Restoration Aquaculture

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Alleway, H. et al. (**2023, in press**). Global principles for restorative aquaculture to foster aquaculture practices that benefit the environment. *Conservation Science and Practice*.

The Nature Conservancy (Alleway, H., R. Brummett, J. Cai, L. Cao, M. R. Cayten, B.A. Costa-Pierce, P. Dobbins, Y-w Dong, S.C. Brandstrup Hansen, R. Jones, S. Liu, Q. Liu, C.C. Shelley, S. Theuerkauf, L. Tucker, T. Waters, and Y. Wang). (**2021**). *Global Principles of Restorative Aquaculture*. The Nature Conservancy, Arlington, VA. https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_PrinciplesofRestorativeAquaculture.pdf

Theuerkauf, S., L. Barrett, H. Alleway, B.A. Costa-Pierce, A. St. Gelais and R. Jones. **(2021).** Habitat value of bivalve shellfish & seaweed aquaculture for fish & invertebrates: pathways, synthesis & next steps. *Reviews in Aquaculture* 2021;00:1–19. doi: 10.1111/raq.12584

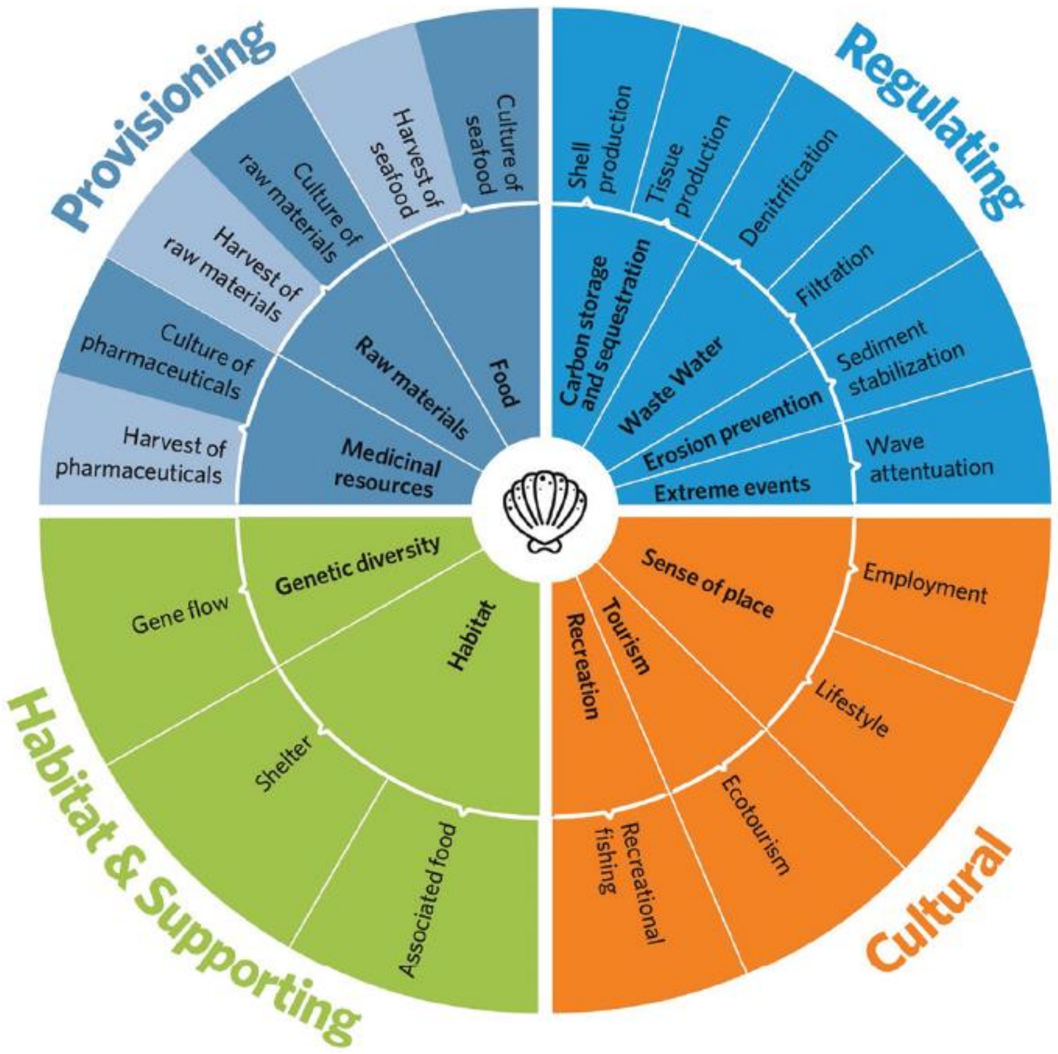
Costa-Pierce, B.A. and C.J. Bridger. **(2002).** The role of marine aquaculture facilities as habitats and ecosystems, p. 105-144. In: R. Stickney & J. McVey (Eds.) *Responsible Marine Aquaculture.* CABI Publishing Co., Wallingford, U.K.

“Nature supports humanity through the delivery of ecosystem services, such as the provision of food and raw materials, the maintenance of clean air and water, and the creation of spiritual and cultural connections that foster well-being.”

Alleway et al. 2019

Alleway, H., C. Gillies, M. Bishop, R. Gentry, S. Theuerkauf, and R. Jones. (2019). The ecosystem services of marine aquaculture: Valuing benefits to people and nature. *BioScience* 69:59-68. https://doi.org/10.1093/biosci/biy137

What are ecosystem services?



Source: Alleway et al. 2018

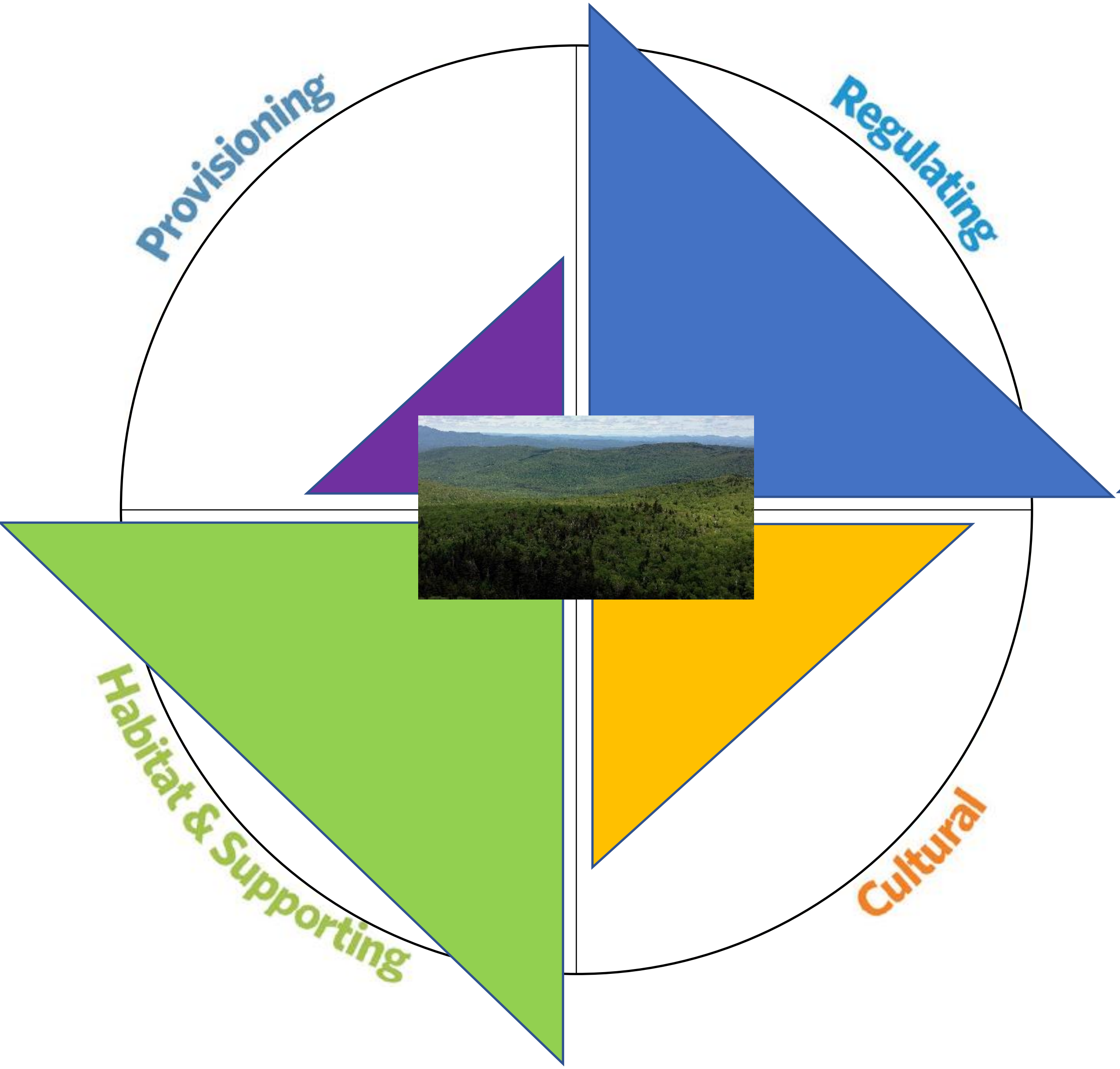
Provisioning Services are ecosystem services that describe the material or energy outputs from ecosystems. They include food, water and other resources.

