STATE OF HAWAIʻI
GREENHOUSE GAS SEQUESTRATION TASK FORCE
Honolulu, Hawaiʻi

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Aquaculture and Marine Use Permitted Interaction Group Report

Prepared by: GHGSTF Member David Forman (University of Hawaiʻi at Mānoa William S. Richardson School of Law), GHGSTF Member Christian Giardina (State of Hawaiʻi Department of Land and Natural Resources), GHGSTF Member Ashley Lukens (Frost Family Foundation), GHGSTF Member Justine Nihipali (State of Hawaiʻi Climate Change Mitigation and Adaptation Commission), and Technical Expert Todd Low (State of Hawaiʻi Aquaculture Development Program)

Report Overview

Problem Statement: Natural and working lands, riparian areas and freshwater resources, and nearshore and marine environments are the focus of meeting Hawaiʻi's food security and self-sufficiency needs. This has been the result of both increasing populations, a growth in the tourism sector, and growing desire to source more food from Hawaiʻi. Impacts from these local food production investments can include reductions in biodiversity and ecosystem health, increases to local GHG emissions, and reductions in sequestration. These run counter to the State of Hawaiʻi legislated goal of becoming carbon net negative by 2045.

Intention of the DRAFT report: This draft report is intended to provide an overview of and preliminary guidance on the role of local aquaculture/mariculture efforts in meeting Hawaiʻi state GHG sequestration goals. Specifically, this Permitted Interaction Group focused on synthesizing and where possible recommending for further study:

- Sequestration benchmarks for aquacultural activities and the marine environment
- Criteria to measure baselines and increases in sequestration and aquacultural product yield from sequestration
- Recommendations to increase climate resiliency
- Recommended aquacultural practices, marine use policies, and mitigation options to sequester GHGs and provide economic benefits to aquacultural operations
- Recommended financial incentives and funding mechanisms to encourage greenhouse gas sequestration for the aquacultural and marine sectors and marine environment in Hawaiʻi

Needs Identified: In organizing this draft report, we have identified the following core needs: 1) comprehensively highlighting the scope of aquaculture and marine management in Hawaiʻi; 2) identify well established problems associated with management of ocean resources from a diversity of sources; 3) identify promising opportunities for growing a sustainable and low impact aquaculture sector while advancing GHG emission reduction and mitigation goals; 4) recommend a process for prioritizing GHG focused aquaculture research needs in Hawaiʻi; and 5) identify relevant statutes that intersect with aquaculture / mariculture efforts, and anticipate conflicts.

Approach of the Report: This report relies on several core publications and reports the PIG used to inform this draft report, as well as member expertise. Members of the PIG engaged this literature and identified core findings as well as a GHG accounting framework for considering benefits and negative impacts of aquaculture/mariculture on GHG emissions, while considering biodiversity and ecosystem health impacts.

Outcomes for Aquaculture/Mariculture of Relevance to the GHG Sequestration Task Force: The desired outcomes of this draft report include increased base level understanding among Task Force members regarding current and potential future contributions of the aquaculture / mariculture sector to GHG emissions and mitigation in Hawaiʻi. The report also seeks to highlight GHG impacts not strictly from the perspective of the Hawaiʻi GHG inventory, but also those associated with the production of commodities in the imported food system.

Definitions

Artificial upwelling and downwelling: A process whereby water from depths that are generally cooler and more nutrient and carbon dioxide rich than surface waters is pumped into the surface ocean. Artificial upwelling has been suggested to generate increased localized primary production and ultimately export production and net CO_2 removal. Artificial downwelling is the downward transport of surface water; this activity has been suggested as a mechanism to counteract eutrophication and hypoxia in coastal regions by increasing ventilation below the pycnocline and to carry carbon into the deep ocean.

Blue carbon: Carbon stored or sequestered by ocean and coastal ecosystems such as mangroves, sea grasses, and salt marshes.

Carbon dioxide removal (CDR): Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage but excludes natural CO_2 uptake not directly caused by human activities.

Electrochemical approaches: Removal of CO_2 or enhancement of the storage capacity of CO_2 in seawater (e.g., in the form of ions, or mineral carbonates) by enhancing its acidity, or alkalinity, respectively. These approaches exploit the pH-dependent solubility of CO_2 by passage of an electric current through water, which by inducing water splitting ("electrolysis"), changes its pH in a confined reaction environment. As one example, ocean alkalinity enhancement may be accomplished by electrochemical approaches.

