RESTORATIVE AQUACULTURE FOR PEOPLE, PROFIT AND PLANET

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Narratives continue to provide the public and decision-makers with a bleak image of aquaculture sites as industrial waste areas, destroying and depleting the natural environment and its biodiversity, and creating a desert from an ocean oasis. However, examples demonstrate how restorative aquaculture could lead sector-wide approaches to decisions on financial allocations for nutrient removal using combined best practices that merge aquaculture into plans to ameliorate damaging coastal pollution while increasing aquaculture growth for both business development and accelerated seafood production.

Harvesting seaweed in the Gulf of Maine, USA

Restorative aquaculture provides the paradigm shift needed to develop new social licenses to operate in the world's new geographies for aquaculture. It places the knowledge-rich "aquaculture toolbox" front and centre in the planning and development of financially feasible pathways for new aquaculture production as well as the restoration of habitats and complex ecosystems.

Bivalve and lower trophic level aquaculture have led the way, as there exist important examples where user conflicts were resolved due not only to technological advances but also to a growing consensus that aquaculture can "fit in" in an environmentally and socially responsible manner in many marine coastal environments, the majority of which are already crowded with existing users. Adoption of restorative aquaculture by aquaculture industries and coastal communities can provide a strong scientific basis for a new social contract for aquaculture by contributing to regional sustainable development planning, advancing new policies and investments to accelerate aquatic food production; and by using the many methods of ecological aquaculture for environmental restoration to replace hearsay, junk science, and misinformed advocacy.

Setting the stage for restorative aquaculture

For all its advances over the past 50 years, global aquaculture remains concentrated in Asia, which accounts for about 90% of the production from this sector. The region farms the largest number and variety of aquaculture species and most of the world's aquafarmers are Asian[1].

China dominates Asian production (65%); Egypt dominates Africa (73%); Chile dominates the Americas (34%); and Norway dominates Europe (45%). The largest ecosystem on Earth, Oceania, has a tiny amount of global aquaculture production (0.2%) (Table 1). Only Norway, Chile and Egypt produce more than 1 million tonnes/year; but these production successes outside of Asia remain regionally-concentrated (tilapias in the upper Nile, salmon in southernmost Chile); as well as limited in the diversity of species farmed and systems used (salmonids in net cages, tilapias in ponds).

[1] Mair, G.C., Halwart, M., Derun, Y. et al. A decadal outlook for global aquaculture. Journal of the World Aquaculture Society (2023) 54, 196-205. https://doi.org/10.1111/jwas.12977

Many rightfully tout the awesome growth of aquaculture worldwide, with the world's seafood press and scientists boasting to policymakers that aquaculture now provides "half of the world's seafood supplies". However, for most of the world's geographies, and for most nations outside of Asia, 50% of their seafood supplies do not come from aquaculture[2]. Many analysts and organizations examining future needs for global and local seafood supplies have called for this to change and argue that aquaculture development is vitally important to sustain seafood supplies to meet growing world demand[3].

TABLE 1. Animal aquaculture production, by region and leading producers (million MT). Source: FAO 2020

	World	Asia	Africa	Americas	Europe	Oceania
Inland	51.3	47.7	1.9	1.2	0.5	0.0
Marine	30.8	25.1	0.3	2.6	2.6	0.2
Total	82.1	72.8 China (47.6)	2.2 Egypt (1.6)	3.8 Chile (1.3)	3.1 Norway (1.4)	0.2

Notes: Marine includes coastal and brackishwater aquaculture. Less than 0.1 MMT is reported by FAO as "zero."

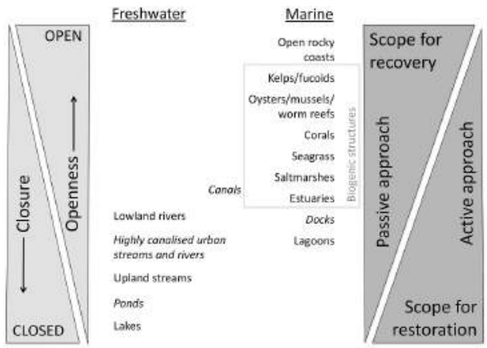
Why has aquaculture development been prevented or slowed across large areas of the world outside of Asia, in these vast areas of great potential for growth; i.e. areas of the world that are the "new geographies for aquaculture"? As one of the first authors to collate the potential of restorative aquaculture in 2002[4], we reviewed the poor performance of growth in aquaculture production in Europe and North America from 1995 to 2002 (which has continued to today) and gave our opinion that:

