Improving the Aquaculture Development Program (ADP) Strategic Plan

For Hawai'i

Department of Agriculture
STATE OF HAWAII

HATCH
Innovation Services

Photo: Blue Ocean Mariculture

Contents

Acknowledgement

This report has been put together by Hatch Innovation Services on the 10th of January 2024 and reflects our recommendations to the Hawai'i Department of Agriculture (HDOA) to improve its existing Aquaculture Development Program (ADP) strategic plan. The objective of the report was to provide recommendations for key improvement areas that local, state, and federal agencies can focus on to drive the industry forward and develop and grow a robust, sustainable food production industry that will contribute meaningfully to the economy, the community, and the environment.

The HDOA's tactical priority areas for supporting Hawai'i's aquaculture development focus on **Commercial Activity, Environmental Restoration, and Support Equipment & Services**. These areas will serve as the cornerstone of the report's recommended roadmap and proposed tactical steps to grow the aquaculture industry in Hawai'i sustainably.

Developing a smart, cohesive, forward-thinking aquaculture roadmap for Hawai'i will benefit its people, economy, and the environment. The Hawai'i aquaculture sector is already well established, but it needs to attract more industry players, entrepreneurs and capital. This will help stimulate more commercial activity, increase the sector's economic and social contribution, and ultimately allow the region to fulfil its potential for supplying sustainable and healthy seafood.

To inform these recommendations, Hatch Innovation Services drew on the extensive and diverse experience of its full team. A global scan of successful aquaculture regions, 'best in class' private and public partnerships and Clusters was undertaken to obtain a holistic worldview of proven successful strategies. The local ecosystem was mapped, and key gaps and opportunities were identified. Stakeholders across the industry were invited to provide input and commentary either in-person or online, in addition to our long-term engagement with the local industry to understand its social, economic, and environmental drivers.

Hatch Innovation Services is a specialized aquaculture consultancy unit of Hatch Blue, a global innovation and venture capital company focused exclusively on sustainable and climate-smart seafood systems. With a global footprint, including offices in Hawai'i, Europe and Asia, Hatch Blue collaborates with various entities including governments, NGOs, research institutions, industry players, and emerging ventures to scale up aquaculture ecosystems globally. Hatch Blue has four business units ranging from investment, ecosystem services, and media to consultancy services. For this report, Hatch Innovation Services has leveraged on its global team of aquaculture experts.

Our gratitude extends to the Hawai'i Department of Agriculture for enabling us to assist in improving its aquaculture development plan. We also express our profound appreciation for the invaluable contributions and insights provided by a diverse panel of stakeholders, which greatly shaped the strategy and substance of the report.

Director
Tanja Hoel
Hatch Innovation Services

Glossary

'Ama'ama	>>>	Mullet *Mugil cephalus*
ʻĀholehole	>>>	Hawaiian Flagtail *Kuhlia sandvicensis* (also known as ʻĀhole)
Aloha ʻāina	>>>	Love of the land or of one's country
Awa	>>>	Milkfish *Chanos chanos*
Hoʻomau	>>>	Ongoing research (to continue, keep on, persist, renew, perpetuate)
Kahala	>>>	Kampachi / Kanpachi / Amberjack / Yellowtail *Seriola dumerili*
Limu	>>>	Seaweed and plants living under water, both fresh and salt.
Lōkahi	>>>	Unity, agreement, accord, harmony
Loko iʻa	>>>	Fishpond
Mahimahi	>>>	Dolphinfish *Coryphaena hippurus*
Mālama ʻĀina	>>>	To take care of the land - to tend, attend, care for, preserve, protect it
Moʻolelo	>>>	Oral tradition, story passed down through the generations
Moi	>>>	Pacific Threadfin *Polydactylus sexfilis*
Nenue	>>>	Chub / Rudderfish *Kyphosus bigibbus*, *K. vaigiensis*
Opihi	>>>	Limpets - there are three types in Hawaiʻi: kōʻele (*Cellana talcosa*), ʻālinalina (*C. sandwicensis*), and makaiauli (*C. exarata*)
Pono	>>>	Righteousness, goodness
Uku	>>>	Snapper *Aprion virescens*

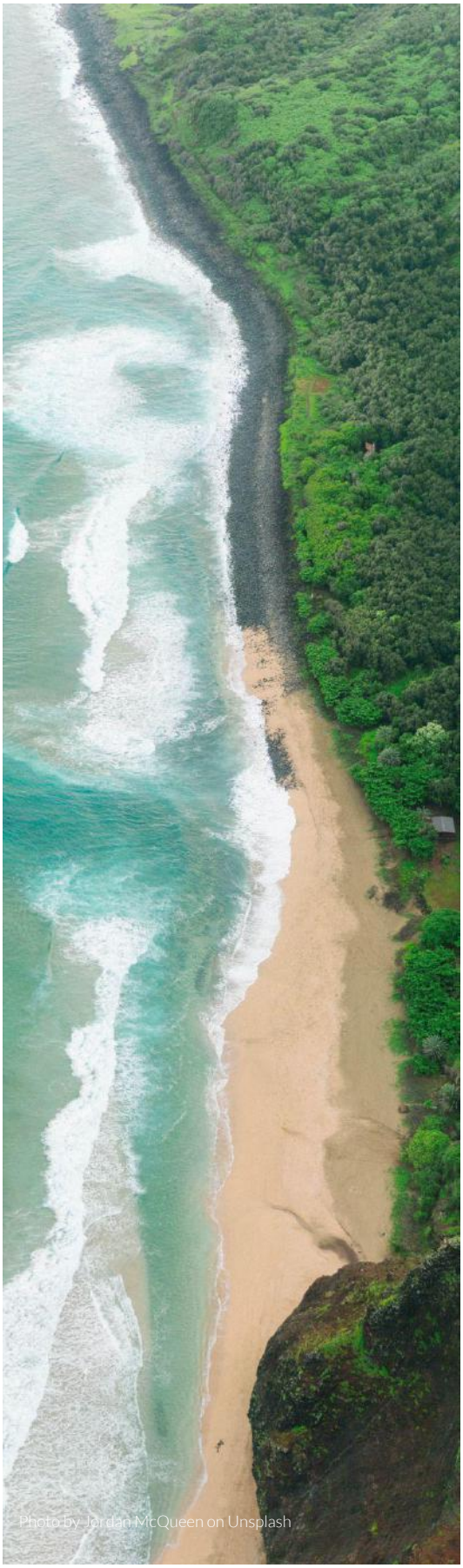


Photo by Jordan McQueen on Unsplash

Source: 42

Aquaculture	>>>	the breeding, rearing, and harvesting of fish, shellfish, algae, and other organisms in any type of water environment.
Acidification	>>>	the ongoing decrease in the pH value of the Earth's oceans, caused by the uptake of carbon dioxide from the atmosphere.
Algal Bloom	>>>	the overgrowth of algae in water. Red tides, blue-green algae, and cyanobacteria are examples of harmful algal blooms that can have severe impacts on human health, aquatic ecosystems, and the economy.
Blue Carbon	>>>	refers to greenhouse gasses, specifically carbon dioxide, captured by the world's ocean and coastal ecosystems.
Blue Foods	>>>	or seafood include fish, invertebrates, algae and aquatic plants captured or cultured in freshwater and marine ecosystems.
Bivalve	>>>	a shellfish or mollusk that has two hinged shells, which are called valves.
Broodstock	>>>	mature individuals used in aquaculture for breeding purposes in captivity.
Eutrophication	>>>	is the process in which a body of water becomes overly rich in phosphates, nitrates, and organic nutrients such that it promotes a proliferation of plant life, especially algae.
Hatchery	>>>	is a facility where the hatching of aquatic species is artificially controlled for commercial purposes.
Herbivorous	>>>	an organism that mostly feeds on plants.
Macroalgae	>>>	another term for seaweed. Macroalgae are sometimes described as "aquatic plants," but are actually large algae and are taxonomically distinct from plants.
Microalgae	>>>	microscopic version of macroalgae, single-celled and may exist independently or in colonies.
Mariculture	>>>	a branch of aquaculture involving the cultivation of marine organisms in the open ocean, an enclosed section of the ocean, or in tanks, ponds or raceways which are filled with seawater.
Multi-trophic	>>>	is where multiple aquatic species from different trophic levels are farmed to improve efficiency, reduce waste, and provide ecosystem services, like bioremediation.
Low-trophic	>>>	species in marine ecosystems comprise organisms that are generally plankton feeders for the majority of their life cycle.
Restorative aquaculture	>>>	when commercial or subsistence aquaculture provides direct ecological benefits to the environment, with the potential to generate net positive environmental outcome
Regenerative aquaculture	>>>	the production of food from the sea that provides benefits to the ecosystem, such as water filtering by bivalves (eg oysters, mussels and clams) or carbon sequestration by seaweed.
Specific Pathogen-free	>>>	means that a predetermined consortium of pathogenic organisms is absent from an animal

Acronyms & Abbreviations

ACFR	Ānuenue Fisheries Research Center
AI	Artificial Intelligence
AQD	Aquaculture Department
B-C	Benefit to Cost [ratio]
BOM	Blue Ocean Mariculture
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CO^2	Carbon Dioxide
COVID	Coronavirus Disease (of 2019)
CTSA	Center for Tropical & Subtropical Aquaculture
DAR	Department of Aquatic Resources
DBEDT	Department of Business, Economic Development & Tourism
EU	European Union
FAO	Food & Agriculture Organization
FCR	Food Conversion Rate
FOLU	Food and Land Use Coalition
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HAAA	Hawai'i Aquaculture & Aquaponics Association
HAC	Hawai'i Aquaculture Collaborative
HDOA	Hawai'i Department of Agriculture
HI	Hawai'i
HOST	Hawaiian Ocean and Science Technology
HPU	Hawai'i Pacific University
HTDC	Hawai'i Technology and Development Corporation
IOC	Iceland Ocean Cluster
IoT	Internet of Things
IP	Intellectual Property
KUA	Kua'Āina Ulu'Auamo
MAC	Marine Aquaculture Center
MAIC	Maine Aquaculture Innovation Center
MERIP	Marine and Environmental Research Institute of Pohnpei
NASS	National Agricultural Statistics Service
NELHA	Natural Energy Laboratory of Hawai'i Authority
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
OI	Oceanic Institute
OPEX	Operating expenses
PACRC	Pacific Aquaculture & Coastal Resources Center
PPPD	Per Person Per Day
R&D	Research and Development
RAS	Recirculating Aquaculture System
ROI	Return on Investment
SAIC	Scottish Aquaculture Innovation Center
SDGs	Sustainable Development Goals
SEAFDEC	Southeast Asian Fisheries Development Center
SIS	Shrimp Improvement System
SME	Small and Medium Enterprises
SPF	Specific Pathogen-Free
SPR	Specific Pathogen-Resistant
UH	University of Hawai'i
UHero	University of Hawai'i Economic Research Organization
UN	United Nations
US	United States
USA	United States of America
USD	US Dollar
USDA	United States Department of Agriculture

Introduction

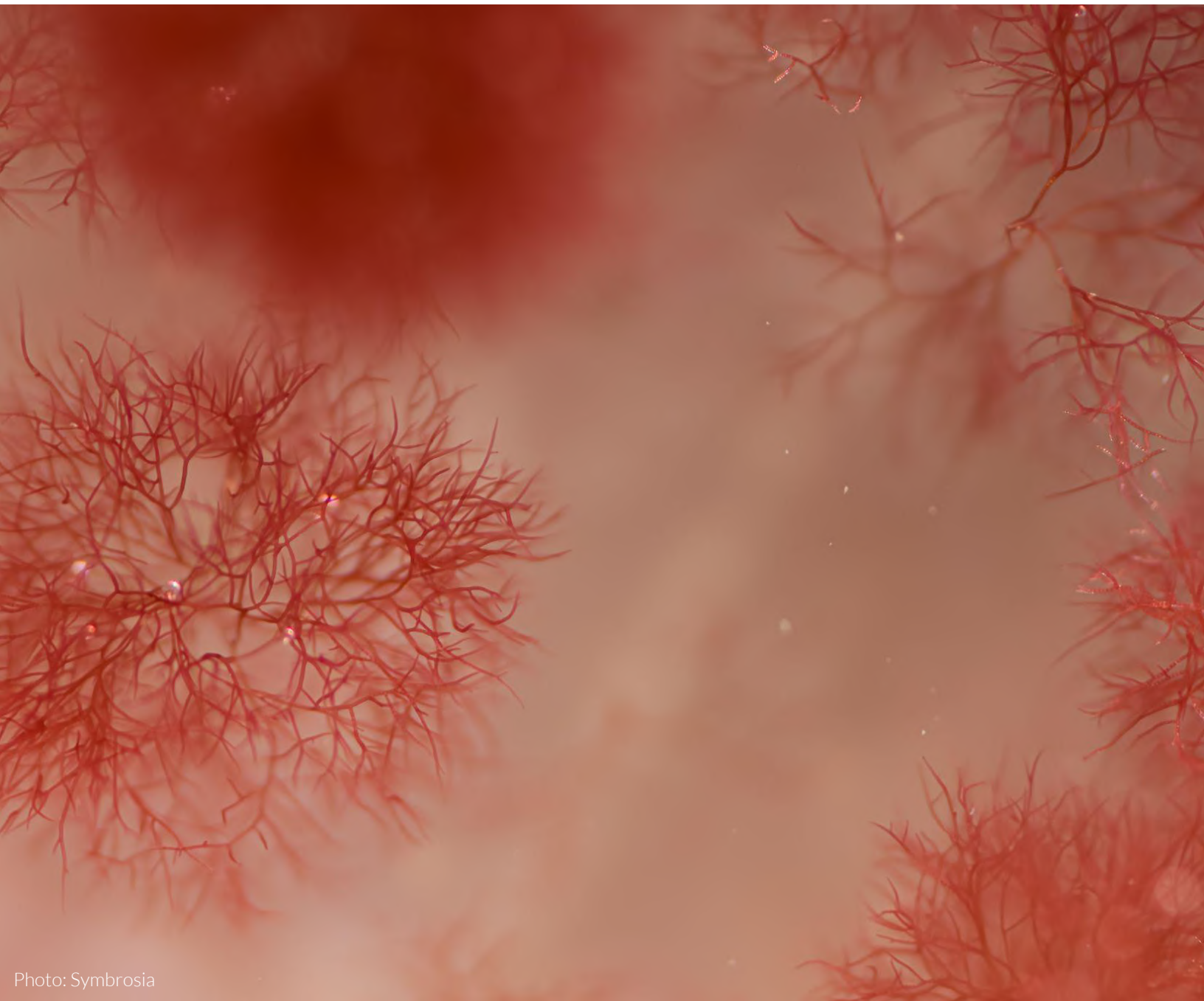


Photo: Symbrosia

The critical role of oceans in supporting livelihoods and to restore coastal ecosystems

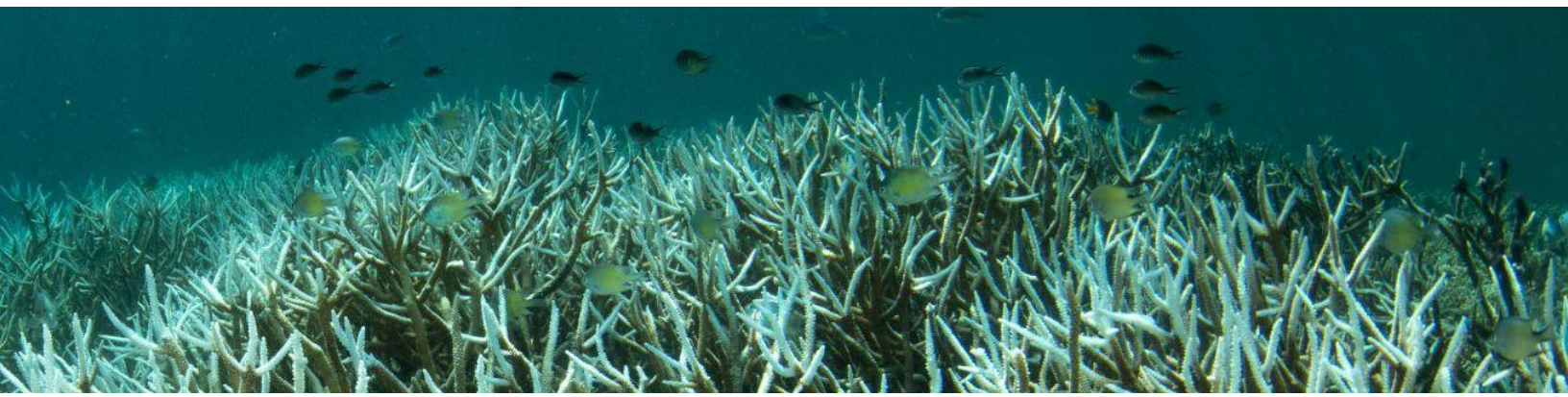
Our ocean, a vast and vital component of our earth, plays a great role in sustaining human life and preserving ecological harmony. It feeds us, entertains us, connects us, and inspires us. The ocean provides us with the source of oxygen, food, and medicine, enriching our lives not just physically but also through recreation, discovery, and as a deep wellspring of cultural identity and heritage.[5] The ocean is one of the key pillars in supporting global health and prosperity, we benefit from the important role it has in mitigating the impacts of climate change and supporting diverse marine ecosystems and communities.

Humanity is very much dependent on the ocean, as it supports the economic activities of over three billion people. For Hawai'i, key ocean industries like seafood, tourism, and shipping, which are pivotal for income, foreign exchange, and employment, are highly dependent on ocean resources.[1] Not only crucial for supporting life, over the past two and a half centuries, the ocean has been an incredibly effective 'carbon sink'. It has absorbed a quarter of humankind's CO_2 emissions and captured 93% of the excess heat generated from greenhouse gas emissions.[4,5] However, for a sustainable and long-lasting relationship with our planet and its oceans, it's vital to develop ocean-based industries in a way that prioritizes environmental and social sustainability.[8]

On a global scale, we are seeing the devastating effects of a changing and struggling marine environment. In some oceans, mismanagement, overfishing, and a lack of restoration have significantly affected marine resources. This has intensely impacted the social and economic circumstances of local communities. Parallel to this, changes in pollution, temperature, acidity, and oxygen levels have had severe implications for biodiversity, productivity, and ocean circulation.[2,3]

With its abundant resources and benefits, the ocean is closely tied to human health. The quality of the resources we obtain from the ocean has a direct impact on our overall well-being.[8]

Hawai'i, with its distinct location in the middle of the Pacific Ocean and its strong cultural linkages to the ocean, could become a driving force in global aquaculture. Being an isolated archipelago, Hawai'i has developed a unique culture and ecosystem. Hawai'i's proactive stance in environment protection, ocean stewardship, and sustainable practices contributes to maintaining the ocean's health and productivity without causing damage to marine ecosystems. Hawai'i's commitments not only benefit local and global communities but also contribute to maintaining the balance of our Earth's ecosystems. Hawai'i has a long ocean heritage of fostering a relationship with the ocean, where protection, prosperity, and sustainable production[5] are prioritized. Hawai'i's commitment to sustainably managing the ocean and marine resources can serve as an example for other regions globally.



The importance of increasing food production sustainably

The ocean plays a particularly significant role in addressing global food security and resiliency. There are various factors that affect the food security issue, including malnutrition, economic disparity, climate change, resource depletion, and growing protein demand, ***all of which call for a substantial increase in food production***. With the global population expected to hit 9.7 billion by 2050, food production needs to grow by 70% while also being environmentally sustainable.[9] Currently, food production contributes to nearly a quarter of global greenhouse gas emissions and heavily impacts freshwater usage and habitat degradation. Increased demand for food exceeds the capabilities of terrestrial ecosystems alone. Traditional agricultural practices, known for their high greenhouse gas emissions, are unsustainable in meeting these growing needs.[10]

The ocean, when effectively managed, has the potential to greatly address this food security challenge, with the capacity to produce over six times more food than it currently does.[7]

Innovating for more efficient and sustainable food production methods is imperative. This approach involves rethinking how to nourish the expanding global population with minimal environmental and climate impact. Transforming our food production techniques can significantly decrease resource usage, improve efficiency, and play a crucial role in combating climate change and preserving biodiversity.

Figure 1 - Global Food Security Challenge

.....Finding a balance between increasing food production and environmental health is within our reach.....

Finding a balance between increasing food production and environmental health is within our reach. This balance involves utilizing the potential of both land and sea, integrating technologies and practices that are ecologically sound and economically viable. As we look towards a future of sustainable growth, the focus must also be on equitable distribution and access to food resources, ensuring that the benefits of increased production reach all segments of society. With collaborative efforts across sectors and communities, it is possible to build a food-secure world that also safeguards our planet's health. This leads us to the realization that transitioning to a sustainable food supply is a crucial step forward.

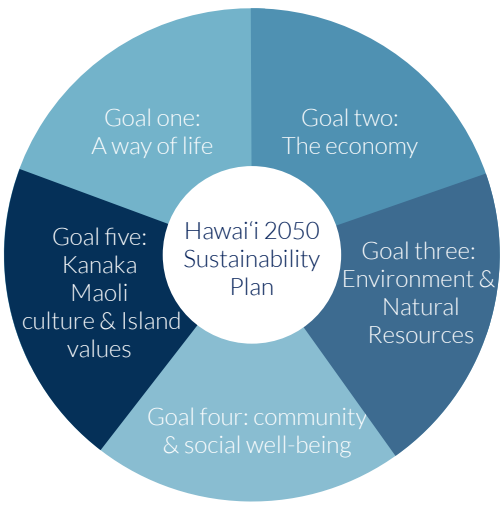
On a global scale, we are seeing governments develop food strategies for the transition towards blue food - a term encompassing various types of seafood and aquatic plants that are caught or farmed in freshwater and marine environments. This is increasingly seen as a vital response to global food security, ending human malnutrition and building a healthy,[12] ***environmentally sustainable and resilient food system without putting further pressure on land resources.*** The Director of the Fisheries and Aquaculture Division at the Food and Agriculture Organization (FAO) at the United Nations believes that: **"The Blue Transformation initiative is an effort to convince everyone that there are very clear steps one needs to take to make sure that we move in the direction of ending hunger and poverty."** [11]

Hawai'i's rich marine biodiversity and strategic Pacific location present a unique opportunity to advance the ocean economy sector, addressing climate change, and scaling up its blue food production. For Hawai'i, blue food production is deeply rooted in the island's culture and prosperity, with many local communities depending heavily on these resources. By focusing on sustainable practices in blue food production and consumption, Hawai'i is preserving its own coastal and marine ecosystems and setting an example for other regions. Hawai'i's unique cultural and environmental context provides a valuable model for integrating traditional knowledge with modern sustainability practices, showcasing how local actions can have a global impact in the fight against climate change.

For Hawai'i, scaling up its blue food production can significantly contribute to the existing Hawai'i 2050 Sustainability Plan, complementing its objectives that nurture cultural values and aid in achieving the state's sustainability aims. These objectives include economic stability, environmental respect, and the conservation of resources for upcoming generations.
The Hawai'i 2050 Sustainability Plan is an initiative by the State of Hawai'i Office of Planning, which serves as the state's strategic action plan for sustainability and climate adaptation. This plan aligns with the United Nations Sustainable Development Goals (SDGs) and outlines sustainability and climate change actions for the 2020–2030 period. The people of Hawai'i are committed to and have built positive momentum toward achieving these goals across a range of public and private efforts to achieve SDGs by 2030.[15]

There's a collaborative effort involving state policies, local agency programs, and voluntary initiatives to enhance Hawai'i's climate resilience and socio-economic and environmental sustainability. Key areas of focus in the plan include sea level rise planning, greenhouse gas reduction, economic diversification, food security, and support for indigenous Native Hawai'i culture. ***Scaling-up the blue food sector sustainably can contribute to a diversified, competitive economy by creating jobs and supporting local businesses. The approach respects and perpetuates indigenous cultures and values, maintaining a crucial link to Hawai'i's social context.***

Figure 2 - Hawai'i 2050 Sustainability Plan



The transformation to blue food strongly aligns with and is expected to act as a catalyst, potentially promoting all five goals of Hawai'i's sustainability plan, thereby fostering a holistic approach to sustainable development across the state.

Blue Food Impact on Sustainable Development

UNs Sustainable Development Goals (SDGs) that have previously been outlined as an integral concept for the Hawai'i 2050 Sustainability Plan are a good indicator to showcase the diverse range of socio-economic impacts of blue food. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides specific goals to be reached by 2030 for people and the planet.[35]

Transforming today's food challenges into opportunities can create a food system that is not just sustainable but also fosters positive growth for communities, economies, and our oceans. Blue foods are integral in catalyzing this transformation. The table on the right illustrates how the production of blue foods can support the different SDGs agenda.

Blue foods provide us with nutritional security, enhanced sustainability, climate resilience, and community prosperity. Blue foods act as a cornerstone of the sustainable ocean economy, offering diverse opportunities for economic growth and ecological balance to ensure healthy oceans. In terms of nourishing life, blue food offers easily accessible and affordable animal proteins and essential micronutrients. These are critical for overall health and cognitive development.[12] Rich in essential nutrients like omega-3 fatty acids, zinc, iron, and vitamins A, D, and B12, blue foods are a healthy source of animal protein, contributing significantly to global health and well-being.[14] Despite its benefits, the integration of blue food into public health nutrition policies remains limited for now. Current policies may need to recognize and integrate the consumption of blue food for society.[13]

On a global scale, blue food production already supports 58.5 million jobs in the primary sector, and 600 million livelihoods. The trade in aquatic products provides an important source of hard currency and income for exporting countries and regions.[11] The FAO anticipates that by 2030, two-thirds of the global seafood supply will be farmed, with a looming deficit of an additional 30-40 million tonnes of seafood needed to meet the world's food requirements in the next three to four decades.[11] Therefore, it's critical to develop food systems that not only aid in restoring degraded ecosystems but also cater to the escalating demands for food and livelihoods. ***Aquaculture plays a critical role in blue food production and provides a solution to meet future seafood demands without depleting marine resources.***

Table 1 - Blue Food´s SDGs Impact

SDGs	Benefits
1 NO POVERTY	Inclusive economic development and jobs with fair wage
2 ZERO HUNGER	Enhanced food security based on sustainable and nutritious blue foods
3 GOOD HEALTH AND WELL-BEING	Enhancing health and well-being
7 AFFORDABLE AND CLEAN ENERGY	Supporting affordable energy
8 DECENT WORK AND ECONOMIC GROWTH	Direct and indirect job creation in a green economy
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Incentives for investment in innovation and infrastructure that brings prosperity
10 REDUCED INEQUALITIES	Sustainable resource use that empowers long-term prosperity of indigenous and marginalized groups
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Strengthened coastal communities through restoration of coastal ecosystem and sustainable local development
13 CLIMATE ACTION	Low environmental footprint raw materials and carbon sequestration potential of filter feeders species
14 LIFE BELOW WATER	Ocean regeneration through assimilation of nutrient and CO_2 uptake and biodiversity enhancement
15 LIFE ON LAND	Alternatives to emission intensive fertilizer and feed ingredients to agriculture

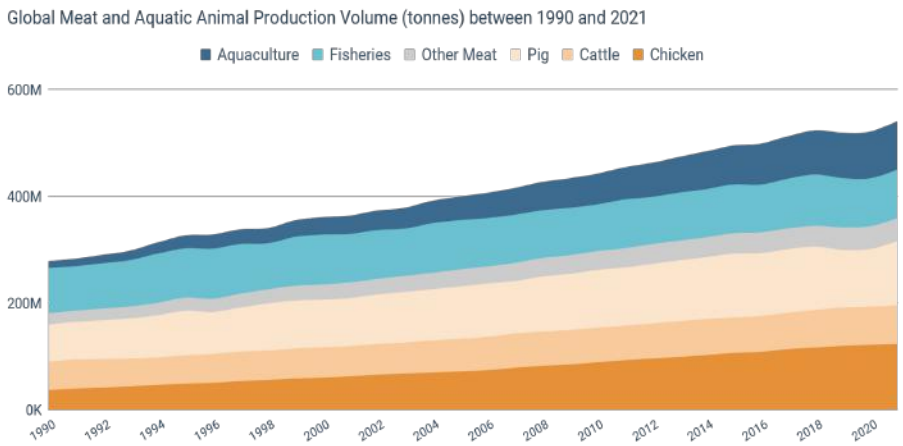
Aquaculture has undeniably established its crucial role in global food security and nutrition, reducing the supply-demand gap for aquatic food.

Aquaculture is rapidly growing globally with the benefit of a lower carbon footprint compared to other animal proteins. Currently, it provides over half of the blue food consumed globally and with the global population expected to reach 10 billion by 2050, its growth is projected to continue.[16] This contrasts with the static volumes of wild-caught fisheries since the late 1980s. As wild fishery catch rates show a trend of stagnation or decline, the need for sustainable aquaculture practices grows ever clearer. Without diversification towards more aquaculture production, there will be a severe gap between supply and demand in the future. The FAO statistics figures reveal that the wild-caught fish industry has more or less stagnated, and conversely, aquaculture has achieved impressive growth.[17] The surge in demand for seafood and the decreasing amount of captured wild fish is anticipated to propel the growth of aquaculture in the coming years.

The chart indicates a significant rise in aquaculture production compared to fisheries, which aligns with a global shift towards more controlled, sustainable, and predictable methods of producing seafood which meet increasing demand and reduce pressure on natural fish stocks.

As the market demand continues to grow, there has been remarkable engineering and technological progress in the industry.

Figure 3 - Global Meat and Aquaculture Production



Source: 16

Aquaculture can be performed with lower environmental resource requirements than its terrestrial counterparts. With fishing resources at, or above, their maximum sustainable yields; competing coastal uses; and land, water, and other resources exhausted; the aquaculture industry can only continue expanding by continuously advancing technology and improving ecological efficiency, using fewer natural resources to produce more.

With the right methods, species and locations, aquaculture has the potential to strike a delicate balance, fostering food production that bolsters the health of aquatic ecosystems. Going beyond the concept of sustainable aquaculture practices, restorative design looks at whole systems - human, non-human and their interactions - with the aim of nourishing the fundamental processes and interconnections that support them in positive feedback loops.

Large-scale production will have to take place in the open ocean – where available areas, stronger currents, and greater depths increase the carrying capacity of the environment. Raising fish in exposed, high-energy areas in the open ocean presents an opportunity for restorative aquaculture. Best practice open ocean farms utilize ocean currents to dilute waste, protecting the seafloor from degradation and reducing their carbon footprint. With increasing advances in research, technology, and feed innovation, deep water open ocean aquaculture offers an environmentally sustainable solution, with huge capacity for growth. Fish that are native to the region can be farmed in their natural habitat, decreasing the pressure on wild fish populations, and contributing to food sovereignty and security.

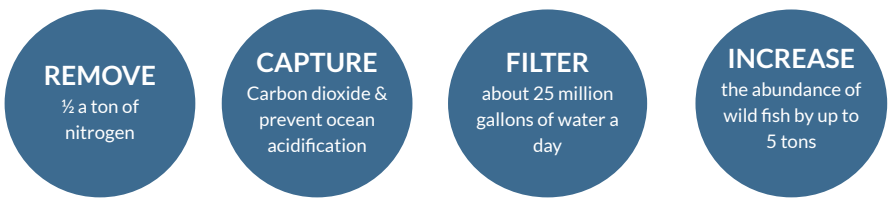
Hawai'i aquaculture is strongly linked to restorative practices

Despite its abundant natural resources, Hawai'i is highly dependent on food imports, with up to 90% of its food brought in from outside the state. This dependency places Hawai'i at risk, particularly in the face of natural disasters, economic uncertainties and even pandemics.[29] Strengthening Hawai'i's capacity to do aquaculture sustainably emerges as a critical strategy to mitigate vulnerability to these external pressures. Environmental Restoration is one of HDOA's tactical priority areas for supporting Hawai'i's aquaculture development as part of Hawai'i's ADP Strategic Plan.[23] These days, there is a growing movement towards adopting aquaculture systems that are both productive and restorative, focusing on healing and improving the ecosystems from which they derive, thereby preserving or even enhancing the natural balance of our aquatic environments. This concept is known as restorative aquaculture. Restorative aquaculture is defined as ***"the intentional use of aquaculture to positively affect (ecosystem) services"*** it is a concept "***when commercial or subsistence aquaculture provides direct ecological benefits to the environment, with the potential to generate net positive environmental outcomes"***. [24]

The principles of restorative aquaculture are not a new concept, even though it has recently been gaining more traction. The concept of restorative aquaculture is strongly embedded in the cultural context of Hawai'i Island communities. For thousands of years, the Hawaiians have practiced living in balance with the natural environment. Long before modern agricultural and aquacultural practices were developed, ancient civilizations with profound respect for the land and sea practiced sustainable farming and aquaculture, enriching the environment for future generations. For example, Hawai'i is the only known place in Oceania where the people practiced a "pure" form of fishpond aquaculture. The ancient loko i'a (fishponds) are masterpieces of ecological stewardship and ingenuity. These fishponds not only provide a vital food source but also preserved the health of the ecosystem.[28]

Restorative aquaculture, if implemented on a large scale, can significantly boost economic opportunities for coastal communities globally by contributing to the aquaculture sector with $264 billion in revenue and supporting 20 million jobs. [25]. The interest in restorative aquaculture as a tool for climate change mitigation, particularly through the direct storage and sequestration of carbon, is also growing swiftly.

Figure 4 - A single hectare of restorative aquaculture can:



Research in nutrient-rich and degraded environments has shown that seaweeds and shellfish can offer three primary advantages: enhancement of water quality, provision of habitat, and contribution to climate mitigation.[24]

The introduction of native finfish as a means of restorative aquaculture brings with it diversified ecosystems. For instance, fish like the Hawai'i mullet and Pacific threadfin can contribute to ecological dynamics, attracting other species and maintaining a balanced food web. Blue Ocean Mariculture (BOM), a prominent aquaculture company in Hawai'i, has effectively integrated native Hawaiian finfish (Kanpachi) into their practices in a way that supports restoration and sustainability. However, other less-studied low-trophic species, like sea cucumbers, sea sponges, snails, abalone, and sea squirts, also contribute significantly to natural ecosystems and could yield restorative advantages in thoughtfully designed aquaculture settings. Restorative aquaculture extends its advantages beyond mere ecological rejuvenation, offering a twofold benefit for both people and the environment.

Aquaculture has the highest potential to meet the world's rising demand for sustainable and climate-friendly food

Aquaculture is essential for global food supply in a changing climate. Increasing consumer demand for responsibly sourced blue foods is steering the industry towards sustainable practices. Retailers, NGOs, and nonprofits are actively raising awareness about ecological friendly blue food. Recent surveys have revealed a strong consensus on the benefits of blue foods.More than 80% of consumers acknowledge the health advantages of blue foods, while a substantial majority, ranging from 75% to 89%, express confidence in the industry's ability to operate in a sustainable and responsible manner. This reflects the growing trend towards environmentally friendly, health-conscious dietary choices.[18]

Seafood farming is one of the most eco-efficient and sustainable forms of animal protein available. Fish has one of the lowest carbon footprints, high protein retention, and an efficient feed conversion ratio.

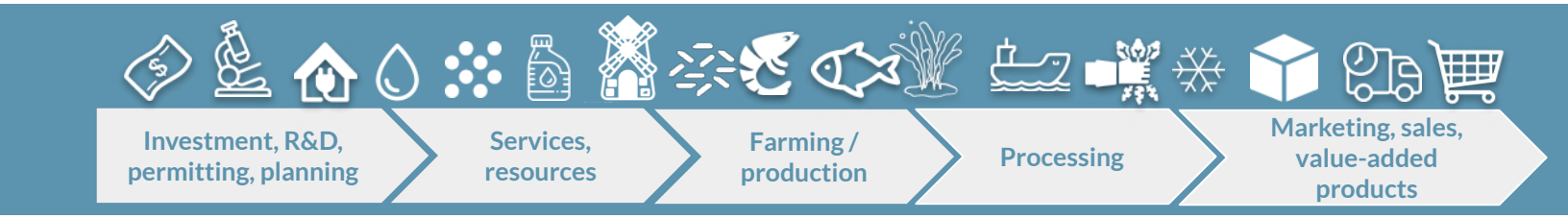
Fish ranks as the most resource-efficient among animal protein sources when compared to others.