Nutrient fertilization: Addition of micronutrients (e.g., iron) and/or macronutrients (e.g., phosphorus or nitrogen) to the surface ocean may in some settings increase photosynthesis by marine phytoplankton and can thus enhance uptake of CO_2 and transfer of organic carbon to the deep sea where it can be sequestered for timescales of a century or longer. As such, nutrient fertilization essentially locally enhances the natural ocean biological carbon pump using energy from the sun, and in the case of iron, relatively small amounts are needed.

Ocean alkalinity enhancement: Chemical alteration of seawater chemistry via addition of alkalinity through various mechanisms including enhanced mineral weathering and electrochemical or thermal reactions releasing alkalinity to the ocean, with the aim of removing CO_2 from the atmosphere.

Recovery of ocean and coastal ecosystems: Carbon dioxide removal and sequestration through protection and restoration of coastal ecosystems, such as kelp forests and free-floating *Sargassum*, and the recovery of fishes, whales, and other animals in the oceans.

Restorative aquaculture: Occurs when commercial or subsistence aquaculture provides direct ecological benefits to the environment, with the potential to generate net-positive environmental outcomes.

Seaweed cultivation: The process of producing macrophyte organic carbon biomass via photosynthesis and transporting that carbon into a carbon reservoir removes CO_2 from the upper ocean. Large-scale farming of macrophytes (seaweed) can act as a CDR approach by transporting organic carbon to the deep sea or into sediments.

Challenges to Ocean Carbon Dioxide Removal (CDR)

Based on: the National Academies of Sciences, Engineering, and Medicine 2021. A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration. Washington, DC: The National Academies Press. *https://doi.org/10.17226/26278.*

The below list was identified in the report as common challenges of ocean CDR:

Knowledge: The knowledge base is inadequate, based in many cases only on laboratory-scale experiments, conceptual theory and/or numerical models and needs to be expanded to better understand risks and benefits to responsibly scale up any of the ocean-based CDR approaches.

Governance: Social and regulatory acceptability is likely to be a barrier to many ocean CDR approaches, particularly ones requiring industrial infrastructure. There will be both project-specific and approach specific social, political, and regulatory discussions, as well as contestation around the role of CDR broadly. Field-scale trials are likely to be a site of wider societal debate around decarbonization and climate response strategies.

Unknown environmental and social impacts: All ocean-based CDR approaches will modify the marine environment in some way, with both intended and unintended impacts. However, the knowledge base is weak on the unintended impacts and the consequences of both intended and unintended CDR impacts on marine ecosystems and coastal human communities.

Monitoring and verification: Monitoring and verification activities are essential to quantify the efficacy and the durability of carbon storage of ocean-based CDR approaches and to identify environmental and social impacts. Potential synergies may exist with other ocean and environmental or climate observing systems. Substantial challenges remain, however, particularly for observing impacts on marine organisms and the resulting implications for marine ecosystems as well as documenting regional- to global-scale impacts on ocean carbon storage.

Cost: Accurate estimation of the cost of a CO_2 removal approach at low technological readiness is challenging, and costs presented come with considerable uncertainty. It is typical for early-stage assessments to underestimate costs, and for that reason some recommend the inclusion of capital cost contingencies over 100 percent (effectively doubling the calculated capital cost). Cost discovery will be an important feature of a research strategy that aims to investigate approaches through increasing technology readiness.

Options for Ocean CDR for Hawai‘i

Based on: The National Academies of Sciences, Engineering, and Medicine 2021. A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration. Washington, DC: The National Academies Press. *https://doi.org/10.17226/26278; and AR Jones, HK Alleway, D McAfee, P Reis-Santos, SJ Theuerkauf, & RC Jones 2022. Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture.* BioScience, 72*(2), 123–143. https://doi.org/10.1093/biosci/biab126*.

The *Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration* report was the result of a project to conduct a study exclusively focused on carbon dioxide removal (CDR) and sequestration conducted in coastal and open ocean waters to identify the most urgent unanswered scientific and technical questions, as well as questions surrounding governance, needed to: (i) assess the benefits, risks, and potential scale for carbon dioxide removal and sequestration approaches; and (ii) increase the viability of responsible carbon dioxide removal and sequestration.