Regulating Services are the services that ecosystems provide by acting as regulators eg. regulating the quality of air and soil or by providing flood and disease control.

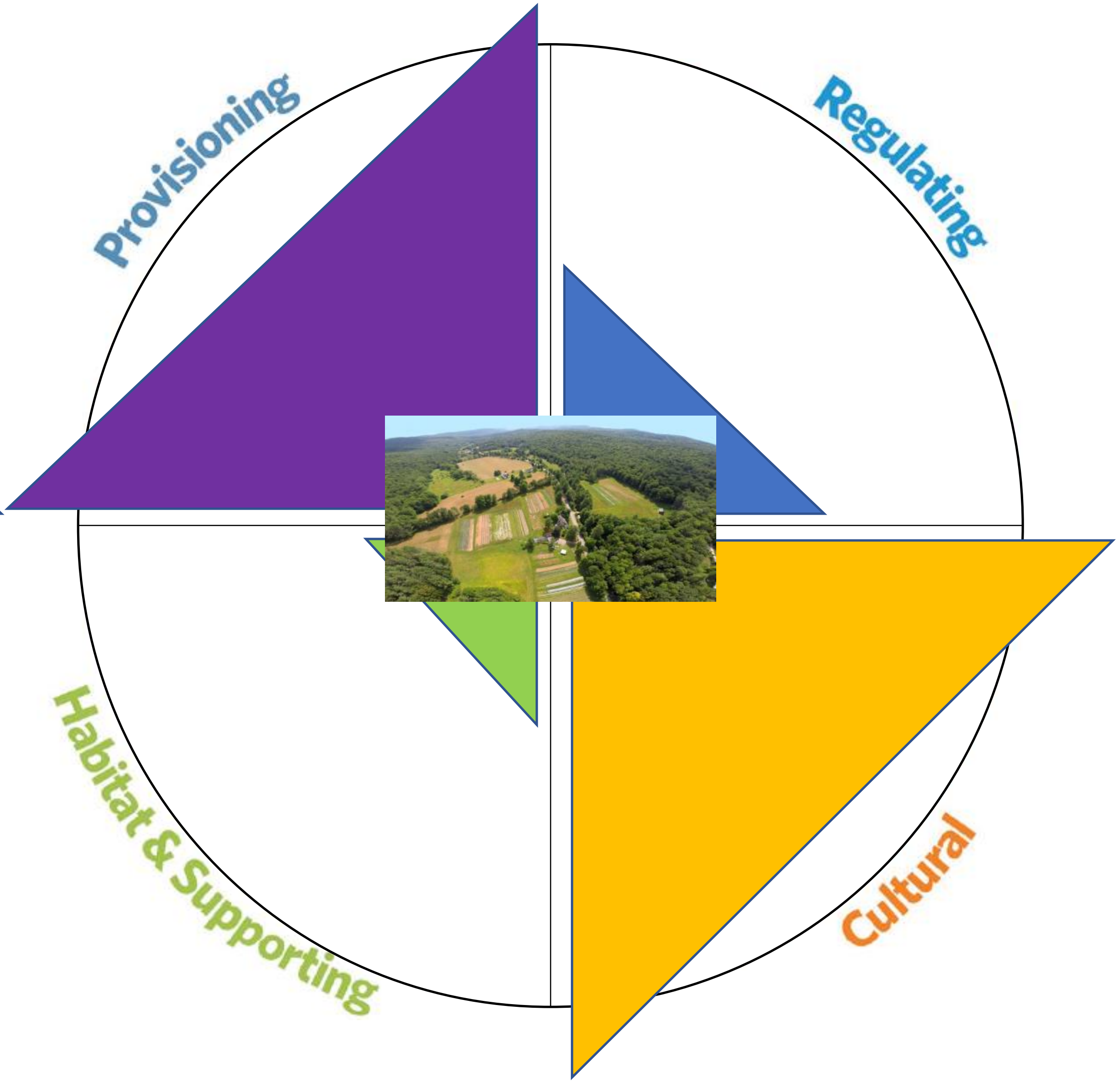
Habitat and Supporting Services allow the Earth to sustain basic life forms and whole ecosystems and people. Without supporting services, provisional, regulating, and cultural services cannot exist.

Cultural Services are a non-material benefits that contribute to the development and cultural advancement of people, including how ecosystems play a role in local, national, and global cultures; the building of knowledge and the spreading of ideas; creativity born from interactions with nature (music, art, architecture); and recreation.