Table 2 : Resource efficiency in terms of feed use and freshwater consumption for fish (salmon), poultry, pork and beef.
Source: 19,20,21,22

Protein	Fish	Poultry	Pork	Beef
GHG emissions kg CO2eq [19,20]	**5.2**	9.87	12.31	99.48
Freshwater consumption, liter per kg edible meat [21]	**1,400**	4,300	6,000	15,400
Feed conversion ratio [22]	**1.08**	1.9	3.9	8
Calorie retention [22]	**25%**	27%	16%	7%
Protein retention [22]	**28%**	37%	21%	13%

The Importance of the whole value chain approach towards a sustainable aquaculture industry

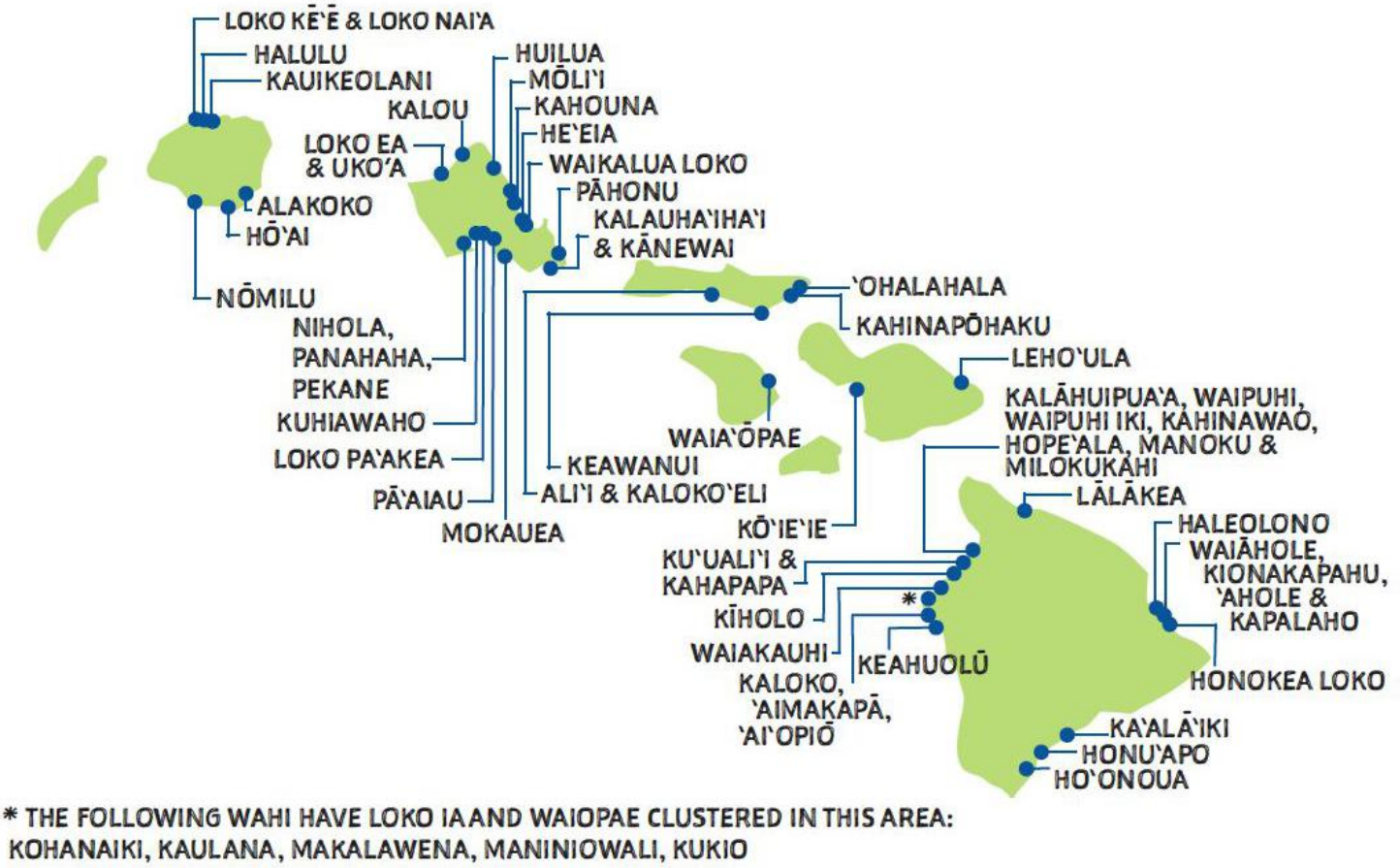
Table 2 highlights that aquaculture proteins emit the least greenhouse gases among animal protein sources. Rising public awareness is driving the demand for environmentally and climate-conscious food production. Individual choices are increasingly shaping a global shift towards sustainability. Realizing that our everyday food choices can make a significant statement about our commitment to the health of our planet and the well-being of future generations is a powerful notion. In this context, it is crucial to focus on developing the aquaculture value chain in terms of building out climate-smart and viable, sustainable solutions that can support the future sustainable growth of the aquaculture industry. This includes investment in research for sustainable aquaculture farming, focusing on environmentally responsible methods and regulatory compliance. The cultivation phase particularly requires solutions to minimise ecosystem impacts and reduce carbon emissions, while the final product and marketing stage turns blue foods into economically viable, nutritious, and sustainable products. This value chain illustrates aquaculture's vital role in planetary health and sustainable resource management, underlining its significance in addressing climate challenges.



Hawaiian fishponds are examples of restorative aquaculture, strongly embedded in the social context of island community culture and food supply

Hawaiian fishponds used to yield an average of 400–600 pounds of fish per acre annually, resulting in an annual fish harvest exceeding 2 million pounds across the Hawai'i Islands.[28] These ponds were typically constructed by building rock walls across coastal inlets or sections of reef flats, utilizing natural tidal flows for water circulation. The mākāhā, a sluice gate with wooden slats, allowed juvenile fish from the ocean to enter the pond with the incoming tide. Once inside, they couldn't escape as they grew larger. Algae, nurtured by the nutrient exchange between the pond and the ocean, as well as by any excess nutrients from adjacent taro fields, served as a fundamental food source within the pond. As algae thrive in nutrient-rich environments, these fishponds became self-sustaining habitats where fish could feed and grow, essentially creating a natural fish farm that capitalized on the nutrient cycles and biological productivity of the area.

Figure 5 - Loko i'a distributions



The restoration of loko i'a and the near-shore environments around them (fisheries, coral, and seaweed beds) is gaining momentum. This is in the sure and steadfast knowledge that loko i'a "maintain the potential to contribute to healthy and robust food and ecological systems."[30]

CHAPTER 2

Methodology

Photo: Blue Ocean Mariculture

Scope of the project

Hatch Innovation Services was commissioned to investigate the state of aquaculture in Hawai'i and make recommendations to the Hawai'i Department of Agriculture (HDOA) on how they can improve the existing Aquaculture Development Program (ADP) Strategic Plan.[23] The objective of the report was to provide recommendations for key areas that local state and federal agencies can focus on to drive the industry forward and develop and grow a robust, sustainable food production industry that will contribute meaningfully to the economy, the community, and the environment.

Driving Hawai'i's ADP Strategic Plan forward

To promote aquaculture in Hawai'i, the Aquaculture Development Program (ADP) has devised a 10-year strategic plan. This plan is aiming to achieve the dual goals of increasing aquaculture food production and supporting initiatives for restorative aquaculture.

HDOA's tactical priority areas for supporting Hawai'i's aquaculture development focus on **Commercial Activity, Environmental Restoration**, and **Support Equipment & Services**. The anticipated result is to create socio-economic benefits for the island communities of Hawai'i. These areas will form the cornerstone of this project's improvement strategy.

Figure 6 - HDOA Tactical Priority

Developing a smart, cohesive, forward-thinking plan for Hawai'i's aquaculture will benefit its people, its economy, and its environment. The Hawai'i aquaculture sector is already well established, but it needs to attract more industry players, entrepreneurs, and investors to stimulate more commercial activity and grow more opportunity to fulfill its ultimate potential.

This project will serve as a catalyst to:

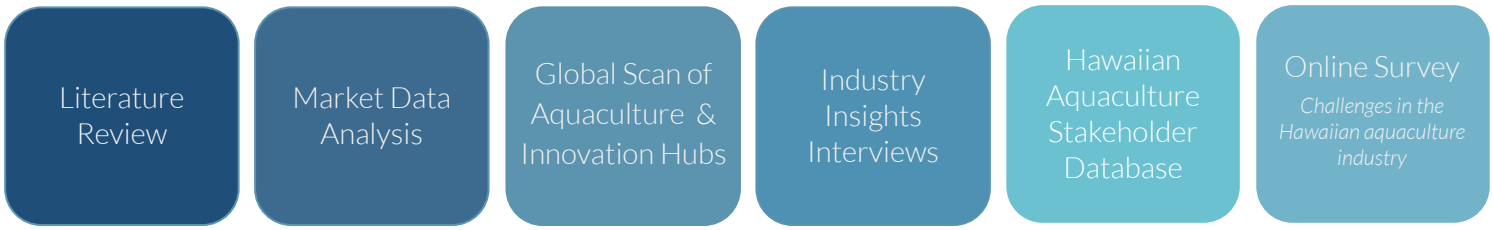
- Support future commercial activity combined with environmental restoration to support the commercial development of equipment and services.
- Identify the competitive advantages of Hawai'i to support the future development of sustainable aquaculture production and restorative practices.
- Identify successful private public partnership from a scan of global best practices that support aquaculture and ocean health.
- Tactical steps towards the goals of building sustainable aquaculture production and developing a viable research and development sector.
- Clearly communicate the socio-economic benefits of sustainable aquaculture production and restorative practices.

To inform these recommendations, Hatch Blue drew on the extensive and diverse experience of its full team. A global scan of 'best in class' institutions, partnerships, and businesses was undertaken to obtain a holistic worldview of proven strategies. The industry ecosystem was mapped, and key gaps and opportunities were identified. Stakeholders across the industry were invited to provide input and commentary either in-person or online, and the Hatch team immersed itself in the local industry to understand its social, economic, and environmental drivers.

Research approach & sources

The foundation of this report was based on 6 knowledge pillars and information sources

Information sources to provide recommendations to improve Hawai'i's ADP Strategic Plan



- A **comprehensive review of relevant literature,** including scientific literature, grey literature and market reports
- A **market data analysis** was performed on other leading aquaculture regions taking a deeper investigation of the governmental and supportive frameworks that help with the development of the sector. Market analysis used global public aquaculture market trade databases as well as US and Hawai'i specific focused datasets.
- A **global mapping exercise of clusters and innovations centers** connected to Aquaculture & Ocean Health. Detailed results of the global scan are provided in appendix 7.3.
- A **series of industry insights interviews** with industry experts, producers, entrepreneurs, academics, government representatives and community leaders. Check appendix 7.2 for more information on interview guidelines /topics.
- A **Hawaiian aquaculture stakeholder database** - more than 280 Hawaiian aquaculture industry stakeholders were mapped and populated with current data, including representatives' names and designations, contact details, website addresses, geographic locations, and a brief description of the primary business or occupation of the entity.
- An **online survey** - based on the database, all stakeholders were invited to engage with Hatch Blue and provide input on a broad spectrum of challenges and issues in the aquaculture industry in Hawai'i. Details on key trends and observations can be found in the appendix. Survey topics included:

Governance	**Education, workforce, training & capacity building**	**Innovation, technology & services**
Funding & investment	**Infrastructure**	**Community & social responsibility**
Consumer market & marketing	**R&D**	**Restorative & regenerative aquaculture**

To create a platform through which stakeholders could provide input on a new roadmap for aquaculture in Hawai'i, voice concerns, suggest solutions and provide comments to ensure broad engagement and support, a variety of tools, including a series of interviews and meetings with key stakeholders and an online survey, were used. Using a holistic approach, Hatch Blue engaged in feedback from a wide variety of stakeholders from the following focus groups: research and education, industry, nonprofits and community, government, investors, and new venture businesses.

CHAPTER 3

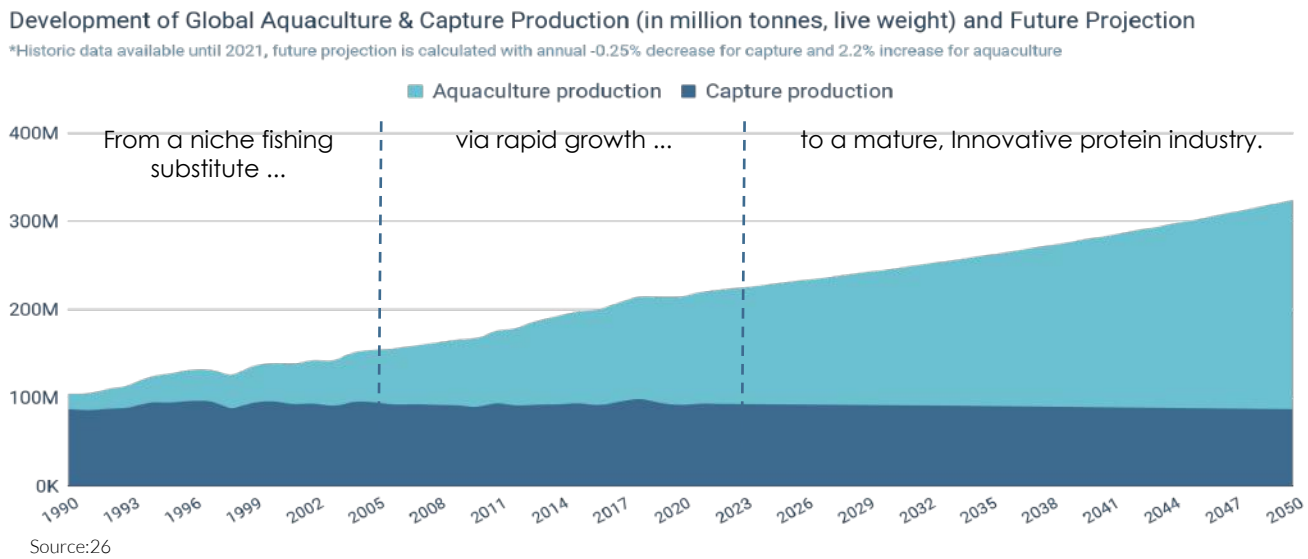
Hawai‘i’s Market Opportunity

Bridging the Gap between Seafood Supply & Demand

Photo: Molokai Broodstock Company

Worldwide demand for premium seafood is high and expected to grow. The growth potential is underpinned by an increasing global population and, importantly, heightened wealth, particularly among the expanding middle class in Asia. In 2021, global aquaculture production, including seaweed, surpassed 120 million tonnes (live weight), with an annual growth rate of about 4.5% from 2010 to 2021. Despite this, the contribution of the United States to this production is minimal on a global scale, and its output has been stagnant in recent years. [26]

Figure 7 - Aquaculture vs Capture



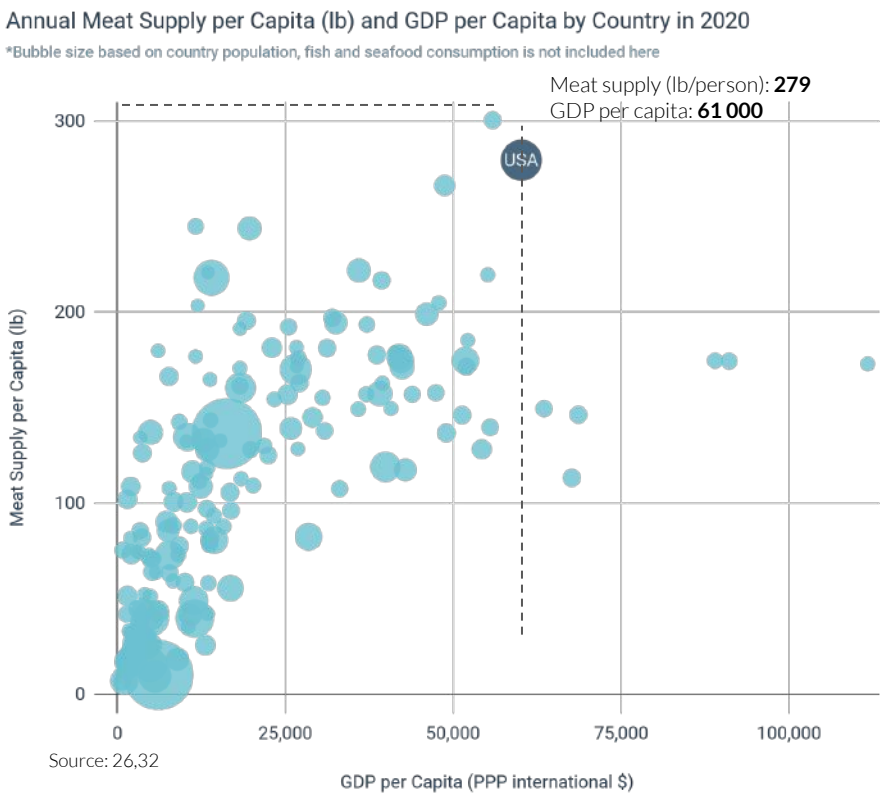
Source:26

While the worldwide volume of wild-caught seafood has largely remained the same since the late 1980s, the amount produced through aquaculture has risen dramatically. This growth has largely come from outside of the United States. Around 90% of all aquaculture volume, close to 115 million tonnes in 2021, is produced in Asia. Even with seaweed excluded, Asia's share is more than 80%, with China, India and Southeast Asia contributing the most to the region's dominant performance..[26] Europe and Latin America also play important roles in aquaculture, though their production is much smaller than Asia's. They are known for farming high-value species like Atlantic Salmon and Whiteleg Shrimp.

Globally, the United States ranks as a relatively minor player in aquaculture, currently positioned 18th worldwide (NOAA), a decline from its previous status among the top five producers. The U.S. imports between 70–85% of its seafood, with over half of these imports coming from foreign aquaculture. This reliance on imports has led to a significant increase in the national seafood trade deficit, reaching $17 billion in 2020.[31]

Aquaculture's potential to meet US food demand

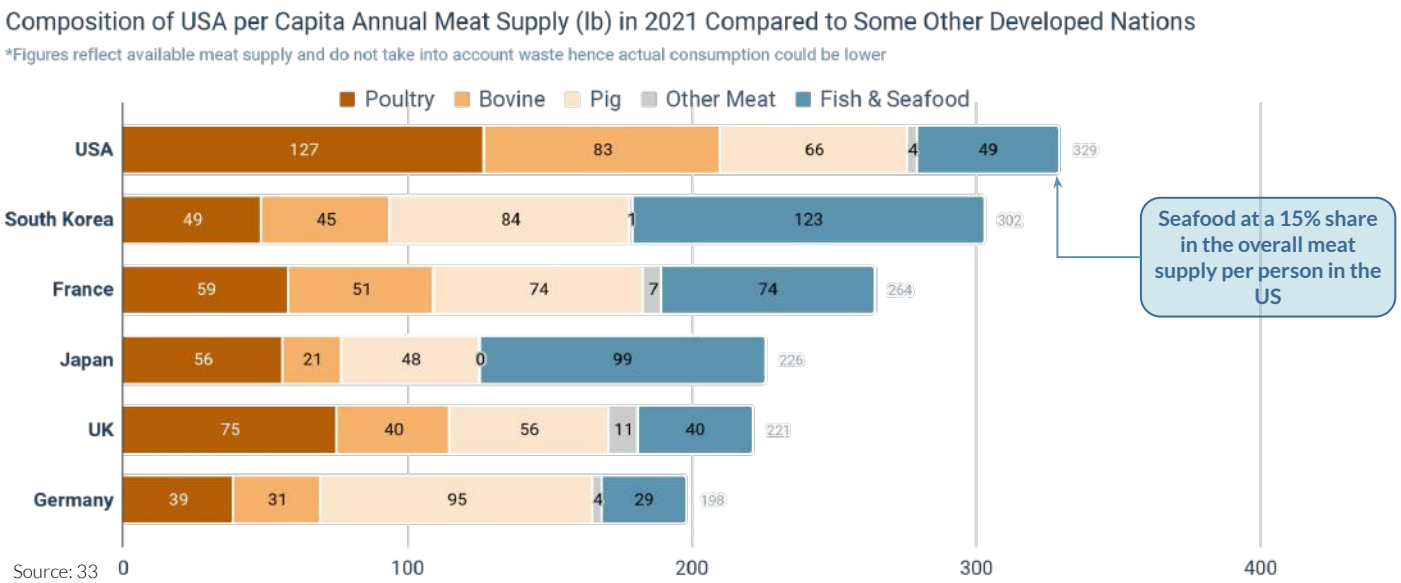
Figure 8 - Annual Meat Supply per Capita



Source: 26,32

The United States has one of the highest meat demand per capita figures in the globe. The supply of meat and a country's economic wealth are strongly correlated. Since the US is one of the strongest economies in the world, with high population and strong appetite for meat, this means that the US has a high meat demand both in absolute terms and also per person. According to the FAO, in 2020, on average, a US person had almost 280 lbs of meat supply available.[26] This figure is calculated by adding up all meat production and imports in a given year and dividing it by the population, but it does not account for edible weight conversions or food waste. Therefore, actual per person consumption is usually considerably lower than this figure. Still, this allows for a comparison with other nations - and the results are clear. The US consumes vast amounts of meat annually and has done in the past too, with only a slight increase in recent years in available supply.

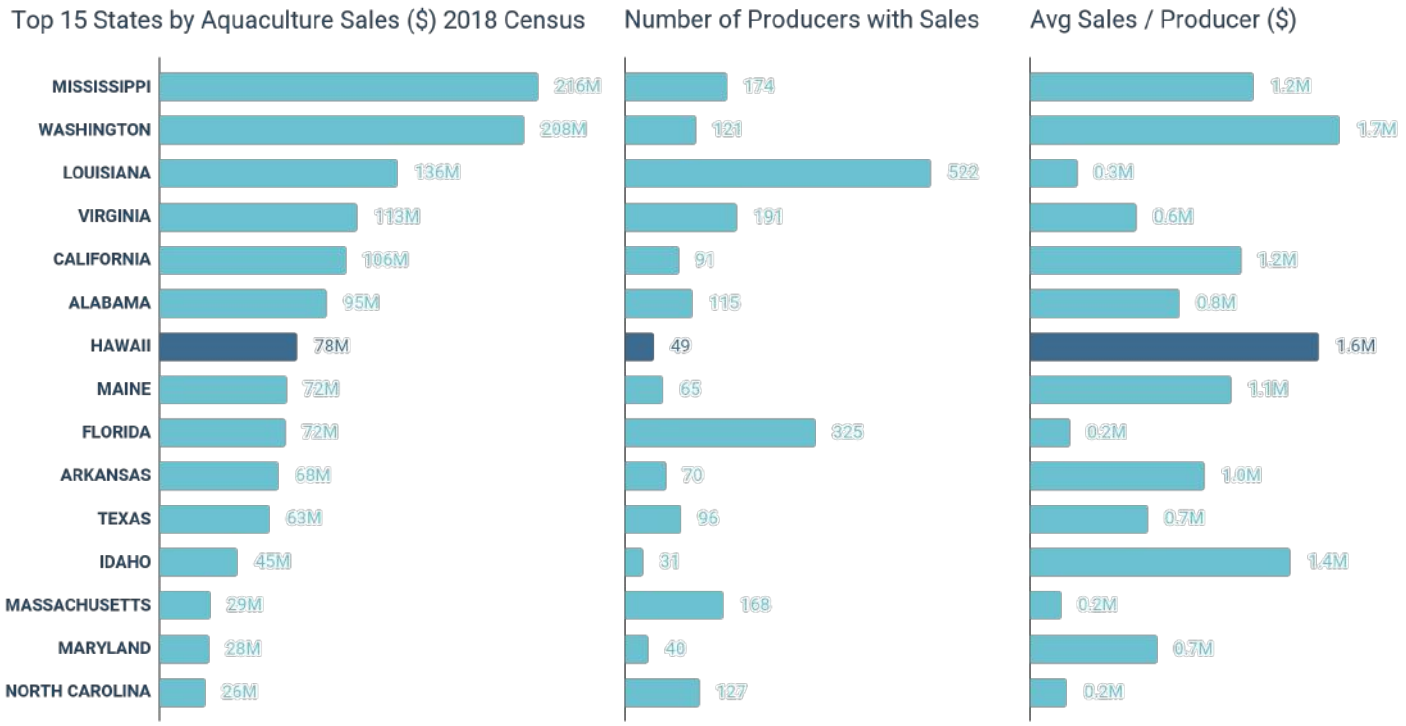
When it comes to meat supply, every nation has quite a unique, different composition of what that meat supply is made up of. As a result of economic, geographic, and cultural differences, some countries tend to consume more seafood than others. Below, the US is compared to a sample of other high population, developed countries with strong economies. It is clear that meat consumption patterns differ significantly, for instance, in many coastal Asian countries there are high levels of seafood availability. As shown by the FAO's meat supply statistics, in the US the contribution of seafood to the overall available meat supply per capita is roughly 15% or 49 lbs as reported in 2021.[26] Several studies and organizations (such as NOAA) are promoting the regular consumption of seafood for health benefits. In the past years, there was already slight growth in US seafood consumption , but any further increase means the US will need to either increase domestic seafood production or rely even more on foreign trade.



Source: 33

In a US context, Hawai'i is among the leading states when it comes to sales of aquaculture production with relatively small number of producers and a consolidated sector.

Figure 9 - Top Aquaculture Sales



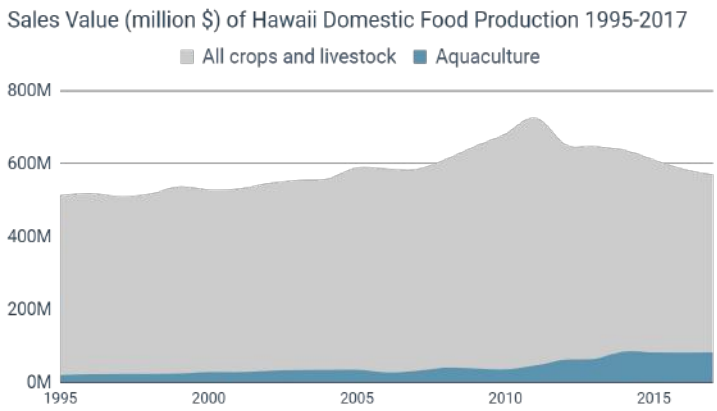
Source: 34

According to the USDA National Agricultural Statistics Service (NASS) aquaculture census, Hawai'i was ranked 7th in aquaculture sales among U.S. states based on data from 2018. The state generated about $78.5 million in sales, which is notably high considering Hawai'i's population is much smaller than some of the other leading states in aquaculture sales. Additionally, Hawai'i's unique status as a major tourist destination, attracting far more visitors than its residential population, opens up additional markets for its local seafood beyond just its residents.

Compared to other states, the number of operating aquaculture businesses (farms and producers with recorded sales) with sales was fairly low, only 49 producers, as reported by NASS. In return, the average sales / producer was among the highest among the member states, around 1.6 million dollars per business. This indicates that Hawai'i's aquaculture sector is quite consolidated, relying on a small number of key players. This pattern of consolidation is often seen in other regions and in industries where aquaculture has reached a certain level of maturity, similar to the salmon farming industry in major producing regions like Norway and Scotland, where just a few companies now account for more than 80% of production volumes.

Local food production in Hawai'i has been decreasing since the early 2010s with both crops and livestock sales declining and only aquaculture sales figures showing growth.

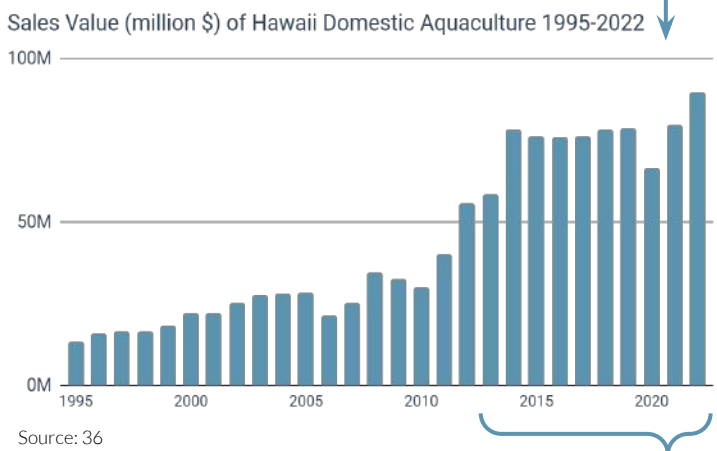
Figure 10 - Annual Meat Supply per Capita



Source: 36

Amidst a decreasing local food production trend, Hawai'i aquaculture demonstrates visible growth.

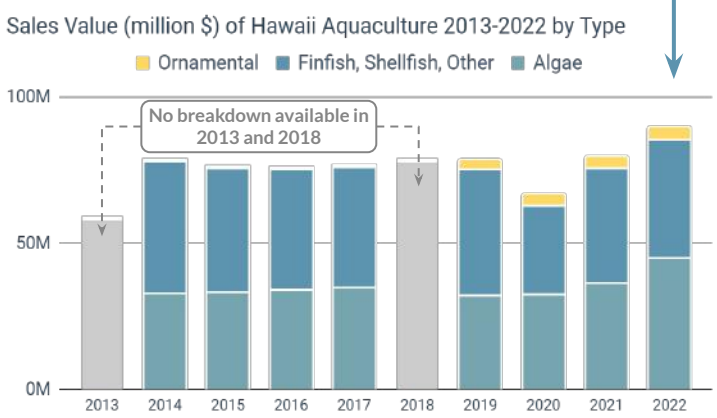
Figure 11 - Sales Value



Source: 36

Aquaculture sales heavily relies in algae, which had the most contribution in last year's increase.

Figure 12 - Sales Value by type



Source: 37

In the past decade, Hawai'i has experienced a moderate decline in overall local food production. Sales value of sugar cane, pineapple and other crops have shown a significant decrease since the early 2010s, and livestock production showed a gradual decline too. Since its peak value of around 720 million dollars in 2011, the general trend pointed downwards in sales value.[36] This, considering that food prices are usually trending up as a result of price inflation, suggest that production volumes have been decreasing even more dramatically.

The exception from this trend was the growth of the aquaculture sector, which showed an annual growth rate of 7.6% in sales value between 2011 ($40 million) and 2022 ($89 million) as reported by the DBEDT. Arguably, at least a part of this growth can be attributed to the general food inflation rates, which were high - especially in 2022 when the sector showcased a 12.5% growth in sales compared to the previous year. It is also worth noting that the initial high growth of the sector in the early 2010s has since slowed down and more or less plateaued.[36]

In terms of the composition of these aquaculture sales, much of the value comes from algae production. This sector has seen growth over the past 2-3 years, increasing from $33 million in 2020 to over $45 million in 2022. While a consolidated, high volume sector can come with economic synergies and efficiencies, at the same time relying on a small number of species / product type may pose considerable risks and dependencies as well for the sector. The contribution of finfish, shellfish and other species stayed roughly the same, around $40 million in 2021-2022.[37] The same can be said for ornamental fish, but with regards to a much smaller share.

The unique tourism profile of Hawai'i presents strong opportunities for local aquaculture growth.

Hawai'i Residents

- **1.455 million residents** live in Hawai'i based on the 2020 population census
- This translates to around 530 million "feedable" days annually (1.455m * 365)

Group Profile Assumption: When it comes to food, residents are more price conscious but they also care more about health, the environment, sustainability, and local community development.

Visiting Tourists

- **9.2 million visitors** arrived in Hawai'i in 2022 according to the official visitor statistics
- With an average stay length of 9.2 days, this resulted in over 85 million visitor days

Group Profile Assumption: Tourists tend to value local food delicacies and spend more money on eating out in restaurants, purchasing high quality food that is specific to the given region.

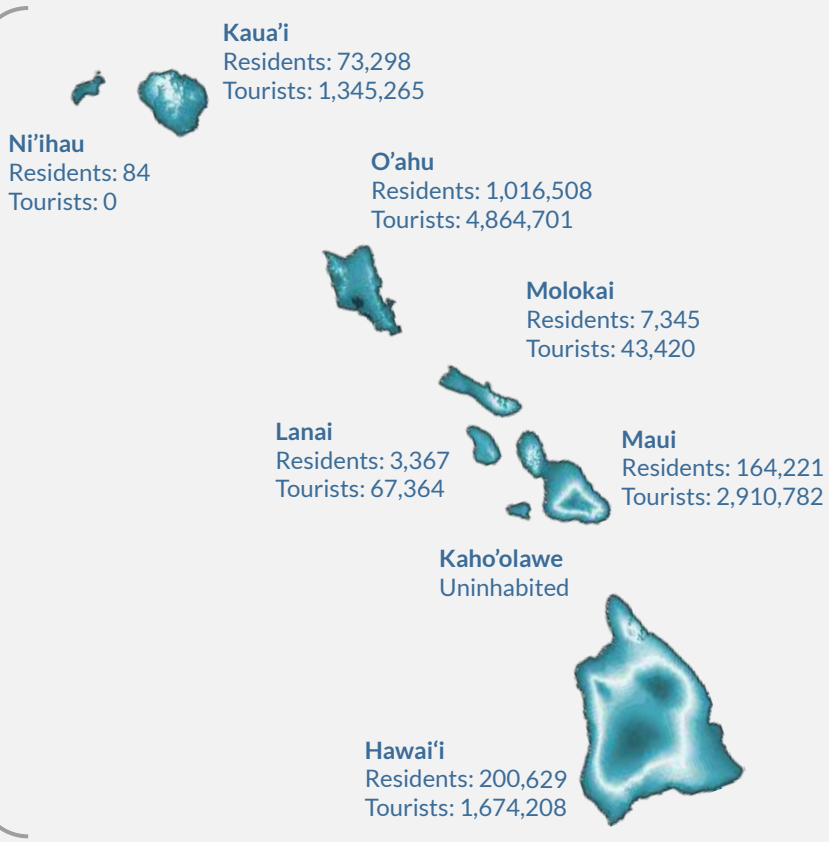
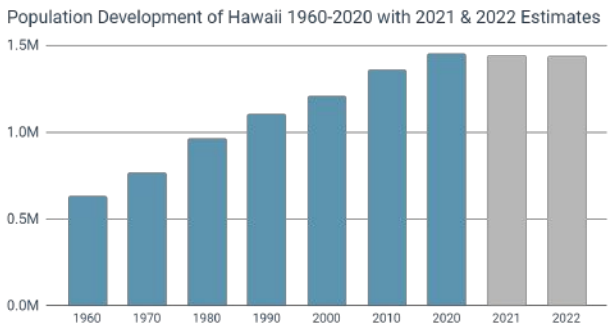
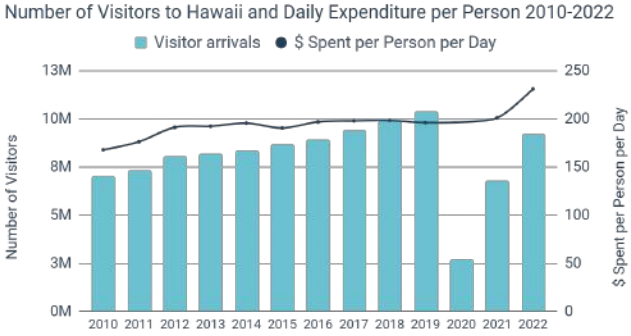


Figure 13- Population in Hawaii



Source: 45

Figure 14- Number of Visitors to Hawaii and Daily Expenditure



Source: 38

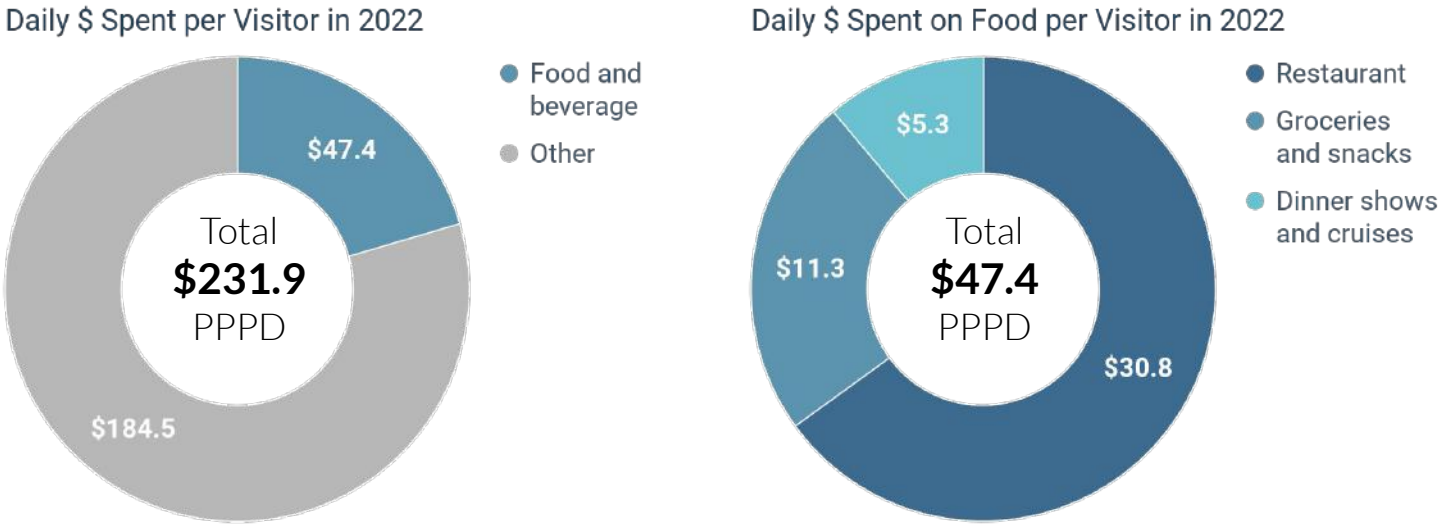
The resident population of the islands has grown rapidly in recent decades. From around 0.6 million people in the 60s, the population more than doubled to reach close to 1.46 million in 2020. Data and estimates of the Department of Business, Economic Development & Tourism (DBEDT) shows that population in recent years has plateaued and forecasts expect it to further stagnate or slightly decrease in the upcoming 2-3 years and float around 1.44 million.