The carbon dioxide removal approaches that were examined include:

- ***Seaweed cultivation***
- ***Recovery of ocean and coastal ecosystems, including large marine organisms***
- Iron, nitrogen, or phosphorus fertilization
- Artificial upwelling and downwelling
- Ocean alkalinity enhancement
- Electrochemical approaches

This PIG found that this report dovetailed with its need to identify viable options for ocean CDR so it could fulfill the stated tasks of establishing short-term and long-term benchmarks that would indicate how effectively ocean and aquacultural activities have been helping the State to reach greenhouse gas neutrality, and what appropriate criteria that may be used in a certification program to measure baseline levels and increases in carbon sequestration, improvements in water quality, and other key indicators of greenhouse gas benefits from beneficial ocean and aquacultural practices.

For discussion, this PIG will focus on seaweed cultivation, which Jones et al. (2022) highlight as the lowest emissions mariculture practice they reviewed, and the recovery of ocean and coastal ecosystems. Both approaches have long histories in Hawaiʻi and are currently active. While not specific to Hawaiʻi, below are tables from the report which summarizes the potential for scale-up for both approaches.

Summary Ocean Carbon Dioxide Removal (CDR) Scale-Up Potential		
Category	**Seaweed Cultivation**	**Ecosystem Recovery**
Knowledge Base What is known about the system (low, mostly theoretical, few in situ experiments; medium, lab and some fieldwork, few CDR publications; high, multiple in situ studies, growing body of literature)	**Medium–High** Science of macrophyte biology and ecology is mature; many mariculture facilities are in place globally. Less is known about the fate of macrophyte organic carbon and methods for transport to deep ocean or sediments.	**Low–Medium** There is abundant evidence that marine ecosystems can uptake large amounts of carbon and that anthropogenic impacts are widespread but quantifying the collective impact of these changes and the CDR benefits of reversing them is complex and difficult.
Efficacy What is the confidence level that this approach will remove atmospheric CO_2 and lead to net increase in ocean carbon storage (low, medium, high)	**Medium** The growth and sequestration of seaweed crops should lead to net CDR. Uncertainties about how much existing net primary production (NPP) and carbon export downstream would be reduced due to large-scale farming.	**Low-Medium** Given the diversity of approaches and ecosystems, CDR efficacy is likely to vary considerably. Kelp forest restoration,[1] marine protected areas, fisheries management, and restoring marine vertebrate carbon are promising tools.
Durability Will it remove CO_2 durably away from surface ocean and atmosphere (low, <10 years; medium, >10 years and <100 years; high, >100 years) and what is the confidence (low, medium, high)	**Medium–High** >10–100 years Dependent on whether the sequestered biomass is conveyed to appropriate sites (e.g., deep ocean with slow return time of waters to surface ocean).	**Medium** 10–100 years The durability of ecosystem recovery ranges from biomass in macroalgae to deep-sea whale falls expected to last >100 years.
Scalability Potential scalability at some future date with global-scale implementation (low, <0.1 Gt CO_2/yr; medium, >0.1 Gt CO_2/yr and <1.0 Gt CO_2/yr; high, >1.0 Gt CO_2/yr), and what is the confidence level (low, medium, high)	**Medium** Potential C removal >0.1 Gt CO_2/yr and <1.0 Gt CO_2/yr. (medium confidence) Farms need to be many million hectares, which creates many logistic and cost issues. Uncertainties about nutrient availability and durability of sequestration, seasonality will limit sites, etc.	**Low–Medium** Potential C removal <0.1–1.0 Gt CO_2/yr. (low–medium confidence) Given the widespread degradation of much of the coastal ocean, there are plenty of opportunities to restore ecosystems and depleted species. However, ecosystems and trophic interactions are complex and changing and research will be necessary to explore upper limits.

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[1] Not applicable in Hawaiʻi.