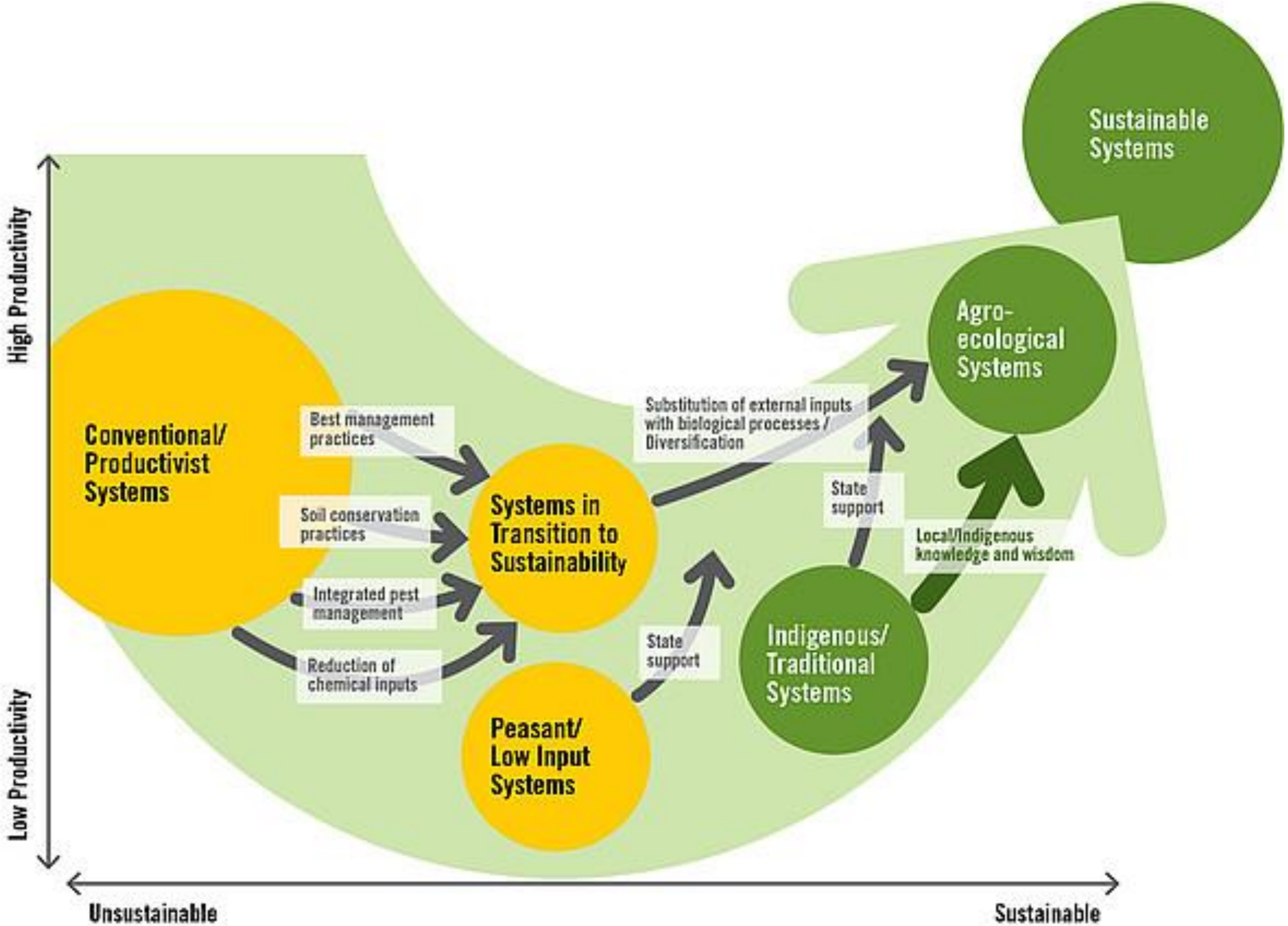
Natural Ecosystem



Managed Ecosystem



How does aquaculture contribute to ecosystem services?



Source: Latin America and the Caribbean, Summary for Decision Makers, p. 9

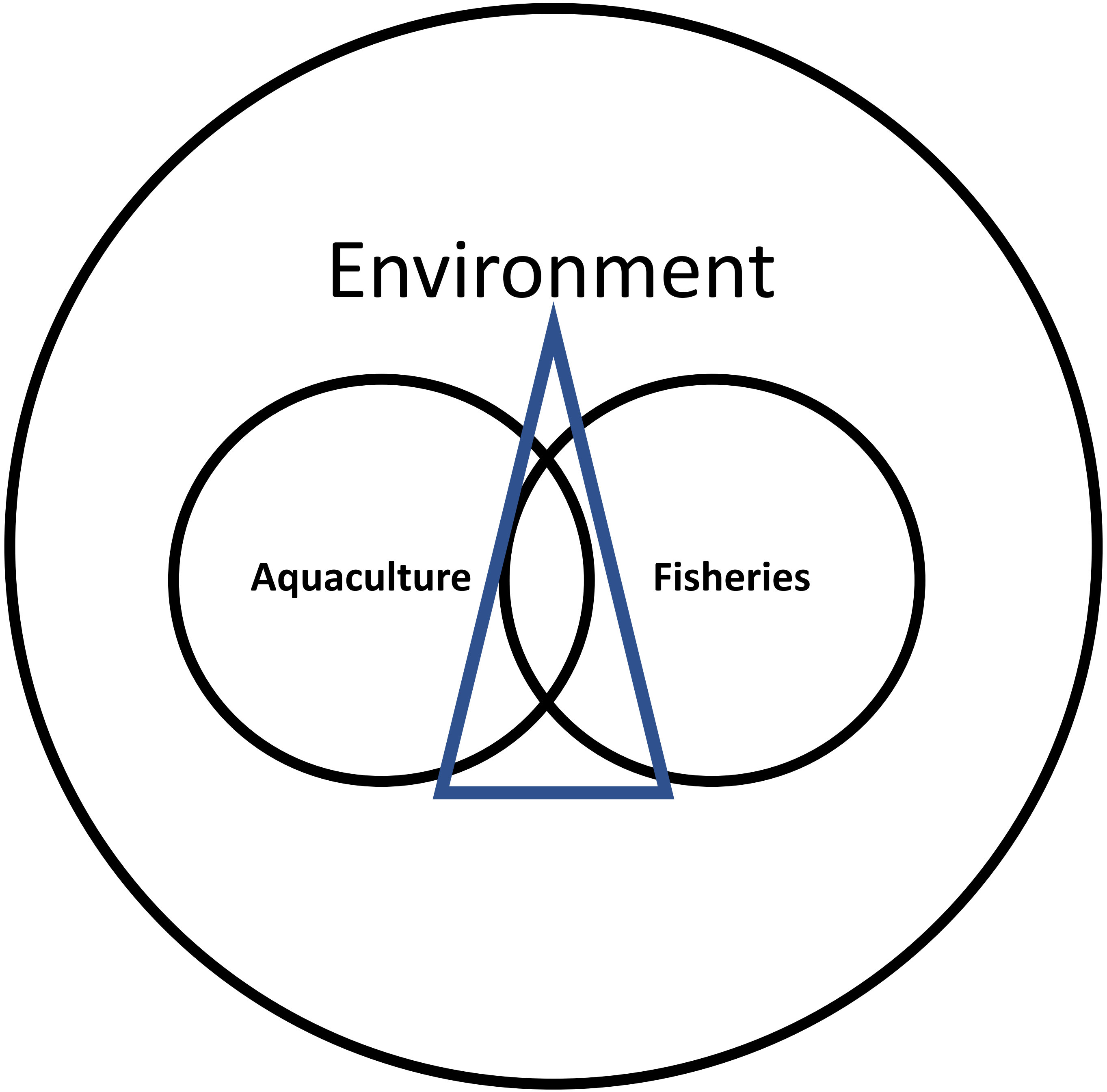
“Basal Ecosystem”
The ecosystem and associated functions

Prior to agricultural intervention

what was added, what was removed?

Agroecology: what was added, what was removed?

What about this? What was added? What was removed?


Environment
Aquaculture
Fisheries

Restoration Aquaculture

Costa-Pierce, B.A. and C.J. Bridger. 2002. The role of marine aquaculture facilities as habitats and ecosystems, p. 105-144. In: R. Stickney & J. McVey (Eds.) *Responsible Marine Aquaculture*. CABI Publishing Co., Wallingford, U.K.

USE THE <u>Aquaculture Toolbox</u>
to
Restore Marine Fisheries, Marine Ecosystems and Coastal Societies

Beyond old arguments, artificial divides and balkanization

The “aquaculture toolbox”

Conservation/Restoration Aquaculture

Marine Agronomy for Environmental Rehabilitation & Enhancement

- *Spartina* Aquaculture
- Mangrove Aquaculture
- Seagrass Aquaculture
- Live Rock Aquaculture

Coastal Wetland Habitats

Nearshore Habitats

Reef Habitats

Costa-Pierce, B.A. and C.J. Bridger. 2002. The role of marine aquaculture facilities as habitats and ecosystems, p. 105-144. In: R. Stickney & J. McVey (Eds.) Responsible Marine Aquaculture. *CABI Publishing Co., Wallingford, U.K.*

Marine Pollution Bulletin 95 (2015) 89–99

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Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

An effective seed protection method for planting *Zostera marina* (eelgrass) seeds: Implications for their large-scale restoration

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Zostera marina
Seed protection
Restoration
Seedling establishment
New patches
Seed density

ABSTRACT

We describe an innovative method of planting *Zostera marina* (eelgrass) seeds in which hessian bags filled with high-silted sediments are used as a seed protecting device. Here, we evaluated the effectiveness of the method through a field seed-sowing experiment over a three year period. The suitable seed planting density required by the seeds of *Z. marina* in this method was also investigated. In the spring following seed distribution, seedling establishment rate of *Z. marina* subjected to different seed densities of 200–500 seeds bag^{-1} ranged from 16% to 26%. New eelgrass patches from seed were fully developed and well maintained after 2–3 years following distribution. The seed planting density of 400 seeds bag^{-1} may be the most suitable for the establishment of new eelgrass patches. Our results demonstrate that seed-based restoration can be an effective restoration tool and the technique presented should be considered for future large-scale *Z. marina* restoration projects.