After a strong setback caused by the global COVID pandemic, Hawaiiantourism is on track to get back to pre-COVID levels. 2022 visitor numbers surpassed 9.2 million and DBEDT's forecast predicts that this figure will exceed 10 million visitors in 2024, resulting in close to 90 million visitor days, significantly boosting visitor expenditure on the islands. Average daily expenditure has been increasing, especially in last years' high inflation economic environment. The majority of visitors are from high income markets such as the US mainland, Japan, or Canada. [38]

Food and eating out accounts for a significant share in daily tourist expenditure, which presents great opportunities for high value local produced seafood products.

Tourist food consumption habits tend to differ significantly from local consumption. In the case of Hawai'i, the daily average expenditures per visitor have increased steadily in previous years to reach $232 per person per day (PPPD) in 2022 according to DBEDT visitor statistics. The biggest element in spending was unsurprisingly lodging, a little over 46% of the total. However, the second biggest slice in daily expenditures was food & beverage with a share of 20.4% ($47.4), putting the category ahead of transportation (11%), shopping (10%), and entertainment (9%).

Figure 15- Daily Spend per Visitor and Spend on Food per Visitor

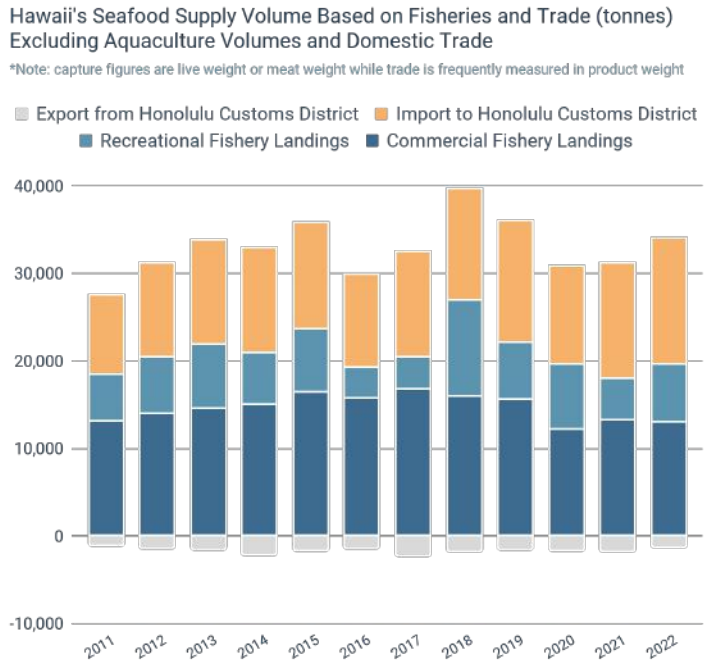


Source: 38

Within the food & beverage category, by far the most money was spent on eating out in restaurants. In 2022, roughly two thirds of all food & beverage spendings by visitors were falling into the restaurant category, which meant $30.8 or around 13.3% of the total daily spending. Capturing just a proportion of these spendings with local aquaculture produced seafood could result in tremendous economic value, given the approximately 85 million annual visitor days and the willingness of visitors to pay premium price for locally sourced sustainable and high quality seafood. As an example, by assuming that an average of $5 share can be captured by locally farmed seafood of the $47 daily food & beverage spending, and then calculating with the 2022 visitor days, this would translate to $425 million in sales. [38]

Hawai‘i is heavily dependent on seafood imports from other countries, which, given its unique location, is a costly operation.

Figure 15 - Hawai‘i Seafood Supply

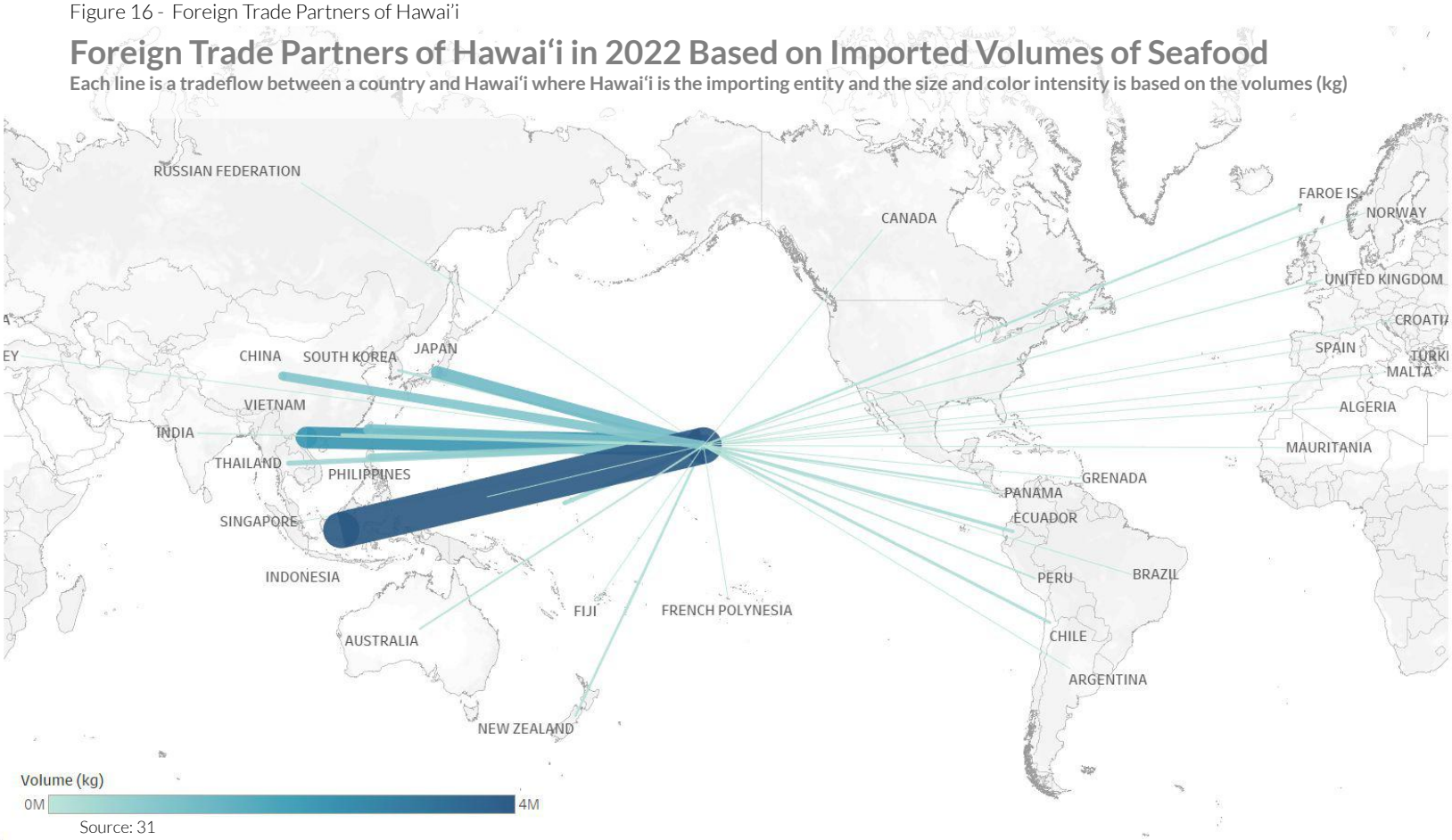


Source: 31

While commercial fishery landings decreased strongly in the past 5-6 years, the volume of seafood imports from foreign countries increased substantially. Between 2011 and 2022 the annual average growth in import quantities was 4.3%. In 2022, the imported volumes peaked at 14 000 tonnes, while just a decade before in 2011 this figure was slightly below 9 000 tonnes based on data from NOAA. Similarly to fisheries, the export quantities have also been declining since 2017 and by 2022 the export-import ratio was less than 1 to 10.

Most of the foreign seafood trade partners of Hawai‘i are East and Southeast Asian countries. The largest quantities according to 2022 import statistics arrived from Indonesia, Vietnam, Japan, Taiwan, and China. The key products / species imported were dominantly tuna, shrimp, salmon, squid, and dolphinfish but in smaller quantities a wide variety of marine and freshwater fish were also part of the import mix of 2022. [31]

Figure 16 - Foreign Trade Partners of Hawai‘i



Source: 31

Towards Sustainable Aquaculture

CHAPTER 4

Socio-Economic & Environmental Benefits for Hawai'i

Photo: Oceanic Institute of Hawai'i Pacific University

A holistic approach to protect, produce & prosper from ocean activities

The US is a committed member of the inter-government partnership network of the High Level Ocean Panel in fostering a sustainable ocean economy agenda. In 2021, the US joined this coalition, aligning with 18 global leaders from six continents who are committed towards unlocking the potential of the ocean economy. The Ocean Panel has proposed a transformative ocean action agenda that moves beyond the conventional belief that economic growth must come at the cost of environmental protection. This new holistic approach emphasizes cooperation and partnerships among diverse stakeholders to fulfill three critical goals, the three Ps - protection, production, and prosperity—in both current and future ocean activities:

- protect: reduce greenhouse gas (GHG) emissions while safeguarding biodiversity;
- produce: contribute to sustainably powering and feeding a planet of 9.7 billion people in 2050; and
- prosper: create better jobs and support more equitable economic growth, household income and well-being. [39]

High socio-economic returns from sustainable ocean-based investments

According to the High-Level Ocean Panel, sustainable ocean-based investments (including different sectors) could yield returns at least five times greater than the costs over a 30 year period (2020-50). The Benefit-cost ratio varies across sectors and interventions, ranging between 3-to-1 (conservation & restoration of mangroves) and 12-to-1 (Scale up open ocean energy production).

"Every $1 invested in increasing production of sustainably sourced ocean-based protein (to ensure a healthy, balanced diet by 2050) is estimated to yield $10 in benefits."
[including wild-capture fisheries and aquaculture production][39]

Hawai'i's rich marine biodiversity and strategic Pacific location present a unique opportunity to lead in improving its aquaculture development. The state's extensive coastal and oceanic areas hold untapped potential for substantial economic, environmental, and social benefits, particularly through sustainable and responsible aquaculture. Hawai'i's move towards sustainable aquaculture development could set a global example, offering economic, environmental, and social returns that significantly outweigh the costs, marking it as both a responsible and profitable venture.

Action-based scenario for Hawai'i for a sustainable pathway of aquaculture development

The sustainable aquaculture production pathway is likely to result in a more balanced and resilient sector, considering environmental, economic, and social factors. While the existing status, with less interventions, may offer short-term gains, the long-term sustainability and resilience of the aquaculture industry in Hawai'i depends on transitioning towards more sustainable practices.

Hawai'i stands at a crossroads, faced with the consequences of choosing between the current state of the aquaculture production landscape and a sustainable pathway for aquaculture production development. The public is left with a call to action, urging collective efforts to preserve Hawai'i's marine heritage for future generations. The choice is clear - a sustainable pathway is not just a choice for the environment, but a commitment to the identity, culture, and prosperity of Hawai'i.

There is much room to diversify Hawai'i's aquaculture industry towards a more sustainable and resilient one, however these developments need to be guided by a clear value proposition and a pathway that addresses the current industry gaps and barriers outlined.

Current practice and a future sustainable pathway for Hawai'i's aquaculture sector

Hawai'i holds significant promise for a sustainable ocean economy transformation. A sustainable pathway for Hawai'i's aquaculture promises environmental benefits, economic growth, social well-being, biodiversity conservation, innovation, and enhanced tourism experiences. The table below provides a comparative analysis of current practices and the emerging sustainable pathway, considering aquaculture´s environmental, social, and economic dimensions:

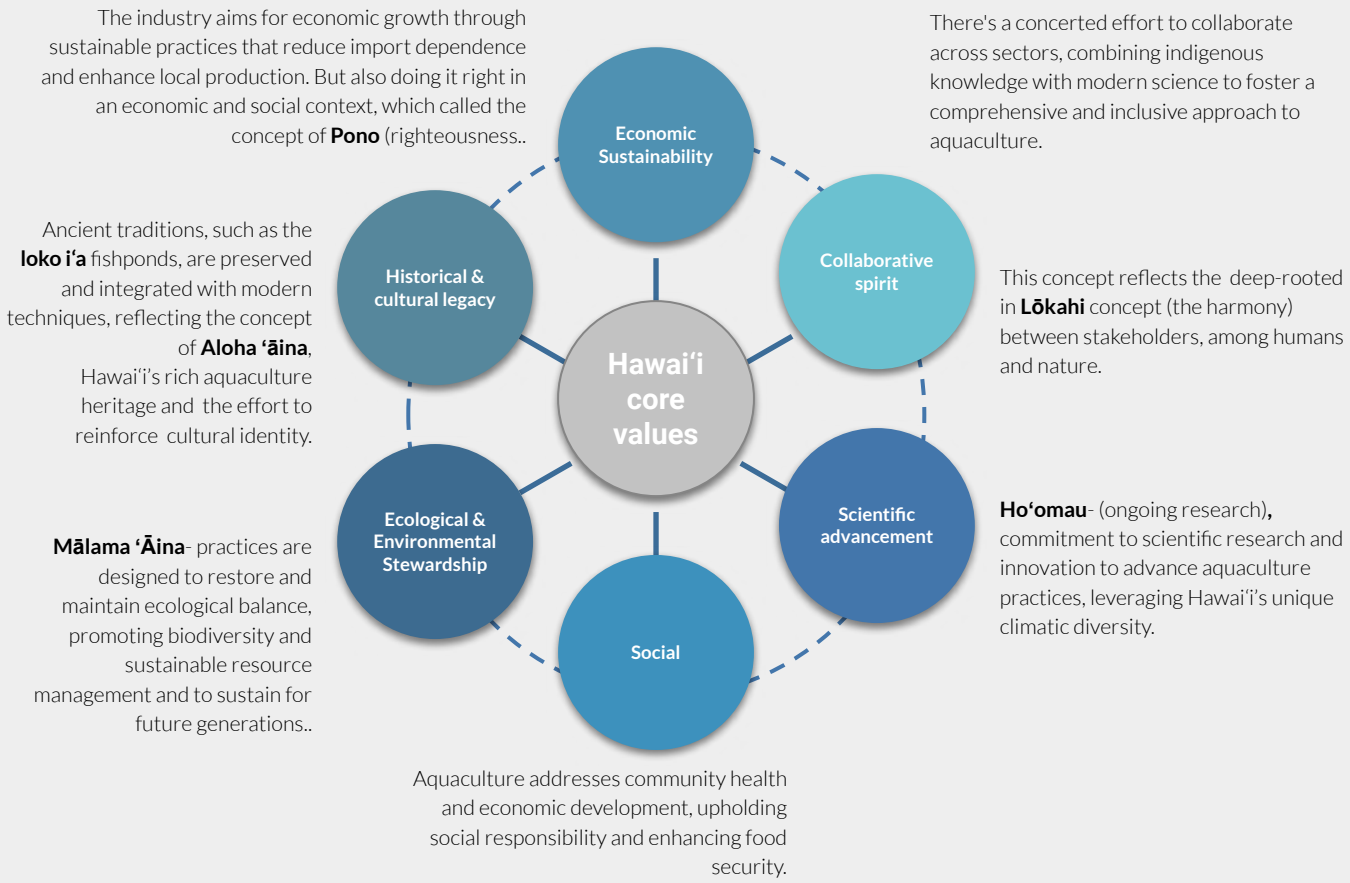
Table 3 - Current Landscape vs Sustainable Pathway

	Aspect	Current Landscape	Sustainable Expansion Pathway with Aquaculture
Environmental Impact	**Carbon Footprint**	High due to current dependency on imports and air freight transportation of seafood products: Importing seafood by air involves significant carbon emissions, making Hawai'i´s seafood consumption environmentally unfriendly.	Significantly reduced with local aquaculture production: local aquaculture production reduces the need for transportation and long distance air freight, decreasing significantly the overall carbon footprint of the value chain.
	Ecosystems	Potential negative impacts on local ecosystems: wild fisheries practices can lead to habitat degradation and pollution.	Positive or neutral impact on ecosystems: Adoption of restorative aquaculture methods aimed to restore ecosystems: Focus on generative and regenerative farming practices.
	Biodiversity & Habitat Provision	Limited range of species: conventional practices often focus on a few species. Not yet maximizing the benefits of endemic regenerative and generative species.	Diversify species, tailored to local environment and climate adaptation: programs and methods to promote species diversity for expansion of aquaculture.
Economic Impact	**Benefit Technology & innovation**	Limited funding and permitted space on/offshore for testing of new technology and innovations for aquaculture development	Innovative methods i.e precision farming, or novel farming systems, can enhance production efficiency, lower environmental impact, reduce costs, and potentially open up new markets for sustainable aquaculture products.
	Viability & Profitability	Vulnerable to market fluctuations: price volatility can affect profitability.	Market development to secure more stable, sustainable profitability for farmers: all year production with sustainable practices aim for consistent profits and premium prices.
	Viability & Local Development	Limited local economic impact: a significant portion of profits may leave the local economy from importing seafood out-of-state and internationally.	Supporting more local farmers in island communities to boost local economy and job creation: local production generates jobs and economic benefits.
Social Impact	**Food Security**	High reliance on imports: increased dependency on imports raises concerns about long term food and nutritional security.	Decreased reliance, increased local supply: a sustainable approach enhances food nutritional security.
	Community Benefits	Limited local benefits: profits may not always directly benefit local communities.	Direct benefits like job creation and education, technology advancement. Sustainability generates local benefits.Integration of eco-aquaculture with tourism for educational experiences: sustainability enhances tourist experiences.
	Community Health	Limited or only seasonal access to locally produced seafood.	Improved access to nutritious local seafood: sustainability supports community health through local food sources.
	Cultural Identity	Only a moderate focus on local pride in seafood consumption	Locally Hawaiianproduced identity branding, encapsulates the essence of local seafood production rooted in Hawaiianculture and sustainability.

Hawai'i's rich cultural heritage is embodied in its aquaculture practices

Grounded in traditional and cultural practices, Hawai'i aquaculture represents a legacy of careful ocean stewardship, effective resource management, and a commitment to sustainable practices in ocean management. These fundamental principles are key in steering the industry towards a harmonious balance that incorporates both socio-economic and environmental considerations. This approach also ensures that aquaculture practices are grounded in the local context of Hawai'i's ocean economy.

Figure 16 - Hawai'i Values



Socio-Economic gain of sustainable aquaculture development

Developing Hawaiian aquaculture and promoting the goals of Hawai'i's ADP Strategic Plan to increase aquaculture food production and supporting sustainability initiatives like restorative aquaculture can foster socio-economic and environmental value to Hawai'i island communities

In the subsequent sections, we will delve into HDOA's three tactical priority areas for supporting Hawai'i's aquaculture development, illustrating their role in providing socio-economic benefits to the community, businesses, and government organizations.

Figure 17- HDOA Tactical Priority

Commercial Activity

Developing commercial aquaculture that incorporates sustainable practices will not only enrich Hawai'i, but also contribute to the alleviation of global food shortages. The projects mostly involve local communities, providing educational and participatory opportunities.

Commercial activity fosters investment into infrastructure, technology, innovation and R&D, and necessitates the development of new resources and facilities on the Island. This, in turn, enhances employment prospects for Hawai'i's residents and boosts the overall economy of the island. Local markets and the tourism and hospitality industry will also benefit from increased availability of produce and the spillover effect of increased economic activity. Attracting new entrants to the industry and developing existing entities will also attract providers of technology and services in Hawai'i and may lead to investment into innovation hubs and similar industry-related centers. Regenerative and restorative practices and research into new technologies for a greener future should be incentivized. Restorative commercial farming will help restore damaged and overfished marine areas, and also contribute to the global reduction of Greenhouse gases (GHGs) and Hawai'i's attainment of the 2030 environmental SDGs. Developing aquaculture in Hawai'i has the potential to lead to significant partnerships between industry, state, and community to develop innovation and technology to care for and restore the ocean and arable land, contribute meaningfully to the economy and well-being of Hawai'i residents, and play a part in the easing the global carbon footprint.

Table 4 - Socio-economic Benefits

ENVIRONMENTAL VALUE			SOCIAL VALUE			ECONOMICAL VALUE		
R&D and sustainable practices	Commercially viable regenerative aquaculture	Habitat provision & animal health	Food security and food sovereignty	Community health & welfare	Capacity building and education	Direct market opportunities	Indirect opportunities	Job opportunities
Increased R&D and development of new technological solutions to environmental concerns / sustainable practices	Restoration of reefs, the sea floor, fishponds, seaweed grounds / bivalve and limu farming / local feed production	Creation of hatcheries and nursery grounds / genetic R&D for enhanced survival and disease-free waters	Increased local market / less imports = less dependence on mainland USA / better food prices / focus on local species	More work in community areas - less migration of labour / more nutritious & better quality products / potential for alternative livelihoods / increased tourism markets	More jobs and increased competition for talent = better wages / increased R&D and technology will attract top researchers and educators strengthening the sector	Increase of state budgets for R&D, grants, infrastructure, accelerators, etc. / potential for local feed mills & processing plants / attracts global service and technology providers	Attracts investment into R&D and infrastructure / increases tourism & hospitality industries / allows for development of sideline industries such as health products	More jobs, more training opportunities, increased labour retention / attracts excellent teachers and researchers increasing reputation of the sector

Environmental Restoration (Restorative Aquaculture)

Hawai'i's Ocean Resource Management Plan highlights the role of restorative aquaculture in supporting coastal ecosystems, enhancing water quality, and benefiting coral reefs.[40] Nearly all continents and most coastal countries have the potential for restorative aquaculture in marine environments when considering enabling environmental, socio-economic, and human health factors for development .[24]

Limu farming, with its ecological and economic advantages, helps in erosion prevention, oxygen production, and serves as a crucial part of the marine food web. Limu farming is essential for supporting local fisheries and mitigating global warming through carbon sequestration. Restorative aquaculture promises significant environmental, social, and commercial benefits for Hawai'i, fostering food security and lessening dependence on external funding.

This form of aquaculture is intrinsically linked to a thriving tourism industry and healthy fisheries, with potential for substantial economic growth. Successful aquaculture activities that achieve restoration of degraded coastal habitats can have a ripple effect and aggregate large-scale economic worth. Similarly, greater investment and development into restorative aquaculture can accelerate businesses and bring significant yields and returns to the state. Restorative aquaculture provides an immense opportunity to invest in green workforce development and upscale the labor force to compete in the global market. This enhancement of economic growth in a novel sector will allow Hawai'i to become more self-sufficient, relying less on imports and utilizing existing resources while building an economy that serves and is driven by the local population. There are also the economic opportunities that come with the ecosystem services provided, which could save the state resources it currently spends on direct water treatment, such as nitrogen removal. Once native Hawai'i species prove their efficiency to provide these ecosystem services and they can be quantified, nothing stands in the way for Hawai'i.

The decline in Hawai'i's biodiversity risks its ecosystem, economy, and native cultural practices. Restorative aquaculture respects this heritage, prioritizing native species and community-led management, which strengthens local connections. Locally grown products are fresher and more nutritious compared to imported goods, which lose freshness during transportation. Focusing on local consumption, Hawai'i's aquaculture can lead towards greater self-sufficiency.

Table 5 - Socio-economic Benefits

ENVIRONMENTAL VALUE			SOCIAL VALUE			ECONOMICAL VALUE		
Water quality improvement	Climate change mitigation & adaptation	Habitat provision	Cultural significance	Community health	Alternative livelihoods	Direct market opportunities	Indirect opportunities	Job opportunities
Removal of excess nitrogen, phosphorus and suspended solids from surrounding environments	CO^2 and nutrient sequestration / Ocean acidification mitigation / Carbon reduction potential of end product	Creation of structured habitat for fish and inverte-brates / hatching and nursery grounds / enhances biodiversity	Restoring indigenous culture / Preserving intergenerat ional knowledge / Reconnectin g to the ocean	Healthy and accessible food provision / nutritional benefits / food security	Coastal community resilience / Small business ownership & wealth creation / inclusion / climate justice	Commercially viable local or export market for product or application with further growth opportunities	Waste water treatment savings / blue carbon & nutrient credit markets / increased fisheries value	Direct employment growth potential / productive training opportunities and retention of talent

Support Equipment & Services (Innovation)

Hawai'i has hosted various research initiatives focused on developing remote monitoring and maintenance technologies, exploring free-floating open ocean cage systems, and investigating alternative options for fish feed. While rich in R&D, Hawai'i needs more technology and service providers in areas to capitalize its commercial blue food production. An inclusive category that encompasses value-added processing and other services to increase the efficiency of aquaculture operations and the effectiveness of related processes. A primary focus is developing new opportunities through cross industry innovation in aquaculture IP, equipment and support services.

An expanded service sector would attract businesses, researchers, and innovators, creating a competitive environment for technological advancement. This growth would offer more job opportunities, skill development, and reduce labor migration, while lowering production costs and reducing reliance on seafood imports. The enhanced sector would also attract investors, fostering innovation and the creation of new value-added products.

"Emerging and disruptive technologies will increasingly offer novel ways to enhance the production, profitability and sustainability of the farmed seafood industry globally. These technologies include genomic selection (GS), genome editing (GE), information/digital technology, recirculating aquaculture systems (RAS) and renewable energy, offshore (open ocean) farming, oral vaccines, novel marketing strategies with blockchain and the integration of different parts of aquaculture with the internet of things (IOT), among several others." [41]

Table 6 - Socio-economic Benefits

ENVIRONMENTAL VALUE			SOCIAL VALUE			ECONOMICAL VALUE		
Innovation for sustainable practices	Climate change mitigation	Habitat provision	Food security	Community health & welfare	Alternative livelihoods	Direct market opportunities	Indirect opportunities	Job opportunities
New technologies & automated solutions / competitive market for innovative designs	Lower carbon footprint / In-state services - less imports, less fossil fuel burnt	Local veterinary, pathology, animal disease experts will mitIgate against spread of disease / technology and services designed to protect ocean and land health and habitats	Companies that can provide infrastructure and technology and offer maintenance services to producers will speed up and increase production locally	More work opportunities and increased diversity in the job market / More training and skills development opportunities / Better marketing services will increase local sales	Competitive market environment will increase output, diversity and innovation for value-added products	An increase in availability of local services & technology will attract top entrepreneurs, industries, educators and innovators to Hawai'i / More efficient sector = less costly / Increase in tax collection by state	Larger, more efficient industry will increase tourism & hospitality industries / Better marketing to local consumers will reduce import reliance	Increased workforce requirements means more jobs for locals / the increase and diversity of available opportunities will reduce labour migration

CHAPTER 5

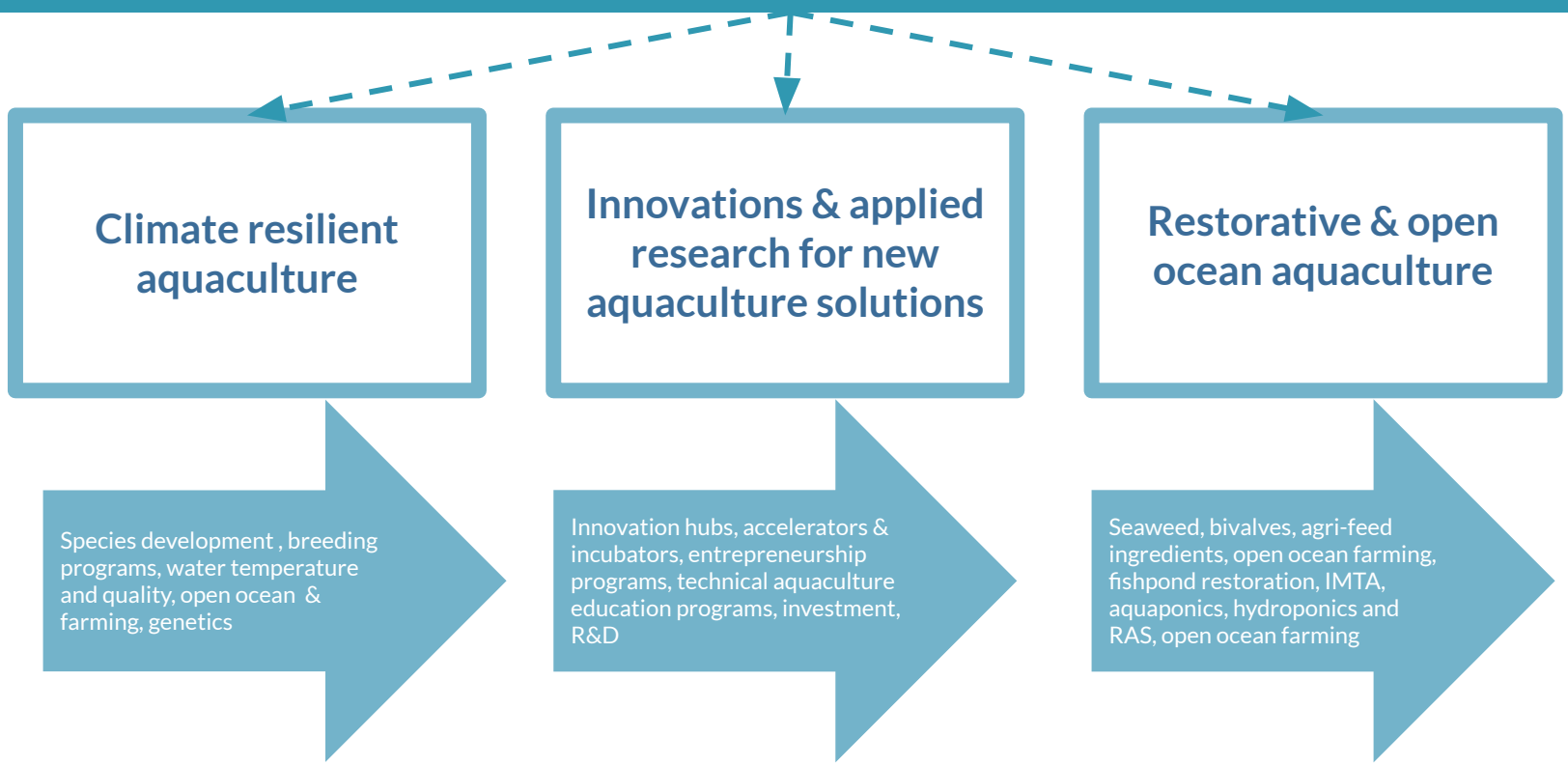
Hawai‘i’s Competitive Advantages

Hawai'i has an opportunity to take a leading position for the development of warm water aquaculture focusing on restorative and open ocean farming

Hawai'i's aquaculture industry is already well-established and the islands offer a competitive edge over mainland USA and other areas in a number of ways:

- The Hawai'i Islands have a favorable climate with critical biosecurity through natural isolation. The islands also have access to varied water temperatures - from warmer tropical water to pristine deep cold water. This gives Hawai'i the unique advantage of being able to farm a much wider variety of species compared to the mainland and elsewhere.
- An open ocean aquaculture licence has recently been awarded in Hawai'i - the first such licence to be awarded in the US - positioning the state at the forefront of open ocean aquaculture. This provides a unique opportunity to set a precedent for sustainable open ocean aquaculture that nurtures the environment, the community, and the economy.
- Hawai'i's fishponds are a unique part of the Hawaiian culture and identity. Restorative aquaculture at these sites, as well as regenerative projects such as limu and bivalve farming, are already ongoing in the state and have the support of the community at large. Initiating further projects and/or securing investment, infrastructure development, marketing and research to augment and stimulate these areas of aquaculture ticks all the boxes in terms of climate, community, and culture.
- Hawai'i's current aquaculture research environment provides an excellent infrastructure to test and validate new aquaculture concepts, but further investments to scale its applied research capabilities are needed. The universities of Hawai'i and the community colleges on the islands offer exceptional support to aquaculture R&D and capacity building, but dedicated technical educational programs for aquaculture is required to expand the knowledge base for the sector. Strengthening these relationships with the education sector could catapult Hawai'i to the forefront of aquaculture technology and innovation.

Based on preliminary research, Hawai'i is well-placed to position itself as a leader in:



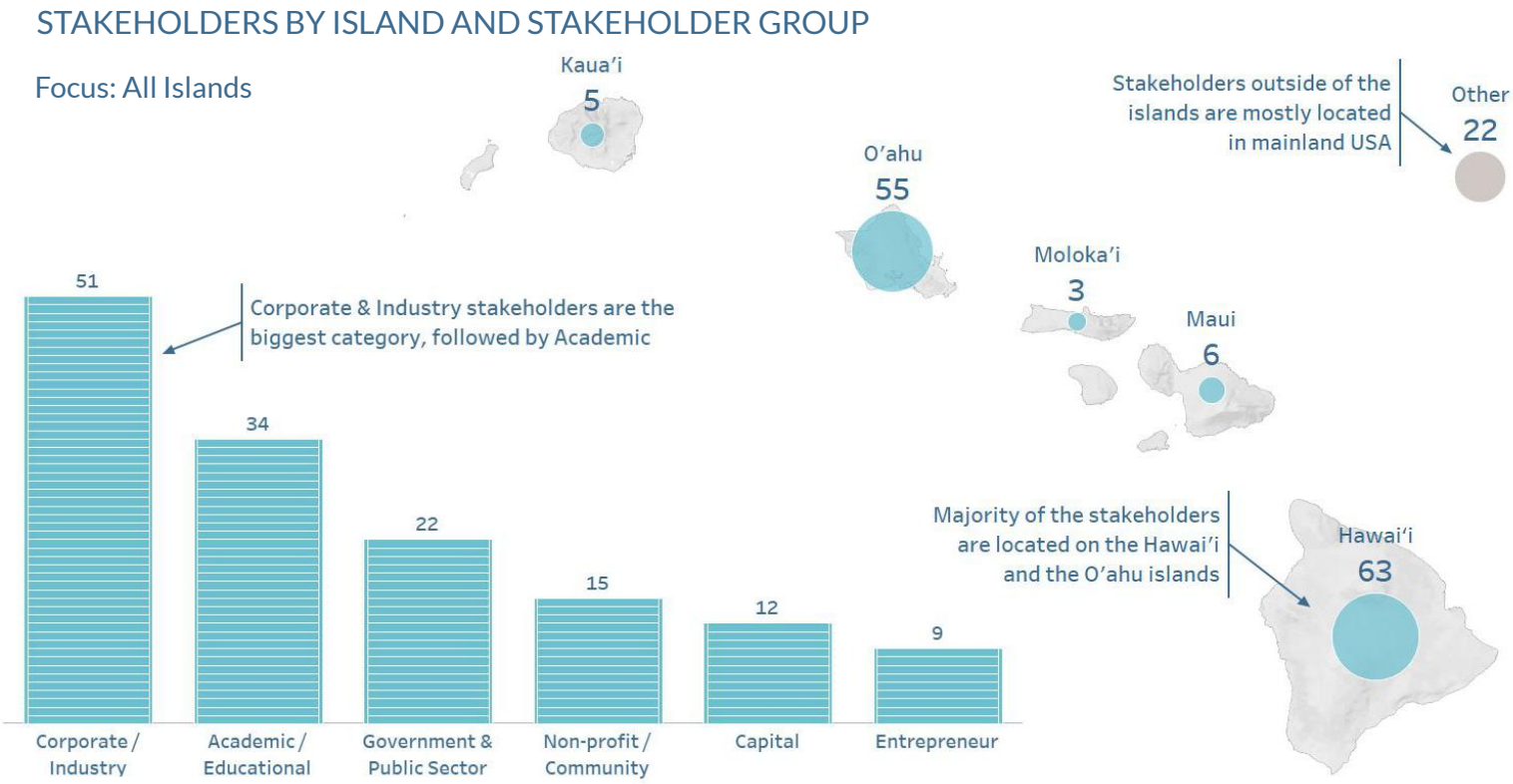
Hawai'i has a highly diverse aquaculture ecosystem that caters adequately to the current industry; however, there is room for improvement and development. Hatch has identified almost 150 stakeholders state-wide across six sectors: academic, commercial, community, government, capital, and entrepreneurs.

