

“Intensely local:” The Intersection of Community, Science, and
Policy in Alaska’s Mariculture Industry

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Abstract

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In the United States, policymakers, researchers, and government agencies have recognized marine aquaculture as an important form of food production, with potential benefits ranging across economic, social, and environmental dimensions. In Alaska, the commercial production of shellfish and seaweed is widely envisioned as a way to diversify and bolster coastal and rural livelihoods, while benefiting from existing marine knowledge and fisheries infrastructure. However, areas of concern have been raised around aquaculture’s ability to reach its potential in a sustainable and equitable manner. This study explored perspectives of participants in the Alaska mariculture industry to better understand what gaps exist and to highlight policy solutions that better align aquaculture governance with community needs and wellbeing in coastal communities. Our research objectives were to: (1) Characterize the development of the mariculture industry in the Gulf of Alaska over the last 10–15 years, with a focus on kelp farming; and (2) Examine interactions among actors and governance systems in mariculture to a) highlight existing strengths and opportunities in the development of mariculture to meet

community goals and b) identify areas of alignment or misalignment on the future vision of the industry amongst participants. We performed thematic analysis on digital content—including news media, gray literature, and government documents—and transcripts from semi-structured interviews with industry participants, including farmers, researchers, and state and federal agency staff. We identified five major themes across archival and interview data: (1) collaboration, coordination, and human capacity within the industry; (2) communication and policy gaps within institutions; (3) place-based needs and values of participants; (4) balancing community and commercial success as the industry looks ahead; and (5) the uncertain viability of mariculture as a livelihood diversification tool. Participants emphasized that mariculture can diversify livelihoods and stabilize communities, but that it currently carries significant risk and vulnerability for participants, especially kelp farmers. Participants also identified the importance of prioritizing both commercial and community success and cultivating an understanding of the differences between the two. Additionally, building social capital through alternative ownership structures and participatory governance may better align regulations and policies with community needs.

1. Introduction

The transformational promise of aquaculture in the United States is often centered around boosting domestic seafood production as a component of the “blue economy,” securing the economies of coastal communities, and addressing rising demand for seafood amongst a growing population (Froehlich et al., 2021; Diana 2013; Costello et al., 2020; Gephart et al., 2021; Helvey et al., 2017; Rubino 2023). Researchers often characterize non-fed marine aquaculture—specifically the commercial production of shellfish and seaweed—as a form of food production that has the potential to provide a variety of ecosystem services, and possibly serve as a marine analog of regenerative terrestrial agriculture (Duarte et al., 2017; Froehlich et al., 2019; Krause-Jensen et al., 2018; Krumhansl et al., 2017; Theuerkauf et al., 2021; Loring 2023). Additionally, aquaculture is often touted as a means of livelihood diversification for those participating in commercial fisheries (Cleaver et al., 2018; Stoll et al., 2019; Miller, 2021).

Despite the potential for aquaculture to contribute solutions to a broad range of issues, from food security to economic development, researchers have forecasted that rapid industry expansion may generate issues around sustainability and equity, as well as diluted outcomes regarding community wellbeing (Miller, 2021; D’Anna and Murray, 2015; Campbell et al., 2021; Gephart et al., 2021). The social dynamics among industry, governments, and the general public have emerged as a critical dimension of both collaboration and conflict in aquaculture development (Rubino, 2023; Fong et al., 2024; Froehlich et al., 2017; Campbell et al., 2021; Mather and Fanning, 2019). Although fisheries have a rich history of diversification in the face of environmental and socioeconomic change (Beaudreau et al., 2019; Szymkowiak and Steinkruger, 2023; Cinner and Bodin, 2010), the contribution of aquaculture to livelihood diversification within the seafood industry has shown varied success (Stoll et al., 2019; Krause et al., 2015; Spillias et al., 2023; Grebe et al., 2022).