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MARINE POLICY
www.elsevier.com/locate/marpol

Farming the reef: is aquaculture a solution for reducing fishing pressure on coral reefs?

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Ecological engineering for successful management and restoration of mangrove forests

Roy R. Lewis III*

Lewis Environmental Services, Inc., P.O. Box 5430, Salt Springs, FL 32134, USA

Received 2 January 2004; received in revised form 22 September 2004; accepted 29 October 2004

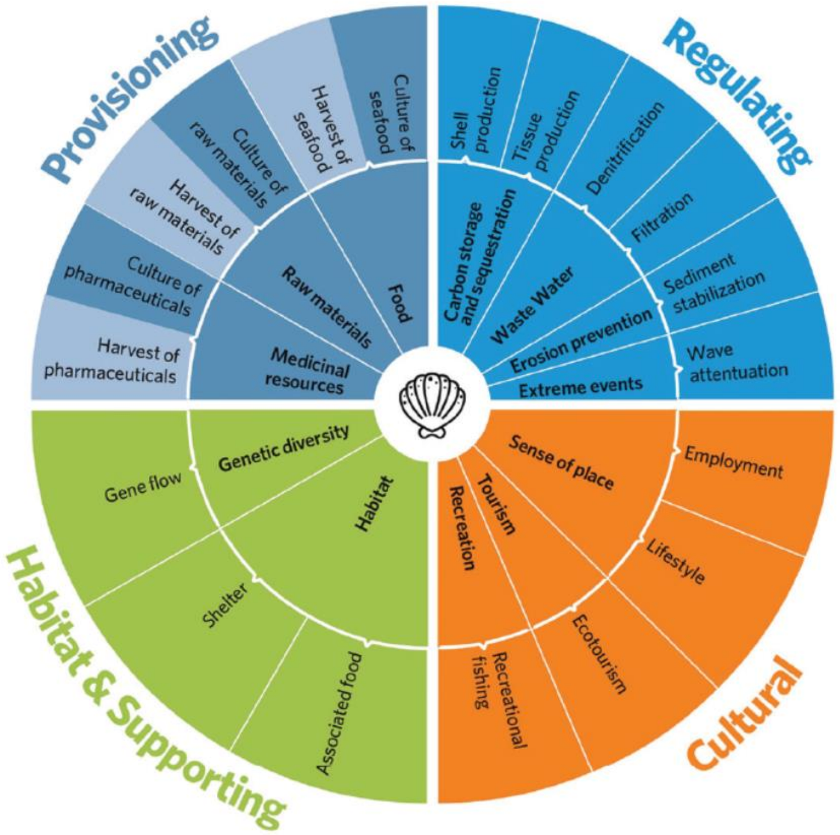
Abstract

Great potential exists to reverse the loss of mangrove forests worldwide through the application of basic principles of ecological restoration using ecological engineering approaches, including careful cost evaluations prior to design and construction. Previous documented attempts to restore mangroves, where successful, have largely concentrated on creation of plantations of mangroves consisting of just a few species, and targeted for harvesting as wood products, or temporarily used to collect eroded soil and raise intertidal areas to usable terrestrial agricultural uses. I document here the importance of assessing the existing hydrology of natural extant mangrove ecosystems, and applying this knowledge to first protect existing mangroves, and second to achieve successful and cost-effective ecological restoration, if needed. Previous research has documented the general principle that mangrove forests worldwide exist largely in a raised and sloped platform above mean sea level, and inundated at approximately 30%, or less of the time by tidal waters. More frequent flooding causes stress and death of these tree species. Prevention of such damage requires application of the same understanding of mangrove hydrology.

Keywords: Mangrove forests; Restoration of mangrove forests; Ecological restoration; Mangroves