The state is home to internationally acclaimed aquaculture companies that are world leaders in their fields, such as Blue Ocean Mariculture, Cyanotech, Symbrosia, and Makai Ocean Engineering, amongst others. On the academic front, the Oceanic Institute at the Hawai'i Pacific University (HPU) on O'ahu is the forefather of all SPF shrimp broodstock and a world leader in RAS technology. There is a healthy non-profit sector, with Kua'aina Ulu 'Auamo coordinating a network of loko I'a communities and organizations and the Hawai'i Aquaculture and Aquaponics Association representing the industry on legislative issues. Hatch Incubator and Accelerator companies provide aquaculture start-ups with the impetus they need to enter the industry, and the Hawai'i Technology and Development Corporation (HTDC) is a dynamic state agency responsible for diversifying the economy by investing in technology and infrastructure.

The largest sector is the commercial sector, closely followed by the academic sector. The least represented sectors are the capital investment sector and the entrepreneur sector. The entrepreneur sector does cross-pollinate with the commercial sector and thus may be underrepresented in these figures. However, the lack of capital investors in the industry is worrying.

The strongest aquaculture hubs are concentrated on O'ahu and Hawai'i, the most populous islands. But significant contributions also come from other islands: Kaua'i Sea Farms on Kauai Island combines traditional methods with modern tech at Nompilo Fishpond, and Kona Bay Shrimp, a major SPF shrimp broodstock producer, is also based there. Maui has Kulahaven Farms, employing aquaponics for Rainbow trout farming, while Molokai boasts Molokai Sea Farms (working with SPF and SPR shrimp broodstock) and Hui o Kuapa, dedicated to fishpond restoration.

Figure 18 - Stakeholders Map



Hatch's global scan of innovation hubs (see appendix) proved that successful ecosystems are often built around strong research and educational facilities. The University of Hawai'i's (UH) Hilo campus and the Pacific Aquaculture & Coastal Resources Center (PACRC) are on the Big Island, as well as NELHA's HOST Park, a world-class aquaculture facility that attracts national and international tenants. These are major draw cards for the industry on Hawai'i. Commercial stakeholders dominate on Hawai'i, possibly due to the testing and validation facilities and pre-permitted aquaculture areas offered at NELHA.

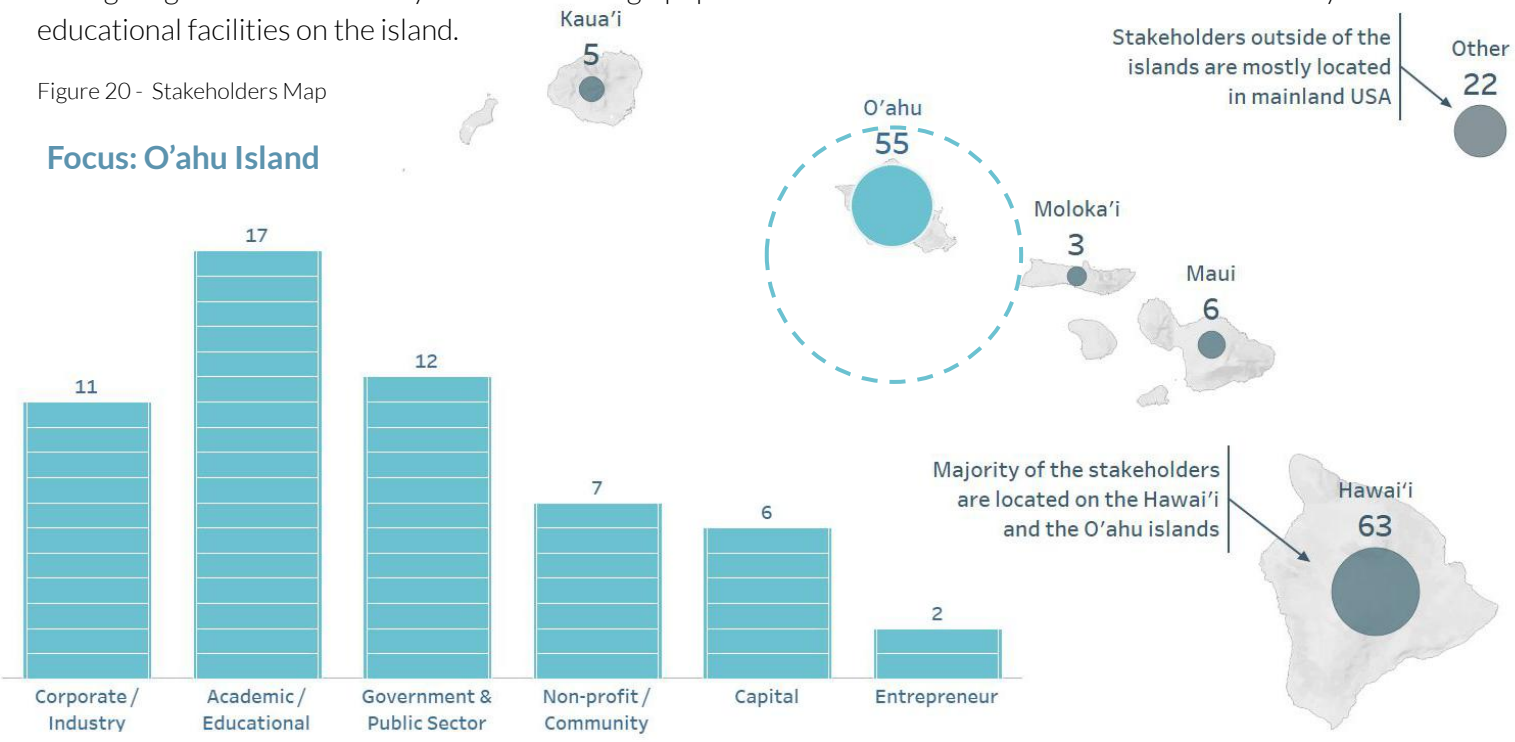
Figure 19 - Stakeholders Map

Focus: Hawai'i Island

O'ahu has an exceptionally strong research cluster, with UH Manoa being home to the School of Ocean and Earth Science and Technology (SOEST), the College of Tropical Agriculture & Human Resources, the Hawai'i Marine Laboratory, and the Sea Grant program. In addition, Honolulu on O'ahu is the seat of the government, which serves as a strong magnet for the industry. O'ahu has a large population of academic stakeholders due to the many research and educational facilities on the island.

Figure 20 - Stakeholders Map

Focus: O'ahu Island



On Hawai'i, ***NELHA*** offers fantastic facilities at its HOST Park, including tanks, classroom spaces, wet and dry labs, pumped sea water, and pre-permitted areas for testing and research purposes. Hatch Incubator and Accelerator companies (also based at NELHA) provide intensive boot camps for new entries to the industry, offering them networking opportunities, investment, access to R&D space and facilities, workshops, etc.

The ***Oceanic Institute (OI) at the Hawai'i Pacific University*** on O'ahu also offers pre-permitted areas for research, as well as tanks and laboratory space. They also supply some fish fingerlings from their hatchery to loko i'a for restocking the fish ponds.

The ***PACRC*** provides infrastructure needed for world-class aquaculture and marine science programs at UH Hilo, supports commercial aquaculture, fisheries and conservation in East Hawai'i. Resources include laboratories, tanks, research facilities.

Although OI and PACRC are already established, they still have space to be upgraded and expand with additional funding to reach their full potential.

Although Hawai'i's current aquaculture research environment provides an excellent infrastructure basis to test and validate new aquaculture concepts, there remains an acute need for further investments into Hawai'i´s infrastructure to accelerate applied research and innovation capacity across academia and the industry. Most infrastructure and supply chain requirements are only available on O'ahu and the Big Island. There are insufficient breeding facilities (broodstock, hatcheries, and nurseries) and no processing or cold storage facilities available to serve small scale producers. Existing breeding programs are mostly private facilities in vertically integrated companies. According to Hatch's research, there is only one government-run breeding facility at the Anuenue Fisheries Resource Center on O'ahu. Two diagnostic labs services the needs of the whole industry. Feed is almost exclusively imported, and wet and dry labs, offices, and working spaces are also limited. Maui, Kauai and Moloka'i are all significantly lacking in all infrastructure and services. The slow permitting process and the lack of infrastructure and service support it difficult for entrepreneurs grow their farm operations and for start-ups to validate or test their technologies and solutions.

Table 7 - Overview of critical infrastructure per Island

Infrastructure Type	Hawai'i	O'ahu	Kauai	Maui	Moloka'i	Total
Algae production facilities for feed or biofuels	4	2	1	0	0	7
Aquaponics / hydroponics	1	1	0	0	0	2
Broodstock	4	2	1	0	1	8
Genetics programs	5	1	1	0	0	7
Hatchery	9	3	2	1	0	15
Learning centers / tours	9	5	0	0	0	14
Nursery	4	3	2	0	0	9
Off-shore infrastructure / research	4	3	0	0	0	7
Office / working spaces / labs / equipment rental	4	3	0	0	0	7
On land grow-out tanks / testing facilities / RAS systems	7	4	1	0	0	12
Renewable energy R&D / solutions	5	4	2	1	0	12
Research facilities	12	7	1	1	0	21
Restoration R&D	0	3	1	0	0	4
Specialist equipment	1	3	0	0	0	4
Veterinary services	1	1	0	0	0	2
Total	70	45	12	3	1	131

Hawai'i's Aquaculture Ecosystem:
Highly diverse, primarily concentrated on Hawai'i Island & O'ahu

Figure 21- Hawaii´Aquaculture Ecosystem Map

*This graphic illustrates a non-exhaustive representation of aquaculture related stakeholders by sector and by island using company or institution logos.

Sector-dependent Infrastructure

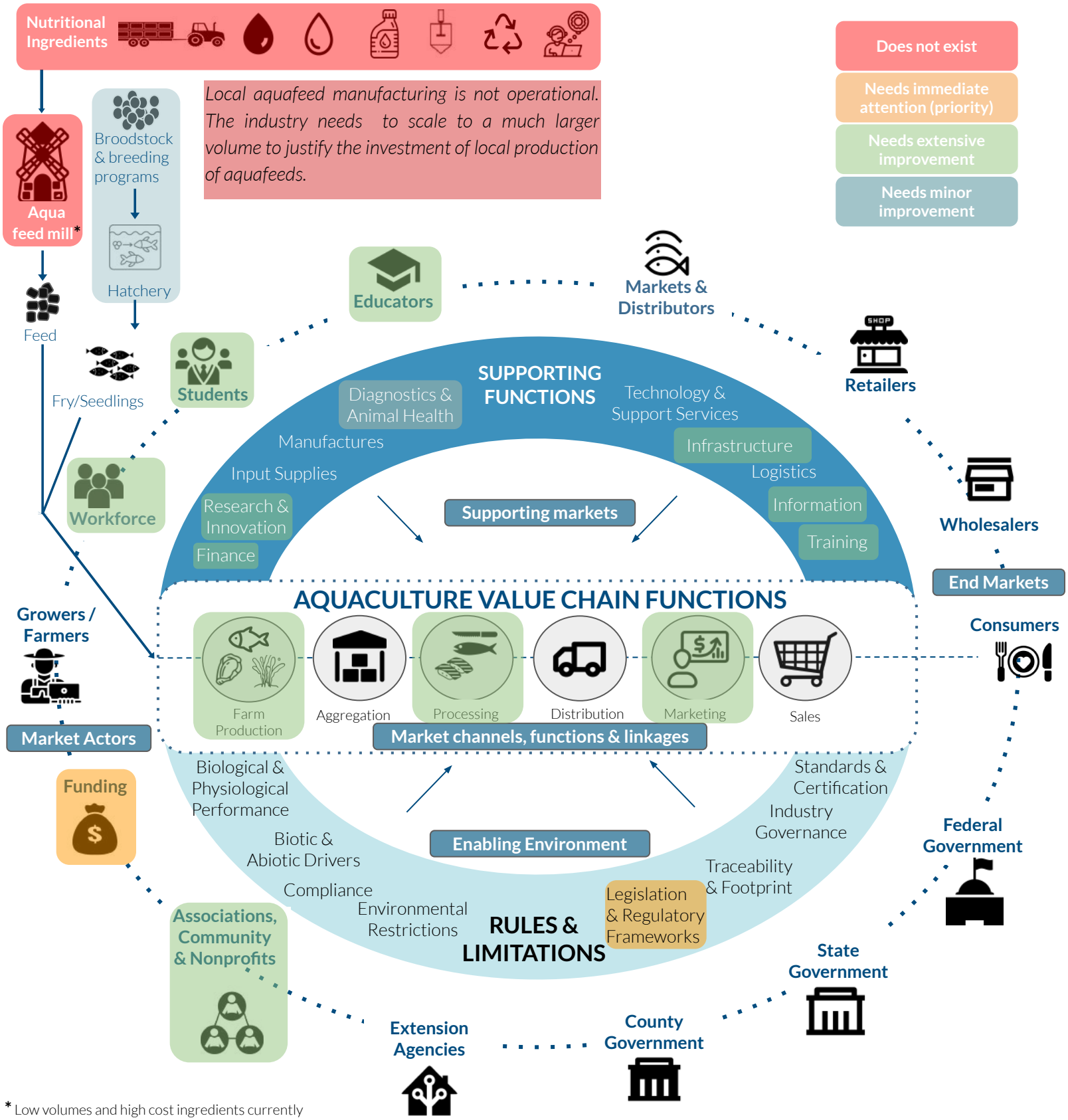
The corporate and industry sector operates the highest number of crucial infrastructure elements in Hawai'i, but most of these are for private, commercial use. Some companies open their facilities for research purposes, enjoying a symbiotic relationship with the research institute. Academic institutes provide diverse facilities, including labs, learning centers, tanks, genetic R&D, and veterinary / diagnostic services. According to the research, the government holds a substantially smaller proportion of the needed infrastructure for aquaculture operations, especially infrastructure related to supply chain requirements, such as breeding, feed, and processing, and training facilities for workforce development.

Table 8- Overview of critical infrastructure per sector. The table is illustrating sector-dependent affiliation of critical infrastructure separated by infrasture type

Infrastructure Type	Corporate / Industry	Academic	Governmnent	Capital	Total
Algae production facilities for feed or biofuels	6	1	0	0	7
Aquaponics / hydroponics	2	0	0	0	2
Broodstock	6	1	1	0	8
Genetics programs	5	2	0	0	7
Hatchery	13	1	1	0	15
Learning centers / tours	2	9	3	0	14
Nursery	7	1	1	0	9
Off-shore infrastructure / research	3	2	2	0	7
Office / working spaces / labs / equipment rental	0	4	3	0	7
On land grow-out tanks / testing facilities / RAS systems	7	3	1	1	12
Renewable energy R&D / solutions	8	3	1	0	12
Research facilities	9	8	3	1	21
Restoration R&D	1	2	1	0	4
Specialist equipment	1	2	1	0	4
Veterinary services	0	2	0	0	2
Total	70	41	18	2	131

Photo: Hawai'i Ocean Science and Technology Park

Critical to support a sustainable aquaculture industry are value chain services that support a fully integrated value chain. The figure below presents the status of existing as well as missing market actors and supporting functions for the case of Hawai'i.



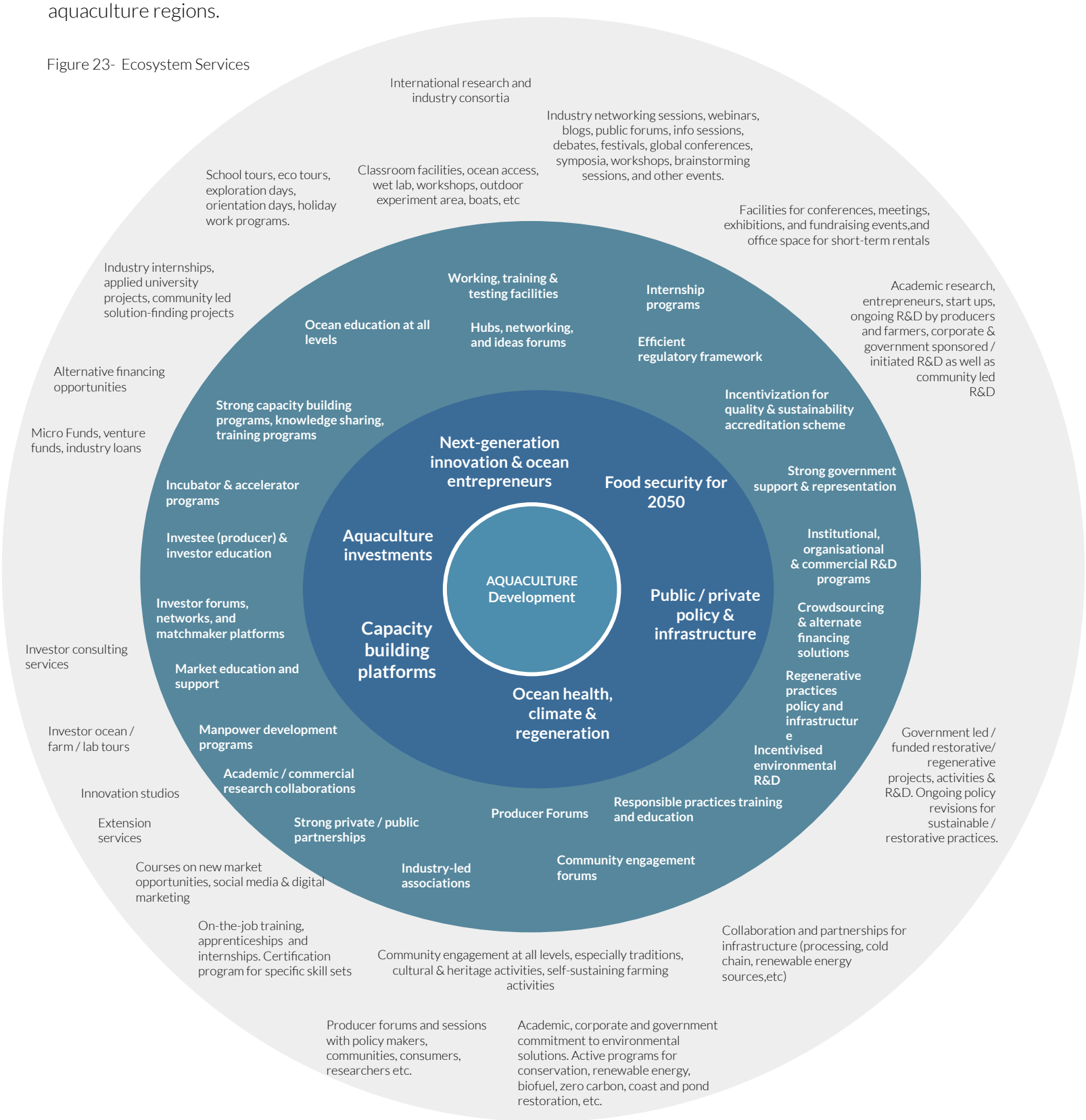
* Low volumes and high cost ingredients currently do not justify a local aquafeed mill

Figure 22- Value Chain Gaps

Ecosystem Services Are Required To Support a Sustainable Aquaculture Development

To operate efficiently and in order to grow the aquaculture sector, the industry needs certain facilities, services and activities to support it. Our research has identified "ecosystem services" that need to be in place in order to support the development of a commercial aquaculture sector. The graphic below showcases some of the services for the industry to operate at its full potential. Different ecosystems and environments will require different strategies, and this graphic only provides an overview of the types of services, facilities and activities that we have found in highly successful aquaculture regions.

Figure 23- Ecosystem Services



Area´s of Improvements for Hawai'i's Aquaculture Ecosystem

While Hawai'i has an established aquaculture industry, in order to sustain and grow the industry, it needs to expand and develop its services, resources and facilities. Many services and facilities are currently available in Hawai'i but they cannot sustain the growth of the industry in their current form. Hawai'i needs to innovate, encourage and incentivize the growth and initiation of facilities, resources and service in the state.

Figure 24 - Improvements for Hawai'i Aquaculture Ecosystems

Improvements for Hawai'i's Aquaculture Ecosystem

EXISTING SERVICES IN THE Hawai'i ECOSYSTEM	SERVICES EXIST BUT NEED IMPROVEMENT OR DEVELOPMENT	GAPS / EXTENSIVE IMPROVEMENT NEEDED
Strict regulatory framework and environmental protection policies	International research and industry project collaboration	Government funding & alternative financing opportunities
Academic research	Private / public partnerships, Industry networking sessions, matchmaker platforms public forums, info sessions, debates, festivals, global conferences, workshops sessions, and other seafood & aquaculture events.	Micro funds, venture funds, industry loans
Ongoing R&D by producers and farmers	Government sponsored more applied R&D	Industry representation in government
Government led / funded projects, activities & R&D.	School tours, eco tours, orientation days and holiday work programs.	Permitting processes and long term leasing. Open ocean permits and logistic and processing infrastructure
Academic, corporate and government commitment to environmental solutions	Regenerative practices & policy	Stakeholder sessions with policy makers, communities, consumers, researchers etc.
Active programs for conservation, renewable energy, coast and pond restoration, etc.	Incentivised environmental R&D	Industry-related courses on new market opportunities, social media & digital marketing
Investor consulting services	Well funded industry-led associations	Market education and support
Incubator & accelerator programs	Strong aquaculture capacity building programs, knowledge sharing, training programs	Public private (academic / commercial) research collaborations
	Commercial training & testing facilities	Training and education on responsible practices
	Central aquaculture hubs with consolidated resources	On-the-job training, apprenticeships and internships
	Policies for sustainable practices.	Certification programs for specific skill sets
	Community engagement between all stakeholder levels, especially traditions, cultural & heritage activities, self-sustaining farming activities	Aquaculture extension services
	Classroom demonstration facilities, ocean access, wet lab, workshops, outdoor experiment area, boats, etc	Applied university research & projects
		Community/industry led solution-finding projects
		Collaboration and partnerships for infrastructure (processing, cold chain etc.)

Hawai‘i Aquaculture Roadmap

CHAPTER 6

Tactical steps towards the goals of building sustainable aquaculture production and developing a viable research and development sector

Image: Ocean Era

Roadmap: Key Improvement Areas

Hatch Innovation Services was commissioned to make recommendations on how Hawai'i's existing Aquaculture Development Program (ADP) Strategic Plan can be improved. The objective of this report was to provide recommendations for key areas that local state and federal agencies can focus on to drive the industry forward and develop and grow a robust, sustainable food production industry that will contribute meaningfully to the economy, the community, and the environment.

Based on the research tools used for executing this report (incl. online survey, literature research and the 1-to-1 interviews with stakeholders across the aquaculture industry ecosystem) and taking into account HDOA's three tactical priority areas (Commercial Activity, Environmental Restoration, and Support Equipment & Services) as defined in the ADP Strategic Plan, ***Hatch has identified four strategic improvement areas for Hawai'i*** to focus on in order to achieve the overarching goal to increase aquaculture food production and restorative aquaculture initiatives:

REGULATORY DEVELOPMENT & EFFICIENCY

APPLIED RESEARCH & ENTREPRENEURSHIP

WORKFORCE DEVELOPMENT

ECONOMIC VIABILITY & GROWTH

The present chapter will focus on all four improvement areas, highlighting key improvement action areas and providing tactical steps for bringing each improvement area forward.

Photo : Big Island Abalone Company

Overview of Hawai'i's Aquaculture Roadmap

To Improve the
Aquaculture Development Program (ADP) Strategic Plan

ADP Strategic Plan

GOALS

The ADP has developed a 10-year strategic plan supporting the dual goals of increasing aquaculture food production and restorative aquaculture initiatives.

TACTICAL PRIORITY AREAS

- COMMERCIAL ACTIVITY
- ENVIRONMENTAL RESTORATION
- SUPPORT EQUIPMENT & SERVICES

Roadmap for Improving Hawai'i's aquaculture development plan

IMPROVEMENT AREAS

1	2	3	4
REGULATORY DEVELOPMENT & EFFICIENCY	APPLIED RESEARCH & ENTREPRENEURSHIP	WORKFORCE DEVELOPMENT	ECONOMIC VIABILITY & GROWTH
Simplify and consolidate regulation and regulatory processes and pathways for permit applications, streamline monitoring services by agencies	Develop a dynamic innovation ecosystem to build a pipeline of applied commercial solutions for warm water aquaculture	Build the future workforce, capacity building initiatives, aquaculture technical education and certificate programs and training	Support more public & private investment in commercial aquaculture production and supply chain services, market development and foster commercial partnerships

IMPROVEMENT ACTION AREAS

- **Streamlining permitting process for aquaculture**
- **Exploration of new aquaculture development zones**
- **Research permits**
- **Environmental reporting and public communication**
- **Commercialization programs for emerging species and technologies**
- **Stock enhancement program for loko i'a**
- **Investing in applied research infrastructure**
- **Specialized higher learning education programs in aquaculture**
- **Raise awareness of aquaculture careers**
- **Educational tours in partnership with farmers**
- **Innovation Cluster Program for the growth and development of Hawai'i's aquaculture**
- **Market activities**
- **Assessment of the Blue Carbon Market**
- **Access to Capital and funding**

MARKET ACTORS

- Government & Agencies
- Industry & Producers
- Educators
- Investors & Funders
- Associations Community NGO's
- Entrepreneurs

NETWORK & RESOURCES

Funding & Incentives
Public Private Partnerships & Collaborations
Market Development
Collaboration and Networking
Community Engagement

Recommendations for short-mid and long-term priorities of tactical actions

Short Term Priority-recommendations for the next three years

- *Streamline aquaculture permitting by promoting coordination and harmonization among regulating agencies.*
- *Stock enhancement program, including the development of state of the art multi-species hatcheries for stock enhancement recovery targeted for loko i'a and small-scale farmers*
- *Strengthen environmental data collection and public communication around environmental, economic, and societal sustainability from aquaculture production.*
- *Seek opportunities with private stakeholders to develop a centralized diagnostic lab*
- *Incentivize funding for more applied research and commercialization, as well as collaboration with industry on research topics.*
- *Secure more flexible permits for staff housing and leased land for staff, seasonal workers, and interns and develop low-cost housing options*
- *Support funding for entrepreneurship, accelerator and incubation programs to attract and grow new businesses and scale innovative aquaculture solutions*
- *Market insights and market development activities to incentivize investment to scale aquaculture production in Hawai'i, in recognition of the role aquaculture can play in reaching state food security, environmental and economic impact targets.*

Medium Term Priority-recommendations for the next five years

- *Quantify the social, economic, and environmental benefits and ecosystem services and products from restorative aquaculture (carbon sequestration, carbon dioxide removal (CDR), nitrogen uptake, etc.)*
- *Investigate the viability of a public-private partnership for a centralized processing facility together with cold storage for value-added seafood products*
- *Develop tailored aquaculture training programs and secure long-term funding to ensure continuity and effectiveness to the industry.*
- *Support funding for educational tours to the general public, schools, and researchers.*
- *Secure long term funding to expand local aquaculture research infrastructure and capabilities for new species and technology development onshore, open ocean farming, and restorative farming*

Long Term Priority-recommendations for the next ten years

- *Evaluate opportunities to establish research permits (time limited) for testing and validation of new species and technology commercialization.*
- *Develop a ten year applied research plan to grow and expand Hawai'i's aquaculture industry.*
- *Increase funding for career awareness activities to attract and retain future workforce.*
- *To provide funding and/ or other tax incentives to attract more private funding in the commercialization of new aquaculture farming concepts.*

Streamlining the permitting process for aquaculture

Aquaculture in Hawai'i operates within one of the most exhaustive regulatory frameworks in the world. This framework encompasses various environmental aspects, including disease management, fish habitat, threatened and endangered species, seafood safety, and spatial conflicts. What makes it especially difficult is the lack of a lead agency - at both federal and state levels. Establishing one lead agency could effectively coordinate and streamline regulatory and permitting processes, resulting in timely decisions and more certainty for investment in either new enterprises or expansion of existing operations. Not only commercial businesses are hampered by these circumstances.

All stakeholders consulted in this process agree that better interagency communication is key. One significant issue that has been highlighted is the limited capacity within aquaculture legislation to actively engage and collaborate with the sector, hindering the acquisition of firsthand knowledge about aquaculture. Other obstacles highlighted included a lack of funding and staffing in the agencies related to aquaculture. Streamlining the process requires political consensus and executional resources, which can set the direction for industry development.

Other U.S states have already successfully in streamed their permitting processes for aquaculture producers. Joint efforts from *NOAA and Sea Grant* established an Alaska aquaculture permitting portal and guidance platform to streamline the permission process. In Hawai'i, the clear benefits of easing the regulatory environment for responsible farming can be seen at NELHA, where the combination of pre-permitting, technical assistance, and infrastructure enables both large and small companies to grow.

Exploration of new aquaculture development zones and research permits

Exploration of aquaculture development zones in marine coastal areas should be the next step to establish a responsible coastal leasing system for the expansion of Hawai'i aquaculture. Marine spatial planning is a method of enabling community agreement about appropriate locations for a range of marine activities, from preservation or protection to utilization. Recently established community-based subsistence fishery management areas could be worth emulating, where engagement with native Hawaiian communities' farming practices could occur.

The establishment of aquaculture development zones and permits has been, and will most likely continue to be, a major factor to attract investment in the Hawai'i aquaculture industry. Work to identify new aquaculture development zones will most likely consider areas suitable for restorative aquaculture farming, including generative and regenerative open ocean finfish, seaweed and bivalves production, as well as coastal land-based sites. Recent industry interest for the grow out of marine species in land-based facilities may require investigation of suitable locations for both coastal and inland sites. Technological and engineering advances in open ocean farming also make aquaculture possible in more exposed oceanic waters. Hawai'i is perfectly positioned to take a leading role in open ocean aquaculture, as it is home to large exposed areas of ocean. Hawai'i has proven to be suitable for large-scale open ocean farming commercial aquaculture and in the future, it holds the potential to become a pivotal opportunity for industry expansion. The designation of areas suitable for open ocean aquaculture should be based on clear and transparent environmental criteria and tools which can help identify new areas.

Furthermore, the assessment of specialized research permits for aquaculture (time limited) should be explored. Norway has more than 20 years of successful experience in running research licenses that are reserved for research purposes within a dedicated research area such as fish health, feed, breeding and technology development. Currently, Norway has over 100 active research permits that are operated in partnerships with the aquaculture industry and research institutions (for more information, here in this page).

Strengthen public communication around the environmental effects of aquaculture production

A negative perception held by local stakeholders in relation to aquaculture activities, particularly around their impact on the environment and other economic activities, is often an obstacle to the establishment of new aquaculture facilities. On the other hand, the benefits of aquaculture (such as providing jobs in remote areas, as a low-carbon source of food, or offering ecosystem services) are largely unknown to the public.

Collecting accurate data is necessary to present facts about the environmental, economic and societal sustainability around aquaculture operations and to ensure the appropriate planning of aquaculture activities. It will also be necessary to provide more structured guidance on how to obtain and report environmental data from aquaculture operations. Data reporting should also apply to socio-economic and animal welfare indicators and cover aquaculture production beyond environmental impacts. Accurate data is necessary to assess and monitor the social, economic and environmental performance of Hawai'i´s aquaculture sector and its critical role to support Hawai'i and US food and nutritional security. Transparency and data reporting are also important for maintaining the trust of the consumer and other stakeholders in the sector.

A good example of a public website with facts about the environmental, economic, and societal sustainability of commercial aquaculture operations can be found here https://www.barentswatch.no/en/
New Zealand Government approach to reporting environmental effects of aquaculture production
(Report on a method and approach for measuring the environmental effects of aquaculture)

Tactical steps

Streamline aquaculture permitting by promoting coordination and harmonization among regulating agencies. Efforts should be concentrated on refining the language and structure of documentation and facilitating cooperation among relevant authorities responsible for aquaculture planning, licensing, and monitoring. Focus on establishing clear procedures (and timelines) among regulatory agencies and improving transparency, interaction, and efficiency in the permitting process application.

Strengthen data collection and public communication around environmental, economic, and societal sustainability from aquaculture production. HDOA to develop a method to consistently measure and report on the environmental performance of the sector. This should also create a pathway to manage and reduce the environmental effects of aquaculture as the industry grows. Building a public database around aggregated and non-sensitive data from the industry to increase industry transparency and drive sustainable aquaculture growth.

Quantify the social, economic, and environmental benefits and ecosystem services and products from restorative aquaculture (carbon sequestration, carbon dioxide reduction (CDR), nitrogen uptake, etc.)

Evaluate opportunities to establish research permits (should be time-limited) for testing and validation of new species and technology commercialization. Special permits designed for the commercialization of research projects, demonstration, and commercial pilot projects in the sea and on land.

Applied research & commercialization program for emerging species development to support the expansion of the Hawaiian aquaculture industry

Existing knowledge gaps of native species present a barrier to the expansion of Hawai'i aquaculture, with limited available information concerning the growth requirements and commercial applications.

Our market analysis confirms that the US is the largest importer of fisheries and aquaculture products in the world. Hawai'i has over recent years increased its seafood imports. In 2022 the imported volumes peaked at 14 000 tonnes, while just a decade before in 2011 the figure was slightly below 9 000 tonnes based on data from NOAA.

An efficient, sustainable, and market-oriented expansion of the Hawai'i aquaculture sector based on commercially available, non-native species, as well as emerging opportunities for native species, will reduce the dependence of Hawai'i and the US on seafood imports, reduce the pressure on over-exploited fisheries and explore new segments and tailor-made products for the domestic market.

In the face of increasing food security challenges from climate change, disease outbreaks, market fluctuations, and other disturbances, species diversification has become a widely recognized and endorsed development strategy in the policy and scientific communities for the growth and resilience of the aquaculture sector globally. However, many attempts to establish new species have yielded little long-term success, and the private sector often concentrates efforts on the most advantageous species for rapid growth. This calls for the need for more public-private partnerships to attract more investments into diversifying Hawai'i´s aquaculture industry.

As an example, only a limited number of seafood species currently produced in aquaculture systems in Hawai'i are also consumed locally. These include oysters (*C. gigas*, *C. virginicia*, *C. sikamea*), abalone (*Haliotis sp*), clams (*Venerupis philippinarum*), kahala (*Seriola dumerili*), Pacific white shrimp (*Penaeus vannamei*), and macroalgae (*Gracilaria sp.*), most of them being non-native species. Moi (*Pacific threadfin*) and mullets are now produced locally for grow-out in fishponds.

For Hawaiian aquaculture, changes in cultured species and/or different genetic strains can contribute to reduce vulnerability of the sector to climate change, shifting towards more climate-resilient organisms that grow better under changed conditions. The development of new species for aquaculture is vital for a sustainable and secure seafood supply chain. Hawai'i has a highly diverse marine life. Exploring the biological and socio-economic potential of new and emerging candidates of marine species for the expansion of the Hawaiian aquaculture industry will be critical to further growing the industry sustainably.

Such a program needs to have a strong focus on the economic viability of species for commercial aquaculture production. This includes key criterias for efficiencies in biology and genetic enhancement, value chain development to support critical infrastructure for the development of new and emerging species, combined with applied market development to explore the perception of aquaculture products and of specific new fish products. The program should address the market potential and demand factors and motives, consumer and professional buyer preferences, and added value from new product development in relation to added value products.

Promotion of restorative aquaculture practices

The principles of restorative aquaculture are deeply rooted in Hawaiian culture and history. Nested within ahupua'a, or traditional land and resource stewardship frameworks, loko i'a (traditional fishponds)are among the earliest examples of regenerative aquaculture systems in the Pacific.

A sustainable aquaculture pathway for Hawai'i must include restorative practices. In agricultural systems, the term regenerative implies to seek to rehabilitate and enhance the entire ecosystem of a farm. Hawai'i needs to think about restorative aquaculture in the same way. With the right methods, species and locations, aquaculture has the potential to strike a delicate balance, fostering food production that bolsters the health of aquatic ecosystems. Going beyond the concept of sustainable aquaculture practices, restorative farming looks at whole systems - human, non-human, and their interactions - with the aim of nourishing the fundamental processes and interconnections that support them in positive feedback loops. The shift to a restorative aquaculture industry - producing food at sea in ways that work in partnership with the oceans around us, is gaining momentum.

The Hawai'i aquaculture sector still has great scope for further diversification, not only in the farming of promising new species (notably diversification into non-fed and low-trophic species with a lower environmental footprint) but also in production methods (e.g., polyculture in pond aquaculture, integrated multi-trophic aquaculture, restorative aquaculture). Aquaculture also has great potential to mitigate climate change. When subject to an expansion framework, certain types of aquaculture, such as restorative aquaculture with the cultivation of seaweed and mollusks can provide climate-mitigation services (such as carbon sequestration) or climate-adaptation services (such as nature-based coastal protection). Other types of finfish aquaculture, when managed appropriately, like in open ocean farming systems, can help regenerative ocean ecosystems. These types of restorative aquaculture should be promoted in the expansion of Hawai'i´s aquaculture industry.

