] [114]Large water withdrawals such as those planned by some RAS operations, can draw wells down and lead to salt water intrusion.[115] Closed RAS systems eliminate the massive daily draw of fresh water requiring minimal makeup water due to losses from evaporation.

KEY FINDING #10: FISH FEED, ADDITIVES, CONTAMINANTS

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[110] https://www.maine.gov/dep/ftp/projects/nordic/pre-filed-testimony/intervenor-Upstream%20Watch_Northport%20Village%20Corporation/BRYDEN_NVCUPSTREAM8.pdf

[111] https://www.frontiersin.org/articles/10.3389/fmars.2021.666662/full

[112] https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_12dd7a59189643b38ba78941c603cc82.pdf?index=true

[113] https://statesatrisk.org/maine/drought

[114] https://www.maine.gov/dacf/ard/water_management/docs/2020-maine-drought-and-agriculture-report.pdf

[115] ht https://8774567e-61ab-4355-a629-8a49a81506a2.filesusr.com/ugd/207e52_360f424dc85546e09aa69ff978d15715.pdf

Currently fish feed is comprised of various mixes of soy, corn, canola, slaughterhouse poultry or pork wastes, bloodmeal, Krill, shrimp and crab, and wild-catch forage fish.[116] The small forage fish ground into fish meal often comprise 20-30 % of the diet. Use of insects and algae are being tested. The five proposed Maine facilities would need over 600,000 pounds per day of feed (220 million pounds a year).

Feeding forage fish to caged fish has become a global issue, as these pelagic species are at the base of the food chain. They feed not only people in lower-income societies, but also many other species in marine environments.[117] Impacts of industrial-scale harvest includes the bycatch of threatened species, depriving traditional fishermen and women of their livelihoods, and communities of important food sources.

Finfish producers are promoting higher percentages of corn and soy, most of which is genetically engineered and grown with herbicides, pesticides and chemical fertilizers, depending upon local regulations. These residues can make their way to the sea, unless fully closed RAS systems are used. Each nation regulates the use of antibiotics, growth hormones, GMO feedstocks and synthetic dyes that can be used.

Fishmeal, depending on the source and local regulations can contain persistent and bioaccumulative toxic substances (PBTSs),[118] [119] including monomethyl mercury in protein, and organohalogen pollutants. Exposure to these chlorinated compounds is known to cause reproductive, neurotoxic, immunotoxic, endocrine, behavioral, and carcinogenic effects in wildlife and humans.

Additives are used to enhance feed intake (amino acids, peptides and betaine), to impart a pink color (natural and/or synthetic astaxanthin), for digestibility of feeds (Bactocell®), and to preserve the feed (Ethoxyquin).[120] Antibiotics and medications including synthetic chemicals can be integrated into the feed pellets.

A study published in *Aquaculture Engineering* found that dissolved phosphorus levels vary with fish diet. "Total phosphorous (most of which was dissolved) was 4 times greater in the culture water of RAS that received a Fishmeal-free diet."[121]

KEY FINDING #11: PUBLIC COMMONS

Humanity has entered the "6th great extinction" an epoch being coined as the "Anthropocene" evidenced by accelerated climate change, pollution, biodiversity losses and collapse of fisheries. Industrial food systems along with fossil fuel use are primary

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[116] https://www.fisheries.noaa.gov/insight/feeds-aquaculture
[117] https://www.sciencedaily.com/releases/2018/06/180614213822.htm
[118] https://pubmed.ncbi.nlm.nih.gov/17133828/
[119] https://www.epa.gov/report-environment/consumable-fish-and-shellfish
[120] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4745505/
[121] Aquacultural Engineering Volume 74, September 2016, Pages 38-51, Effects of feeding a fishmeal-free versus a fishmeal-based diet on post-smolt Atlantic salmon *Salmo salar* performance, water quality, and waste production in recirculation aquaculture systems. JohnDavidson[a]Frederic T.Barrows[b]P. BrettKenney[c]ChristopherGood[a]KarenSchroyer[a]Steven T.Summerfelt[a]

contributors. Bold restoration efforts are needed, along with sustainable, local, organic, fair-trade food systems.

A long history of exploitation and poorly regulated extractive fishery practices has collapsed species after species. Large-scale sea-based and land-based aquaculture creates new and profound impacts. Unfortunately, we do not have the luxury to claim these impacts as "unintended consequences" as enough information is now known, both about the real impacts as well as how to support the recovery of wild stocks.

Globally, environmentalists, wild fish advocates, consumers, chefs, independent scientists, wildlife enthusiasts have called attention to the environmental impacts of industrial aquaculture on wild species, water quality, coastal economies, tourism, ecologies and cultures.

Tourism in a region depends upon clean harbors and beaches. If beachgoers begin to experience unhealthy effluent as they swim at beaches near outflow pipes, they might look for cleaner waters for their vacations or homes.