"the degraded state of many aquatic ecosystems combined with public concerns about adding any new sources of aquatic pollution to already over-burdened ecosystems will require aquaculture to develop ecosystem approaches and sustainable operating procedures and to articulate a sustainable, ecological pedagogy. In the 21st century, aquaculture developers will need to spend as much time on designing ecological approaches to aquaculture development that clearly exhibit stewardship of the environment, as they do on technological advances coming to the field. Clear, unambiguous linkages between aquaculture and the environment must be created and fostered, and the complementary roles of aquaculture in contributing to environmental sustainability, rehabilitation and enhancement must be developed and clearly articulated to a highly concerned, increasingly educated and involved public."

Development of restorative aquaculture

While the use of the adjective "restorative" attached to "aquaculture" is a recent development, it follows directly from, and is aligned with, the theories, principles, and practices of many areas of ecological restoration (Figure 1). All were developed by environmental scientists having the overall goal of reversing the major structural and functional damages to Earth/ocean systems due to industrialization and urbanization post-WWII to the 1970s (Box 1).

Figure 1. Scope for restoration and ability to recover naturally (artificial habitats are in italics)



Source: Geist, J., Hawkins, S.J. Habitat recovery and restoration in aquatic ecosystems: current progress and future challenges. Aquatic Conservation: Marine and Freshwater Ecosystems 26, 5, 942-962 (2016). https://doi.org/10.1002/aqc.2702

Box 1. Symptoms and trends of a stressed ecosystem

Energetics

- Community respiration increases
- Production/respiration becomes unbalanced
- Maintenance: biomass structure ratio increases
- Importance of auxiliary energy increases
- Exported or unused primary production increases

Nutrient Cycling

- Nutrient turnover increases
- Horizontal transport increases and vertical cycling of nutrients decreases
- Nutrient loss increases

Community Structure

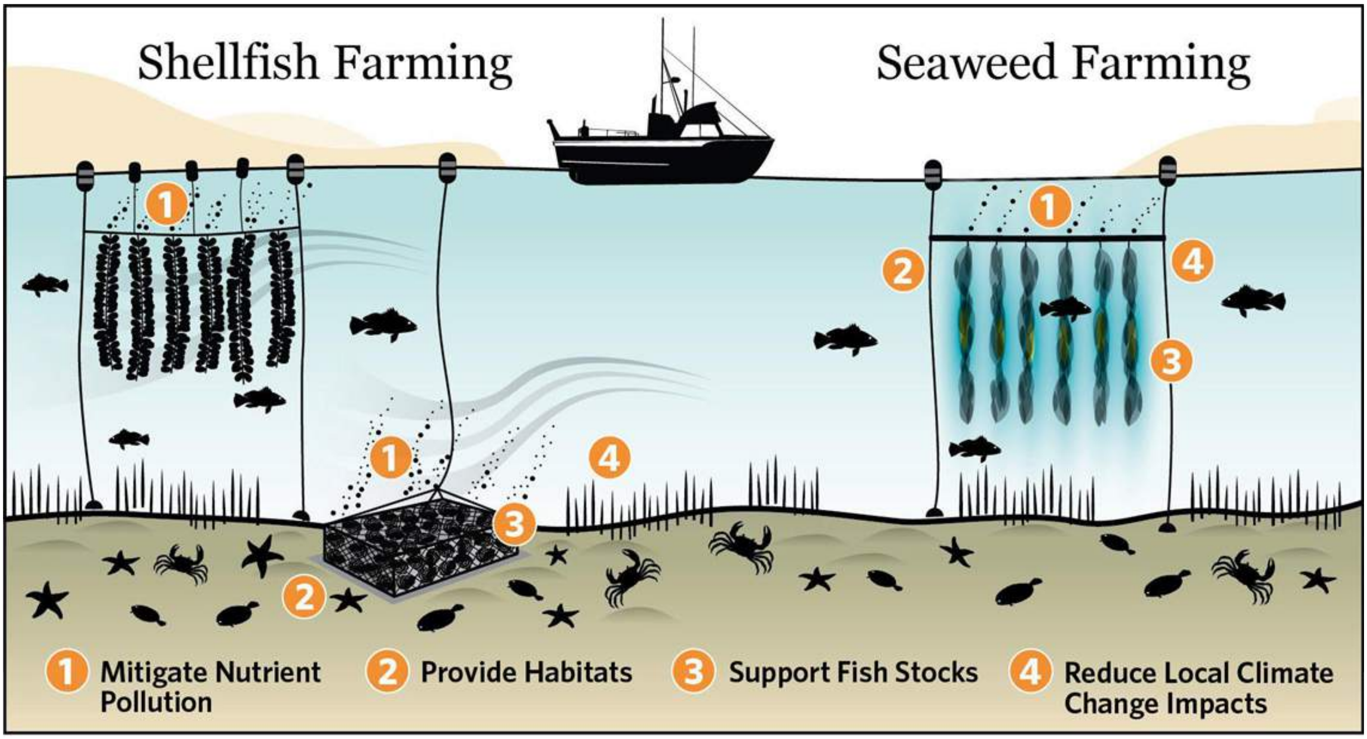
- Proportion of r-strategists increases
- Size of organisms decreases
- Life span of organisms decreases
- Food chains shorten because of reduced energy flow at high trophic levels
- Species diversity decreases and dominance increases