Currently, existing knowledge gaps of native species present a barrier, with limited available information concerning the growth requirements and commercial applications. In the case of limu, each new aquaculture entrant currently needs to develop its own breeding knowledge, hatchery facilities, and seedstock - as there are no commercial-scale hatcheries or seed suppliers. To add to this knowledge gap, government approval for wild seaweed collection for startup inoculation can be challenging and prohibitive to new entrants. This adds to the difficulty of establishing operations, as new entrants burn excessive capital at the research stage.

Finally, ecosystem service products from restorative aquaculture must be evaluated. To do this, further research is required into how native shellfish and seaweed farming can provide significant economic benefits far beyond the products that are sold. Quantification of the environmental benefits from native species (carbon sequestration, nitrogen uptake, etc.) should be calculated, alongside carrying capacity calculations of specific water bodies (such as fishponds). Gaining reliable economic values of these ecosystem services encourages the consideration of these benefits in public policy decisions and can support methodologies to remunerate farmers for the ecological benefits that they create.

Stock enhancement program for loko i'a and small-scale farmers

Traditional Hawaiian fishponds, or loko i'a, were once prominent along the shores of the Hawaiian Islands. In the late 1700s, at the time of James Cook's arrival, there were more than 400 fishponds in operation producing an estimated 2 million pounds of fish per year. Today, most Loko i'a have fallen into disrepair but local community organizations are working together to restore traditional fishponds for cultural and educational purposes, as well as to provide a source of nutritious food. To assist in these efforts, Oceanic Institute & University of Hawai'i (Hilo) scientists have developed captive-rearing techniques for native Hawaiian food fish species, including striped mullet (*Mugil cephalus)* and milkfish *(Chanos chanos)*, to help revitalize ancient Hawaiian fishponds which represent the oldest and most culturally significant form of aquaculture in the U.S.

There is an urgent need for more funding, capabilities, and incentives to loko i'a guardians to remove invasive terrestrial and aquatic species. Program components should include sediment removal for the restoration of ponds back to depths suitable for fish farming caused by silt runoff from erosion. Rebuild walls and sluice gates in fishponds and restore waterways and streams to ensure that these feed loko i'a with clean and pollution-free water.

Lastly, restocking of native species using modern hatchery technologies to revitalize populations and look into stock enhancement possibilities. This should include the develop of a state of the art multi species hatchery (seaweed, shellfish and finfish) for stock recovery and/or enhancements, dedicated towards loko i'a and small-scale farmers.

Loko i'a provide natural nurseries or shallow reef habitats free of predators for juvenile fish. They predominantly target herbivorous fish such as ama'ama (striped mullet), awa (milkfish), moi (Pacific threadfin) and ʻāholehole (Hawaiian flagtail). The ponds benefit from freshwater runoff from irrigated agricultural terraces, and natural streams and springs bring nutrients that stimulate the growth of plankton and algae, which creates a nutritious habitat for juveniles.

Very few loko i'a are commercial enterprises, however, active loko i'a feed their communities and, if permitted, sell at markets. There is potential for loko i'a to expand and increase food production in time, but their current value should not be measured based on production figures alone. Their contribution to wild fish stocks through the provision of natural nurseries and nutrient-rich plankton is significant and often overlooked, and their contribution to education and community health is immeasurable.

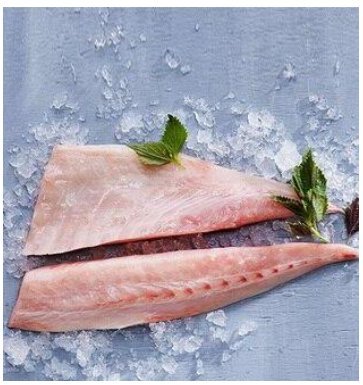
Expansion of open ocean farming

Increased focus on sustainability, consumer demands, food safety and cost-effectiveness in aquaculture production calls for the continuous development of new production technologies and new areas for farming of seafood. In general, aquaculture production affects the environment, but state-of-the-art novel farming methods reduce this effect considerably compared to traditional ways of farming fish, crustaceans, and shellfish. The aquaculture sector needs legislative support and action that enables the development of novel farming techniques, such as open ocean farming. Without a technology-enabling legislative backdrop for aquaculture, Hawai'i and the US will end up causing more environmental damage by inadvertently supporting aquaculture practices with less stringent environmental practices.

Large-scale aquaculture production will have to take place in the open ocean – where available areas, stronger currents, and greater depths increase the carrying capacity of the environment. Raising fish in exposed, high-energy areas in open ocean presents an opportunity in the context of restorative aquaculture. Open ocean farming, or open ocean aquaculture, is an emerging approach to farm aquaculture species in deeper ocean waters utilizing submersible cages or net pens. The Hawai'i archipelago is 1500 miles long with over 740 miles of coastline and the Hawai'i Ocean leasing law allows farm operations in state warm, subtropical marine waters, within 3 miles of shore. In order to meet the growing consumer demand of proteins, we need to farm the seas just like we have farmed the land. The modern, ever-improving open ocean aquaculture technologies enable farmers to do so.

Hawai'i has the first successfully operating commercial open ocean aquaculture cage in the U.S. Fish grow better and are healthier in this natural, high-energy water flowing environment. The locations chosen for open ocean aquaculture are in deeper and less sheltered waters, far from shore and sensitive ecosystems. Strong ocean currents sweep away feed residues and waste, which greatly reduces any environmental impact. Based on this track-record, Hawai'i has the potential to be the world leader of open ocean fish farming as a pioneer of warm water aquaculture technology and development.

Blue Ocean Mariculture (https://www.bofish.com/), situated in the open ocean waters of Kona, has successfully raised and harvested Hawaiian Kampachi sustainably. The premium, sashimi-grade Hawaiian Kampachi is well received by Hawai'i's top chefs and restaurants, as well as the best sushi and "white tablecloth" restaurants throughout the rest of the country. Blue Ocean manages all aspects of its product's life cycle to ensure the highest quality and least environmental impact.



Photos: Blue Ocean Mariculture

Expansion of land-based farming technologies - Recirculating Aquaculture Systems (RAS)

Other opportunities for Hawai'i include land-based aquaculture recirculation systems that offer two immediate advantages: cost-effectiveness and reduced environmental impact. Recirculating aquaculture systems is essentially a technology for farming fish or other aquatic organisms by reusing the water in the production system. The technology is based on the use of mechanical and biological filters, and the method can in principle be used for any species grown in aquaculture such as fish, shrimps, clams, etc. Stringent environmental restrictions to minimize pollution from hatcheries and aquaculture plants have sparked the rapid technological development of recirculation systems. For shrimp, traditional farming continues to be plagued with production inefficiencies related to disease outbreaks. In addition, there are environmental concerns associated with traditional farming, such as habitat destruction and the discharge of organic effluent into surrounding coastal waters. To address these challenges, Oceanic Institute researchers in Hawai'i have developed RAS technology where water is filtered and recirculated to maintain acceptable water quality. Water exchange can be reduced to < 1% per day, thereby minimizing the need for new water and mitigating the introduction of virulent shrimp pathogens into the system. The water recirculation technique also implies that hatcheries no longer necessarily need to be placed in pristine areas near rivers. Now they can be built almost anywhere with a much smaller source of clean germ-free water.

In addition, the capture and treatment of solid waste minimizes nutrient and biological pollution of the nearby environment. Stocking densities of > 500 shrimp/m^2 (3 to 10 times greater than traditional farms) are possible with OI's RAS. This allows for a significant reduction in the size of the footprint of the farm and facilitates the implementation of effective biosecurity protocols. Water temperature can also be controlled more easily, thus allowing year-round production during colder months when traditional farms may be unproductive. In addition, RAS can be used to produce shrimp at inland locations away from sensitive coastal areas where multiple-use conflicts exist and at temperate latitudes closer to major markets. Oceanic Institute's RAS shrimp production technology directly addresses critical environmental and disease concerns and provides a sustainable alternative to traditional farming methods.

Photo : Oceanic Institute

Photo: Rynan Technologies shrimp farm in Vietnam

Adoption of precision farming - digitalization technologies & services

Data repositories, data-sharing platforms, and data ecosystems have been rapidly evolving to accelerate a data-driven economy. In aquaculture, there is a rapid development of IoT, AI, and machine learning technologies entering the industry. The unit cost of hardware production is coming down and satellite communication is ramping up the digitalization of the industry collecting massive datasets across different organisations. In addition, governments and researchers are producing massive amounts of data that could benefit the public and the industry.

Precision farming is a rapidly evolving approach in aquaculture that focuses on (near real-time) observation, measurement, and responses to variability in the farming environment and its animals. It can help increase farm yields and animal welfare performance, reduce costs, including labor costs, and optimize process inputs for farmers. All of these factors are important to increase profitability and help Hawai'i maintain a cost-competitive position in the market. At the same time, precision farming can increase work safety and reduce the environmental impacts of aquaculture and farming practices, thus contributing to the sustainability of aquaculture production.

There is a potential for Hawai'i to capitalize on, and potentially monetize, data for future environmental monitoring and advanced analytics (AI, machine learning), ensuring better data collection for the development of new aquaculture zones and for aquaculture farmers to get more environmental data to improve operations. A solution could be to establish a data-sharing platform as a data repository. As a starting point, we recommend to start mapping out what are available and non-sensitive data sources that can be made available for a future data sharing platform for Hawai'ién aquaculture. What is the data quality and structure and what would be required infrastructure (cloud solution, APIs), privacy and security to enable the sharing of data. This will be a unique data platform for warm water aquaculture on a global scale, and position Hawai'i as a future oriented data driven innovation ecosystem. Furthermore, this will benefit the industry, researchers and entrepreneurs to use the data to build advanced analytic models and to build digital capabilities for future workforce.

There are today, some great examples of data sharing initiatives in aquaculture:

Blue-Cloud 2026 is an intergovernmental collaborative project that leverages Europe's expertise in aquatic environmental observation and data handling. Building on existing infrastructures like Copernicus and EMODnet, Blue-Cloud aims to create a federated ecosystem for fair and open data in marine research. Through a web-based platform, it offers simplified access to multidisciplinary datasets, analytical services, and computing facilities. Blue-Cloud also offers a training academy for harnessing the value of the data.

Over 42 months, Blue-Cloud 2026 will expand its core services, integrate more analytical tools, and enhance data discovery and access. With a focus on supporting the EU Blue Economy and environmental agendas, it strives to contribute to the EU Green Deal and UN Sustainable Development Goals. Coordinated by CNR, Trust-IT Services, and MARIS, the project brings together a team of 40 partners from 13 EU countries. [43]

AquaCloud is an industry-sharing data platform to enhance the sustainability performance of the Norwegian finfish aquaculture industry. AquaCloud was established in 2017 and facilitated by the Cluster Program "NCE Seafood Innovation" together with commercial aquaculture producers, researchers and entrepreneurs. The Data Platform contains unique high-resolution data on operations collected from participating companies along the coast, which is masked and supplemented with external data for holistic datasets. Data which is to be shared with innovators and service providers who creates value back to the fish farmers. The project has served as a catalyst for developing environmental data standards for streamlining the reporting to government agencies on environmental data collection in open sea cages. The standard for environmental data will detail what to measure, where to measure, and how to measure.[44]

Investing in entrepreneurship and applied research infrastructure

From our global scan of successful innovation hubs, a key enabling capability of a dynamic innovation ecosystem is providing incubation and entrepreneurship programs to attract and nurture entrepreneurs together with applied research infrastructure and funding opportunities to test and validate new innovations and solutions. By connecting entrepreneurs, scientists, and industry leaders, state-of-the-art infrastructure is key in accelerating a pipeline of solutions for the growth of sustainable aquaculture. The provision of ecosystem services (i.e entrepreneurship services, capital and market networking) and diluted and non-diluted funding available is critical to support commercialization of new technologies and services and attracting new businesses to relocate to Hawaii.

Hatch Blue is one of the key players in aquaculture entrepreneurship and innovation in Hawai'i. Hatch Blue, in partnership with NELHA has been instrumental in initiating various platforms and hubs like Ocean Foundry and Innovation Studio, as well as organizing community events such as quarterly pau hana's. The work focuses on nurturing innovation and connecting entrepreneurs with opportunities in the growing ocean economy. Other innovation hubs, like Blue Startups Accelerator and Elemental Excelerator are also having a great role in financing the innovation ecosystem in Hawai'i. These incubation and entrepreneurship programs are needed to accelerate impact and catalyze innovation in Hawai'i .

Another key enabling capability of a dynamic innovation ecosystem, is providing applied research infrastructure and funding opportunities to test and validate new innovations and solutions. Further exploration should be made to evaluate how the commercial infrastructure from commercial and academia could be made more available for external companies to test and validate new technologies.

Furthermore, investment in basic infrastructure - such as graded land and utilities - facilitates innovation. NELHA is a prime example. It provides a convenient platform for startups, allowing them to concentrate on their technology, rather than dealing with bureaucratic matters. Making headway in this area could contribute significantly to startup success and thrust Hawai'i into a market-leading position.

Although Hawai'i's existing aquaculture research facilities provide an excellent basis to test and validate new aquaculture concepts for more local grow-out operations, there remains an acute need for further investments to accelerate Hawai'i´s applied research and innovation capacity across academia and the industry. In our ecosystem assessment, Hawai'i has several research aquaculture centers, but most of these are either at capacity, need to be expanded or are well underfunded. As a result, increased investments to upgrade Hawai'i´s infrastructure is needed to accommodate innovative R&D projects solving technological aquaculture challenges.

Continued investment in production infrastructure i.e hatcheries, processing, diagnostic services and logistics is essential for an expansion of aquaculture production.

Investment into innovation is ongoing from the private sector but is minimal in comparison to major aquaculture hubs in Europe and Asia.

Tactical steps

Secure long-term funding to expand local aquaculture research infrastructure and capabilities. To further scale and monetise existing infrastructure capabilities (i.e., Oceanic Institute, PACRC, and NELHA) and resources (biomaterial inventory, infrastructure, permitting, expertise and knowledge) for more applied research and collaboration with industry. This should include investment to expand research capacity (CAPEX) and resources (OPEX), aquaculture permits and licenses to set up applied research projects and programs

Incentivize funding for more applied research and commercialization, collaboration with industry on research topics. This will require strengthening commercialization and operational aquaculture farming expertise in the research sector by incentivizing funding towards more applied research programs together with commercial aquaculture producers.

Develop a 10 year applied research plan to grow and expand Hawai'i's aquaculture industry. This plan should integrate several applied research topics important to scale a sustainable and economically viable aquaculture sector:

- Market insights, market studies and consumer preferences to support market activities around promotion of Hawai'i sustainable seafood products, product development and market knowledge for producers.
- Identifying the most promising economically viable new species to support diversification of the aquaculture sector in Hawaii.
- Species specific breeding programs combined with natural genomic selection on key species identified above.
- Development of new technologies and services for the reduction and re-use of water, waste streams; effluent recycling / treatment /re-use of aquaculture organic discharge.
- Quantifying environmental impacts of sustainable aquaculture farming (i.e offshore fish farming cages, restorative farming of shellfish and seaweed, integrated multi trophic farming of species)
- Development of novel production systems, open ocean farming and RAS production systems to further expand Hawai'i aquaculture production in a restorative and circular economy pathway.

Stock enhancement program including a state of the art multi species modern hatchery (seaweed, shellfish and finfish) for stock enhancement recovery especially for loko I'a and small-scale farmers.

Support funding (diluted and non-diluted) for entrepreneurship, accelerator and incubation programs to attract and grow new businesses and scale innovative aquaculture solutions. Ecosystem development services to attract new businesses, talent and private capital to Hawai'i to fund and scale new applied solutions in warm water aquaculture.

Seek opportunities with private stakeholders to develop a centralized diagnostic lab, to develop an enhanced centralized diagnostic lab or mobile unit for pathogens, bacteria and diseases.

Investigate the viability of a public-private partnership for a centralized processing facility together with cold storage for value-added seafood products (refrigeration and frozen) that could be used by multiple producers (i.e., a shared facility managed either by a public private partnership or through an industry co-operative)

Commercial stakeholders interviewed for this report repeatedly mentioned how challenging it is to attract and retain the level of talent needed for the operations. Salaries must be competitive with the mainland and students encouraged to pursue careers in this space. The current labor shortfall is expected to worsen unless steps are taken to educate a growing labor pool. Engagement with existing aquaculture operators, indigenous groups and parallel industry groups - such as fishing or maritime tourism - on skill transfers, training and development programs will be critical.

Aquaculture production worldwide and for Hawai'i has undergone a transformation from earlier labor-intensive farming methods to new technologies with greater automatization that further changes the need for skills and expertise for the future labor demand in aquaculture. This encompasses essential skill development, best practices, and managerial training to equip individuals with the knowledge and abilities required for sustainable aquaculture. It emphasizes in-field training opportunities and certification programs to ensure that aquaculture professionals are well-prepared to address the industry's evolving challenges and opportunities. The workforce needed for aquaculture development needs to support the entire value chain. Employees will need to be capable of managing remote monitoring and control of production facilities, whether the farm is focused on intensive production, RAS, or large-scale open ocean cages. Use of robotics, AI, and machine learning will become more common to monitor aquaculture farming operations.

Specialized higher learning education programs in aquaculture

Current challenges from the public scoping survey highlighted the lack of practical training from current College aquaculture education and more collaboration needed with industry practitioners. Currently, there are no aquaculture degrees available in Hawai'i and a need for the development of new, industry-related educational programs in aquaculture. There is a need to incentivize colleges to prioritize aquaculture as a subject and increase hands-on training in running research and stronger linkages with operating aquaculture businesses for practical training through facilitating visits to aquaculture farms, NELHA, OI, and loko i'a.

Furthermore, commercial aquaculture expertise must be increased by college staff in order to teach more career-focused curriculum, internships, certifications that prepare the next generation of aquaculturists to work not only in commercial aquaculture ventures but also on loko i'a that do restorative aquaculture. Based on the public survey, educational institutions need to upgrade their degree/certification pipeline to facilitate professional or commercial career opportunities for Hawai'i residents in aquaculture. Other areas of improvement are lack of subsidized education opportunities and internships for students to collaborate with the industry.

A bottleneck for the industry is the lack of permits for staff housing, leased land for staff, seasonal workers and interns. High living expenses combined with lack of housing availability and / or high cost of housing make it difficult for Hawaiian companies to compete on allowances and to attract workforce. How to retain talent needs to be a key priority to sustain the industry with a qualified future-oriented workforce.

Photo : Taylor Shellfish farms

Educational career awareness

There are several great examples from the aquaculture industry on private-public partnerships to raise awareness of aquaculture careers. An example of educational carrier promotion supported by the Government is Bord Iascaigh Mhara, where The Irish Government is promoting aquaculture carriers with an Aquaculture Remote Classroom (ARC). A mobile classroom that has been designed to raise young people's awareness of aquaculture. The classroom is supported by 4 online lessons, regular webinars direct to schools and a range of learning resources such as the ARC Poster and the ARC workbook. The ARC is available to schools completely free of charge.

Other examples include educational visitor centers in partnership with commercial aquaculture producers, for example Storeblå, an all-digital experience aquaculture visitor center in Norway combined with educational tours to farms.

Photos: BIM Ireland's Seafood Development Agency


Photo : Storeblå Norway

Tactical steps

Develop tailored aquaculture training programs and secure long-term funding to ensure continuity and effectiveness to the industry. Engage with the Hawai'i State Department of Education (HIDOE) for potential implementation of tailored aquaculture programs to their specific criteria, ensuring relevance for each student level from K-12 to higher education also to set up a sustainable plan with clear success criteria and secure long-term funding to ensure the continuity and effectiveness of these aquaculture educational programs.

Increase funding for career awareness activities to attract and retain future workforce. Engage with the Department of Labor and Industrial Relations (DLIR) to discuss the potential of an open career portal and to explore the possibility of workforce development training, internships, and asses the available funding grants.

Supporting funding for educational tours to the general public, schools, and researchers. In partnerships with commercial aquaculture companies and educational organizations explore the opportunity for setting up educational tours. Ensure such a program thoroughly considers health safety, biosecurity, and ADA compliance as crucial elements in both the financial planning and operational aspects of these initiatives.

Secure more flexible permits for staff housing and leased land for staff, seasonal workers and interns and developing low-cost housing options. There is a critical need for more flexible housing solutions for workers in the aquaculture industry.

Photo : Ocean Era

To initiate a 5-year industry growth plan for the funding of an Innovation Cluster Program designed to grow and scale Hawai'i aquaculture sector

Our global scan of successful global public and private partnerships shows that Innovation Clusters and Centers are an emerging global phenomenon as engines for economic growth and development. Increasingly, countries are turning to the concept of Innovation Clusters, private and public partnerships to innovate, for governments and support business growth. Innovation Clusters can be a key tool for the diversification of the economy, jobs, and value creation. We see new clusters rapidly developing, often built around the industries of the future, helping regions, nations and national leaders navigate economic shifts and prepare for new economic growth in future growth industries. Since the early 2000's, the term Innovation Cluster has been evolving, shaping ambitious political and business thinking in Asia, the Americas and Europe.

Globally there are some 7,000 innovation clusters. Business clusters, according to traditional literature, are a naturally emerging phenomenon, developing in places with high density of naturally collaborating firms and along traditional value chains of cooperating companies. Business clusters, or agglomeration economies, are natural phenomenon in many regions and to many economic activities. Clusters have been recognized in management literature since the 1890's, but tracing back to the earliest days of human organized economic activities, as suppliers, customers and partners naturally would group together.

Innovation Clusters are connecting stakeholders from private and public sectors, fostering more applied research and commercialization to enhance industry growth and sustainability

An Innovation Cluster will connect members, partners, stakeholders, startups, corporates and financing bodies from the local ecosystem to accelerate economic growth. In most parts of the world, clusters are understood as geographical clusters, often around a specific industry or field. Media, high tech, life sciences, medical technologies, space, maritime, finance, seafood, energy; these all have strong geographical clusters that have evolved and matured naturally over time.

Innovation Clusters are actively shaped, built, and led. They have formal operating organizations.

They have active members, often paying a nominal membership fee to pay for services.

They have full-time employees, newsletters, web sites, annual reports, and strategy documents.

They develop and run large innovation project portfolios that benefit long-term growth.

Their purpose is to deliver on national and state strategy and plans for the sector

Innovation Clusters	Ecosystems
Specific theme	No specific theme
Clear organization, legal entity	No specific organization, no single entity
CEO, Management team	Multiple themes, industries and domains overlap
Actively recruiting, supporting and developing around one theme	Multiple themes, industries and domains overlap
Counting members, partners	Usually not able to count members across a wide ecosystem
Annual report and frequent communications	No official reports and communications
Actively bluff, nurtured and led over 3,5,10+ years	Emergent, supported by policies and communities, but often evolving

For Hawai'i, a strategy for cluster development should aim to foster and increase collaboration across stakeholders in the aquaculture innovation ecosystem. To strengthen collaboration between stakeholders of the ecosystem and launch new collaborative projects between private, academic and public sector organizations that lead towards more commercial outputs. Attracting more funding and private sector investments in technology research, development, demonstration and commercialization. Important objectives to be included in such a program should include:

- **Increased commercialization of research:** The governance of Innovation Clusters puts industry in charge of establishing of the strategies and providing direction in terms of applied research topics, selecting individual projects and building ecosystem capacity. Traditionally, innovation and research grants have been led by researchers in Hawai'i where the industry has had a less influence on the topic and governance of these government funded projects . It should be expected that business leadership would improve Hawai'i´s limited record of commercialization.

- **Strengthening underdeveloped supply chains**: Innovation Clusters are designed to address gaps in the value chain and address weaknesses in supply chains among anchor firms, and small- and medium-size enterprises (SMEs), building new market relationships and domestic partnerships to increase businesses market orientation and increase market share.

- **Attract and retain talent:** The Innovation Clusters are intended to retain and build on strong talent in key technologies and related businesses. For many years, Hawai'i has been challenged by the exodus of talent in the science and technology fields to the mainland. and around the world. In addition, Innovation Clusters actively engage businesses in workforce development programs to ensure practical training in collaboration with local universities.

- **Increase branding and visibility:** By the creation of these Innovation Clusters, regions become known as a global innovation leader that attract businesses and investors. It is a "one stop shop" for investors, entrepreneurs and businesses seeking marketing opportunities and innovation capabilities to test and validate new solutions. In this respect, many countries and businesses outside Hawai'i are unaware of its leadership in technologies and sectoral strengths.

- **Increase networking and collaboration**: The Innovation Clusters serve to develop and promote strong ecosystems and networks, including new digital and intellectual property (IP) strategies. They serve as a "one stop shop" for businesses or investors to engage and collaborate, where the Cluster organization functions as a strong facilitator to increase collaborative networks across stakeholders in the ecosystem and towards other strong innovation hubs,

Several governments have launched Innovation Cluster Programs as a response to mitigate for environmental, social and economic impacts. The longest-run Government funded Cluster Program is the Norwegian Innovation Cluster, a program aimed to support activities in industrial business clusters composed of companies competing internationally. Norwegian Innovation Clusters (NIC) was established in June 2014. NIC continues the supply of services that until then had been given through the programs Arena (since 2002) and Norwegian Centres of Expertise (NCE) (since 2006), as well as introducing a new program called 'Global Centres of Expertise' (GCE). The aim of NIC is to set up and strengthen cooperative innovation projects in business clusters, focusing on increasing companies' ability to innovate and their competitiveness.[47]

Market studies and market development

Public sentiment is shifting towards a more food secure Hawai'i and aquaculture can align with agriculture to contribute to this important effort. In the roadmap for Hawai'i-based aquaculture, the priority should fall on meeting the needs of local consumption. This way, an isolated island state like Hawai'i can move towards becoming self-sufficient. Along those lines it is crucial to note that seafood and fresh produce are important to Hawai'i's health. Products grown in Hawai'i take less time to get from harvest to plate. They are fresher and retain their nutritional value and taste. Imported food spends a lot of time (and carbon) being transported to Hawai'i and loses its freshness and nutrients during transport and distribution.

Hawai'i's Aloha+ Challenge local food goal was informed by stakeholder and community input to the Hawai'i 2050 Sustainability Plan, which identified doubling local food production by 2030. The Aloha+ Challenge Dashboard measures Hawai'i's progress, examining data on local food production in agriculture. Data shows that there is a need to increase local food production.

Market development activities should be further explored with Hawai'i Marketing Council to promote aquaculture in Hawai'i and inform farmers to develop a marketing strategy to increase local sales, debunk myths, and showcase the value of aquaculture to Hawai'i. Further investments into market development will need to ramp up over time to ensure that there will be demand for the growing volume at prices that can sustain a growth of the industry. Similar to the Agriculture Development Division, the state should launch a market program to assist with research for the expansion of new and existing markets for locally aquaculture produced products. The objective would be to provide information that will assist existing and participating producers and investors to assess the long term market viability for Hawai'i produced aquaculture products. Aquaculture products should also leverage on "Made in Hawai'i", "Grown in Hawai'i" and develop its own quality branding programs for sustainable produced seafood products. They should include the promotion and communication will to realise the potential of a more diversified aquaculture production to meet US and Hawai'i´s current trade deficiency on seafood products. These challenges include increasing the knowledge and consumption of aquaculture products with a lower environmental footprint, in particular under-exploited low-trophic species such as algae, shellfish and other invertebrates, and herbivorous fish. This should include promotion of the use of origin labelling and marketing standards for locally produced aquaculture products in Hawai'i, information campaigns about the Hawai'i aquaculture sector that includes foodservice and retailers, further opening the sector to the public with the opening of farm visits to schools, chefs, educators. This will help to make Hawai'i aquaculture products more market competitive and also ensure a level playing field with other aquaculture products that may not offer equivalent sustainability and quality.

Photo : Blue Ocean Mariculture

Assessment of the blue carbon market for Hawai'i for restorative products

One of the key tools to tackle climate change is the carbon markets, through which organizations and businesses can trade emissions allowances to achieve reduction targets. The vast majority of funding provided by carbon markets is allocated to so-called nature-based solutions (NBS). These are focused on the protection, restoration, and management of natural and modified ecosystems. On land, the most recognizable NBS is planting of trees to restore forests. However, there is an increasing market attention towards so-called blue carbon NBS, which are designed to protect or enhance ecosystems on coasts and in the oceans.

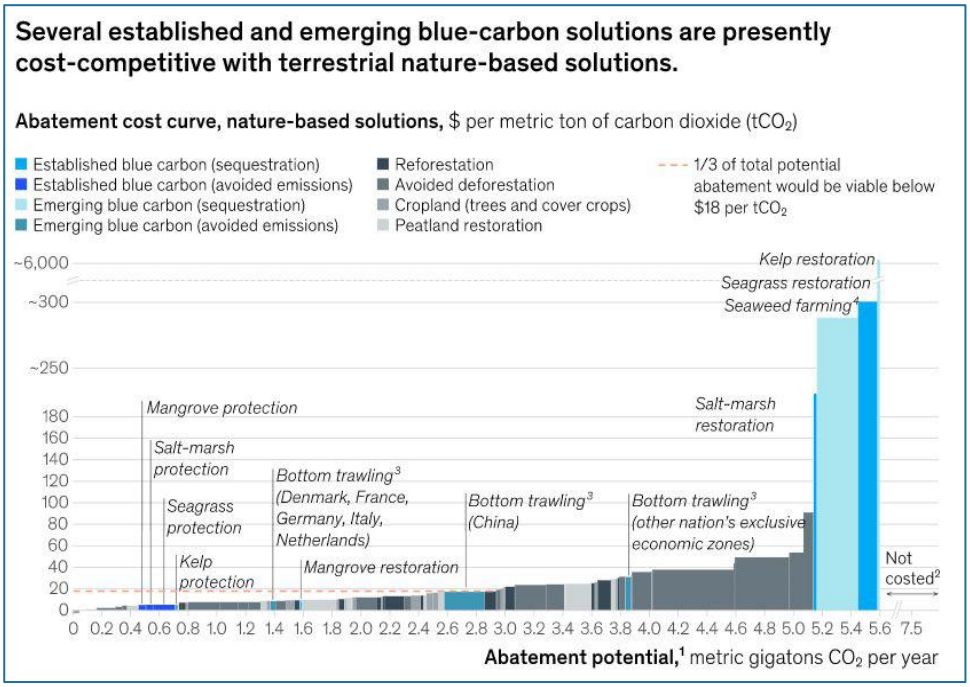
There is no ecosystem service market for either water quality improvement or blue carbon offsets in Hawai'i present today. There is strong international and local interest in these sorts of services, but it is still an emerging area of research. Given the scale required, it may be challenging to generate viable returns from carbon offsetting or nutrient capture as a stand-alone business model.

Japan Blue Economy Association (JBE), the Japanese state-appointed research institute was tasked to establish blue carbon credit standards for the country, validated the science and certified the voluntary blue carbon credit, which can now be sold to buyers interested in offsetting their carbon footprint within Japan. In 2021, voluntary blue carbon credits certified by JBE averaged a sales price of JPY 72,400/t (EUR 500/t), well above all types of carbon credits anywhere around the world, owing primarily to their co-benefits.
Source: https://www.blueeconomy.jp/en/

Seaweed restoration and farming are considered highly cost-competitive options for blue carbon reduction.

Seaweed farming can remove CO_2 by absorption, sequestration, lowering demand for terrestrial crops, and reducing global GHG.

- Blue infrastructure and ocean-based projects can lead to sustainable revenue-generating opportunities.
- Furthermore, seaweed projects can help realise a blue economy for local communities through comprehensive investments in conserving coastal ecosystems and biodiversity. [48]



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Access to capital

Access to capital presents another substantial challenge for Hawai'i aquaculture to scale. There is a rapid development of emerging technologies in aquaculture. Technology and species diversification carry a considerable risk for private sector investors. We have seen that government incentive programs have been catalytic to attract more private investments in the green energy transformation and development of high technology industries. Other countries, like Norway, have incentives for large scale investments in high technology projects through temporary and special permits for aquaculture awarded to concepts that contributes to significant innovation. Hatch Blue is helping the capital investment, building out a large-scale ocean investor landscape and connecting capital with investment opportunities and increase investors domain expertise on investment opportunities in the growing ocean economy. Other examples include tax incentives to attract and de-risk private investments in new species development or high technology development projects in aquaculture.

Tactical steps

To initiate a 5 year industry growth plan for the funding of an Innovation Cluster Program designed to grow and scale Hawai'i aquaculture sector. The program should take a national sector approach to structural reform and address barriers to productivity, competitiveness and innovative capacity level where economic growth can be maximized. Topics to be covered are streamlining regulations and suggesting possible reforms. Improving engagement between research and industry, and within industry, to achieve stronger coordination and collaboration of research and stronger commercialization outcomes. Improving the capability of the aquaculture sectors to engage with domestic markets (islands and mainland). Improved employment opportunities and contribution to the creation of high-skilled jobs for the sector.

To provide funding and/ or other tax incentives to attract more private funding in commercialization of new aquaculture farming concepts. New farming concepts are high risk for investors and incentives should look at different funding schemes to de-risk investment for private investors species development in areas of open ocean farming, RAS and restorative aquaculture farming .

Market insights and market development to incentivize investment to scale aquaculture production in Hawai'i. Diversify and broadening the market campaign strategy from HDOA Seal program that also include locally sourced products (not limited to agricultural products alone) but also aquaculture. Market reports, marketing activities to further incentives production and market insights for farmers, investors, and other stakeholders. The goal should be to incentives aquaculture as an important sector for food security, optimize aquaculture practices, product development, and explore opportunities for scaling up production to meet market and consumer demands (expand both new and existing markets for quality - local aquaculture products, food security, environmental and economic impact targets).

Blue carbon markets assessment to evaluate the economic, environmental and societal potential for carbon credits from local aquaculture production. This should include reviewing examples from other government countries ramping up blue carbon market initiatives i.e Japan, South Korea etc.

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Photo : Blue Ocean Mariculture

CHAPTER 7

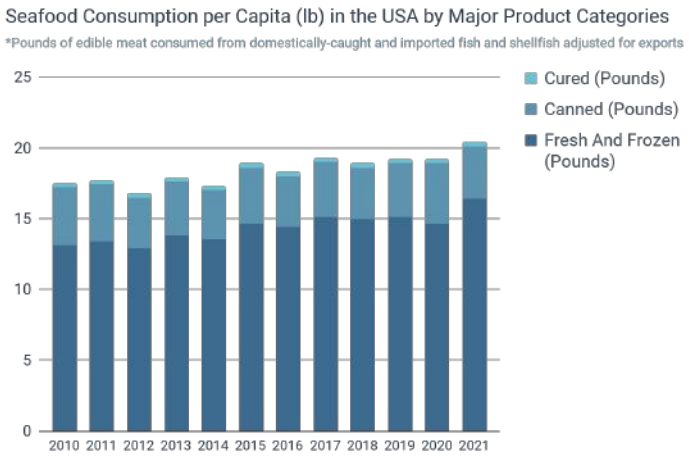
Appendix

Image: Blue Ocean Mariculture

7.1 US Seafood Market

Photo: Kauai Sea Farm

The US has experienced a gradual increase in terms of both available seafood supply per capita and actual consumption per capita. The latter has reached record highs in 2021 according to NOAA, when on average a person in the US ate 20.5 pounds of seafood, a notable 7.9% increase compared to the previous year. The growth was primarily due to the rise of the consumption of fresh/frozen seafood products, which is the largest contributor to the overall seafood category. The FAO data indicates a diverse array of species in the U.S. seafood supply, with crustaceans and freshwater fish comprising nearly half of the total volume. Marine fish (both demersal and pelagic) and molluscs also play crucial roles. Over the past decade, the distribution among these seafood groups has remained relatively consistent, with no major shifts in their proportional contributions.