Environmental Risk Intended and unintended undesirable consequences at scale (unknown, low, medium, high) and what is the confidence level (low, medium, high)	**Medium–High** (low confidence) Environmental impacts are potentially detrimental especially on local scales where seaweeds are farmed (i.e., nutrient removal due to farming will reduce NPP, carbon export, and trophic transfers) and in the deep ocean where the biomass is sequestered (leading to increases in acidification, hypoxia, eutrophication, and organic carbon inputs). The scale and nature of these impacts are highly uncertain.	**Low** (medium–high confidence) Environmental impacts would be generally viewed as positive. Restoration efforts are intended to provide measurable benefits to biodiversity across a diversity of marine ecosystems and taxa.[2]
Social Considerations Encompass use conflicts, governance readiness, opportunities for livelihoods, etc.	Possibility for jobs and livelihoods in seaweed cultivation; potential conflicts with other marine uses. Downstream effects from displaced nutrients will need to be considered.	Trade-offs in marine uses to enhance ecosystem protection and recovery. Social and governance challenges may be less significant than with other approaches.
Co-benefits How significant are the co-benefits as compared to the main goal of CDR and how confident is that assessment	**Medium–High** (medium confidence) Placing cultivation facilities near fish or shellfish aquaculture facilities could help alleviate environmental damages from these activities. Biofuels also possible.	**High** (medium–high confidence) Enhanced biodiversity conservation and the restoration of many ecological functions and ecosystem services damaged by human activities. Existence, spiritual, and other nonuse values. Potential to enhance marine stewardship and tourism.
Cost of Scale-up Estimated costs in dollars per metric ton CO_2 for future deployment at scale; does not include all of monitoring and verification costs needed for smaller deployments during R&D phases Low, <\$50/t CO_2; medium, ~\$100/t CO_2; high, >>\$150/t CO_2	**Medium** ~\$100/t CO_2 (medium confidence) Costs should be less than \$100/t CO_2. No direct energy used to fix CO_2.	**Low** <\$50/t CO_2 (medium confidence) Varies but direct costs would largely be for management and opportunity costs for restricting uses of marine species and the environment. No direct energy used.

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[2] The sequestration value of ecosystem restoration needs to be examined case-by-case given the large number of novel ecosystems assembled in Hawaiʻi's coastal zones. For example, in other geographies where mangrove is native, ecosystem restoration can lead to carbon sequestration. However, in Hawaiʻi, restoration can mean removing high-biomass non-native vegetation (such as mangroves) and replacing it with low-biomass native vegetation, which could result in decreased sequestration capacity.

and confidence in estimate (low, medium, high) Materials costs for pump assembly could be moderate for large-scale persistent deployments. Estimates for a kilometer-scale deployment are in the tens of million dollars.		
Cost and challenges of carbon accounting Relative cost and scientific challenge associated with transparent and quantifiable carbon tracking (low, medium, high)	**Low–Medium** The amount of harvested and sequestered carbon will be known. However, an accounting of the carbon cycle impacts of the displaced nutrients will be required (additionality).	**High** Monitoring net effect on carbon sequestration is challenging.
Cost of environmental monitoring Need to track impacts beyond carbon cycle on marine ecosystems (low, medium, high)	**Medium** (medium–high confidence) All CDR will require monitoring for intended and unintended consequences both locally and downstream of CDR site, and these monitoring costs may be substantial fraction of overall costs during R&D and demonstration-scale field projects. This cost of monitoring for ecosystem recovery may be lower.	
Additional resources needed Relative low, medium, high to primary costs of scale-up	**Medium** Farms will require large amounts of ocean (many million hectares) to achieve CDR at scale.	**Low** Most recovery efforts will likely require few materials and little energy, though enforcement could be an issue. Active restoration of kelp and other ecosystems would require more resources.

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Proposed Budgets

Based on: The National Academies of Sciences, Engineering, and Medicine 2021. A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration. Washington, DC: The National Academies Press. *https://doi.org/10.17226/26278*.

The budget table below details the tasks, costs, and timelines to develop the Seaweed Cultivation and Ecosystem Recovery sectors. While the budgets reflect global costs, it is useful for planning and discussion purposes. In fact, if Hawaiʻi would lead efforts in these areas, the costs may be accurate. The bold items are research priorities.

Topic	Budget ($M/yr)	Duration (years)	Total Cost ($M)
Seaweed Cultivation			
Technologies for efficient large-scale farming and harvesting of seaweed biomass **Build efficient demonstration-scale farms to grow and harvest seaweed**	**15**	**10**	**150**
Engineering studies focused on the conveying of harvested biomass to durable oceanic reservoir with minimal losses of carbon	**2**	**10**	**20**
Assessment of long-term fates of seaweed biomass and by-products **Improve understanding of long-term fates of seaweed carbon**	**5**	**5**	**25**
Implementation and deployment of a demonstration-scale seaweed cultivation and sequestration systems	10	10	100
Validation and monitoring of the CDR performance of a demonstration scale seaweed cultivation and sequestration system	5	10	50
Evaluation of environmental impacts of large-scale seaweed farming and sequestration	**4**	**10**	**40**
Estimated Budget of Research Priorities	**26**	**5**	**235**
Total Estimated Research Budget	41	5-10	385
Ecosystem Recovery			
Restoration ecology and carbon **Estimate the change in carbon storage between natural and restored marine ecosystems**	**8**	**5**	**40**
Marine protected areas **Estimate the ability of ocean conservation and MPA protection to enhance the storage and sequestration of carbon per year until 2050**	**8**	**10**	**80**
Macroalgae **improve understanding of the fate of macroalgal carbon, the range of different species and habitats, and the socioeconomic levers and costs of restoring kelp and other macroalgal habitats**	**5**	**10**	**50**