Placing feedlots or pipelines in navigable waters can interfere with vessel traffic, recreational and commercial fishing, tourist activities, renewable energy infrastructure, migration of marine mammals and other marine fish and animals. Floating or submerged structures full of fish attract wildlife and natural predators, which can become entangled. Installing pipelines can stir up industrial in sediments such as mercury, halocarbons, lead, chromium arsenic.

KEY FINDING #12: AGENCY OVERSIGHT LACKING

Unfortunately, communities are not always aware of the scope of the impacts as this is an emerging industry seen by some as "innovative" and "sustainable." Worldwide, the aquaculture sector has been proactive in lobbying for leniency in regulation and application of existing laws. Citizens have been forced to raise large budgets for legal and technical expertise to obtain objective information. From these experiences it is clear that effective and comprehensive state or federal regulatory and monitoring system are not in place to prevent environmental damage early enough to stop it and avoid unanticipated harm.

Multiple federal agencies regulate different aspects of the US aquaculture industry: Food and Drug Administration, National Oceanic and Atmospheric Administration, US Army Corps of Engineers, US Dept of Agriculture, US Environmental Protection Agency, and US Fish and Wildlife Service. Within NOAA, the National Marine Fisheries Service has attempted to clarify regulations, including considering "harvesting" under the Magnuson-Stevens Fishery Conservation and Management Act as applying to aquaculture as well as wild caught fish. Courts ruled that aquaculture does not fit the definition of 'fishing" so proponents of aquaculture continue to try to expand the industry through policy changes within regulatory agencies and favorable legislative policies.

Various agencies have been willing to suspend or change environmental and health protections. In May 2020, a presidential executive order to "Promote American Seafood Competitiveness and Economic Growth" touted expansion of industrial aquaculture into federally managed waters.

Much of the information that policy makers and the public receive is from the industry itself, or researchers at universities and NGOs who receive funding from this $245 billion industry. Often the same government agencies charged with protecting the marine ecosystem, find themselves in an advocacy role for the aquaculture industry.

When the impacts of the aquaculture industry become apparent, small fines can be considered part of the cost of doing business. In this way, a diverse, multi-stakeholder working waterfront can become dominated by the influence of several corporate interests. Independent and science-based evaluations can be built and policies developed that would ensure zero-effluent and safeguard local ecosystems. Any large-scale project must use the best practicable technology which at this point is zero discharge and carbon neutral. The permitting of small-scale, sustainable polycultures could be researched, streamlined and encouraged.

4. SUMMARY

Restoring wild fish habitat and water quality needs to be our global goal. Adding pollutants such as dissolved nitrogen and carbon emissions when levels are currently greater than assimilative capacity is not prudent. Reducing the use of small pelagic fish for aquaculture feed protects the marine food chain and allows people in developing nations to meet their protein needs with local, native seafood. Encouraging consumers to choose wild-caught fish harvested in well-regulated fisheries can help restore small-scale, family and tribal fisheries throughout the country and world. Keeping waste and chemicals and debris from ocean and coastal regions can help restore healthy oceans and sea life.

Completely 'closed' land-based systems, including polycultures have become operational and solve many of the problems mentioned in the Key Findings. These systems integrate multi-trophic species that recycle nutrients internal to their systems. The benefits include control of disease, pests and weeds without chemical inputs. Further investments in these systems can contribute to a sustainable food system.

Low-trophic-level fish reared in ponds or enclosures with closed recirculating systems currently offer protein around the world. These are generally not the high-value species but fulfill the promise of providing affordable, abundant seafood for our hungry planet.

If state and federal regulators insist that zero-effluent and minimal carbon footprint projects are required, permitting can be streamlined, when quantifiably sustainable designs are demonstrated. The advantages of smaller systems include reduced biosecurity risks when catastrophic die offs or disease or virus outbreaks occur. The smaller systems also reduce risks to communities, ecosystems, investors, and economies.

Humanity is at a crossroads between a brave new world of factory fish and a traditional working waterfront with recovered fish stocks. Just as the Maine Organic Farmers and Gardeners Association (MOFGA) has shown that a food system doesn't have to degrade ecosystems, the same can be said about the seafood sector, where thousands of fishermen and women earn an independent living from the sea. The restoration of a working waterfront with a sustainably managed wild-caught fishery should be a strong priority.

As vital as sustainable food systems are, a reality remains -- the tourism sector yields many times more revenue to Maine's economy than agriculture and seafood combined. The iconic brand that attracts millions of visitors a year is a relatively clean and beautiful environment. Building open and polluting, carbon intensive aquaculture is in stark contrast to the brand that attracts tourists.

We find that 'open' land-based and floating RAS finfish aquaculture projects pose numerous environmental and societal risks, including:

- The spread of virus, disease and pollutants that threaten recovery of nearby wild and endangered fish populations,
- Weakening food sovereignty of the Penobscot Nation,
- Impacts on wild forage fish populations near and distant, and
- Extractive use of the most sensitive marine ecosystems.

The good news is that there are many options for creating sustainable food systems that include sustainably harvested and/or grown seafood, including fin fish that have little or no negative impacts on marine environments.

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