The Nature Conservancy®

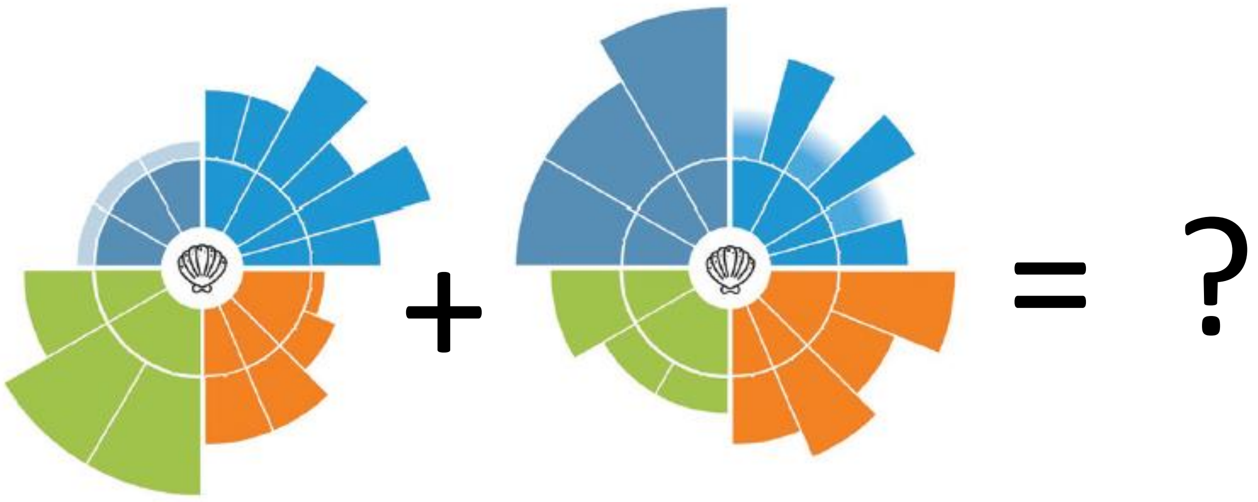
Saving the Last Great Places



Shellfish ecosysems

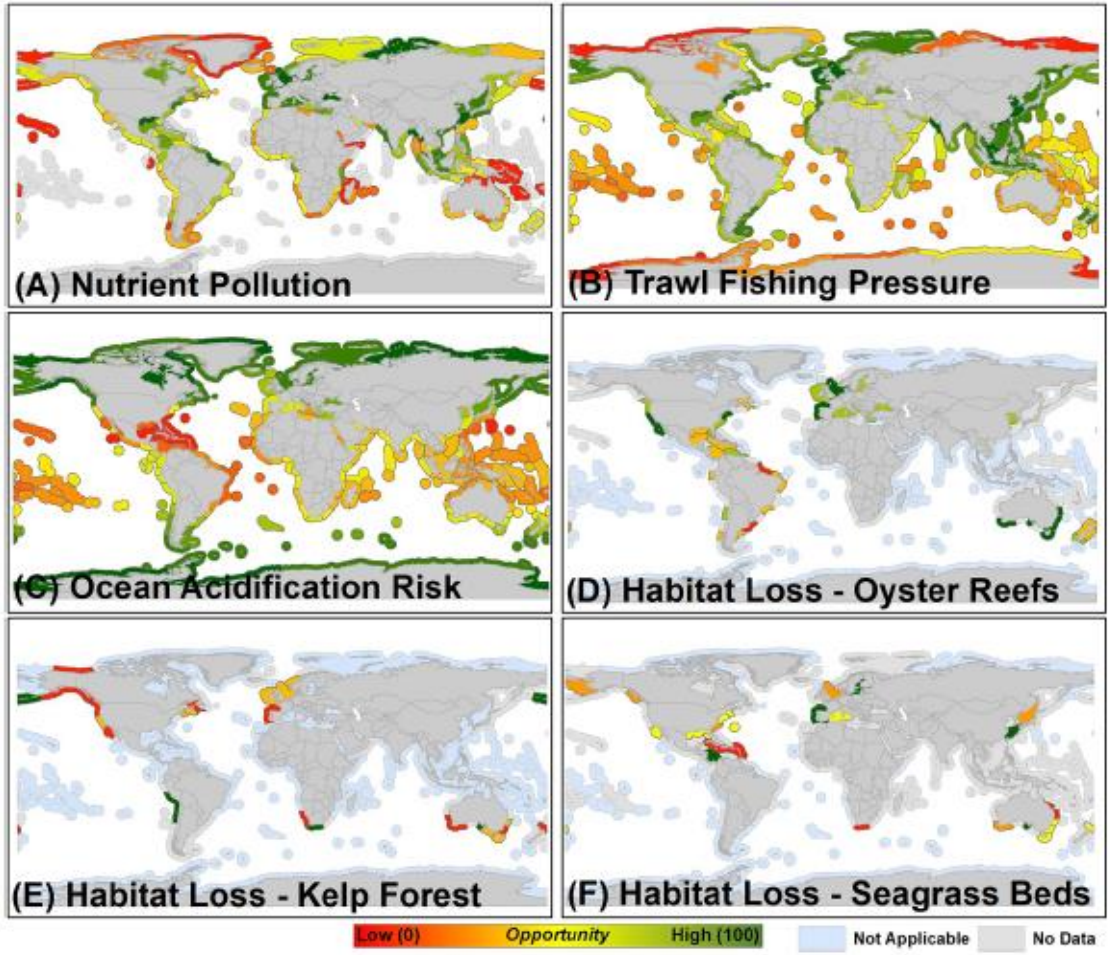
Shellfish mariculture

The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature
BioScience (2019), 69: 59–68,
https://doi.org/10.1093/biosci/biy137



Shellfish ecosysems

Shellfish mariculture



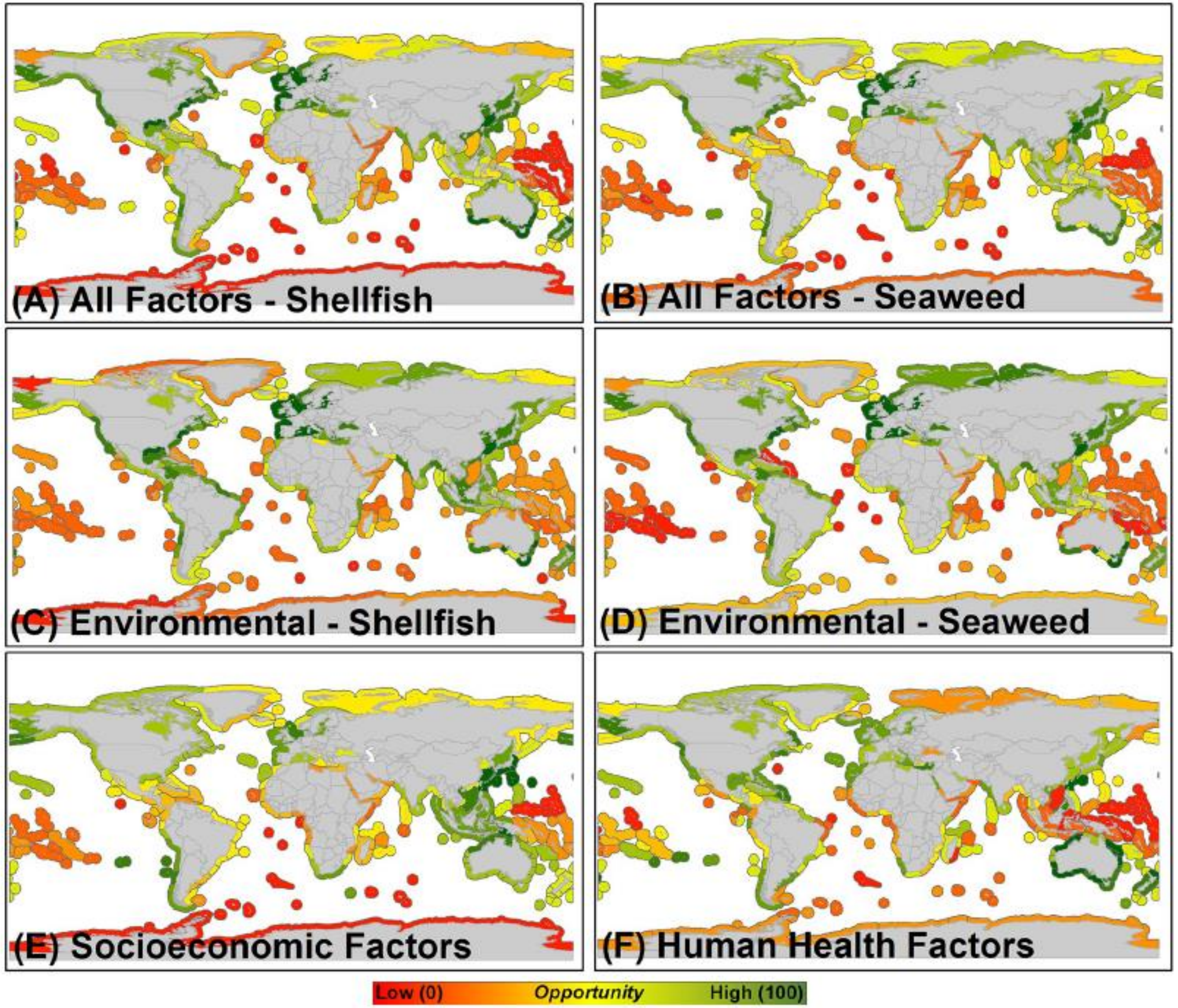
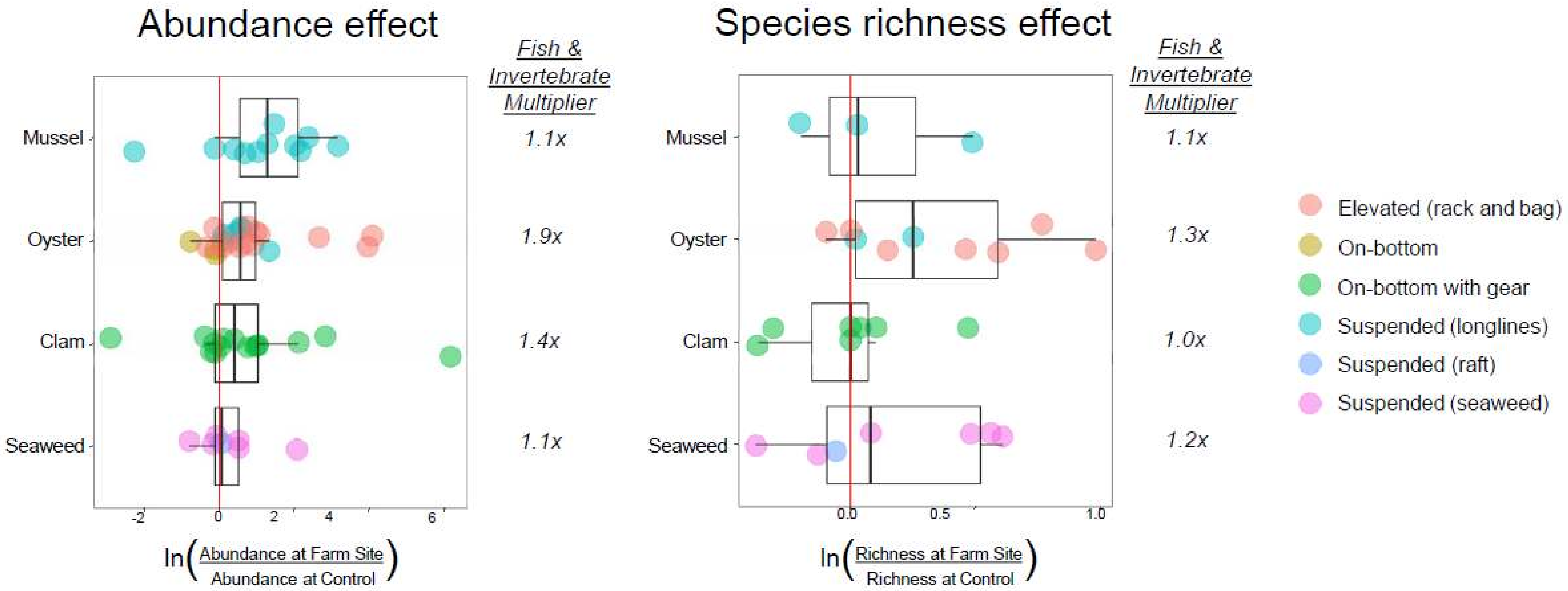


Fig 4. High (green) to low (red) opportunity marine ecoregions for development of (A) shellfish aquaculture and (B) seaweed aquaculture based on the synthesis of all environmental, socioeconomic, and human health factors (Table 1) according to their assigned weights (Table 2) within the restorative aquaculture opportunity index. High opportunity marine ecoregions based on the synthesis of all environmental factors only (C) and (D), socioeconomic factors only (E), and human health factors only (F) according to their assigned weights.