Benthic communities: disturbance and restoration Improve understanding of the impacts of human disturbance on benthic communities and the potential rate of change under different protection scenarios	5	5	25
Marine animals and CO_2 removal **Improve understanding of the direct and indirect impacts of marine animals on CDR including biomass, deadfall carbon, nutrient transfer, and trophic cascades**	**5**	**10**	**50**
Animal nutrient-cycling Test models of movement of iron (vertical) and nitrogen (horizontal) as mediated by whales and other air-breathing vertebrates	5	5	25
Commercial fisheries and marine carbon Improve understanding of fisheries emissions, fish populations and ecological function and the impacts on sedimentary carbon	5	5	25
Estimated Budget of Research Priorities	**26**	**5-10**	**220**
Total Estimated Research Budget	41	5-10	295

Incentives - Discussion of Three Incentive Frameworks

Tax Incentives Framework: Attract innovation and technology companies by instituting a tax credit framework similar to Act 221, Session Laws of Hawaiʻi (SLH) 2001. The proposed framework should apply learning from the challenges of Act 221, SLH 2001 in the following areas, from the University of Hawaiʻi Economic Research Organization's 2009 report, *Small State, Giant Tax Credit: Hawaii's Leap into High Technology Development*[3]:

Reduce the tax credit from Act 221, SLH 2001's 100 percent. A 100 percent tax credit creates numerous problems that would be much less noticeable if the tax credit were smaller. The 100 percent credit attracts high-quality ventures with considerable chance of success but also induces entrance of low-quality ventures with little chance of success. It raises the risk of fraud, both by owners of firms receiving the credits and by Department of Taxation officials. And it promotes opportunistic manipulation of the law's provisions by businesses whose activities are inconsistent with the purpose of the law.

Design the program with proper reporting and monitoring safeguards. Act 221, SLH 2001 used the federal government's Low Income Housing Tax Credit tax credit program as a model. Because the housing program provides generous credits, it contains numerous safeguards including an elaborate process whereby a state agency and a federal agency (the IRS) check and verify applicant information; there is a public disclosure of all funded projects' details, including the value of credits received and contact information; and there are strict reporting requirements with powerful clawback features to prevent cheating and opportunistic manipulation of the law's

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[3] https://uhero.hawaii.edu/wp-content/uploads/2019/08/UHERO_WP2009-03.pdf

provisions. In an effort to expedite high-tech investments, the Hawai‘i legislation stripped away these high transaction cost safeguards while still providing generous tax credits. In so doing, the balance between expediting business transactions and protecting the public interest was lost. The 100 percent tax credit demands a high level of transparency from both the Hawai‘i State Government as well as the firms receiving the credits because the potential for abuse rises with the value of the credits.

Ensure benefits remain in Hawai‘i. Hawai‘i law's allocation exception initially provided incentives for equity in the tax credit allocation partnership deals to be sold to non-Hawai‘i investors while the Hawai‘i investors retained all tax credits. As control shifted to investors outside of Hawai‘i, it was not surprising to see firms relocate to other states. This highly subsidized effort might still have made sense for the State of Hawai‘i if there was a substantial spillover of ideas to other firms more firmly anchored in Hawai‘i. If not, then prior to 2009 the program may just have been providing highly subsidized incubator services to firms that will ultimately generate jobs for workers in other states. Established firms typically move because other factors dominate in the competition to retain maturing businesses. These include complementary infrastructure, connections with research universities, access to high-quality public schools, access to pools of qualified labor, proximity to major markets, state and local taxes, and the business environment. A targeted, smaller investment tax credit could well be one ingredient in the correct public policy mix for retaining new innovative businesses, but clearly cannot carry the full policy load.