General systems-level trends

- Ecosystem becomes more open
- Autogenic successional trends reverse
- Efficiency of resource use decreases
- Parasitism and other negative interactions increase and mutualism and other positive interactions decrease
- Functional properties are more robust than species composition and other structural properties

Source: Odum, E.P. Trends expected in stressed ecosystems. BioScience 35, 419–422. (1985). https://doi.org/10.2307/1310021

[2] *Costa-Pierce, B.A., Chopin, T. The hype, fantasies and realities of aquaculture development globally and in its new geographies. World Aquaculture (2021) 52, 23-35.*
[3] *HLPE. Sustainable fisheries and aquaculture for food security and nutrition. (2014) A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.*
[4] *Costa-Pierce, B.A., Bridger, C.J. The role of marine aquaculture facilities as habitats and ecosystems, (2002), 105-144. In: R. Stickney & J. McVey (Eds.) Responsible Marine Aquaculture. CABI Publishing Co., Wallingford, U.K.*



Source: The Nature Conservancy (TNC). Restorative Aquaculture for Nature and Communities. TNC, Arlington, VA, USA (2023). https://www.nature.org/en-us/what-we-do/our-insights/perspectives/restorative-aquaculture-for-nature-and-communities/

A transformation of food production systems is needed to meet the challenges of simultaneously adhering to planetary dimensions, food security and advancing human health and wellness. The United Nations adopted the 17 Sustainable Development Goals (SDGs) in 2016 as a "universal call to action for people, planet, peace, partnerships, and prosperity". Restorative aquaculture touches many of the SDGs beyond the one goal of "life under water". Troell et al.[5] reviewed how aquaculture contributes to many of the SDGs and what is needed for the future, stating that:

"Marine aquaculture of lower trophic level aquatic species (mostly aquatic invertebrates), such as bivalves, urchins, sea cucumbers, and seaweed aquaculture have the ability to improve water quality, serve as buffers to coastal erosion, ameliorate nutrient pollution, provide essential habitats for other species, and transform carbon, nitrogen, and phosphorus cycles. Such production systems mirror agro-ecosystems, aiming at broad preservation of ecosystem functionality."

Ecosystems goods and services provided by lower trophic level restorative aquaculture of shellfish and seaweeds

Restorative aquaculture can be a cornerstone that changes the dynamic of aquaculture development in its new geographies as it is a critical part of all of the SDGs, sustainable rural development, and enhanced environmental sustainability. But restorative aquaculture is a new rubric, with a new community of practice which doesn't necessarily align with "traditional" aquaculture communities. Development of restorative aquaculture has been facilitated by the new entry of a wider diversity of actors and organizations also concerned with aquaculture's social-ecological impacts (diversity, inclusion, indigenous) beyond its technological progress. This is especially so in aquaculture's new geographies outside of its well-established modern and historical home in Asia.