Thereukauf et al. 2019



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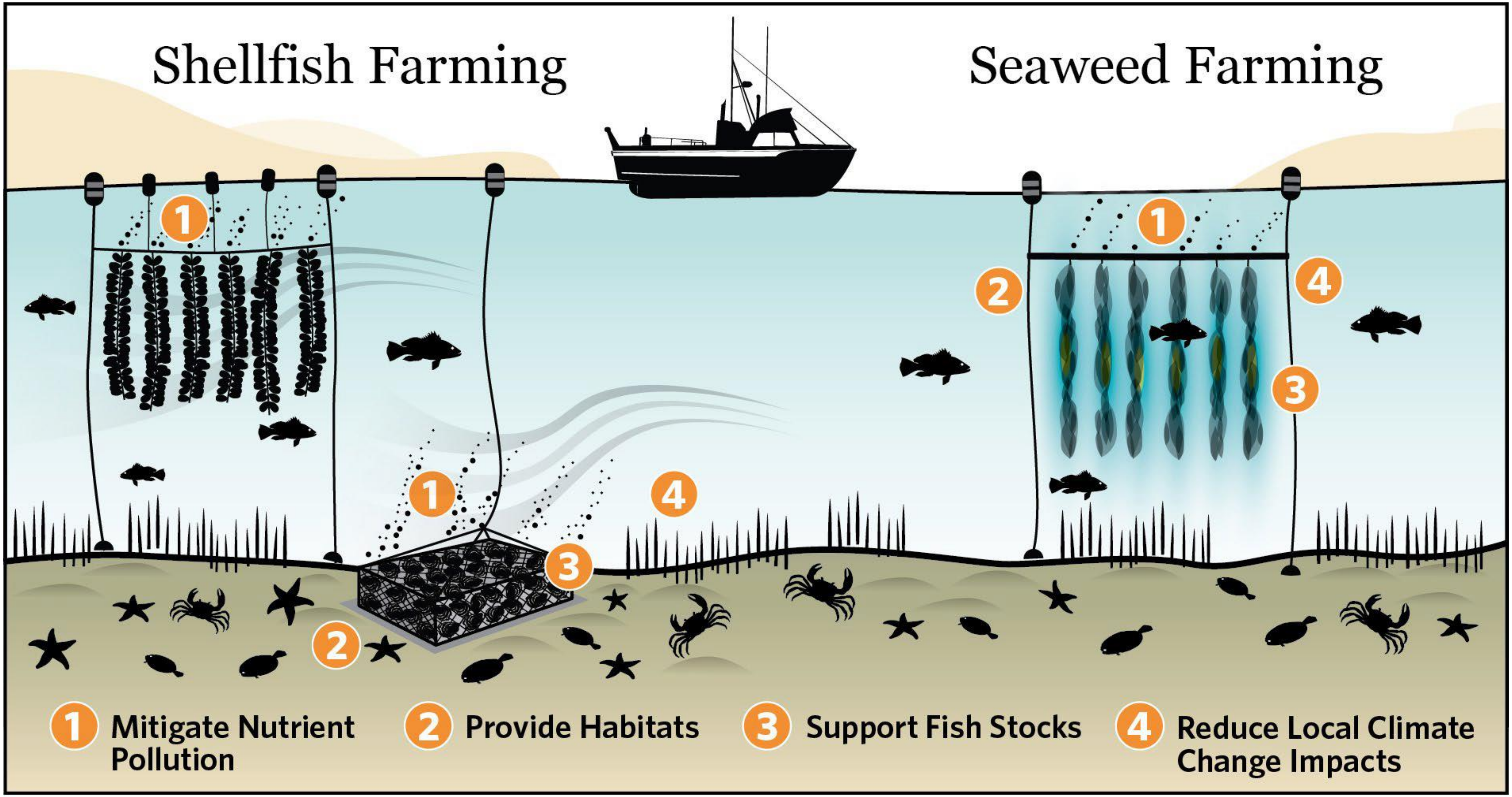
https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_PrinciplesofRestorativeAquaculture.pdf



Regulating Habitat/Supporting Provisioning/Supporting Regulating

Table 1. Examples of abiotic and biotic factors and processes, across successive ecosystem scales, that might influence the capacity of different types of mariculture to deliver ecosystem services.

	Local (farm) scale[a]	**Regional (landscape) scale[b]**	**Biogeographical scale[c]**
Abiotic factors	• Cultivation method, infrastructure and gear used, and farming inputs (e.g., feed, fertilizer) • Local hydrodynamics (e.g., current strength and direction, tidal movement, waves and exposure to wave energy) • Depth or elevation of cultivation • Benthic sediment type—sediment stability and nutrient absorption capacity • Water quality and chemistry parameters and ranges (e.g., pH; dissolved oxygen, nitrogen, phosphorus, and carbon dioxide; and turbidity) • Benthic habitat type (e.g., baskets, bags or rack oyster culture)	• Regional hydrodynamics • Water temperature and salinity ranges • Weather patterns (e.g., rainfall, prevailing wind direction) • Distance between and density of aquaculture operations • Distance from and discharge magnitude of nutrient and pollutant sources • Water quality and chemistry parameters and ranges (e.g., pH; dissolved oxygen, nitrogen, and phosphorus; turbidity) • Solar irradiance (particularly seaweeds)	• Nutrient status of ecosystem (e.g., oligotrophic, eutrophic) • Additional anthropogenic inputs (e.g., land-based runoff, estuarine or delta inputs) • Water temperature and salinity ranges • Weather patterns (e.g., rainfall, prevailing wind direction) • Vulnerability to climate-related disturbances, such as ocean acidification • Solar irradiance (particularly seaweeds)
Biotic factors	• Stocking density of species • Coculture and interaction with multiple species • Benthic habitat type • Benthic community structure and biodiversity • Pathogen dissemination pathways • Marine pest presence and dissemination pathways • Phytoplankton availability (bivalves)	• Prevalence of disease and parasites • Reproductive status of stock (nonreproductive or spawning potential) • Distance to natural habitats • Distance from critical or sensitive habitats, key biodiversity areas, or protected areas • Regional species pool of available colonists • Regional biodiversity and use of hard substrate	• Culture of endemic or naturalized species • Population status of existing wild harvest resources • Conservation status of existing coastal habitat and biodiversity

Note: Factors can occur at multiple scales but at each might generate a different strength of effect. [a]Less than 1 kilometer. [b]Between 2 and 20 kilometers. [c]More than 20 kilometers.