As aquaculture is an intensively place-based method of food production, researchers have suggested that a community-centered approach to understanding the costs and benefits of

aquaculture may allow aquaculture development to reach its potential while still meeting community needs and improving wellbeing (Campbell et al., 2021). However, academic research has predominantly focused on the technical and biological attributes of aquaculture and its potential contributions to economic and carbon mitigation outcomes. This has led to a general lack of understanding about the gaps that can form between formal and informal governance systems and the people that aquaculture development is intended to benefit, such as coastal and rural communities (Krause et al., 2015; Henríquez-Antipa and Cárcamo, 2019). Our goal was to identify and evaluate these gaps and highlight policy solutions that better align aquaculture governance with community needs and wellbeing in Gulf of Alaska communities.

Alaska has played an increasingly important role in marine aquaculture in the United States, serving alongside Maine as one of the leading contributors to farmed seaweed production (Pacific Shellfish Institute, 2025; Robidoux and Concepcion, 2023). Fisheries continue to be a major economic driver in Alaska, but have faced increasing pressures (Beaudreau et al., 2019; Gordon et al., 2022), with marine aquaculture showing promise to diversify seafood systems and contribute to coastal community livelihoods. The scale of aquatic farm operations in Alaska ranges from a few acres to over a hundred acres—including the largest macroalgae farm in the United States (NOAA, 2025). Permitted aquatic farms and associated industry participation are concentrated primarily in the Gulf of Alaska. Although this study focused mostly on the commercial production of macroalgae, kelp and shellfish farming are highly connected in the state, with farms cultivating both species being fairly common.

Although Alaska Native people have been cultivating and harvesting macroalgae and shellfish since time immemorial, the commercial mariculture industry is a more recent development. Commercial farming of finfish is illegal in Alaska (Commercial Use of Fish and Game, 1990), so aquaculture is restricted to marine invertebrates and macroalgae, and takes place almost exclusively in open water. Due to this restriction, in Alaska the term “mariculture” (short for “marine aquaculture”) is used to refer to all commercial aquaculture in the state. Some

commercial shellfish production began in the early 20th century, however, the industry began in earnest in the 1970s and gained official state recognition with the passage of the Alaska Aquatic Farm Act in 1988 (Miller, 2021; RaLonde, 1992). The Alaska Fisheries Development Foundation led the creation of the Alaska Mariculture Initiative in 2014, and its subsequent evolution—the Alaska Mariculture Task Force (hereafter, “AMTF”), created in 2015 by an administrative order of Governor Bill Walker (Walker, 2016)—created momentum for the commercial production of macroalgae, which was first commercially harvested in 2017 (Alaska Mariculture Task Force, 2017). In 2022, the U.S. Economic Development Administration awarded \$49 million through its Build Back Better Regional Challenge to the Alaska Mariculture Cluster—an industry-led coalition including farmers, regional partners, and state, federal, and tribal governments (U.S. Economic Development Administration, 2022). In 2023, NOAA selected Alaska as the location of its third Aquaculture Opportunity Area, signaling the state’s role within national aquaculture development plans (NOAA, 2023; Rubino et al., 2024).

We examined the mariculture industry in Alaska at a critical inflection point in its growth—an influx of grant money, several years of determined and strategic efforts to achieve rapid commercialization while overcoming significant roadblocks, and a media environment that could rightfully be characterized as ambitiously optimistic (Rosen, 2023; White, 2016a; White, 2016b). In this context, industry, community, and management actions will likely have both short- and long-term social-ecological consequences as the industry matures and solidifies its future direction. Our research objectives were to: (1) Characterize the development of the mariculture industry in the Gulf of Alaska over the last 10–15 years; and (2) Examine interactions among actors and governance systems in mariculture to (a) highlight existing strengths and opportunities in the development of mariculture to meet community goals and (b) identify areas of alignment or misalignment on the future vision of the industry amongst participants. To explore these dimensions of Gulf of Alaska mariculture, we drew from

qualitative analyses of public records and interviews, and used a social-ecological systems framework for aquaculture to organize and interpret results.

1.1 Social Ecological Systems Framework for Aquaculture

We used a social-ecological system (SES) framework for interdisciplinary research on marine aquaculture (Johnson et al., 2019), adapted from Ostrom's generalized SES framework (McGinnis and Ostrom, 2014), to better understand the social and governance dimensions of Gulf of Alaska mariculture. The SES framework consists of four major subcomponents: Resource System, Resource Units, Governance System, and Actors (Figure 1).