The leading organizations in the funding and development of restorative aquaculture to date are not traditional industry or academic organizations, but large international conservation NGOs such as The Nature Conservancy (TNC) and the International Union for the Conservation of Nature (IUCN). IUCN has incorporated aquaculture into its portfolio of "Nature-based Solutions"[6&7]; meanwhile, TNC has developed the "Global Principles of Restorative Aquaculture"[8&9] which define restorative aquaculture as:*"...occurring when commercial or subsistence aquaculture provides direct ecological benefits to the environment, with the potential to generate net positive environmental outcomes."*

[5] *Troell, M., Costa-Pierce, B., Stead, S. et al. Perspectives on aquaculture's contribution to the Sustainable Development Goals for improved human and planetary health. Jo. World Aquacul. Soc. 54, 251–342 (2023). https://doi.org/10.1111/jwas.12946*

[6] *Le Gouvello, R., Brugere, C., Simard, F. Aquaculture and Nature-based Solutions. Identifying Synergies Between Sustainable Development of Coastal Communities, Aquaculture, and Marine and Coastal Conservation. IUCN, Gland, Switzerland (2022). https://doi:10.2305/IUCN.CH.2022.02.en*

[7] *Le Gouvello, R., Cohen-Shacham, E., Herr, D. et al. The IUCN global standard for Nature- based Solutions™ as a tool for enhancing the sustainable development of marine aquaculture. Front. Mar. Sci. 10:1162487 (2023). https://doi.org/10.3389/fmars.2023.1146637*

[8] *The Nature Conservancy (TNC). Global Principles of Restorative Aquaculture. TNC, Arlington, VA, USA (2021). https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_PrinciplesofRestorativeAqua culture.pdf*

[9] *Alleway, H. K., Waters, T. J., Brummett, R. et al. Global principles for restorative aquaculture to foster aquaculture practices that benefit the environment. Cons. Sci. Practice, e12982 (2023). https://doi.org/10.1111/csp2.12982*

Restorative Atlantic salmon aquaculture farm, New Brunswick, Canada

What sets the standard for determining what is, and what is not, "restorative aquaculture" is the clear emphasis on the "net positive" for the environment which puts a higher standard of environmental values than articulated for ecological aquaculture[10]. This is not to say that these organizations leading and supporting restorative aquaculture do not care about its allied economic and social impacts; rather, as organizations founded on the creed of environmental/nature preservation/conservation, they have core values that require that credible positive benefits to the environment be demonstrated.

[10] Costa-Pierce, B.A. 2021. The principles and practices of ecological aquaculture and the ecosystem approach to aquaculture. World Aquaculture 52 (1): 25-31. CP_2021_WA_52_1_-libre.pdf (d1wqtxts1xzle7.cloudfront.net)

Examples of restorative aquaculture

Aquaculture today is a transdisciplinary science which can be defined as investigations of "wicked problems" that need creative solutions; reliance on stakeholder involvement; and engaged, socially responsible science[11].

Included in TNC's foundation document, the "Global Principles for Restorative Aquaculture", are three examples and roadmaps for restorative aquaculture at a significant scale: (i) impacts of filter-feeding carps on lake water quality in China; (ii) the emergent seaweed industry in Belize; and (iii) the large oyster restorative aquaculture initiative called SOAR (Supporting Oyster Aquaculture and Restoration). There are many others being recognized and developed; ten examples are given in Table 2. All include innovative partnerships and multiple opportunities for the aquaculture industry, for applied research, for communications professionals, and for communities. As can be seen, restorative aquaculture is not limited to animals but also includes "freshwater and marine agronomy", a sophisticated form of higher- and lower-plant aquaculture which produces not only commodities for sale, but also assimilates nutrients and creates and restores disturbed natural habitats worldwide. Tidal wetland, mangrove forest and seagrass restoration are all forms of restorative aquaculture that create, enhance, and maintain productive ecosystems and habitats in a long-term, sustainable manner.

[11] Bernstein, J. H. Transdisciplinarity: A review of its origins, development, and current issues. J. Res. Prac. 11, 1-20. http://jrp.icaap.org/index.php/jrp/article/view/510/412