REVIEWS IN Aquaculture

Reviews in Aquaculture (2020) **12**, 3–25 doi: 10.1111/raq.12301

A global review of the ecosystem services provided by bivalve aquaculture

Andrew van der Schatte Olivier[1], Laurence Jones[2], Lewis Le Vay[1], Michael Christie[3], James Wilson[4] and Shelagh K. Malham[1]

1 School of Ocean Sciences, Bangor University, Menai Bridge, UK
2 Centre for Ecology and Hydrology, Bangor, UK
3 Aberystwyth Business School, Aberystwyth University, Aberystwyth, UK
4 Deepdock Ltd, Bangor, UK

Provisioning : $23.9 billion
Regulating: $1.2 billion
Total Non-Food Services: $3-10 billion

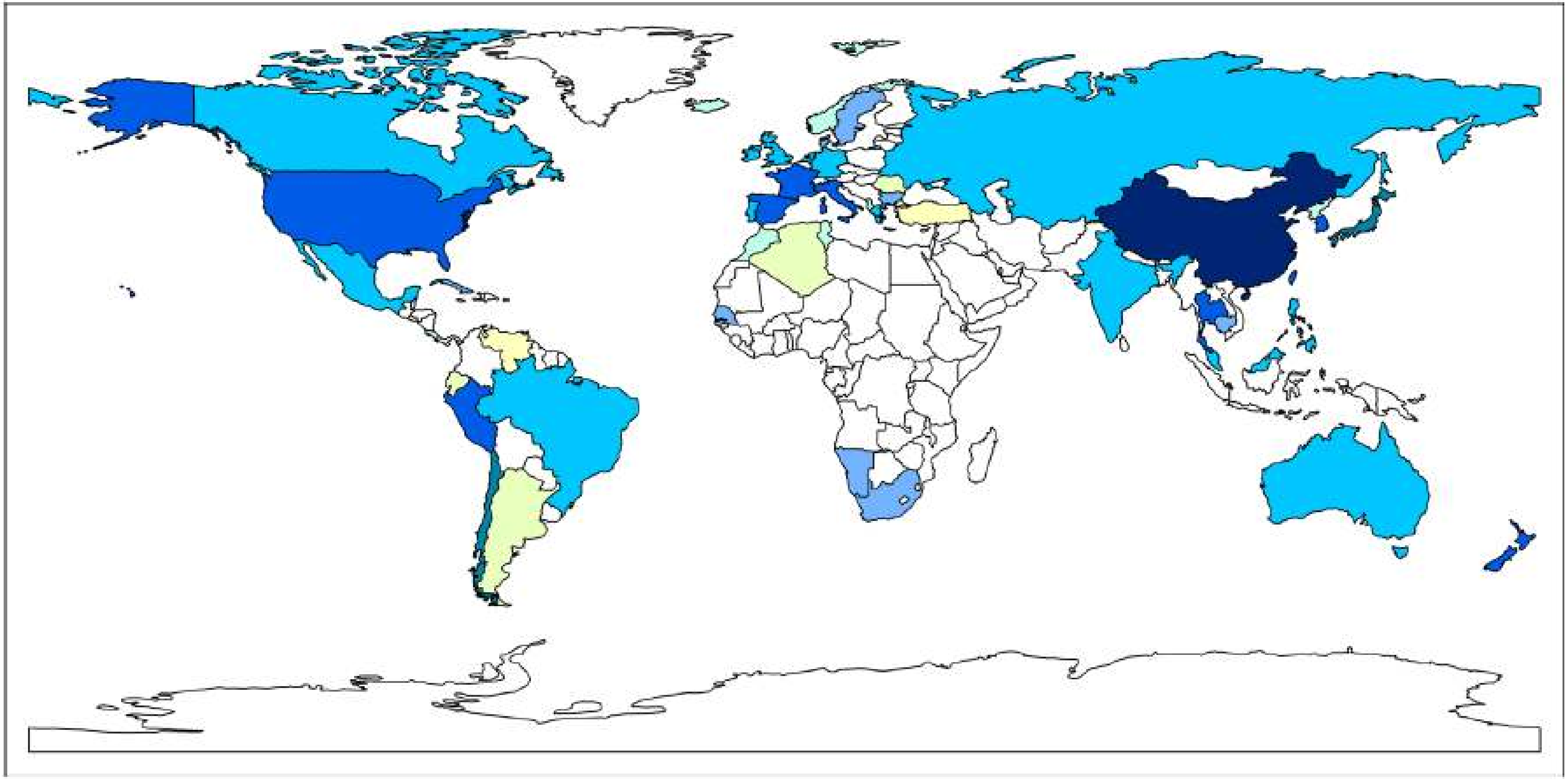


Figure 2 World map showing the potential combined value of carbon sequestration, nitrogen and phosphorus remediation and the use of oyster shells for aggregate ($). (☐) No FAO data; (☐) ≤ 10,000; (☐) 10,001 – 100,000; (☐) 100,001 – 1,000,000; (☐) 1,000,001 – 10,000,000; (☐) 10,000,001 – 100,000,000; (☐) 100,000,001 – 1,000,000,000; (☐) 1000,000,001 – 10,000,000,000; (☐) 10,000,000,001 – 25, 000,000,000.

Conservation Biology

Contributed Paper

Aquaculture and the displacement of fisheries captures

Stefano B. Longo,[1,5] Brett Clark,[2] Richard York,[3] and Andrew K. Jorgenson[4]

"In modern aquaculture, animal-production technology is used to increase aquatic food sources. Such controlled rearing of seafood can, in principle, shift the pressure off wild stocks and aquatic ecosystems by reducing fishing activities, which may advance marine conservation goals…

We estimated 9 models to assess whether aquaculture production suppresses captures once other factors related to demand have been controlled for. Only 1 model predicted significant suppression of fisheries captures associated with aquaculture systems within nations over time.

These results suggest that global aquaculture production does not substantially displace fisheries capture; instead, aquaculture production largely supplements fisheries capture."


Aquaculture farms as nature-based coastal protection: Random wave attenuation by suspended and submerged canopies

Longhuan Zhu [a,*], Kimberly Huguenard [a], Qing-Ping Zou [b], David W. Fredriksson [c], Dongmei Xie [d]

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[b] *The Lyell Centre for Earth and Marine Science and Technology, Institute for Infrastructure and Environment, Heriot-Watt University, Edinburgh, UK*

[c] *Department of Naval Architecture and Ocean Engineering, U.S. Naval Academy, Annapolis, MD, 21402, USA*

[d] *College of Harbour, Coastal and Offshore Engineering, Hohai University, Nanjing, 210098, China*

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Green gravel as a vector of dispersal for kelp restoration

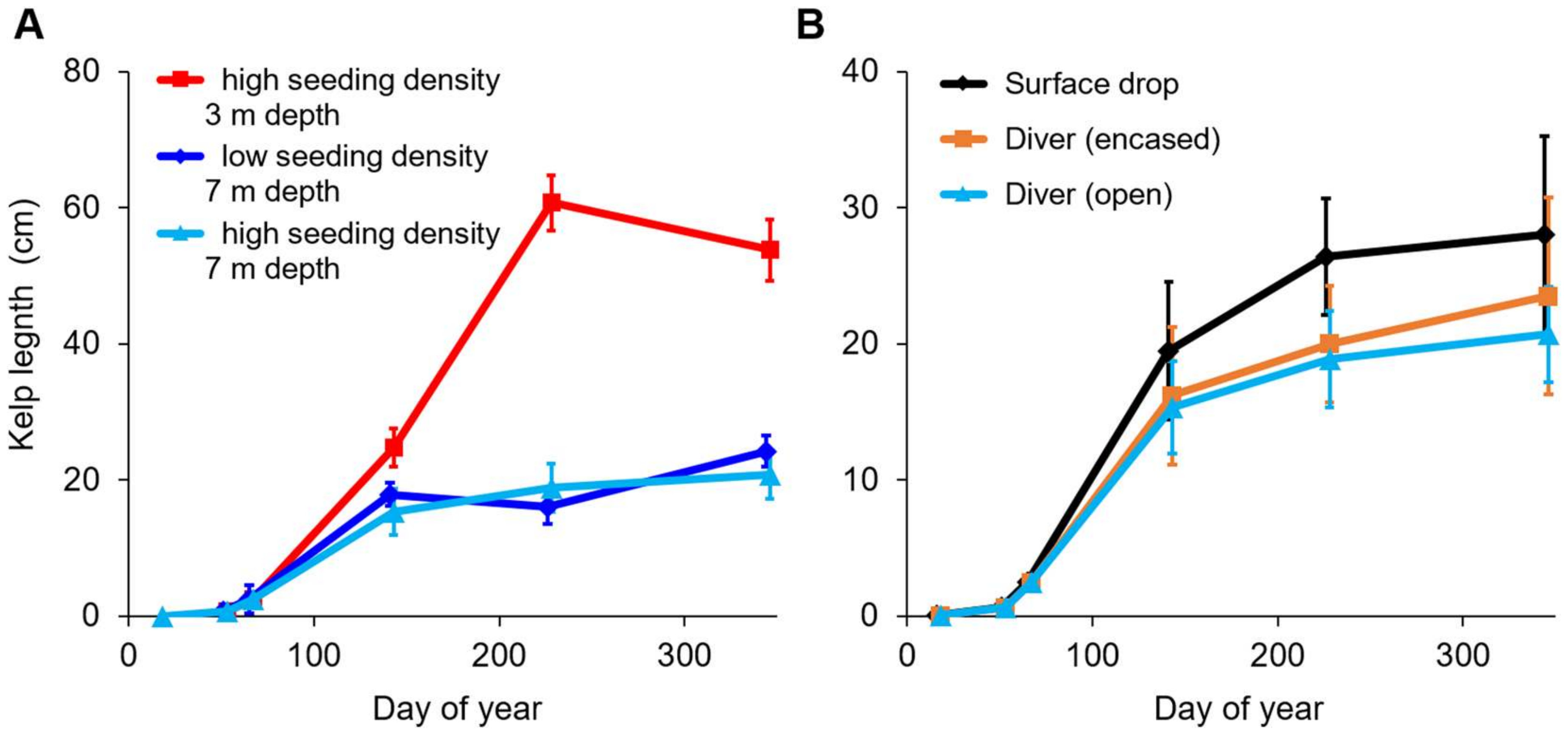
Nahlah A. Alsuwaiyan[1,2*], Karen Filbee-Dexter[1,3], Sofie Vranken[1], Celina Burkholz[1], Marion Cambridge[1], Melinda A. Coleman[1,4,5] and Thomas Wernberg[1,3,6*]