Establish a Hawai‘i Carbon Removal Program in the USDA National Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP): Precedence has been set with the Rhode Island Oyster Restoration Initiative to support restorative aquaculture activities.[4] This program works with aquaculture oyster growers to help restore the functions and values of oyster reefs by creating new reefs in approved areas. EQIP has funding to assist with the NRCS conservation practice of Restoration and Management of Declining Habitats. This practice payment rate includes the process of obtaining approved spat on shell through grow out and deployment at approved restoration sites, the obtaining and deployment of cultch (shell) for which the live oysters are placed on top, and for monitoring the success of the site. This PIG recommends that Hawai‘i establish a similar program for seaweed and oyster culture for the purposes of carbon removal and water quality improvement.

Establish Blue Carbon Positive Incentives: Follow the growing trend of carbon sequestration initiatives to create a financial incentive that incorporates carbon-sequestering marine and aquacultural activities. Such an incentive would also reduce cost hurdles for producers to implement industry best practices, and it could be designed to create linkage between the State's local food production or conservation goals and its sequestration goals as well.

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[4] https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/ri/programs/financial/eqip/?cid=nrcseprd429442

Challenges of Industrial Finfish Aquaculture

More consultation and research are needed than this PIG can provide to determine what a robust, sustainable aquaculture industry would look like in Hawaiʻi. However, there are multiple concerns regarding industrial offshore finfish aquaculture (the mass cultivation of finfish in the ocean in net pens, pods, and/or cages) that the State will need to consider should it decide to include such aquaculture in its sequestration, food production, and ocean management programs.

Finfish aquaculture involves a greater number of sources of greenhouse gas emissions than either bivalve or seaweed aquaculture, and while exact figures vary depending on the species of fish farmed, per equivalent weight of biomass, finfish aquaculture frequently has the largest GHG footprint of the three.[5] Because much of the life cycle analysis budget for finfish is attributable to feed production, transportation of that feed to the fish farm, and then transport of the finfish to market, the greenhouse gas budget of loko iʻa aquaculture practice is important to investigate as a potentially more sustainable model of finfish production. However, it appears that the carbon sequestration benefits of finfish aquaculture may be marginal.

In addition, commercial cultivation of finfish in marine and coastal ecosystems can have associated negative impacts which climate change may exacerbate.[6] Examples include:

- Escape of farmed fish into the wild
- Outcompeting wild fish for habitat
- Spread of diseases and parasites from farmed fish to wild fish and other marine life

Climate change continues to increase the intensity of storms in the Pacific Islands region, with implications for offshore aquaculture facilities' abilities to secure equipment under the force of a major, or series of major storms. Such weather events can lead to breaches that result in increased fish escape occurrences. These fish escapes can impact local stocks in various ways including predation; competition for food, habitat, and spawning areas; and interbreeding with wild populations of the same fish.[7] Climate change can also potentially exacerbate pathogen prevalence, virulence, transmission, and host susceptibility to disease, and fish escapes further increase the probability of spreading parasites and diseases to wild stocks.[8,9]

Another concern is pollution (from excess feed, wastes, and any antibiotics or other chemicals used) in the effluent flowing through fish pens into open waters. Models of multitrophic aquaculture have been proposed as part of a restorative aquaculture strategy to mitigate these impacts, but it is beyond the capacity of this PIG report to evaluate a given model or design. Thus, any decision to include or exclude industrial-scale finfish aquaculture as part of achieving the State's sequestration and other sustainability goals will require expert evaluation of a proposed design's ability, if any, to mitigate environmental and public health risks, notwithstanding previously stated reservations about the sequestration potential of finfish aquaculture.

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[5] https://doi.org/10.1093/biosci/biab126

[6] Ibid.

[7] https://www.regulations.gov/document/NOAA-NMFS-2021-0044-0003

[8] http://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1152846/

[9] https://clf.jhsph.edu/sites/default/files/2019-09/ecosystem-and-public-health-risks-from-nearshore-and-offshore-finfish-aquaculture.pdf

Marine Policies

The following section provides a listing of State statutes (HRS) and administrative rules (HAR) related to land, water, and natural resources that may be applicable to aquaculture/mariculture activities. A core research need is to assess each statute or rule for relevance and applicability to aquaculture/mariculture efforts in Hawaiʻi.