Table 2. Ten notable examples of restorative aquaculture development

Ecosystems	Target restorative aquaculture species	Principal partners; references
Inner Bay of Fundy, Canada	Atlantic salmon	National Parks Canada, Fort Folly First Nation, University of New Brunswick, Cooke Aquaculture Fundy Salmon (youtube.com)
Veta La Palma, Spain	Mullet, eel, seabass, sea bream, shrimp, carp, meagre, sole	La Palma Parque Natural, Universidad de Sevilla, Universidad de Pablo Olavide de Sevilla TED Talk Dan Barber (on youtube.com)
Pacific NW Coast, British Columbia, Canada	Littleneck clams *(Leukoma staminea)*, Butter clams *(Saxidomus giganteus)*	Northern Coast Salish and Southern Kwakwaka'wakw First Nations, Laich-kwil-tach Treaty Society, Simon Fraser University, University of Washington[a], Pacific Sea Garden Collective[b]
Hawai'i, ancient fish ponds	Hard clams *(Mercenaria mercenaria)*, milkfish, mullet, moi, ogo *(seaweed, Gracilaria parvispora)*, sea cucumbers, *akulikuli* (native edible coastal vine *(Sesuvium portulacastrum)*	Kauai Sea Farms, County of Kauai, Hui Mālama Loko I'a & Kua'Āina Ulu'Auamo (KUA)
SOAR (Supporting Oyster Aquaculture and Restoration)	Eastern oysters *(Crassostrea virginica)*	The Nature Conservancy, Pew Charitable Trusts, U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Dept. of Agriculture SOAR (Supporting Oyster Aquaculture and Restoration)
Coastal estuaries, Cape Cod, USA	Eastern oysters, Hard clams	Massachusetts Towns, State Government, The Green Center
Coastal fjords, Norway	Seaweed *(Saccharina latissimi, Laminaria hyperborea)*	Urchinomics, Norwegian Institute for Water Research, Nofima, Nosan Corp., Nippon Telegraph and Telephone Corp.
Coastal tropics	Mangrove aquaculture ecosystems	Guangxi Province, China; Ca Mau Province, Vietnam[c]
Coastal tropics	Coral reefs	Indo-Pacific Nearshore Ecosystems[d]
Coastal temperate	Marine agronomy of seagrasses	Shandong Peninsula, China lagoon/estuarye

[a] Groesbeck, A. S., Rowell, K., Lepofsky, D. et al. Ancient clam gardens increased shellfish production: adaptive strategies from the past can inform food security today. PLoS ONE 9:e91235 (2014). https://doi: 10.1371/journal.pone.0091235

[b] Pacific Sea Garden Collective. Sea Gardens Across the Pacific: Reawakening Ancestral Mariculture Innovations. Version 1. Washington Sea Grant at the University of Washington (2022). https://www.seagardens.net

[c] Romañach, S., DeAngelis, D.L., Koh, H.L. et al. Conservation and restoration of mangroves: Global status, perspectives, and prognosis. Ocean & Coastal Mgt. 154, 72-82 (2018) https://doi.org/10.1016/j.ocecoaman.2018.01.009

[d] Zhang, D., Fang, C., Liu, J. et al. An effective seed protection method for planting Zostera marina (eelgrass) seeds: Implications for their large-scale restoration. Mar. Poll. Bull. 95, 89-99 (2015). https://doi.org/10.1016/j.marpol.2004.09.001

[e] Pomeroy, R.S., Parks, J.E., Balboa, C.M. Farming the reef: is aquaculture a solution for reducing fishing pressure on coral reefs? Mar. Policy 30, 111-130 (2006). https://doi.org/10.1016/j.marpol.2004.09.001

A new social construct for aquaculture expansion

As one of the world's most widely traded foods, globalization has affected seafood communities locally by accentuating production places, regions and exports. All direct consumption and developments remain, however, in one way or another, regionally- and locally-contextualized. Development of community-based, hyper-local restorative aquaculture ecosystems serve to demonstrate new aquatic food production systems with shortened value chains that assist in the evolution of the "culture of aquaculture". Community-based restorative aquaculture systems can ameliorate nutrient pollution and climate change and reclaim and help preserve the Earth's remaining biodiversity while contributing significantly to local economic and cultural development. With the proper documentation - and the development of new narratives – the development of cooperative, transdisciplinary restorative aquaculture ecosystems can yield greater returns for a community's "return on investment" (ROI). Two hyper-local examples in the USA illustrate the potential for new conceptual frameworks for ROIs.

Louisiana has lost millions of hectares of coastal wetlands but is home to about 68 000 ha of red swamp crayfish *(Procambrus clarkii)* aquaculture/ rice wetlands. From mid-autumn to mid-spring, aquafarmers cultivate crayfish, then in summer they grow rice. This crayfish/rice aquaculture ecosystem is an essential habitat for colonial water birds. It can be argued that the crayfish aquaculture wetlands have allowed a stunning recovery of birds, many of which are considered endangered and threatened. The Lake Martin rookery east of Lafayette, Louisiana is an example. This rookery is surrounded by more than 13 000 ha of aquaculture crayfish wetlands which support robust nesting populations of egrets, herons, ibis, and spoonbills, all of which have rebounded dramatically. Bird predation causes economic losses to crayfish farmers, but bird tourism, recreation, and sport hunting incomes are worth millions of additional dollars a year to rural communities (see also Veta La Palma, Spain, in Table 2).