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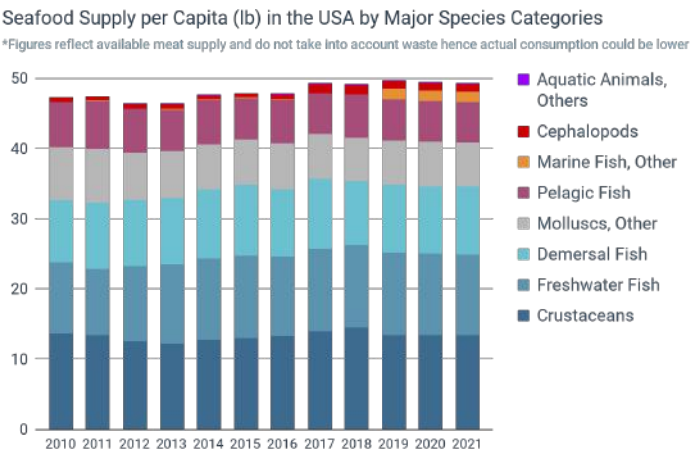

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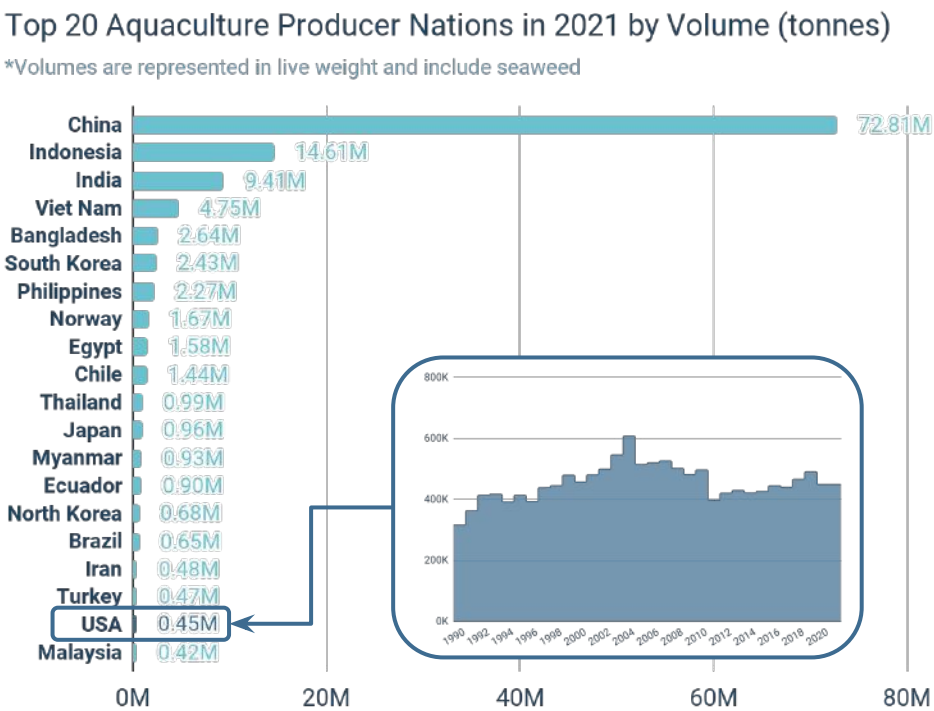
As the U.S. gradually increases its seafood consumption, a key question arises: how will supply keep up with this growing demand? Unlike many regions where rising seafood consumption is matched by growing aquaculture outputs, the U.S. story differs. Here, increased demand is predominantly met through imports rather than increased domestic production.



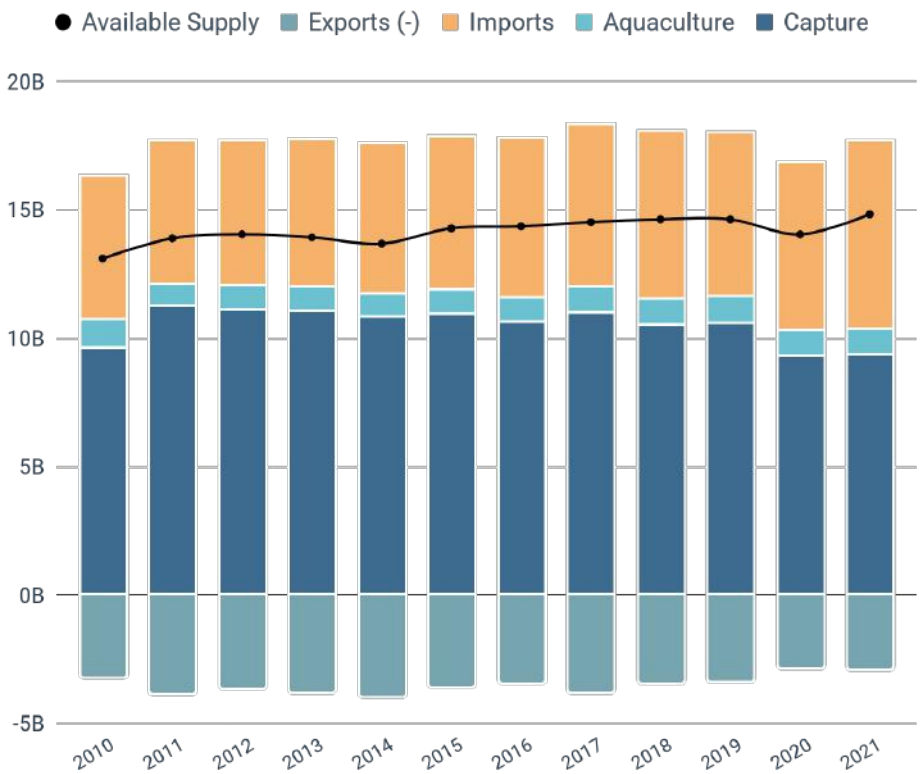
Source: 26

Despite the growing demand for seafood, the US has not been able to ramp up its domestic production in recent decades. This holds true for both wild catch and aquaculture. Once among the top producers, now the US is lagging behind in aquaculture production. Based on 2021 statistics by the FAO, the US has produced around 0.45 million tonnes (live weight) of seafood with an estimated farmgate value of 1.2 billion dollars. Additionally, the trend in U.S. aquaculture production has been either stagnant or slightly declining over the past decades. The annual growth rates have varied, sometimes positive and sometimes negative, depending on the year considered. However, since its peak in 2004, the output volumes of U.S. aquaculture have generally declined.

Due to decreasing wild catch volumes and stagnant aquaculture growth, the U.S. has become the largest importer of seafood in terms of value, showcasing a heavy dependency on foreign nations. This trade deficit could potentially be reduced by increasing domestic production of in-demand species.

USA's Annual Available Seafood Supply Based on Production and Trade (lb)

*Note: capture and aquaculture figures are live weight while trade is in product weight



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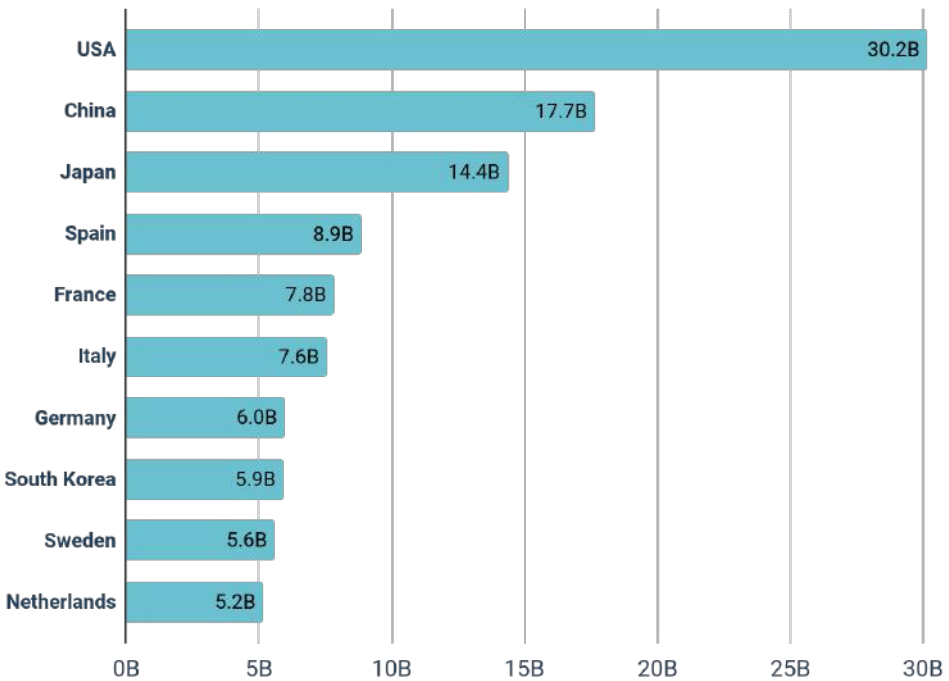
Top 10 Seafood Importer Nations in 2021 by Import Value (USD)



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The FAO's data clearly shows the U.S.'s dependence on imported seafood. In 2021, the disparity was notable: the U.S. imported over 7.2 billion pounds of seafood while exporting only about 2.8 billion pounds. This marked difference underscores the U.S.'s heavy reliance on imports for its seafood needs.

The vast difference between the volume of imports and the output from domestic aquaculture indicates that much of the economic benefits from the seafood industry – including production, processing, employment, and related activities – are being generated outside the U.S.

Additionally, this reliance on foreign imports carries significant ecological consequences, considering the environmental cost of transporting seafood over long distances. Many of these imported seafood products, particularly high-value items, are often air-freighted to the U.S. market.

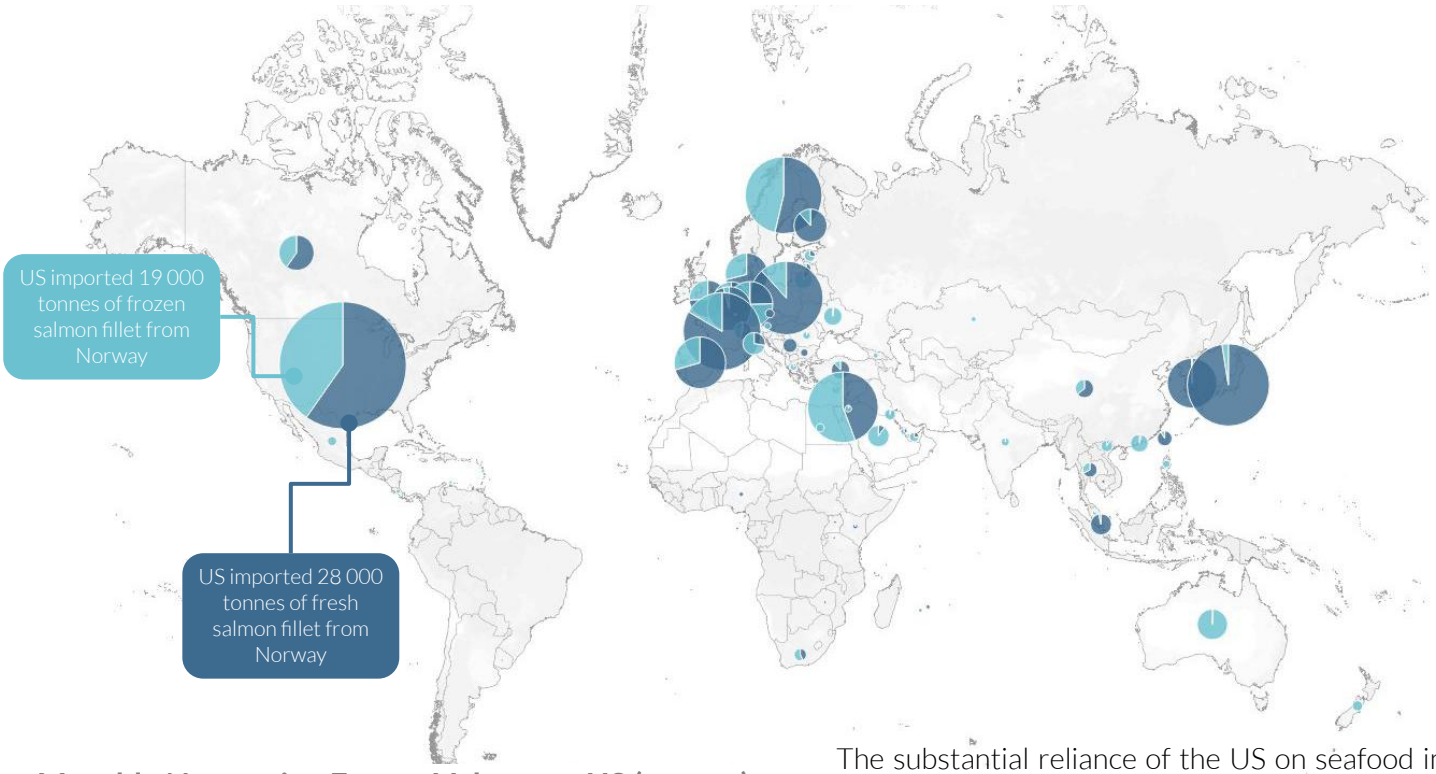
The US imported seafood worth roughly $30 billion in 2021, a figure that is significantly higher than the preceding years, where import values stood at between $20 and $24 billion. This was likely due to the steeper decline in wild catch volumes since 2019 as imports had to compensate for the missing seafood quantities. Despite its low per capita seafood consumption, the country is much more dependent on imported seafood and fish than other countries whose seafood consumption is higher.

One of the clear examples of the foreign seafood dependency of the US is the case of imported Norwegian salmon, which is showcased on the next page.

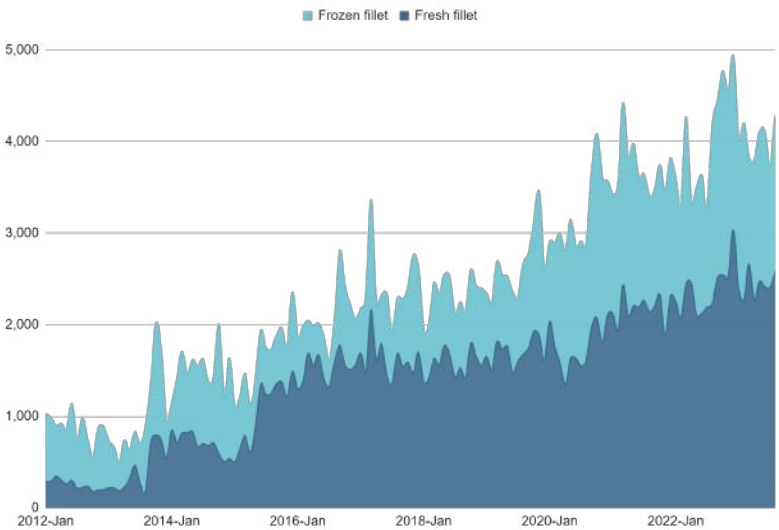
Americans consume a lot of Atlantic Salmon, second only to shrimp in their seafood diet. To meet this demand, the U.S. imports 95% of the salmon it consumes, adding about $3.4 billion every year to the trade deficit, as reported by the USDA. This high demand has positioned the US as the leading global importer of high-quality Norwegian farmed salmon fillet. Over just a decade, the US has seen a significant increase in both fresh and frozen salmon fillet imports from Norway. This trend reflects the US's status as a lucrative market for high volumes of salmon fillets, driven by growing seafood consumption trends, particularly for salmon, according to data from the Norwegian Seafood Council Monthly Export Statistics. In 2022, the US alone imported more than 28 000 tonnes of fresh fillet from Norway and roughly 19 000 tonnes of frozen fillet, positioning the country as the #1 importer of both fresh and frozen Norwegian salmon fillet. Moreover, the US imports significant amounts of salmon from other countries too, most notably Chile.

Norwegian Export Volumes of Fresh and Frozen Salmon Fillet (metric tonnes) in 2022

Each bubble is a partner country, importing salmon from Norway and the pie slice shows the difference for fresh vs frozen fillet imports



Monthly Norwegian Export Volume to US (tonnes)



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The substantial reliance of the US on seafood imports, in this example high-value salmon fillets, highlights several missed opportunities: the potential for domestic economic growth, creation of jobs in production and processing, and marketing prospects for locally produced seafood that could benefit community development. This heavy dependency also results in a higher environmental footprint, largely due to transportation, including airfreight, especially for fresh or chilled seafood products. The increasing trend in salmon fillet imports reflects the US's growing preference for quality seafood and its dependence on foreign producers. The Norwegian Seafood Council acknowledges the US as a key market, planning to intensify its marketing efforts to promote salmon in the US despite already significant past efforts.

7.2 Public Scoping Analysis

Photo: Ocean Era

- A series of industry insights interviews with industry experts, producers, entrepreneurs, academics, government representatives and community leaders.
- A Hawaiian aquaculture stakeholder database - more than 280 Hawaiian aquaculture industry stakeholders were mapped and populated with current data, including representatives' names and designations, contact details, website addresses, geographic locations, and a brief description of the primary business or occupation of the entity.
- An online survey - based on the database all stakeholders were invited to engage with Hatch Blue and provide input on a broad spectrum of challenges and issues in the aquaculture industry in Hawai'i.
-

The following points on the table below informed the dialogue between the Hatch Blue interviewer and the interviewee. Questions were adapted in line with the expertise or knowledge field of the interviewee. The stakeholders were invited to participate in the online survey. 45 completed question sets were received, including six that were completed verbally. A return rate of 16%. The largest number of respondents came from the academic and industry sectors (40% and 38% respectively). ***Key trends and observations are reported in the following chapter. The key findings have informed the recommendations.***

Topics	Interview guide
Knowledge	• Capacity building: Future need of aquaculture workforce, educational programs and business support to scale and support commercial activity in Hawai'i • Community building initiatives: Community supported programs and initiatives to support more environmental restoration in Hawai'i
Solution-driven R & D	• Research areas (topics) to increase the return of investment on research and innovation to further scale and accelerate commercial activity in Hawai'i • Infrastructure gaps and needs to support value chain and commercial (labs, testing facilities, hatchery)
Entrepreneurship & Innovation	• Tactical innovation support to enable Hawai'i to successfully scale sustainable aquaculture production to enhance food security for Hawai'i and US • Industry Best Practices that could support the commercial development of equipment and services in Hawai'i to support local and national aquaculture food production • Novel feeds. Commercial opportunities for the production of novel feed ingredients that can support feed manufacturers with cost-effective choices in feed ingredients suitable for marine and freshwater aquaculture production.
Capital & Commercialization	• Value chain development (locally). Primary and secondary value chain gaps and needs to further scale aquaculture production in Hawai'i • Global value chains. Market and business support to connect Hawai'i aquaculture industry to global value chains • Capital
Environmental Sustainability & Ocean Restoration	• Sustainable practices: Open ocean deep water farming, restorative fishpond aquaculture, seaweed and bivalve regenerative farming practices • Carbon footprint: Renewable energy, greenhouse gases, biofuels • Consumer education: Food sovereignty and security

Governance

- Urge government to set a food security target so industry and government can find the financing and generate the workforce needed to implement a plan to achieve it.
- Aquaculture needs to be elevated in status in the governmental divisions.
- The budget allocated to agriculture (and thereby to aquaculture) must be significantly increased.
- More staff with aquaculture industry expertise or better training should be provided to staff.
- Permitting processes are prohibitive and time-consuming and that it seriously hinders the growth of the industry.
- There is significantly insufficient industry representation at government levels for aquaculture.
- All staff should engage with the industry regularly on farms and sites so that they get a better understanding of the industry and their needs.
- There is a lack of communication between government and industry and opportunity for industry to meet with the legislature.

Investment & Funding

- Barriers to investment in Hawai'i include high initial costs, inhibitive regulatory environment, risk and uncertainty, and the timeframe to return on investment.
- More financial support is needed for small, medium & large producers.
- More funding should be available to small companies who wish to expand pilot projects and undertake grow-out research with native species for aquaculture.
- The government should reintroduce tax credits for investment into aquaculture

"There is very little opportunity for industry to engage the government although there seems to be more progress and attention from the state towards industry representation."

"The application process was extremely time consuming and unclear. The process often becomes more convoluted and complex due to the lack of clear criteria to begin with."
"The HDOA Aquaculture Development Program does not communicate with industry on a regular basis."

"We need much better direct support for producers. It seems that most funds go towards studies, research and tech. We need to build more farms and that requires far greater support."

"Agricultural budget is less than 0.5% of State budget. That says it all…."

"I think from a macro level, we've seen the same pattern happen in Hawai'i over and over again, whether it was in pineapple or other agricultural things. It is so expensive to do business here because of shipping and everything else, that the state is going to have to step in and help deregulate some of the things - our power costs have to be addressed, some of our tax - the whole weight that businesses carry in Hawai'i is not sustainable."

"Grant money is hard to rely on when most have end dates. It would be beneficial to have project that can be sustained over long periods of time.(decades)."

"More funding should be available to small companies who wish to expand pilot projects and undertake research with native species for aquaculture."

Consumer Market & Marketing

- Respondents are aware of any marketing driven by the government that promotes either aquaculture derived seafood.
- Development of aquacultured products could be increased by statewide marketing campaign. This campaign needs to be implemented to increase consumer awareness of the benefits of aquaculture to the community and environment. This campaign could also dispel misconceptions and assist with local sales.
- In addition to core aquaculture operations by producers, more aquaculture-tourism is encourage to provide additional revenue or for marketing or educational purposes.

Education, Workforce Development & Capacity Building

- Academic education
    - College aquaculture education is producing researchers rather than production / industry practitioners.
    - Commercial aquaculture expertise must be increased by college staff in order to teach more career-focused curriculum, internships, certifications that prepare the next generation of aquaculturists to work not only in commercial aquaculture ventures but also on loko iʻa that do restorative aquaculture.
    - Institutions need to upgrade their degree/certification pipeline to facilitate professional or commercial career opportunities for Hawaiʻi residents in aquaculture.
- Training:
    - There are insufficient subsidized education opportunities and internships
    - Industry is open to offering training opportunities and education or awareness activities but needs support from the state to cover a wage for the interns and other costs.
    - Internships are difficult to accommodate due to lack of affordable housing for students and young professionals. Other inhibitors are biosecurity risks, lack of time for mentoring and the additional admin tasks associated with interns.

"A collaboration between government and private farms in a generic marketing campaign can help all species and scales of farms and should be a cornerstone of State assistance."

"Agritourism is the most reliable way to increase revenues without substantial increases to overhead."

"I have encountered significant pushback on 'farmed' fish. We need better public education on what we do and why."

"The recent THRIVE Hawaiʻi Agrifood Summit was an excellent promotion of Hawaiʻi Aquaculture and should be funded to repeat biannually."

"The HI Aquaculture Collaborative is supported by a NOAA grant, which is ending soon. Perhaps one of the new HDOA ADP positions can be allocated to sustain this industry partnership.."

"There needs to be more action in working with the university systems in having a pipeline of degrees to careers for Hawaiʻi resident professionals in aquaculture."

"Aquaculture training in Hawaiʻi is mainly theoretical and unlikely to create innovation and or successful farms, farmers and economy."

"Aquaculture education and training can be a greater contributor to the State economy, if staff aquaculture expertise increased (e.g.,, a Chair of Aquaculture to build from) and UH staff collaborated with private companies."

Infrastructure

- **Housing:**
  Hawai'i is now listed as the state with the highest index of cost of living in the USA. Extreme elevated housing costs is contributing to labor migration as the industry is finding it difficult to compete with salaries on the mainland. Subsidised housing or permitting processes connected supplying labour housing onsite on farms needs to be addressed urgently
- **Pre-permitted applied research aquaculture hubs:**
  More multipurpose aquaculture hubs, similar to NELHA, that offer pre-permitted areas, infrastructure, networking opportunities are needed to support all types of aquaculture: land-based, inshore, open ocean and loko i'a. The function and activities by hubs need to be strategic and complementary to each other to avoid duplicated similar efforts and diluting funds
- **Hatcheries:**
  There are insufficient hatcheries and breeding programs of native species in Hawai'i. Currently, depending on the species, broodstock, seed, and fingerlings are imported or companies have to produce their own in vertically integrated operations. This makes it difficult and costly for small scale farmers and new entries. New aquaculture hubs should make seed supply to the industry a priority.
- **Feedmill:**
  All aquafeed (not including all live feed) is imported from the mainland. Building a local aquafeed feedmill would be the obvious solution but the economic feasibility of a local feedmill is very questionable as Hawai'i does not have local raw ingredient resources for feed production, nor is there not nearly a high enough demand yet to meet the economic feasibility threshold of a commercially viable aquafeed mill. Nevertheless, there are efforts being made to explore this opportunity at a small scale to initiate with.
- **Processing plants:**
  A centralized processing plant and cold storage facilities would be welcomed, but would need careful management to accommodate different species and different health & safety regulations etc.

"The State could establish another multi-use aquaculture/ocean park similar to NELHA and provide turnkey access to resources and infrastructure for innovation and experimentation at a reasonable cost."

"Finding and gaining access to sites is a major obstacle for startups and expansion and government should provide direct assistance."

"More need for hatchery supply of native low trophic species suitable for stocking in fishponds or nearshore areas if these areas are to expand to meaningful production."

"We need more state, city, federal funded hatcheries. Private hatchery owners need to work other jobs to keep the bills paid."

"If a mom and pop farmer can outsource their fish through a centralized facility, that could be a benefit to the community. But I think it would be difficult to have an aquaculture produced processing facility shared with commercial fishermen (wild caught) from a USDA, FDA, Department of health regulations and financial standpoint."

"Asking a large producer to switch feeds is a major request, as their entire production for the next 6 months will be reliant on the decision."

Applied Research & Entrepreneurship

Research & Development

- Applied research on scalable production protocols of native high value species is crucial. Economically viability is essential for the sustainability of aquaculture in Hawai'i.
- Practitioners and researchers should be learning from leading industries and institutions and not trying to reinvent production protocols.
- Technological innovation, automation, nutrition, water quality, disease, species selection and genetics are areas that need most R&D, especially innovation and AI, which are driving new systems across the industry.
- Other innovations and research fields that are important are renewable energies, environmental impact of open ocean farms and workable ideas to increase AI into farm operations to reduce labor costs.

Innovation, Technology & Support Services

- Access to machinery, equipment and third-party support services is inadequate. Rather than attracting off-Island service providers, the state should incentivize and make it easier for local businesses and residents to fill these gaps by importing or developing their own IP and services.

Community

- Industry fragmentation and a lack of collaboration is hindering the growth potential of aquaculture in Hawai'i. The state should support opportunities for collaboration, knowledge sharing, and networking.
- State should increase or incentivize funding for attending more conferences and similar events of state, national and international importance.
- There needs to be a stronger and more representative industry association.
- More meaningful engagement between industry and the communities in which they operate is required. This will result in better buy-in and more collaboration between the sectors. Industry needs to be held accountable for social responsibility in terms of the environment and community where they operate.

"Current academic activities are not well aligned with industry needs nor are adequate collaborations occurring between academics and industry."

"Academics seem to still have this sigma, instilled decades ago, that they shouldn't work with the "Ag" industry in Hawai'i. They seem to be disincentivized to collaborate with industry or the funding just isn't allocated to these sorts of research with industry.

There seems to still be this stigma by academics that they're disincentivize to work with industry. This stigma was instilled decades ago

"There is a need for academic institutions to develop more career-focused curriculum, internships, certifications that prepare the next generation of aquaculturists to work not only in commercial aquaculture ventures but also on loko i'a that do restorative aquaculture. Government agencies need to get involved more to support these activities. This training should be made available in schools and colleges and through subsidized internship and school awareness programs.."

"The recent THRIVE Hawai'i Agrifood Summit was an excellent promotion of Hawai'i Aquaculture and should be funded to repeat biannually."

"Aquaculture development ought to be guided by the best science for industry practices and safeguards for the environment, while leading in local community engagement, and equitable and inclusive practices. Aquaculture development ought to be guided by the best science for industry practices and safeguards for the environment, while leading in local community engagement, and equitable and inclusive practices."

Restorative & Regenerative Aquaculture

Less than half of the respondents indicated that they were pursuing restorative or regenerative aquaculture. Some of the reasons for this were the environmental unsuitability of Hawai'i, species viability, insufficient incentives or support, access to hatcheries for native species, and cost to benefit ratio.

Almost all respondents are in favor of more investment into bi-valve and limu production as restorative and regenerative aquaculture activities despite their benefits and commercial viability not being proven. However, permitting is viewed as more important and funding.

More research is required to investigate the impacts and benefits of coastal restorative aquaculture on the environment, economy and community

"Regenerative aquaculture around fish ponds is generally not cost-effective, especially in Hawai'i with its high labor wages. So, a supportive program should be developed by government."

"Hawai'i is made up of volcanic islands with no shallow continental shelf like the mainland , hence sites are limited. Further, near shore tropical waters are nutrient poor and won't support large scale shellfish or seaweed culture."

"The modern definition of regenerative aquaculture is not compatible with Hawaiian ecosystems. We should used traditional loko i'a methods which sustained practices and communities in these exact locations."

Photo: Taylor Shellfish Farm

7.3 Global Scan of Best Practices that Support Aquaculture and Ocean Health

Global analysis & case studies

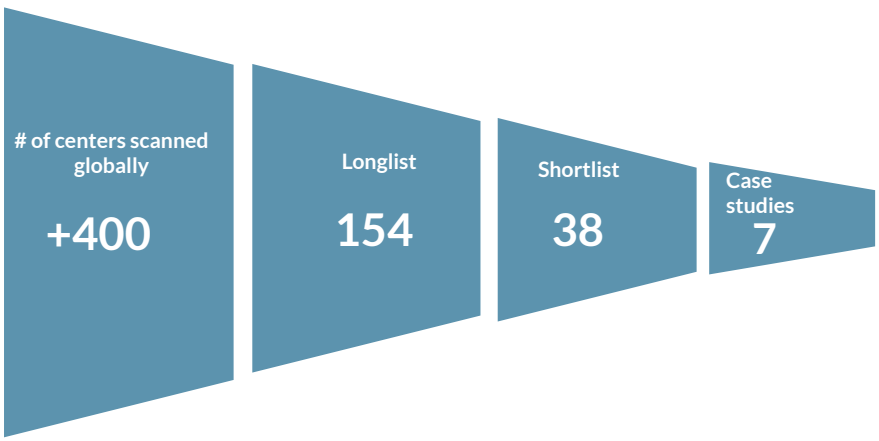
- Overview of Innovation hub & cluster centers
- Global Analysis: Aquaculture Centers
- Global Analysis: Public-Private Partnerships to Increase Aquaculture Production
- Global Analysis: Commercial Bivalve Farming, Indonesia
- Global Analysis: Commercial Seaweed Aquaculture, Canada
- Global Analysis: Restorative Aquaculture, Madagascar & the Philippines

Geographical Location of 'best in Class' Clusters and Centers in Aquaculture & Ocean Health

Of the more than 400 centers scanned for this mapping exercise, more than half were not analysed in greater detail, as from their name and location it is fair to conclude that most are solely academic or government research institutes.

Hatch has assessed 154 centers that made it to the longlist and were analysed more closely, 116 would exclusively fall under ocean and aquaculture themes as presented in the map below. It is clear from this analysis that the majority of aquaculture and ocean centers, in fact only 10% of all centers scanned, match with the definition of an Aquaculture and Ocean Innovation Center employed in this analysis. These 38 centers were further analysed to identify key success criterias to support industry growth and development. Further, deep dive case studies can be found in the appendix, in reference to the table below.

NELHA/ HOST PARK	Hawaiian Ocean and Science Technology Park	Kailua-Kona, Hawai'i	SAIC	Scottish Aquaculture Innovation Center	Stirling, Scotland
COVE	COVE	Nova Scotia, Canada	NCE	NCE Seafood Innovation Cluster	Bergen, Norway
MAIC	Maine Aquaculture Innovation Centre	Maine, USA	SEAFDEC/ AQD	Southeast Asian Fisheries Development Center (Aquaculture Department	Panay Island, The Philippines
IOC	Iceland Ocean Cluster	Reykjavík, Iceland	MAC	St. John's Marine Aquaculture Center (MAC)	St. John's Island, Singapore



These blue economy hubs have been chosen for the following features:

- Strong industry lead / support
- Building on established industry / critical mass
- Strong linkages to academia / research base
- Network of ambitious ocean innovators
- Plug a recognised gap in current innovation support
- Have high political awareness
- Value and protect the ecosystem

Different types of Innovation Centers

Research Center

- Infrastructure for doing research
- May specialize in basic research or may be oriented to applied research

e.g.

Marine Aquaculture Centre, Singapore

Innovation Supercluster

- Massive innovation systems
- Designed around Industries of the future
- Built around the five stakeholder groups, often cluster closely together
- Has a formal organisation, board, CEO, staff, budget and annual reporting.

e.g. Norwegian Centres of Expertise NCE Seafood Innovation Cluster

Innovation Hubs

- Office spaces, innovation parks, co-working space, incubators or creative lofts
- Member of innovation clusters
- Hubs are single buildings or larger centers with labs, offices, test facilities and more.

e.g. COVE

Innovation Districts

- Large scale innovation areas in cities and regions, often development by long-term public planning and intervention
- Frequently located in amenity-rich residential and commercial environments,
- Often near universities and host clusters

E.g. marineholmen

Research Parks

- Near to universities
- Tend to practice a more closed approach to innovation
- Will have a Tech Transfer Office (TTO) to help commercialize the research.

E.g. SEAFDEC/AQD Southeast Asian Fisheries Development Center / Aquaculture Department

Cluster

- Either naturally emergent or built
- Often very local by design and focus
- Built around supply chains and/or the Triple Helix framework.
- Small in size, limited funding. Often relying on project funding.

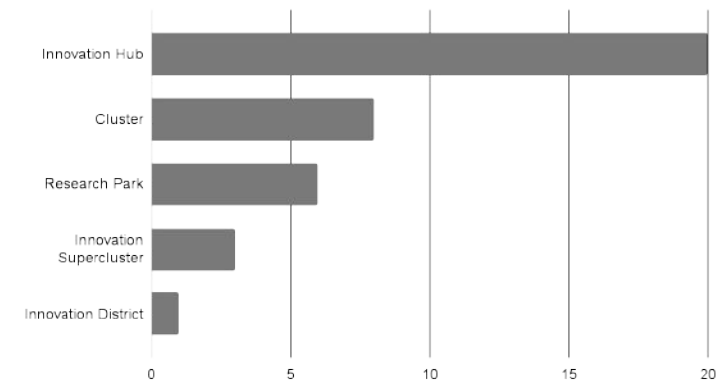
E.g. AOC ALASKA OCEAN CLUSTER

What are the core services recognizing these innovation functions?

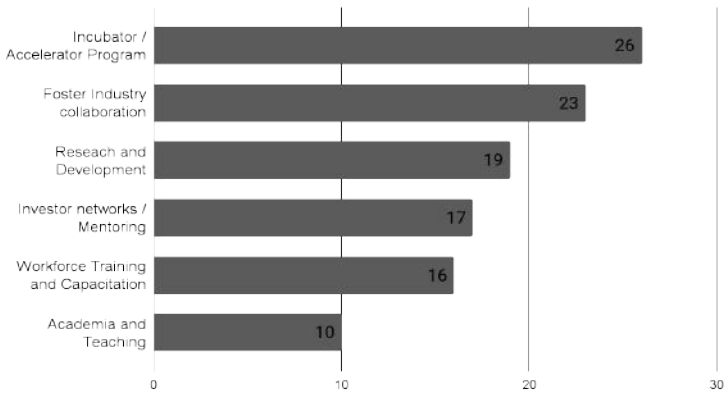
More than half of the centers shortlisted can be classified as innovation hubs - they are physical spaces that offer offices, labs, testing sites and other shared facilities.

The main objective of the majority of these centers is to foster entrepreneurship through incubator and accelerator programs and industry collaboration by hosting joint projects, events, etc.

Share of different innovation center type



Main functions of entities



Engagement from all stakeholders is fundamental to successful innovation centers

Most clusters and cluster programs around the world are based on the Triple Helix framework. Originating in the late 1980's, the underlying theoretical framework of the cluster was getting industry, academia and government to better collaborate. The Triple Helix was a key construct as societies emerged into the knowledge-economy. That paradigm is rapidly getting outdated. Since the early 2010's, a growing number of clusters and cluster programs have been upgrading and expanding their theoretical frameworks to include capital and entrepreneurs. Through work by Professors Torger Reve (BI Norwegian Business School) and Scott Stern (MIT), we are seeing a shift from the Triple Helix to the Pentagram. This shift is both a theoretical shift in the underlying 'idea of the cluster' as well as a practical shift.

Today, any cluster needs to update its foundation to better include, involve, activate and serve startups, scale ups, accelerators, incubators, business angels, venture firms, PE funds and large investment companies. Welcome to a new cluster paradigm.

Hatch mapped out the Hawai'i aquaculture stakeholders and populated a database that listed critical details on each stakeholder. Information collected for each stakeholder included the infrastructure, services, and facilities offered, as well as contact details, website addresses, and a synopsis of the type of services they offered or functions they performed. The database was categorized by sector and geographic location. From this information and other collected research material, Hatch was able to ascertain the gaps, limitations, and opportunities of the Hawai'i aquaculture industry.