[1]University of Western Australia (UWA) Oceans Institute and School of Biological Sciences, University of Western Australia, Crawley, Crawley, WA, Australia, [2]Department of Biology, Unaizah College of Sciences and Arts, Qassim University, Unaizah, Saudi Arabia, [3]Institute of Marine Research, His, Norway, [4]National Marine Science Centre, Southern Cross University, Coffs Harbour, NSW, Australia, [5]Department of Primary Industries, National Marine Science Centre, Coffs Harbour, NSW, Australia, [6]Department of Science and Environment, Roskilde University, Roskilde, Denmark

SCIENTIFIC REPORTS
natureresearch

Green gravel: a novel restoration tool to combat kelp forest decline

Stein Fredriksen[1,2*], Karen Filbee-Dexter[1,3], Kjell Magnus Norderhaug[1], Henning Steen[1], Torjan Bodvin[1,5], Melinda A. Coleman[4], Frithjof Moy[1] & Thomas Wernberg[3*]


A
B
Kelp legnth (cm)
0
20
40
60
80
high seeding density
3 m depth
low seeding density
7 m depth
high seeding density
7 m depth
0
100
200
300
Day of year
0
10
20
30
40
Surface drop
Diver (encased)
Diver (open)
0
100
200
300
Day of year

Fish?

Restoration

mangroves
eelgrasses
corals
Seaweeds
sea cucumbers

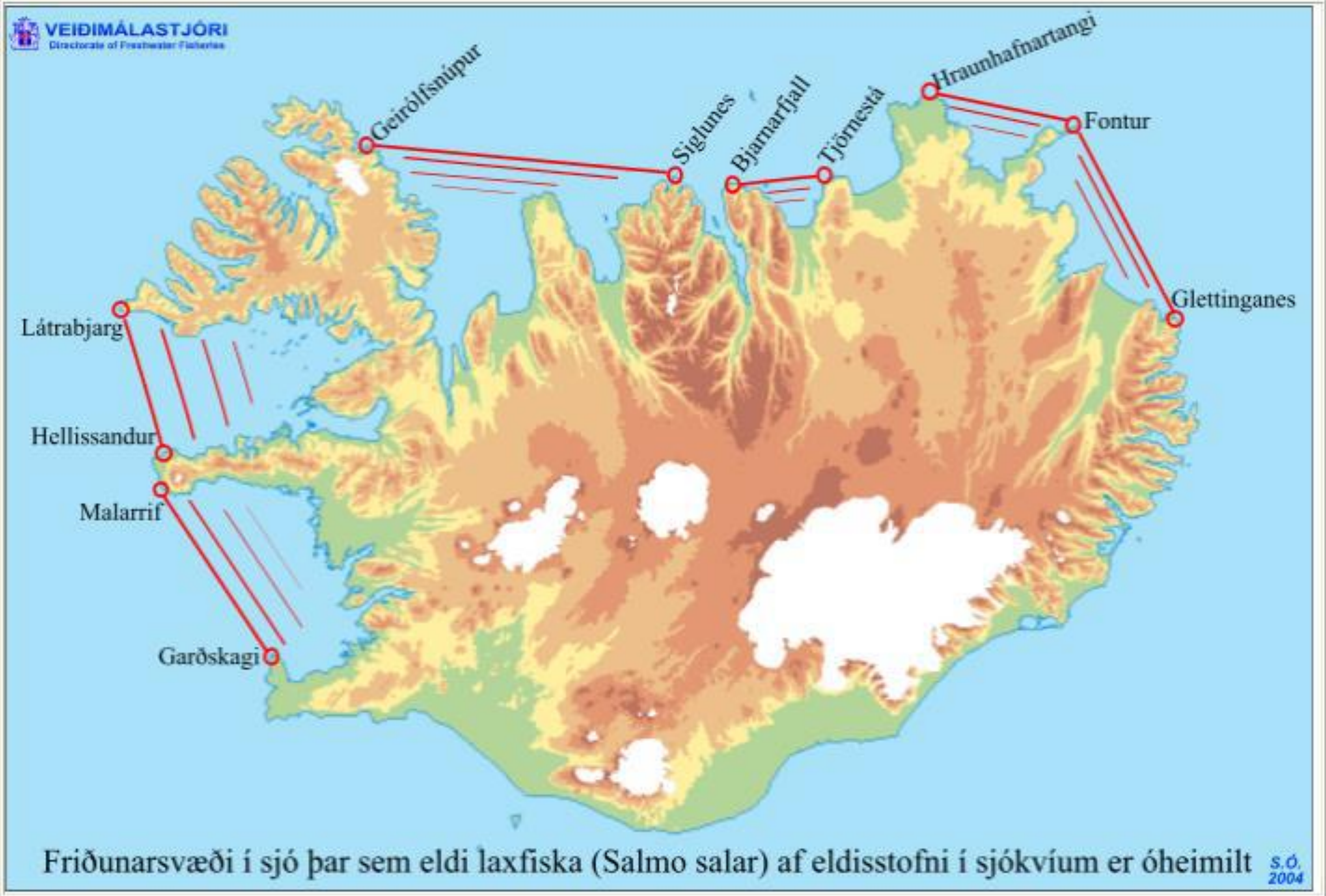
Most
LTL species?

WHY HAVE ATLANTIC SALMON NOT RECOVERED?

Pollution, damming, overfishing, climate change?? Hatchery effect?? Not enough fish!!!???!!

Corey Clarke
Fundy National Park

Fundy Salmon Recovery's Wild Salmon Marine Conservation Farm, Dark Harbour, N.B.


VEIÐIMÁLASTJÓRI
Directorate of Freshwater Fisheries
Geirólfsnúpur
Siglunes
Bjarnarfjall
Tjörnestá
Hraunhafnartangi
Fontur
Glettinganes
Látrabjarg
Hellissandur
Malarrif
Garðskagi
Friðunarsvæði í sjó þar sem eldi laxfiska (Salmo salar) af eldisstofni í sjókvíum er óheimilt
S.Ó.
2004

COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

long-lived, ~40-50 y old, therefore it takes a long time for populations to respond to recovery actions. This program has been in place since 1988.

- studying and monitoring the endangered fish,
- managing habitat and river flows,
- *stocking* the endangered fish and
- managing non-native fish which outcompete the native endangered species.

Muchas gracias

Thank you

Mahalo nui loa

Tusen takk

Tack så mycket

Shukran jazilan

Muito obrigado