Another very important example of restorative aquaculture has been developing over the last 10–15 years in towns along the estuary-rich coast of Cape Cod, Massachusetts, USA. Towns in this region urgently need to control water pollution that has led to an increased number and severity of harmful algal blooms in coastal estuaries and freshwater ponds, principally due to accelerating inputs of nitrogen and phosphorus to aquatic ecosystems in the warmer months of the year. The Massachusetts Estuaries Project (MEP) was created in partnership with the University of Massachusetts to conduct detailed scientific reviews and modelling studies[12] that determine the total daily maximum load (TMDL) necessary to support healthy estuarine ecosystems. This is followed by actions of towns who develop watershed plans to remove nitrogen loads to achieve the target TMDLs.

Traditionally, water quality restoration goals have been met almost universally by a focus on capital-intensive development of sewer systems (this very public debate continues everywhere). Falmouth, a coastal town on Cape Cod which has about 30 000 residents (around 90 000 in summer), is seeking a new solution. The town has 14 diverse estuaries. In 2002, Falmouth was cited for violations of the US Clean Water Act due largely to nitrogen pollution, especially nitrate from septic systems which leached nitrogen into groundwater and then into estuaries; in addition, one highly-impacted estuary receives 70% of the effluents from a wastewater treatment plant. Nitrogen loadings are very high; total loadings were estimated for some estuaries as high as 30.2 tonnes of nitrogen per year. Over the past years, Falmouth has included shellfish aquaculture and residential urine diversion in its nitrogen-removal strategies, to complement the traditional sewer approach.

Incorporating shellfish aquaculture and urine diversion into plans has demonstrated how restorative aquaculture and individual homeowners, via urine diversion, could contribute to more comprehensive nutrient remediation and environmental restoration. Urine diversion is the concept of diverting urine from wastewater to manage nitrogen, since 80% of the nitrogen in wastewater is from urine, but urine is only about 1% of its volume (about 120 gallons [454 L/person/year])[13&14]. Thus, managing urine is a very efficient and cost-effective method of nitrogen removal from the environment. Using these two more affordable methods of nitrogen reduction means less reliance on the traditional demands by governments for increased taxes to fund ever-increasing and very costly capital investments in sewering.

Innovative restorative aquaculture is in part of the plans in Falmouth, which has zoned areas for both commercial and recreational shellfish farming for nitrogen removal to ameliorate damaging coastal pollution. Nutrient credits that will accrue to the town, that the State would give for the amount of nitrogen the shellfish harvests remove each year, are an active part of the on-going discussions. Any town resident can harvest a limit of one bushel of oysters per harvest trip (about 10–15 kg) during the permitted season (late Fall to early Spring). Commercial shellfish farmers are contracted by the town and pay a USD 20 000 access fee for 0.5 acres (0.2 ha) of coastal bay. Shellfish farmers are obligated to grow a maximum biomass on the lease. In 2023, shellfish farmers harvested 1.43 million oysters from just 1.5 acres (0.6 ha). The town has determined that nitrogen nutrient credits per oyster harvested would be 0.28 g N/ oyster. In 2023, it was estimated that a total of 400 kg of nitrogen was removed from the 1.5 acres (0.6 ha) of oysters. This removal could offset about USD 3 million in costs for additional sewer infrastructure. The oysters harvested produced an estimated commercial gross revenue of USD 350 000 to USD 700 000. This restorative aquaculture scheme is so successful that the area is expected to increase ten-fold in 2024.