Entrepreneur

- Building a powerhouse for entrepreneurship, by attracting capital and supporting entrepreneurship in the ocean industries globally
- Accelerating entrepreneurship with business growth programs and risk-capital access to rejuvenate new product ideas to boost innovation in ocean industries
- Build a long-term culture of entrepreneurship, from early stage to IPOC

Capital

- Build out a large-scale ocean investor landscape
- Connecting capital with investment opportunities and increase investors domain expertise on investment opportunities in the growing ocean economy
- Develop a network of business angels
- Significantly improve value creation in the ocean space for investors

Corporate & Industry

- Faster adaptation of knowledge and new technology
- Shorten the Time to Market for new innovations by accessing knowledge and infrastructure for testing
- Speed up innovation through Corporate Venture Capital (CVC)
- Start working with open innovation, through new partnerships, collaboration projects with start-ups and scale-ups

Academic & Education

- Collaborate with industry on new R&D programs
- Attract more funding for R&D projects
- Develop new, industry-related educational programs
- Deliver ocean learning products and engagement with communities
- Work more closely with entrepreneurs and venture capital investors to create more relevant educational program

Government & Public Sector

- Translate government strategies into operational and actionable activities.
- Ensure policy and public support programs promote economic growth and jobs
- Support industry and job creation through new, innovative formats

BLUE ECONOMY INNOVATION HUBS ARE:

Private-public partnerships
developed by design

Engines
of economic growth, by connecting 100's of members and collaborators

Solving
industry-level challenges & opportunities

Magnets
that attract talent, capital, researchers and companies

Trust-based
collaboration platforms

Collaboration networks
built around the industries of the future

Global Analysis: Innovation & Services

Process

Following a worldwide scan of the 400+ existing aquaculture or innovation hubs with a 'blue economy' theme, seven were chosen as 'best in class' to showcase the key criteria for successful innovation hubs. Not included in this analysis is Hawai'i's own NELHA HOST Park in Kona Bay which is profiled separately.

For the purposes of this report, we have used the defining characteristics listed on the left to select 'best in class' centers.

Additional inclusion criteria were that the centers must have a physical location and must offer shared resources (such as connectivity, water access, investor networks, training, mentoring, incubator or accelerator programs etc.)

A full analysis of each hub is available in the appendix but the key takeaways from the analysis are listed below.

Key Takeaways from 'Best In Class' Centers

- All have very strong links to academia - they are often located in close proximity to a university or a research institute to promote applied or industry focused research
- Most can be categorized as innovation hubs - they are physical spaces that offer offices, labs, testing sites and/or other shared infrastructure
- They have a cluster building component that fosters collaboration and innovation across different stakeholders on a regional or global level is of high importance
- The back bone organisation plays an important role in securing program/project funding from available funding resources from the public and private sector
- The main function is to foster entrepreneurship through business support, incubator, accelerator, and scale up programs with a focus on innovation and environment, as well as capacity building programs and initiatives for the workforce
- Substantial support from government usually unlocks private sector follow-on investment

	Scottish Aquaculture Innovation Center (SAIC)	NCE Seafood Innovation Cluster	Maine Aquaculture Innovation Center	COVE	Iceland Ocean Cluster	St. John's Marine Aquaculture Center (MAC)	SEAFDEC / AQD
Year Established	2014	2015	1988	2017	2012	2003	1973
Location	Stirling, Scotland	Bergen, Norway	Walpole, Maine, USA	Nova Scotia, Canada	Reykjavík, Iceland	St. John's Island, Singapore	Panay Island, Philippines
Website	https://www.sustainableaquaculture.com/	https://seafoodinnovation.no/	https://www.maineaquaculture.org/	https://coveocean.com/	https://www.sjavarklasinn.is/en	https://www.sfa.gov.sg/homepage	https://www.seafdec.org.ph/
University link	University of Stirling & other Scottish universities	Many Norwegian Universities	University of Maine	Dalhousie University, Nova Scotia	Reykjavíc University, University of Iceland	Singapore Research institutes and Institutes of Higher Learning (IHLs)	South East Asian (SEA) universities and research institutes
Members	270	91	N/A	60	70	N/A	11 member countries from the SEA region
Facilities	Research facilities, office space, networking events and database	Access to commercial office, llab space (RASlab), workshop and teaching facilities	Office space, Access to Flowing Seawater Lab, Dry lab and algae culture facilities	Office, lab, incubation and shop space, ocean access, two deep water piers	Office, event and lab space, networking, tours	RAS tank system, incubation modules, feed production services, research facilities	Hatcheries, broodstock tanks, feed development facilities, training facilities, biotech labs, mariculture park
Stakeholders	Academics Industry Government Research funders Startups	Academics Industry Government Research funders Startups	Academics Industry Government Research funders Startups	Academics Industry Government Research funders Startups	Academia Industry Startups Investors	Academics Industry Government Research institutes	Academics Industry Government' Research institutes International agencies
Training	Vocational, Academic, Market	Vocational, Academic, Market, Business Incubation	Vocational, Academic, Market, Business Incubation	Vocational, Academic, Market, Business Incubation	Vocational, Academic, Market, Business Incubation	Vocational Academic Market	Vocational Academic Market Business
Funding	Public Funding, Industry	Public Funding, Industry	Public Funding, Industry	Public Funding, Industry	Industry	Public funding (private funding for projects)	Public Funding Industry

NCE Seafood Innovation, Norway

KEY STAKEHOLDERS & PARTNERS

Government
Investors and risk capitalists

Academia - Norwegian universities, including the universities of Nordland and Bergen, and leading business schools such as BI and NHH.

Fisheries and Aquaculture industries and associations

CENTER ACTIVITIES

Runs / develops projects for cost-effective sustainable seafood production

Provides a range of services for members as well as meeting and training facilities.

Publishes industry insight reports and newsletters, runs webinars and workshops, holds summits, events, conferences.

CENTER VALUE PROPOSITION

The cluster focuses on five industrial areas of priority through knowledge sharing and innovation.. New technologies, innovation and climate key focus points.

NCE provides a range of services, including EU advisory for public funding, mentor forums, and incubator programs for industry-oriented business ideas.
It provides a full training program for students and teachers (Seafood Trainee) as well as a knowledge accelerator for new industry professionals (Seafood Next).

Network and third-party funding opportunities are offered through the Seapoint members-only facility.

PUBLIC FUNDING

30% government / EU funding

PRIVATE FUNDING

45% industry contributions
25% in kind contributions

KEY ECOSYSTEMS & PARTNERS

EU funding bodies and government

Cluster members and partners

RESOURCES

Industry services, including entrepreneurial services, competence programs, and innovation services.

Network of 90+ members across the industry. Regular newsletters and industry reports on priority areas

Symposiums, conferences, workshops, and meeting facilities.

Support for and collaboration on research projects, funding or support for start ups and incubator ideas.

CHANNELS

Website
www.seafoodinnovation.no

Newsletters

Social media:
FaceBook (1700 followers),
LinkedIn (5384 followers),
Twitter (1498 followers)

FUNDING PARTNERS

Industry
Government
Independent investors

MEMBER RELATIONSHIPS

NCE provides facilities for think tanks, workshops, webinars and virtual meetings, and conferences for its members.

NCE provides a competence program for new industry professionals, as well as a highly regarded training program. These have assisted members to attract new young talent to the industry.

Members have access to an extensive network of organisations and industry experts, including R&D and academic institutions, investors, media representatives, start ups, and established producers.

CENTER MEMBERS

102 partners and members, made up of:

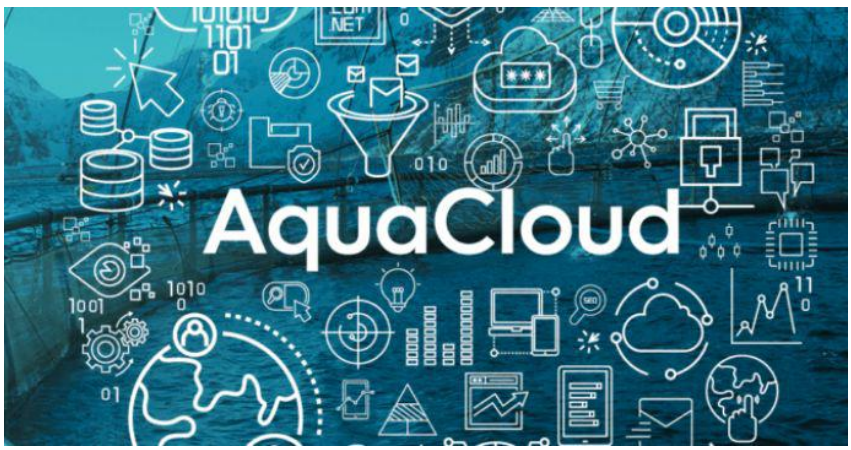
12 R&D partners
20 members
51 Startups
4 risk capital members
5 Financial Collaborators
10 Cluster to cluster collaborators

NCE SEAFOOD INNOVATION PROJECTS

10 -20 projects are ongoing each year. Recent projects have included: **Aquacloud** (data collection), **IFishIENCI** (feeding program), **Mind the Gap** (understanding the gap between science and industry) and **KABIS** (sustainable seafood production).

INDUSTRY PARTNERS

Leroy	Cargill	Grieg Seafood	Benchmark Genetics
MSD	Pharmaq	Elanco	Coast
Deloitte	EY	DNB	Thommessen



Projects that the NCE are involved in include AQUACLOUD (the use of AI in aquaculture) and BLUEMUSSELFEED (a poultry feed made from ocean cleaning blue mussels) amongst many others. Images from NCE SEafood Innovation. (https://seafoodinnovation.no/what-we-do/projects/)

Sources: https://seafoodinnovation.no/wp-content/uploads/2022/04/Annual-Report-2021_NCE-Seafood.pdf, https://seafoodinnovation.no/

SUSTAINABLE AQUACULTURE INNOVATION CENTER (SAIC), UK

KEY STAKEHOLDERS & PARTNERS

Government
Investors and Entrepreneurs

Academia - All Scottish universities, including Stirling, Glasgow Caledonian and, Edinburgh Universities, and other European universities

Fisheries and Aquaculture industries and associations

CENTER ACTIVITIES

Foster R&D and collaborative research into industry / environmental / health / economic / technology issues

Offer skills workshops & training, including internships & leadership programs, learning materials.

Focus primarily on Scottish aquaculture industry but also some global impact research

CENTER VALUE PROPOSITION

SAIC works to reduce the environmental footprint and increase the economic impact of aquaculture, it provides opportunities for start ups and R&D projects that focus on these IPAs.

It connects businesses and academics, funds and supports commercially relevant, collaborative research. SAIC also funds university places and run tailored training programmes.

The SAIC Consortium is a free network for aquaculture professionals and academics to connect, collaborate, and get advice on funding opportunities.

PUBLIC FUNDING

£8.8m (UK gov grant)

PRIVATE FUNDING

£9.8m (leveraged by SAIC for project funding from industry and other sources)

KEY ECOSYSTEMS & PARTNERS

Government bodies

Affiliated academic and research organisations

Consortium members

RESOURCES

Research materials, collaboration, and funding for innovative R&D projects.

Extensive industry network - national and international

Leverage for funding and collaboration from industry and academia

Learning materials, training, conferences, government policy wrangling, nurturing new entrepreneurs and businesses.

CHANNELS

Website
www.sustainableaquaculture.com

Newsletters

Conferences

Social media: FaceBook, Instagram, LinkedIn, YouTube

FUNDING PARTNERS

Industry, government & independent investors

Most SAIC projects are funded only if they have an industry lead partner and a Scottish research partner.

MEMBER RELATIONSHIPS

The SAIC consortium is a free network and industry professionals and academics can join on application.

SAIC interacts closely with the industry through summits, events, newsletters, and publications. Currently have more than 300 business and organisations in the consortium. Publish articles and industry news regularly.

Assists with third-party funding. Has excellent relationship with universities and provides training and learning materials to new entries into the industry, thereby consistently attracting new members.

PROJECT FUNDING

For every £1 of SAIC funding granted to research projects, a further £4.67 is leveraged from industry and other funding sources.

ECONOMIC IMPACT ASSESSMENT [1]

It is predicted that SAIC projects will contribute an increase in aquaculture turnover by £50m and by 2026. SAIC projects are forecast to create 600 new full-time jobs by 2026.

CENTER MEMBERS

270+ members, including
166 (61%) SME members
4 large primary producers

Member of SAIC, Smir supplies innovative solutions that contribute to environmentally friendly and cost-efficient farming. See https://smir.no/

Sources: SAIC Annual Report 2022, https://www.sustainableaquaculture.com

[1] *Frontline Consultants and economist Steve Westbrook*

Public Private Partnerships Driving Communities or Production

SOAR & CHESAPEAKE OYSTER ALLIANCE, USA

Following on from the success of the 2015 Harris Creek reef restoration, Supporting Oyster Aquaculture and Restoration (SOAR) came to the help of farmers in Maryland during the Covid-19 pandemic. With restaurant and shop closures, farmers were left with millions of surplus oysters at the end of 2020. SOAR stepped in and purchased 5 million tons of oysters and placed them on sanctuary reefs in the Chesapeake Bay, helping these reefs to meet their restoration goals.

The Chesapeake Oyster Alliance (made up of community organizations, universities, NGOs, corporate and private partners) came into being in 2019. It aims to add 10 billion oysters in Virginia and Maryland waters by 2025. The key components are to restore oysters in sanctuaries, improve science-based fishery management, and increase oyster aquaculture.

Source: The Nature Conservancy

A+ PROGRAM, NEW ZEALAND

Aquaculture New Zealand launched the A+ Sustainable Management Framework in 2015 and has since tweaked and improved the program. A+ helps aquaculture farmers and processors continuously improve practices to ensure that environments, communities, products, culture and water are cared for, and that seafood is responsibly and ethically produced. It is a voluntary self- regulating industry program, but almost all NZ aquaculture growers are members of the program. Growers complete species-specific checklists annually that cover the key criteria of compliance, ecology, water quality, waste, resources, food safety and animal health, Iwi participation, and community. Members' reporting is verified by independent assessors. The success of the program is undeniable. See the links below for full details.

Source: A+ Aquaculture, 2021 A+ Sustainability report

THE RED SEAWEED PROMISE™ TANZANIA

Seaweed farming is the third-largest export industry in Tanzania. It employs more than 25,000 people, 80% of which are women. The industry produces around 10,000 MT of seaweed annually. In addition, seaweed also serves as an alternate income for fishers to alleviate the threat of overfishing.

To mitigate a stagnating industry due to poor seedstock and water quality, and the impact of less sustainable farming practices, Cargill and The Nature Conservancy (TNC) teamed up with C-Weed Corporation (Tanzania) and the government of Zanzibar to initiate this project.

In year one, TNC will train 100+ farmers on how to site, design and manage their farms to increase yields, while reducing farming impacts to coastal environments at the same time. By 2024, the project aims to have trained up to ten villages - reaching more than 1,000 farmers. Currently, 60% of the producers trained are women.

PUBLIC PRIVATE PARTNERSHIP: TIMOR-LESTE

NATIONAL AQUACULTURE DEVELOPMENT STRATEGY (NADS) 2012-2030

Timor-Leste has been exposed to the impacts of climate change for years. This has hampered domestic food production leading to malnutrition and a dependence on imported food. But a national strategy to prioritise the sustainable growth of fish production through Genetically Improved Farmed Tilapia (GIFT) has helped reverse these trends and also provide new economic opportunities throughout the aquaculture value chain.

Timor-Leste is on track to double fish consumption by 2030, having already generated returns by tripling productivity. They've done this by prioritising and deploying locally adapted solutions and technology. The Timor-Leste government partnered with WorldFish to introduce a public-private partnership model for GIFT hatcheries across the country, ensuring that farmers have access to fish fingerlings in their local area.

The improved tilapia breed addresses nutritional gaps for protein, fatty acids, and micronutrients, while also minimising the burden on the environment. The hatcheries follow rigorous environmental standards, which limits the release of effluence, and also observe strict biosecurity measures.

The implementation of NADS: Partnership for Aquaculture Development in Timor-Leste (PADTL) - phases one and two

The WorldFish public-private partnership hatchery at Leohitu, Timor-Leste. Photo: Shandy Santos

Wins and takeaways from phases one and two

- The new hatcheries have increased production threefold, paving the way for successful scaling of aquaculture across the country
- The long-term commitment to the strategy has allowed the initiative to evolve over time and enabled the testing and validation of technologies and practices.
- Timor-Leste provides learning opportunities for other small island nations (specifically, to date, the Solomon Islands)

Sources: https://worldfishcenter.org

"The PADTL2 project has given me great results. My family eats fish twice per week, which we weren't doing before. I've earned USD 6500 from selling fish, fingerlings, and feed. This is a good outcome compared to other livelihood activities such as growing crops and raising livestock." - Robert Bau Maria, fish farmer

MARINE FOREST CREATION FIRA, SOUTH KOREA

The Korea Fisheries Resources Agency (FIRA) created the Marine Forest Creation project to combat the calcification of the ocean. Calcification refers to the whitening of the seafloor, seabed organisms, and rocks due to the increase in sea temperature caused by ocean pollution and global warming. This results in the deposition of calcium carbonate (chalk powder) in the ocean's depths (ShinaIlbo, 2023).

The aim of the project is to provide a secure, stable supply of marine resources while restoring the coastal ecosystem through systematic management. The goal is to restore the 35,000ha of nearshore coastal habitat around Korea by 2030. The project focuses on indigenous species of seaweed that are adaptive to high water temperatures. Various techniques have been used depending on the environment being restored, including Installation of marine forest plant facilities, submerged mooring ropes, spore pocket techniques, transplant panel techniques, and seagrass transplantation.

These projects are funded by the Ministry of Oceans and Fisheries in Korea and are being rolled out in fishing villages all around Korea. FIRA has also established a Marine Gardening Day (10 May) which is designated as a national seaweed planting day. Its goal is to promote the benefit of seaweed as both a food and habitat. FIRA's projects are part of a national strategy to restore the ocean ecosystem and marine resources in the territorial waters of Korea

In the natural rocky seabed in Sido, Buan County, where seaweed growth was hampered by excessive waves, natural stone facilities were installed to reduce the force of the waves in the area. They induced seaweed settlement more quickly by by building an underwater long-linet facilities to assist seaweed spore release and direct transplantation of species onto the rocky surface.

Shinaibo, 2023

In the Maritime National Park, a habitat restoration method was used that involved using bio polymers made from plankton extracts and eco-friendly attachment substrates mixed with sand to create conditions for seaweed settlement between coastal rocks. The Korea National Park Service successfully applied this technique, creating 85 seaweed habitat areas covering 4,000 square meters.

MedicalNews, 2020

Source: Korea Fisheries Resources Agency

IN PURE KOREAN, CALCIFICATION IS WRITTEN AS 'GAETNOREUM', WHICH MEANS "THE SEAWEED MELTS AWAY".

COMMERCIAL BIVALVE PROJECTS: ATLAS FARMS, INDONESIA

Atlas Farms has a hands-on relationship with the communities where they operate. Community support is crucial to the success of each farm, and the company supports the community in return through education, medical assistance, employment and training, social support, and environmental rehabilitation.

Over the past 30 years, Atlas Pearls has become one of the world's largest producers and distributors of the white & silver South Sea pearls. Operating across 7 farming locations throughout the South Seas, the Company employs more than 1,200 people and in 2023 harvested more than 540,000 pearls. - www.atlaspearls.com.au

Atlas Farms uses ethical, sustainable and non-extractive processes to produce its pearls. They have a rigorous breeding program that maintains a supply of healthy, genetically managed oyster stocks for their farms. The diverse farm locations allows for the stock to be placed in the best possible conditions for their growth, and this also diversifies environmental risk factors such as water temperature and algae. Seeded oysters are moved to the oyster farms in custom transport vessels. With oysters thriving in pristine waters, each farm site works tirelessly with staff and the local community to continuously improve and maintain the health of the oceans in which we operate. The farms employ a dedicated team of people who work with the oysters throughout the process from seeding, to cleaning, maintaining and harvesting.

1,200 employees

Oysters filter an average of **1 ton** of water per day

1,349,236 nucleated oyster stock

60% of harvested pearls are jewellery grade

Hatchery 1-2 months

At sea from 2 months old

Cleaned from 2 months to 4 years

Seeded aged 2 years

At farms from 2 to 4 years

Harvested aged 4 years

7 farms

Spat are **3mm** when they go to sea

2,865,641 oyster stock

20% of the original spat is selected for seeding

547,755 pearls (2023)

source: www.atlaspearls.com.au

COMMERCIAL SEAWEED PROJECT: CANADA

CASCADIA SEAWEED

The goal of Cascadia Seaweed is to build a scalable business that enhances the natural environment and provides economic opportunity for Indigenous and coastal communities. "It's sustainable aquaculture supporting regenerative agriculture — a circular system where every touch point makes a positive impact." – Mike Williamson, Cascadia Seaweed Co-founder & CEO.

Cascadia cultivates seaweed on low-impact ocean farms that produce the same ecosystem services as naturally occurring kelp would. They harvest biomass and manufacture products that address the needs of crop and livestock farmers in the area, and they partner with Indigenous communities in these endeavours.

Cascadia learns from the First Nations coastal communities about ways they have traditionally used to harvest seaweed, and where seaweed grows naturally. Each community is unique and holds valuable local knowledge.

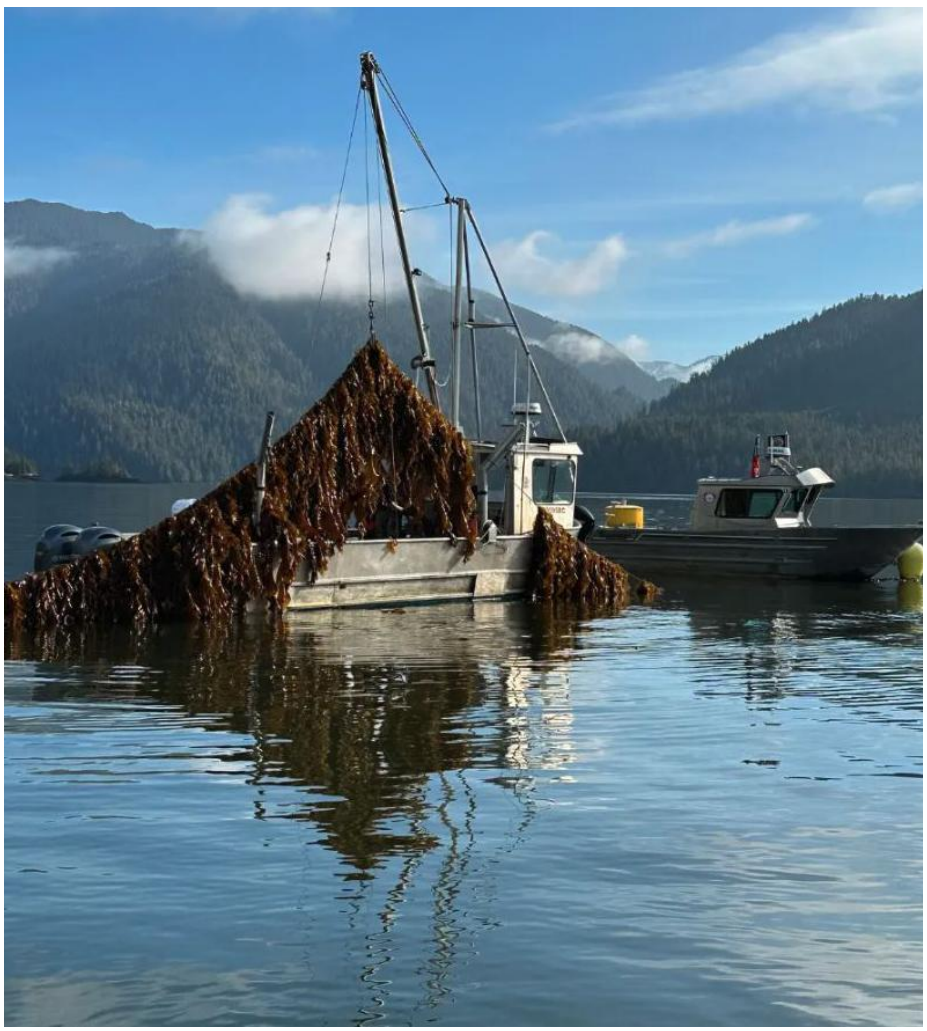
1ST HARVEST 2023

300 tons of kelp harvested

From 10 locations

At an average yield of 13lbs per meter

According to Mavis Underwood, a Tsawout First Nation elder, the partnership between Cascadia and the First Nations communities intends to reclaim and heal the ocean, stimulate young people in the communities, and revitalize the history and culture of living off salt water.



Source and photo: Cascadia Seaweed: https://www.cascadiaseaweed.com/

Commercial Seaweed Projects: Madagascar & Philippines

THE RED SEAWEED PROMISE™ MADAGASCAR

Ocean Farmers (a company formed through a Cargill partnership) works alongside farmers to increase the economic, social, and climate resilience of farming households and communities. Currently, Ocean Farmers is working with 1,700+ seaweed farmers across 40 villages.

Seaweed farming only started to flourish in Madagascar in the 1990s, and until recently the country produced around 500MT per year. Since the initiation of this project, Madagascar produces 1,800MT per year. Depleted marine resources are already showing signs of recovery and local communities are now making a living from seaweed.

"By partnering with farmers, we strengthen agricultural supply chains in an economically and sustainable way that helps build more resilient farms and communities" - Sebastien Jan (Ocean Farmers).

Image © Cargill

THE RED SEAWEED PROMISE™ PHILIPPINES

Although seaweed farming has been practiced in the Philippines since the 1960s, toward the end the 1990s, seaweed farming had dwindled and farmers were using old strains and outdated methods. As a result, they were contributing to overfishing and were responsible for more than 50% of the plastic pollution in their coastal communities.

Cargill and Coast4C started working together in 2020 and the partnership is already showing enormous promise. Coast4C is working on regenerative farming practices with 143 producers across 7 villages; producer-led co-ops are being established; and, in a partnership with the University of Philippines, the first new seaweed strains in 50+ years are being developed.

Cargill's support goes beyond procurement alone, with valuable input in terms of processes and agronomy improving seaweed production practices, and mitigating the impacts of climate change.

Sources: https://www.cargill.com/doc/1432198890865/sustainable-seaweed-red-seaweed-promise-progress-report.pdf; https://coast4c.com/; https://ocean-farmers.com/

7.4 Hawai‘i‘s Leading Aquaculture Companies, research capacities and networks

Hawaii‘s Leading Aquaculture Companies and Research capabilities

- Hawai’i Aquaculture Timeline of key initiatives
- Aquaculture in the Academic Sector in Hawai‘i
- Oceanic Institute
- Pacific Aquaculture and Coastal Research Center (PACRC)
- Evolution of key institutions
- Natural Energy Laboratory of Hawaii Authority (NELHA)
- Hawai‘i Ocean Science and Technology Park (Host Park)
- Cyanotech
- SPF shrimp broodstock
- Blue Ocean Mariculture
- Ocean Era
- Hatch Blue
- Startups in Hawai’i Innovation Ecosystems
- Information and Network facilitators

Photo: Blue Ocean Mariculture

Hawai'i Aquaculture Timeline of Key Initiatives

There are numerous examples of successful aquaculture enterprises in Hawai'i. The most impactful of these are represented in the following pages & appendix. These entities need are models to learn from and/or function as resources that should be invested in and developed further to fulfil Hawai'i's potential to expand as center of aquaculture excellence.

1000s

Loko i'a

An increasing number of Hawai'i's traditional fishponds are becoming active or are in the throes of rehabilitation and restoration. In 1985, a paltry seven active loko i'a were in commercial or subsistence use[1], but thanks to the Hawaiian Renaissance Movement and other organizations, there are now more than 60 fishponds either fully or partially restored, and this number is set to continue to increase. In conversation with Brenda Asuncion, the Hui Mālama Loko I'a Coordinator at Kua'Āina Ulu'Auamo, (KUA), it is apparent that although much work needs to be done, the impact that loko i'a have on the community, environment and economy is emphatic and cannot be ignored.

1960

The Oceanic Institute

The Oceanic Institute (OI) is the foundation of the global SPF shrimp industry and it is estimated that approximately 70% of all SPF broodstock originally emanates from Hawai'i. Their facilities, resources and expertise in shrimp, RAS technology, feed development and other aquaculture and marine sciences studies could be fundamental to the growth of the aquaculture industry

1974

NELHA's HOST Park

This state-of-the art aquaculture center is a world premier facility. Its value to the industry is repeatedly referenced by practitioners, politicians, and academics. The impact it has had on the industry is verified by the reputation of the companies it has spawned. The provision of seawater pumped from three different levels 24/7, 365 days a year is unmatched globally. The pre-permitted areas and the infrastructure and resources it provides on its campus are critical to the development of the industry and offer a unique service to startups, new businesses, and existing companies.

1984

Cyanotech

This company is a world leader in the production of high value natural products from microalgae. They run an environmentally sensitive operation on 96 acres of land in NELHA's HOST Park. They have designed and developed proprietary production and harvesting technologies, systems and processes and operate a hugely successful commercial business in an efficient and sustainable manner.

1991/2

SPF Shrimp Broodstock

The SPF shrimp revolution started at OI and expanded to NELHA through High Health Aquaculture company. Kona Bay and Shrimp Improvement Systems (SIS) developed the broodstock industry exponentially and globally Hawai'i is reckoned to be the gold standard for SPF shrimp.

1992

Ocean Era, Inc

The research company, Ocean Era, is a well-respected aquaculture company renowned for its innovation and research into aquaculture for commercialization. They are world leaders in open ocean aquaculture and are committed to advancing healthy, responsible and sustainable mariculture through industry-leading research into sustainable alternative feed solutions.

2009

Blue Ocean Mariculture

Blue Ocean Mariculture is not only the only open ocean aquaculture farm in the USA but also the only ASC certified fish farm in the US. They are a benchmark operation who are as proud of their economic success as they are of their social and environmental records.

2019

Hatch Blue

Innovation catalyst, entrepreneurial ecosystem builder, early stage investor and senior consultancy dedicated to drive global success in aquaculture

1. Aquaculture in Ancient Hawai'i (Barry A Cosa-Pierce, 1987)

Aquaculture in the Academic Sector in Hawai'i

The Center for Tropical and Subtropical Aquaculture (CTSA) is one of five regional aquaculture centers in the United States established by the U.S. Department of Agriculture. The regional aquaculture centers integrate individual and institutional expertise and resources in support of research toward commercial aquaculture development. CTSA was established in 1986 and was jointly administered by the University of Hawai'i and the Oceanic Institute of Hawai'i Pacific University till 2018. Now, the CTSA is administered by the University of Hawai'i and conducts all operations from the University of Hawai'i Manoa campus.

Members of CTSA in Hawai'i			Strengths, capacity & roles for Hawai'i Aquaculture
Hawai'i Pacific University (HPU) The Oceanic Institute			A non-profit research and development organization dedicated to aquaculture, biotechnology, and coastal resource management. Mission is to develop and transfer environmentally responsible technologies to increase aquatic food production, promoting the sustainable use of ocean resources. Facilities include wet and dry laboratories, permitted areas, RAS systems, test tanks, hatchery.
University of Hawai'i (UH)	UH Manoa (O'ahu)	Sea Grant College Program	Funds innovative aquaculture research every year, usually in partnership with the State. Core program is restorative activities and sustainable planning with a focus on the health and vitality of the nation's coastal resources and communities
		College of Tropical Agriculture & Human Resources	On and off-campus programs, research and teaching. Promotes applications for productive sustainable agriculture
		Hawai'i Institute of Marine Biology	Research and training in tropical marine biology and a world leader in research aimed at understanding and conserving tropical marine ecosystems and the development of new technologies, The Pauley-Pagin marine laboratory is a world class facility for marine biology.
		Freshwater Research Research Center	researches water-related issues distinctive to Hawai'i and the other Pacific islands. Areas. Has an analytic and an environmental biotechnology laboratory.
		Kewalo Marine Laboratory	Research into near-shore marine environment. Resources for collecting and maintaining marine organisms. Fully equipped state-of-the-art marine lab with seawater system and core facilities
		Tuahine Aquaculture Research & Education Center	Construction of the research center is not complete but it is designed to increase hands-on training opportunities for students and research and extension capacity
	UH Hilo (Big Island)	Pacific Aquaculture & Coastal Resources Center (PACRC)	Goals are to provide infrastructure needed for world-class aquaculture and marine science programs at UH Hilo, support commercial aquaculture, fisheries and conservation in East Hawai'i. Resources include laboratories, tanks, research facilities.
Hawai'i community colleges		Hawai'i, Honolulu, Kapi'olani, Kaua'i, Leeward, Maui, and Winward Community Colleges	These colleges all operate under the auspices of the University of Hawai'i. Winward College offers a Marine Option Program open to students who have an interest in the ocean. It is a clearinghouse for marine-oriented education and employment opportunities, a chance for students to network with professionals and fellow students who are involved with the ocean.
Anuenue Fisheries Research Center (AFRC)			Serves as a base yard, hatchery, and culture center for the Division of Aquatic Resources. Laboratory, freshwater fish hatchery, workshop & storage, a thermo controlled hatchery building, and a quarantine facility for aquatic disease studies.
NOAA			Funding and advisory agency, also provides data, publications, news, monitoring services, prediction of changes in climate, weather, oceans and coasts, sharing knowledge.¸
Out of state members of the CTSA include: University of Guam, College of Micronesia, Palau Mariculture Demonstration Center, College of the Marshall Islands, Palau Bureau of Marine Resources (old), Marine and Environmental Research Institute of Pohnpei (MERIP) , Northern Marianas College Northern Mariana College CREES, Rongelap Atoll Local Government, and Palau Community College			

A list of academic courses in aquaculture can be viewed here: https://docs.google.com/spreadsheets/d/1ts2RyDi7zy49kbMCwEATGcf29KyiMq2A/edit#gid=467455855

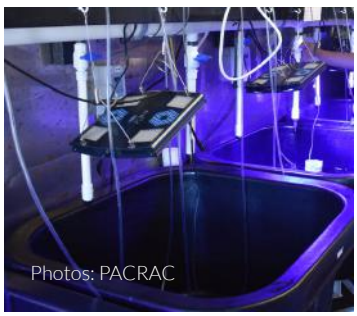
Oceanic Institute of Hawai'i Pacific University (OI) is a non-profit research and development organization dedicated to aquaculture, biotechnology, and coastal resource management. Content experts - Internationally recognized content experts in aquaculture, academic and commercial. In addition to the unparalleled internationally recognized expertise in academic and commercial aquaculture of its researchers and staff, OI also offers the following resources to the industry. Their unique infrastructure, biological inventory, and content expertise has been used over the past decades to help initiate and expand local, national, and global aquaculture industries and should be viewed as an important Hawai'i State asset. Unfortunately, since there heyday in 2003, OI's impacts and contributions to aquaculture have declined significantly, due largely to the lack of financial support. To illustrate this issue from 2003 – 2012, revenue came largely from research grants, with smaller amounts coming from construction grants and technical services. During this time, OI employed an average of 110 people. Thereafter, federal earmark grants abruptly were discontinued statewide. Today and in contrast, from 2021 – 2023, revenue came largely from technical services, with smaller amounts coming from research grants. During this time, OI employed an average of 25 people. Currently, OI's assets are undercapitalized and underutilized and their impacts are nowhere near where they could be with additional investment both in operating capital and for capital improvement / renovation.

Hawai'i should still be a national (and global) leader in aquaculture, both for food security and as an epicenter for aquaculture technology. This latter point is exemplified in the Hawai'i shrimp broodstock industry which originated at OI in the early/mid 1990s. This latter point also is exemplified in the marine ornamental fish industry where OI developed captive rearing techniques for Yellow tang and other difficult-to-rear aquarium fish.

OI can serve as the *de facto* Hawai'i State hatchery to produce all of the fish and shrimp needed by Hawai'i's aquafarmers. OI has all of the important assets to serve in this capacity (unique infrastructure, biological inventory, and content expertise), including the ability to draw up to 2,600 gpm of clean seawater and the permitted dispersion wells to discharge our effluent. It would cost the State tens of millions of dollars, and many years, to replicate OI somewhere else in Hawai'i.