- HRS §141-2.5: Aquaculture program
- HRS §141-2.6: Fees for aquaculture services
- HRS §141-2.7: Aquaculture development special fund
- HRS Chapter 171: Public Lands, Management and Disposition Of
- HRS Chapter 174C: State Water Code
- HRS Chapter 183C: Conservation District
- HRS Chapter 187A: Aquatic Resources *(including HRS §187A-6: Special Activity Permits)*
- HRS Chapter 188: Fishing Rights and Regulations
- HRS Chapter 189: Commercial Fishing
- HRS Chapter 190D: Ocean and Submerged Lands Leasing
- HRS Chapter 195D: Conservation of Aquatic Life, Wildlife, and Land Plants
- HRS Chapter 205A: Coastal Zone Management Law *(including Part II: Special Management Areas and Part III: Shoreline Setbacks)*
- HRS Chapter 262: Airport Zoning Act
- HRS Chapter 266: Harbors
- HRS Chapter 342D: Water Pollution
- HRS Chapter 343: Environmental Impact Statements
- HAR 11-200.1: Environmental Impact Statement Rules
- HAR Chapter 13-5: Conservation District
- HAR Chapter 13-74: License and Permit Provisions and Fees for Fishing, Fish and Fish Products *(including HAR §13-74-43: Aquaculture License and HAR §13-74-44: License to Sell Reared Species)*
- HAR Chapter 13-76: Non-Indigenous Aquatic Species
- HAR Chapter 13-83: Shellfishes
- HAR Chapter 13-95: Rules Regulating the Taking and Selling of Certain Marine Resources
- HAR Chapter 13-99: Introduced Freshwater Fishes
- HAR Chapter 13-222: Shoreline Certifications
- HAR Chapter 11-54: Water Quality Standards
- HAR Chapter 11-55: Water Pollution Control
- Permits and Regulatory Requirements for Aquaculture Hawaiʻi: https://hdoa.hawaii.gov/ai/files/2013/03/Major-Regulatory-Requirements.pdf

The federal government has a number of policies and regulations for aquaculture in place, including:

- Federal Policies for Aquaculture: https://www.fisheries.noaa.gov/topic/aquaculture#regulation-&-policy
- National Oceanic and Atmospheric Administration Marine Aquaculture Policy (2011): https://www.fisheries.noaa.gov/resource/document/noaa-marine-aquaculture-policy-2011
- Department of Commerce Aquaculture Policy (2011): https://media.fisheries.noaa.gov/2021-01/doc-aquaculture-policy-2011.pdf

Recommendations

Create framework for governance and organizational leadership including a science advisory body (e.g., aquaculture and ocean recovery committee): Foster collaboration and stakeholder engagement, share information and inform decision making and set priorities and aspirations for development of the industry.

From National Academies of Science, Engineering, and Medicine (2021):

Aquaculture and ocean recovery committee: *With the goal of reducing atmospheric carbon dioxide, an ad hoc committee would conduct a study exclusively focused on carbon dioxide removal and sequestration conducted in coastal and open ocean waters to:*

- *Identify the most urgent unanswered scientific and technical questions, as well as questions surrounding governance, needed to: (i) assess the benefits, risks, and potential scale for carbon dioxide removal and sequestration approaches; and (ii) increase the viability of responsible carbon dioxide removal and sequestration;*
- *Define the essential components of a research and development program and specific steps that would be required to answer these questions;*
- *Estimate the costs and potential environmental impacts of such a research and development program to the extent possible in the timeframe of the study; and*
- *Recommend ways to implement such a research and development program that could be used by public or private organizations.*

Establish conduits for project financing: Build support and obtain funding from key state and federal government departments and impact investors for strategic research and development projects that support the sector initiatives including tax credits, USDA NRCS program development, and carbon positive incentives.

Identify and fill gaps for research and innovation required for advancement: Follow recommendations from the National Academies of Sciences, Engineering and Medicine 2021 report for projects and budget.

Review existing policy and propose legislation to support development: Propose suggestions to streamline the application process for aquaculture permits.

Develop seaweed and bivalve aquaculture best management practices: With robust environmental, safety, and biosecurity standards for management and monitoring of the aquaculture operations.

Capacity building for sequestration monitoring in loko iʻa: With the goal of creating a network of monitoring sites representing a range of conditions, practices, and loko iʻa maturity, identify and collaborate with relevant organizations to identify ways to partner with loko iʻa practitioners to develop a climate change research and development program that could be used to evaluate life cycle analysis benefits of Hawaiian versus conventional finfish production systems.