Planners have calculated a hypothetical case to determine if combining urine diversion and oyster aquaculture together could eliminate the need for sewering in one watershed. This example watershed has about 4 500 homes. At a 4.5 kg N discharge to groundwater per house/year, the total

[12] *The Massachusetts Estuaries Project and Reports. https://www.mass.gov/guides/the-massachusetts-estuaries-project-and-reports*

[13] *Wald, C. How recycling urine could help save the World. Nature 602, 202-206 (2022). https://mahb.stanford.edu/wp-content/uploads/2022/03/d41586-022-00338-6.pdf*

[14] *Maingay, H., Barnhart, E. Putting urine to work for us. Falmouth Enterprise, February 2, 5 (2024) https://www.capenews.net/falmouth/columns/putting-urine-to-work-for-us/article_b967ca90-5a8d-57de-94cc-7eef9655d947.html*

nitrogen to be removed would be 20 250 kg. Assuming that 75% of the urine can be captured by homeowners (3.4 kg N), urine diversion could remove about 15 300 kg N/year. If 1.5 acres (0.6 ha) of oysters captured 400 kg N, only 12.4 acres (5 ha) of additional shellfish aquaculture could remove all the remaining 4 950 kg of nitrogen.

The future of restorative aquaculture

For the future growth of restorative aquaculture globally and locally, there will be needs for: (i) aquaculture industry adoption and investment; (ii) transparent, third-party requirements of Monitoring, Reporting and Verification (MRV); (iii) alignment into the planning, development, and monitoring of freshwater and marine protected areas (MPAs); (iv) significant engagement of indigenous nations and fostering their leadership; and (v) expansion and development into rewilding initiatives.

There are reviews and roadmaps now available for industry and communities to consider; for example, in restorative shellfish aquaculture[15]. Important commercial examples now exist such as Offshore Shellfish Ltd. and Plymouth University (UK) which have provided the scientific basis for mussel aquaculture development in energetic ocean sites via an array of opportunities and funds that have been obtained to support a diversity of targeted applied aquaculture and environmental studies.

The standard for determining what is "restorative aquaculture" is the clear emphasis on the "net positive" for the environment. As such, all operations claiming to meet this high standard should be required to undergo MRV to ensure that the standard is met. This will be a challenge but could also be an exciting opportunity for aquaculture operations to partner on an equal and strategic basis, and to avoid any exploitation and tokenism too often present in the past. Whether this will evolve into some sort of formal or informal certification regime remains an open question.

Planning and development of restorative aquaculture in community-conserved biodiversity hotspots such as aquaculture in marine protected areas (MPAs), as led by the IUCN, are very important future opportunities for aquaculture growth[16].

Indigenous aquaculture communities are ancestors of all global aquaculture practitioners alive today. Indigenous knowledge systems of aquaculture are part of not only their birthrights but of all humanity[17]. An estimated 80% of the world's remaining biodiversity is in the indigenous nations worldwide. Leadership in restorative aquaculture by indigenous communities can not only reclaim their past wisdom but also advance community-based restorative aquaculture locally and globally. Restorative aquaculture development by traditional knowledge-keepers in indigenous nations can help ameliorate the combined climate and biodiversity crises, while re-orienting economies to more sustainable approaches. Alignment of restorative aquaculture with the IUCN Global Indigenous Network for Aquaculture (GINA) is a tremendous opportunity[18].

15 Carranza, A., zu Ermgassen, PSE. A global overview of restorative shellfish mariculture. Front. Mar. Sci. 7:722 (2020). https://www.doi:10.3389/fmars.2020.00722

16 IUCN. Aquaculture and Marine Protected Areas. Report (2017) IUCN, Gland, Switzerland https://portals.iucn.org/library/node/46692

17 Costa-Pierce, B.A. The anthropology of aquaculture. Front. Sustain. Food Syst. 6:843743 (2022). https://doi.org/10.3389/fsufs.2022.843743

18 Global Indigenous Network for Aquaculture. International Union for the Conservation of Nature (IUCN) Declaration at the World Conservation Congress (2020). https://www.iucncongress2020.org/motion/

Restorative aquaculture is not fully synonymous with the modern concept of "rewilding", as the latter "aspires to reduce human influence on ecosystems" and "emphasizes recovery of ecological structures and functions of ecosystems prior to human influence"[19]. A key feature of rewilding is its focus on replacing human interventions with natural processes with the aim to create resilient, self-regulating, and self-sustaining ecosystems. If restorative aquaculture can become rewilding, a major expansion of the concept could occur as the United Nations has listed rewilding as one of several methods needed to achieve massive-scale restoration of natural ecosystems as part of the 30x30 campaign (protecting 30% of the planet's oceans, lands and freshwater by 2030), and beyond.

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19 Carver, S., Convery, I., Hawkins, S. et al. Guiding principles for rewilding. Cons. Biol. 35, 1882–1893 (2021). https://doi:10.1111/cobi.13730

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