Annotated Map of the Oceanic Institute of Hawai'i Pacific University

The Pacific Aquaculture & Coastal Resource Center (PACRC) of University of Hawai'i in Hilo



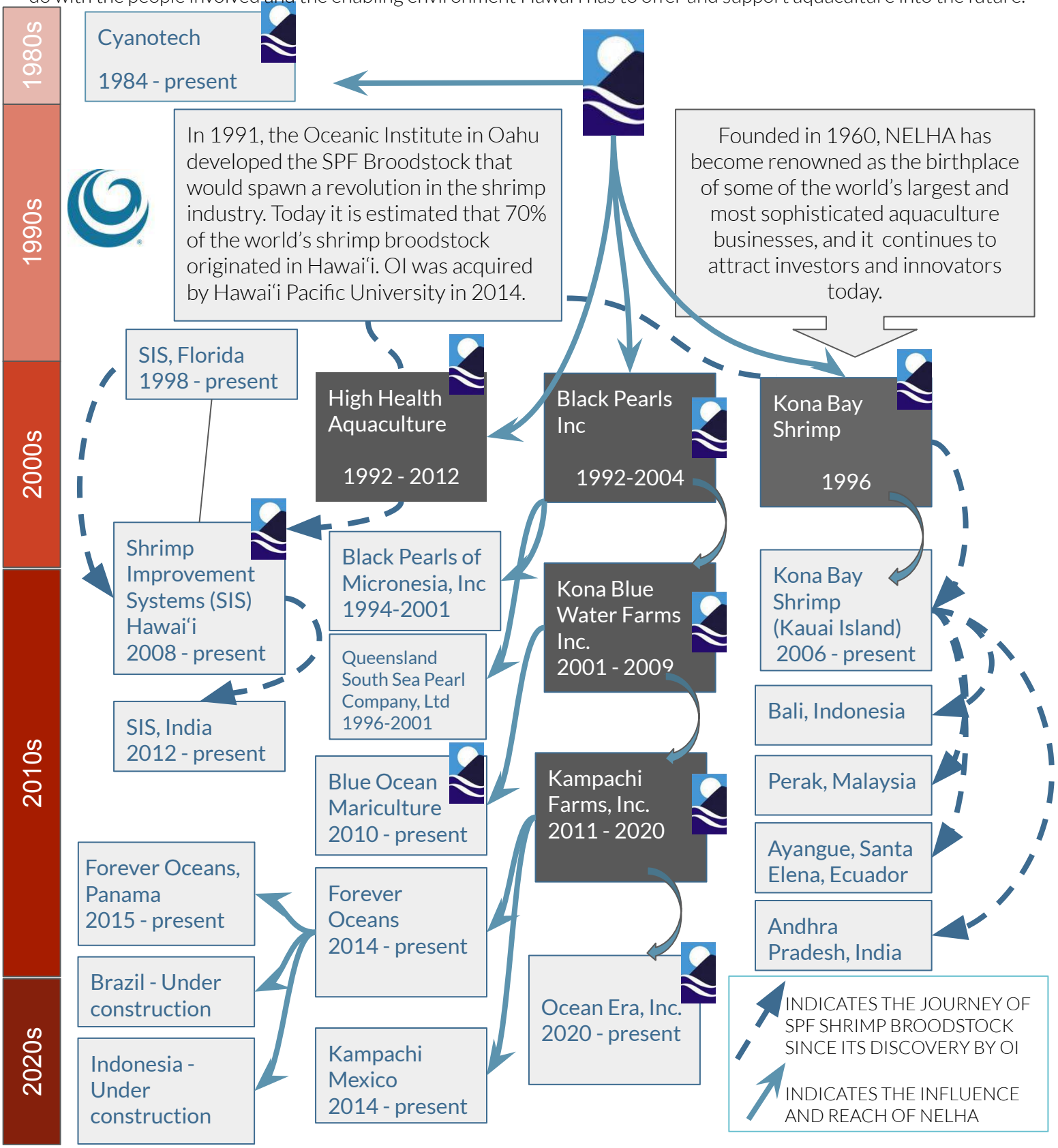
Photos: PACRAC

The PACRC is a coastal site in Keaukaha on the Big Island adjacent to the Port of Hilo. Once an old wastewater treatment plant, the site now focuses on marine ornamental and food fish culture and the cultivation of oysters. The new PACRC facilities, in combination with the UH Hilo Marine Science Building, greatly enhances the international reputation as a premier location for education and research in marine sciences, aquaculture and coastal resources.

The Pacific Aquaculture & Coastal Resources Center (PACRC)'s mission is to advance long-term sustainable use and conservation of coastal areas worldwide through aquaculture and resource management. The center operates aquaculture and coastal resource management projects worldwide, including Ecuador, Fiji, Honduras, Marshall Islands, México, Federated States of Micronesia, Nicaragua, Tanzania, Thailand, and the United States. The Center promotes excellence and innovation in interdisciplinary scientific research, public policy initiatives, outreach activities, and education. The PACRC is a project of the University of Hawai'i at Hilo in cooperation with the County of Hawai'i , the Keaukaha Community Association , and the UH Sea Grant College Program . It has diverse training program that covers marine food fish, marine ornamental fish, freshwater fish, molluscs, microalgae, macroalgae, sea cucumbers.

Annotated map of the Pacific Aquaculture & Coastal Resource Center (PACRC)

The Oceanic Institute and the Natural Energy Laboratory of Hawai'i Authority (NELHA) have been instrumental in initiating and facilitating some of the world's most iconic and influential aquaculture companies in the world today. This is a testament that Hawai'i has been and can continue to be a key aquaculture hub of the world and this has everything to do with the people involved and the enabling environment Hawai'i has to offer and support aquaculture into the future.



Nelha

In 2024, the Natural Energy Laboratory Hawai'i Authority (NELHA) celebrates its 50th anniversary. Since its inception in 1974, the state of Hawai'i has spent more than $130m setting up the ocean science and technology park in Kailua-Kona on the Big Island. Hawai'i Ocean Science and Technology (HOST) Park is an innovative green economic development park that operates at the nexus of water, energy and food. NELHA's mandate for HOST Park is to establish, provide and maintain facilities for energy- and ocean-related research and development and commercial industries using natural energy resources such as ocean water and geothermal energy. It also undertook to support science and technology innovations, tourism activities, retail businesses, and educational services that relate to natural energy and/or the ocean, and to maintain, market and promote the facilities and available natural resources. NELHA is mandated to support ocean research and technology development projects that support national and state interests and foster potential commercial development in the State.

Economic impact

The table below shows the average figures reported by NELHA between 2010 and 2018 (calculated from reports done by UHero, the economic research organization at the University of Hawai'i). It is anticipated that the next UHero report (2023) will reflect an economic impact in the region of $150million. Host Park's 46 tenants include some of the most respected aquaculture companies in the world, and include Ocean Era, Blue Ocean Mariculture, Taylor Shellfish, SIS, Makai Ocean Engineering, and Cyanotech, amongst others, as well as HATCH Ocean Foundry Incubator and Accelerator companies, NOAA, and the Hawai'i Technology Development Corporation (HTDC).

Average figures 2010 - 2018	Initial in-state expenses	Output	Earnings	State taxes	Jobs created
	$58.9 mill	$104.7 mill	$26.4 mill	$4.8 mill	570

Adapted from: *UHero NELHA REPORT: Economic impact of the natural Energy Laboratory Hawai'i Authority tenant on the State of Hawai'i in 2018.*

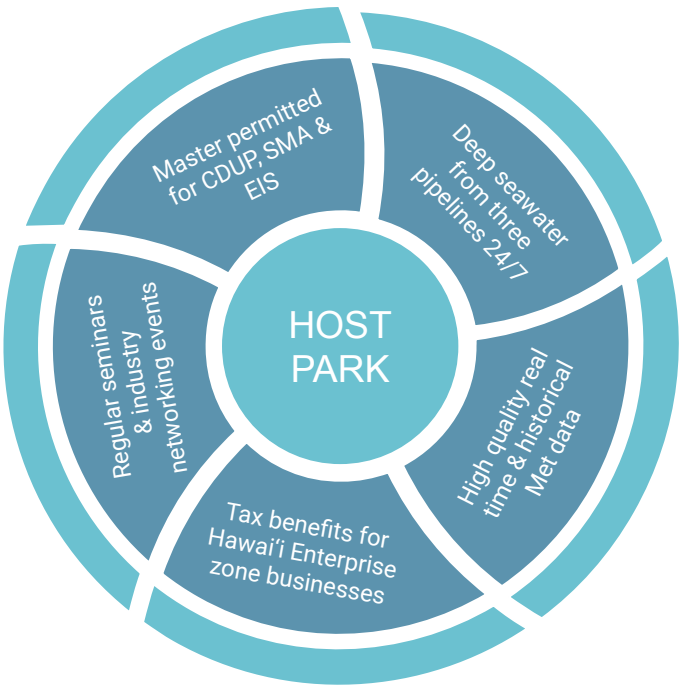
Key features

WORLD'S PREMIER ocean science and technology park, which is held as a benchmark for other aquatic centers around the world.

WORLD'S ONLY technology park with access to deep seawater at three levels, pumped 24/7 365 days a year. Three sets of pipelines deliver cold deep sea water from up to 3,000 ft. depth as well as warm pristine surface seawater. Current equipment and pipeline infrastructure are capable of pumping up to 100,000 gallons per minute of seawater throughout the 900-acre technology park.

WORLD CLASS facilities & services, including office space, R&D space, trial facilities, wet and dry labs, and multi-species systems PLUS pre-permitted areas for energy & aquaculture research & commerce.

DESIGNED TO DRIVE business and innovation, science and technology, applied research, marine biology and environmental science .



Cyanotech

Cyanotech, a world leader in the production of high-value natural products derived from microalgae, was founded in 1983 by Dr Gerald Cysewski in Washington State, but it relocated to Hawai'i in 1984. Cyanotech grows microalgae to produce the natural nutritional dietary supplements Astaxanthin and Spirulina. Starting with 5 acres of land in 1984, Cyanotech now occupies 96 acres of land and is situated in the NELHA HOST Park.

Cyanotech founded the subsidiary Nutrex (short for Nutritional Excellence) in 1990 under which label it sold Hawaiian Spirulina and, later, BioAstin and Hawaiian Astaxanthin. In 1996, Cyanotech went public in order to raise funds, which was used to complete the building of the production systems.

Following clinical trials, Hawaiian Spirulina achieved the FDA's Generally Regarded As Safe (GRAS) status and BioAstin followed suit in 2010.

In 2014, a 648KW photovoltaic system was commissioned at Cyanotech, which reduced its greenhouse gas emissions by 97 metric tons of carbon dioxide annually - the use of solar to power the farm is in line with the company's sustainability goals. Cyanotech also runs an onsite supercritical carbon dioxide extraction plant to produce BioAstin - this system is the world's only commercial scale 1,000 bar (14,700psi) extraction plant.

Recognized as a leader in quality, BioAstin is now sold in over 66 countries with expansive distribution in the US, including ecommerce, club warehouses, vitamin stores, and natural retailers. Hawaiian Spirulina Pacifica® holds more third party certifications than any other brand of spirulina.

Cyanotech

FDA GRAS GENERALLY RECOGNIZED AS SAFE

SPIRULINA HAWAIIAN PACIFICA

SPIRULINA PACIFICA

BioAstin® NATURAL ASTAXANTHIN

nutrex HAWAII

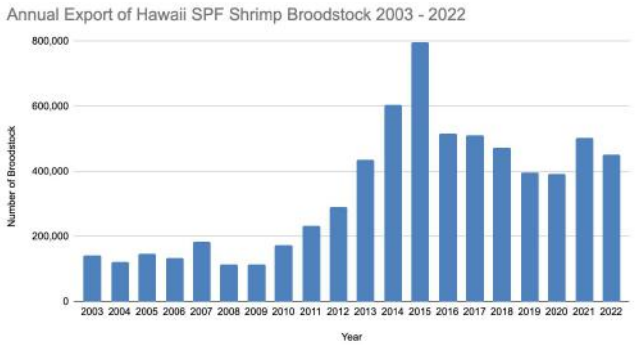
Photos: https://www.cyanotech.com/

Image: Cyanotech

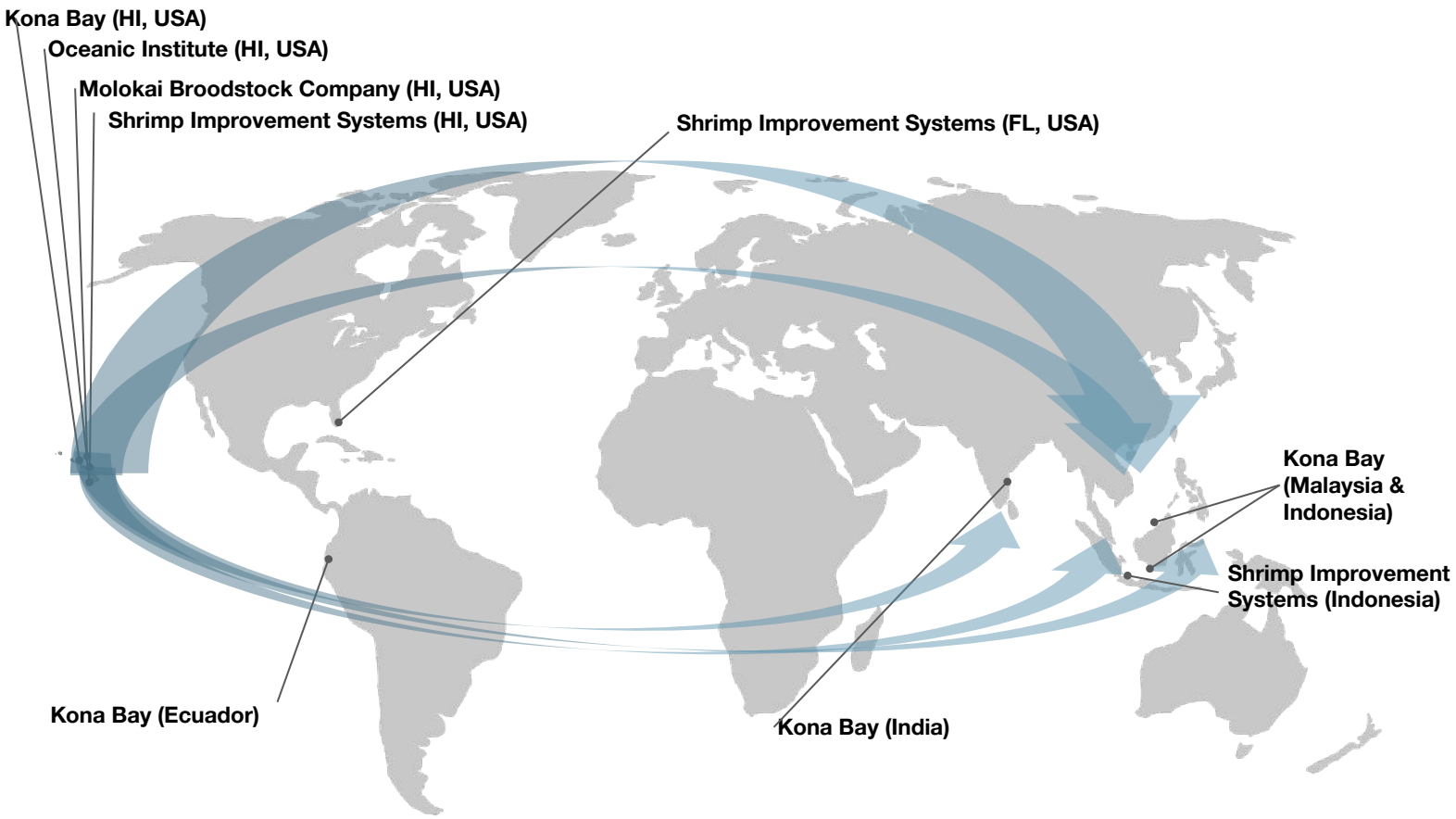
Hawai'i: the gold standard for SPF shrimp broodstock

For three decades, Hawai'i has dominated the Specific Pathogen Free (SPF) shrimp industry. In 1991, trials began on SPF *L. vannamei* at the Oceanic Institute (OI) on the Big Island. The results were impressive and they spawned a revolution in the shrimp industry. High Health Aquaculture spearheaded the commercial Hawai'i broodstock shrimp industry, but it was soon joined by Kona Bay Shrimp and Molokai Broodstock. In 2012, Shrimp Improvement Systems purchased High Health Aquaculture and are today one of the largest broodstock suppliers in the world with their headquarters at NELHA in Hawai'i.

The figure shows the exponential growth of the industry, showing that, from 2003 to 2015, the numbers of broodstock increase from nearly 100,000 in 2013 to 800,000 in 2015. In 2017, the export value was nearly US$ 30 million.



The figure below shows shrimp broodstock suppliers that originated in Hawai'i, their global expansion and their trade flows from Hawai'i.



Most SPF shrimp broostock is exported to Asia with most going to India, China, Vietnam and Indonesia. These countries are some of the world's largest shrimp producers supplying the US consumers with shrimp and are still very dependent on Hawaii for supply quality genetics for their hatcheries

Blue Ocean MARICULTURE

HATCH Innovation Services

Blue Ocean Mariculture (BOM) started out as a demonstration project in 2001. It was such a success that its founders decided to to launch it as a commercial operation in 2009. It is the only open ocean commercial aquaculture operation in the US and the only ASC-certified fish farm in the country. The BOM staff monitor and analyze water and seafloor samples continually to ensure any impact on the environment is minimal. Fish densities are controlled to preserve seabed health. Blue Ocean Aquaculture is an exceptional model of commercially viable sustainable aquaculture.

BOM operates an onshore hatchery at NELHA, where the process starts. BOM broodstock spawn naturally without any chemical intervention. Around 400 million eggs are collected annually. The fish are transferred into nursery tanks at NELHA and then into a nursery net in the open ocean. At about 450g, they are moved to the submersible pens off Keahole Point. The pens are located half a mile open ocean in areas of high water exchange. Fish stocking densities are restricted to preserve water quality and seabed health. To eliminate the risk of wildlife entanglement, BOM uses stringently engineered anchoring systems and net-pen moorings. The pens are fully submerged to minimize the visual impact of the farm and preserve the stunning open ocean views of the Hawai'i islands.

FARMED RESPONSIBLY asc CERTIFIED ASC-AQUA.ORG TM

The only ASC certified fish farm in the US

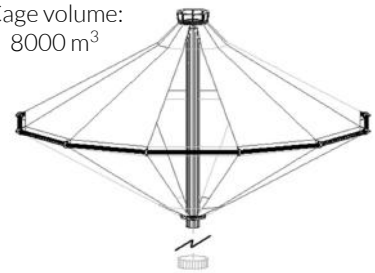
The only open ocean finfish farm in the US

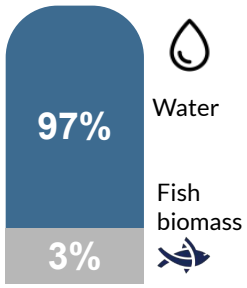
Kanpachi fish have more than enough room to grow and thrive in the submersible cages to ensure maximum health and welfare

Features

- Innovative technology
- Continual environmental monitoring & water quality testing
- Very small carbon footprint
- Ongoing research
- Hormone & antibiotic-free production
- Social audit & USA safety standards

Cage volume: 8000 m^3





Current production output:

900 tons Kanpachi = **4 million meals**

Local market sales **60%**

Export market sales **40%**

Potential (permitted) production:

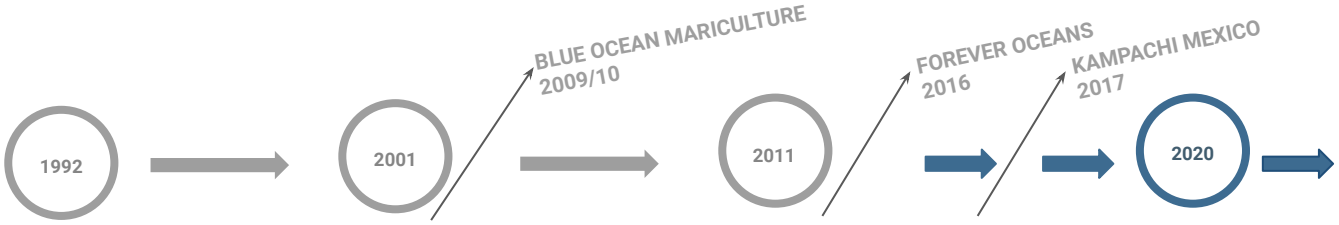
2,400 tons Kanpachi = **10 million meals**

Workforce **70**

Cages **8**

Source:Blue Ocean Mariculture infodeck; https://bofish.com/

Ocean Era is a leader in developing open ocean aquaculture systems and supportive technologies for high-value marine finfish, herbivorous fish, and macroalgae culture.



BLACK PEARLS, INC.

Black Pearls Inc, co-founded by Neil Sims, worked with innovative hatchery technologies for black-lip pearl oysters in Hawai'i, the Pacific Islands and South East Asia. Using economic incentives to drive environmental imperatives, they focussed on the development of the lucrative pearl culture industries in remote regions, coupled with stock enhancement and other conservation goals for the over-exploited species.

KONA BLUE WATER FARMS, INC.

The hatchery technologies developed in Kona catalyzed expansion into the open ocean aquaculture industry. Kona Blue were the first commercial company in the world to successfully raise several high value marine fish. After three years of consultation and consensus-building for the open ocean leases they obtained permits for open ocean operations in 2004. Between 2006 and 2008 Kona Blue's sales volumes rose from around $2m to $6m, with volumes peaking at 500 tons p.a. .

KAMPACHI FARMS, LLC

Kona Blue assets were sold to Blue Ocean Mariculture (BOM) and Kampachi Farms, LLC, which continued operating the research facilities. Kampachi Farms partnered with National Science Foundation and Lockheed-Martin in the Velella Projects. These were demonstration projects pioneering the world's first unanchored fish pen (recognized by *Time Magazine* as one of 25 best inventions of the Year for 2012), and the world's deepest-anchored net pen, that was operated completely remotely by wireless bridge.

OCEAN ERA, INC.

In 2020, Kampachi Farms rebranded as Ocean Era, Inc. the Lockheed-Martin partners in the Velella projects partnered with Ocean Era in founding Forever Oceans, a spin-off for developing next-generation technologies for 'over-the-horizon' aquaculture. Ocean Era principals also founded Kampachi Mexico (or The Kampachi Company) a commercial hatchery and open ocean grow-out operation in Baja Sur, California, which received ASC certification. Ocean Era continues to collaborate with Blue Ocean Mariculture and Forever Oceans in open ocean aquaculture, hatchery and grow-out technologies. Ocean Era are currently pursuing permits for anopen ocean aquaculture array off 'Ewa Beach on Oahu to co-culture marine fish and macroalgae, and pioneering permitting pathways for open ocean demonstration and commercial aquaculture off the Florida coast.

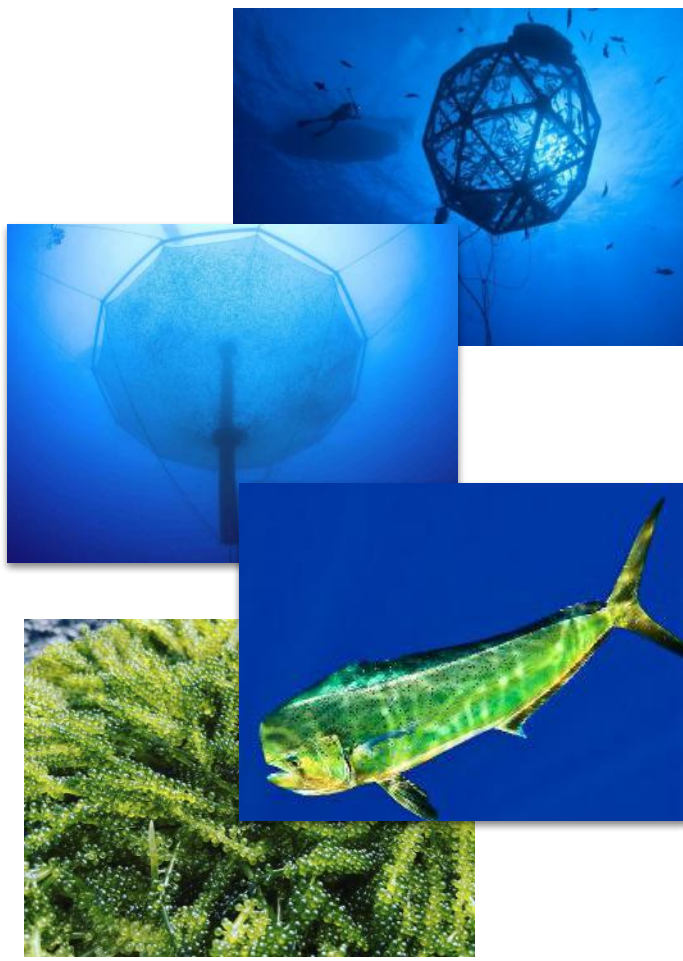
Ocean Era, Inc. is committed to advancing healthy, responsible and sustainable mariculture.

In the Velella Beta project, Ocean Era tested the use of an unanchored, copper-alloy meshed Aquapod. The subsequent Velella Gamma project trialled a single-point mooring in 6,000 ft deep water open ocean of Keauhou, Kona.

The Ocean Era MARINER (Macroalgae Research Inspiring Novel Energy Resources) team is applying for a licence for a three-year permit to deploy a submersible growing platform for seaweed. The platform will be about 8 nautical miles open ocean of Keahole Point, in Hawai'i, moored to the ocean bottom in about 1200 ft water depth.

Ocean Era continues to pursue research into more sustainable feeds and new species for culture. The company has developed hatchery and grow-out technologies for nenue, a native Hawai'i herbivorous reef fish, which could potentially be grown on a highly sustainable and economical diets of seaweed or other plant matter. Research also explores potential for mahi mahi or dolphin fish, a pelagic fish in high demand.

Ocean Era also conducts industry-leading feeds research, focused on reducing reliance on fishmeal and fish oil from wild stocks, replacing them with scalable agricultural proteins and oils.



Hatch Blue - Financing & Innovation Initiatives for Aquaculture in Hawaii

In 2019, Hatch Blue set up a strategic hub on the big island of Hawai'i to foster aquaculture innovation within Hawaii and the wider Americas.

Operating within the industrial Hawai'i Ocean & Science Technology (HOST) Park, and in partnership with the Natural Energy Laboratory of Hawai'i Authority (NELHA), the Hatch Blue office services as an incubator campus for the development of world class aquaculture innovation & technologies.

Hatch Blue hosts, stimulates, guides, develops and supports the world's best aquaculture and innovation talent in their drive to solve key aquaculture & sustainability challenges. Uniquely positioned where R&D intersects with the world's largest multi-species subtropical aquaculture location, the Hatch Blue aquaculture hub facilitates entrepreneurs from all around the world who seek to develop their technologies and build successful scalable businesses.

Hatch Blue's aquaculture entrepreneur and innovation activities and initiatives in Hawai'i are the Hatch Ocean Foundry Platform, the Hatch Aquaculture Innovation Studio program and the Hatch Aquaculture Accelerator program. In addition to providing free entrepreneur support, facilities and financing for startups, Hatch Blue also hosts network and ecosystem building events for the aquaculture and supporting community in Hawai'i.

HATCH ocean foundry

HATCH innovation studios

HATCH Aquaculture Accelerator

A few other institutions that are supporting the growth of innovation and small businesses in Hawai'i are University of Hawaii, Blue Starts, Elemental Excelerator, HTDC, The Nature Conservancy, NELHA, Silver Spiral Seas, Ulupono, Hawai'i SBDC and HiPlan.

Some innovation & impactful startups fostered by the Hawai'i Innovation Ecosystem

Symbrosia

Made from the red seaweed *Asparagopsis taxiformis*, SeaGraze™ is good for cows, great for farmers, and even better for the planet.

Breakthrough research has shown that adding just a sprinkle of this seaweed to livestock feed increases growth rate and reduces livestock methane emissions by over 90%.

MINNOWTECH

Shrimp farming is a significant pillar of the global food chain, but it's a tough business. Farmers struggle with high risks and low profits, and existing industry technologies fall short in providing the data they need to make crucial decisions.

Farmers are often left guessing about how many shrimp to stock and how much and how often to feed them. And they can miss early signs of devastating events, like disease outbreaks. Minnowtech want to change that.

Kauai Sea Farm

Production of native Hawaiian sea cucumbers, mullet, milkfish, seaweeds, hard clams and oysters in Nomilo Fishpond.

KAS

Kuehnle AgroSystems, Inc. (KAS) is a Hawai'i biotechnology company with a world-class team of professionals. They research, develop and produce specialty chemicals and raw materials to make life better.

Customers include multinational corporations along with valued regional companies and brands that require sustainable plant-based ingredients for aqua feeds, food, and personal care.

PACIFIC HYBREED

Pacific Hybreed develops shellfish seed optimized for specific growing conditions.

They're focused on developing better broodstock for the US West Coast and Mexican markets for Pacific Oysters, with the next species being Manila clams and kumamoto oysters.

HALOPHILIC Marine Agriculture

Hallophilic Marine Agriculture, a spin off of Olakai in Oahu, cultivates salt tolerant vegetables and seaweed in large land-based marine hydroponic systems.

The technology enables cultivation of a high value vegetable crop (Salicornia) integrated with seaweed, using full strength ocean water. There are a plethora of applications for this including salt water aquaponics, agricultural productivity from arid coastal land, and economically sustainable open ocean carbon sequestration.

Aquaculture Information & Network Facilitators in Hawai'i

Hawai'i Aquaculture Collaborative

The purpose of the Hawai'i Aquaculture Collaborative (HAC) is to (1) engage industry to identify and act upon collaborative opportunities to grow and strengthen aquaculture in Hawai'i, and (2) to organize and leverage resources and public partners to support industry-driven initiatives.

Collaboration is vital to capitalize on the potential and brand of Hawai'i's aquaculture industry to contribute to future food sustainability and economic diversity in our state. We revere Hawai'i's 800+ years of tradition, culture, and innovation in aquaculture. The path forward will be through technological advances that build upon these traditions, and synergy that unites the industry to increase and share efficiencies; increase information sharing and research; increase communication and collaboration between businesses, the public sector, and our community; and increase opportunities to work together, as appropriate. This collaborative also recognizes that partnering and aligning with agriculture, the fishing industry, and other food-focused initiatives will strengthen our collective efforts and impacts towards what we believe are our common goals: to increase Hawai'i's food security and diversify our economy.

Sea Grant
University of Hawai'i

HAWAII AQUACULTURE AND AQUAPONICS ASSOCIATION

Hawai'i Aquaculture and Aquaponics Association (HAAA) has worked closely with the State Legislature and State and County governments to provide industry advocacy and support since 1975. The purpose of HAAA is to provide a unified industry voice for Legislative issues, networking and fellowship with other aquaculture and aquaponics producers, researchers, and supporters, local and national recognition and support of aquaculture, aquaponics, and business related issues, and business advantages for commercial members

HAAA's mission is ***to foster the development of commercial aquaculture and aquaponics production in Hawai'i.***

7.5 Aquaculture species in Hawai‘i

Photo: Big Island Abalone

Current status of aquaculture species and their level of commercialization in Hawaii

Hawaiian name	Common name (Species name)	Origin	Water	Diet	Purpose of culture	Level I: Preliminary research	Level II: Developing Culture Methods	Level III: Proof of concept	Level IV: Small scale production	Level V: Large scale production	Selective Breeding
kahala kanpachi	Short-finned amberjack (*Seriola rivoliana*)	Native	SW	C	HC					✅	✅
pāua	Ezo abalone (*Haliotis discus hannai*)	Non-native	SW	H	HC					✅	✅
ʻŌpae	Pacific white shrimp (*Litopenaeus vannamei*)	Non-native	SW	O	BE					✅	✅
ʻŌpae	Black tiger prawn (*Penaeus monodon*)	Non-native	SW	C	BE					✅	✅
olepe	Pacfic oyster (*Crassostrea gigas*)	Non-native	SW	SF	HC					✅	✅
olepe	Kumomoto Oyster (*Crassostrea Sikamea*)	Non-native	SW	SF	HC					✅	✅
olepe	Manila Clam (*Venerupis Philippinarum*)	Non-native	SW	SF	HC					✅	✅
n/a	Tilapia, various sp.	Non-native	FW	H	HC					✅	✅
n/a	Spirulina (*Arthrospira platensis*)	Non-native	FW	P	HS					✅	✅
n/a	Astaxanthin (*Hematococcus sp.*)	Non-native	FW	P	HS					✅	✅
Ogo	Gorilla Ogo (*Gracilaria salicornia*)	Non-native	SW	P	HC					✅	
awa	Milkfish (*Chanos chanos*)	Native	SW	H	HC				✅		
ʻAmaʻama	Striped mullet (*Mugil cephalus*)	Native	SW	H	HC				✅		
moi	Moi, Pacific threadfin (*Polydactylus sexfilis*)	Native	SW	C	HC				✅		
n/a	Sea Asparagus (*Salicornia*)	Non-native	SW	P	HC				✅		
moʻo lio	Seahorses, various species	Non-native	SW	C	OT				✅		
n/a	Catfish (*Clarius fuscus*)	Non-native	FW	C	HC				✅		
Ōpae 'oeha'a	Freshwater prawn (*Macrobrachium sp.*)	Non-native	FW	C	HC				✅		
n/a	Rainbow Trout (*Oncorhynchus mykiss*)	Non-native	FW	C	HC				✅		
Wana	Hawaii collector urchin (*Tripneustes gratilla*)	Native	SW	H	HR			✅			
lau'ipala	Yellow tang (*Zebrasoma flavescens*)	Native	SW	H	OT			✅			
limu Kohu	Red seaweed (*Asparagopsis taxiformis*)	Native	SW	P	CFS			✅			
nenue	Rudderfish (*Kyphosus vaigiensis*)	Native	SW	H	HC			✅			
umaumalei	Flame angelfish (*Centropyge loriculus*)	Native	SW	C	OT			✅			
palau	Pearl oysters (*Pinctada margaritifera)*	Native	SW	SF	LG			✅			
n/a	Sea grapes (*Caulerpa sp.*)	Native	SW	P	HC			✅			
n/a	Calanoid copepod (*Parvocalanus crassirostris*)	Non-native	SW	H	LF			✅			
n/a	Seed Clam (*Mercenaria mercenaria)*	Non-native	SW	SF	HC			✅			
Mahi Mahi	Mahi Mahi (*Coryphaena hippurus*)	Native	SW	C	HC		✅				
Unknown	Rabbit Fish (*Siganus argenteus*)	Non-native	SW	O	HC		✅				
Roi	Peacock Grouper (*Cephalopholis argus*)	Non-native	SW	C	HC		✅				
ʻOmilu	Bluefin trevally (*Caranx melampygus*)	Native	SW	C	HC		✅				
Kumu	Whitesaddle goatfish (*Parupeneus porphyreus*)	Native	SW	C	HC		✅				
Ulua	Giant trevally (*Caranx ignobilis*)	Native	SW	C	HC		✅				
Laenihi	Cleaner wrasse (*Labroides phthirophagus*)	Native	SW	C	OT		✅				
Unknown	Dottybacks (*Pseudochromis spp.*)	Native	SW	C	OT		✅				
Heʻe	Octopus	Native	SW	C	HC		✅				
ʻIna	Sea urchin (*Tripneustes gratilla*)	Native	SW	H	HC		✅				
ʻopihi ʻalinalina	Yellowfoot limpet (Cellana sandwicensis)	Native	SW	H	HC		✅				
Unknown	Benthic polychaete (*Marphysa sanguinea*)	Native	SW	D	LF		✅				
Uku	Uku (Aprion virescens)	Native	SW	C	HC	✅					
Loli or ʻunae	Sea cucumber (*Stichopus horrens*)	Native	SW	D	HC	✅					
Unknown	Sea lettuce (*Ulva sp.*)	Native	SW	P	HC	✅					
Ogo	Seaweed (*Gracilaria Coronopifolia sp.*)	Native	SW	P	HC	✅					
Ogo	Seaweed (*Grateloupia sp.*)	Native	SW	P	HC	✅					
Limu lepe O Hina	Seaweed (*Halymenia Hawaiiana sp.*)	Native	SW	P	HC	✅					

Key:

Water
SW - Saltwater
FW - Freshwater

Diet (feeding habits)
C - Carnivore
D - Detritivore
H - Herbivore
O - Omnivore
P - Photosynthesis
SF - Suspension feeder

Purpose of culture
CFS - Cattle feed supplement
BE - Broodstock for export
HC - Human consumption
HS - Health supplement
LG - Luxury goods
LF - Live feed for larval rearing
OT - Ornamental trade

Level of aquaculture domestication for commercial production

Level I:
Preliminary research
Early stage of exploratory research

Level II:
Developing culture methods
Research of various stages of the life cycle still need to be completed and achieved under controlled conditions

Level III:
Proof of concept
All life stages successfully reproduced in captivity. Ie the entire production cycle from egg to harvest is replicable under controlled conditions with high levels of guaranteed success and predictable outcomes

Level IV:
Small scale production
Production is predictable and is produced in small quantities with established SOP's

Level V:
Large scale production
Production is consistent and done at a large scale with refined and optimized SOP's with some level of selective breeding of broodstock

Almost all commercial scaled species in Hawaii are non-native species except for the kahala kanpachi.

There are many species that are currently still undergoing research to investigate their economic and sustainable viability however efforts and funding can be diluted by researching too many species simultaneously without focusing on key objectives, using the wrong culture system designs or not learning or collaborating with international culture experts.

Other species not mentioned in the table but have a history in Hawaii are sturgeon, snappers, halibut, groupers, sablefish and various ornamental, urchin and microalgae species.