The Resource System is the biogeographic space of our study area (Gulf of Alaska) as well as the particular industry that we studied (mariculture), which sets biophysical conditions for participants, such as site suitability, distance from infrastructure, and growing period. Resource Units consist of the actual outputs and products of the Resource System, such as shellfish, kelp, ecosystem services of farms, and the physical space of farms. The Governance System consists of formal and informal institutions, such as state and federal agencies or non-governmental organizations (NGOs), which set socioeconomic and political conditions for participants, partly through defining and setting rules, but also through actions such as industry advocacy, grant distribution, and lobbying (Table 1). Actors consist of the individuals who participate in the industry, including farmers, researchers, NGO employees, state and federal agency staff, and Alaska Native communities (Table 2).

Johnson and co-authors (2019) define the space where interactions between participants and the rest of the system occur as focal action situations, which can be thought of as the place where interactions—such as farming, coordinating, sharing information, deliberating, investing, processing, and selling—transform into outcomes. The social-ecological system is dynamic and evolving, as outcomes create a feedback loop into the four subcomponents, and influence the conditions, rules, and manner in which interactions take place. There are also exogenous

influences that act upon the social-ecological system, such as social, political, and economic settings, as well as related ecosystems (Johnson et al., 2019). In this study, we generally chose to omit analysis of those external forces and focused primarily on two subcomponents of the framework—Governance Systems and Actors—and their associated relationships and interactions within the social-ecological system, which yielded insights specific to our research objectives.

2. Methods

2.1 Land Acknowledgement and Positionality

Indigenous peoples in coastal areas of Alaska, and throughout the world, are the original stewards of both land and water, and have been sustainably practicing restoration and cultivation of seaweeds and shellfish since time immemorial. We are grateful for their longstanding stewardship and governance. The researchers and participants in this study live and work in Indigenous Lands across the North Pacific, including those of Coast Salish, Tlingit, Haida, Tsimshian, Eyak, Dena'ina, and Alutiiq/Sugpiaq peoples.

We, the author team, are early- and mid-career researchers who completed this work at the University of Washington. We hold shared values around the importance of resilient food systems that meet community needs across social, economic, and ecological dimensions, as well as the central role that community engagement plays in adaptive natural resource management. AHB lived in Juneau, Alaska for close to a decade before relocating to Washington, and drew from her personal and professional ties to Southeast Alaska communities in the development of this research. LLW grew up adjacent to agriculture in the Midwest before moving to coastal Maine and working on fruit and vegetable farms, as well as running his farm's stand at the Portland farmer's market.

2.2 Archival Research and Interview Guide Development

In contrast with Alaska fisheries records, neither public comment records nor robust harvest data related to mariculture in Alaska are widely available. However, since the formation of the Alaska Mariculture Initiative in 2013, governmental and non-governmental organizations have created a number of reports, public meetings, analyses, press releases, and other strategic documents, and there has been substantial media coverage of the mariculture industry. Researchers have used analysis of media articles, public comments, and other archival records to reveal insights related to public perception, policy, and conflict in fisheries and aquaculture (Harrison et al. 2019; Froehlich et al. 2017). Thus, as a starting point for our exploration of mariculture development (Objective 1), we conducted a detailed archival review of digital content related to mariculture development in the Gulf of Alaska from 2015–2024 (Table 3). This review also served to inform the recruitment of interview participants and aided development of our interview guide (see section 2.3).

We identified digital content, including news media, gray literature, and government documents, via keyword searches (see Appendix 1 for details). We drew from principles of key informant methodology (Bernard, 2018) where several key organizations were identified and relevant data were collected from their websites and digital archives, analyzed, and assigned inclusion or exclusion for further analysis based on criteria that established relevance to the study's research questions (Appendix 1). We inductively analyzed archival data for themes following thematic analysis approaches detailed in Braun and Clarke (2006) and Attride-Stirling (2001). First, we summarized individual keywords and phrases for each source, defined as “basic themes,” which were the lowest-order data in our analysis. Next, we observed patterns of related meaning across basic themes and arranged data into clusters accordingly, with those clusters then representing an “organizing theme” or middle-order data that reveals meaning at the textual or text group level. Finally, the interrelation between different organizing themes allowed us to recognize super-ordinate patterns of meaning that are revealing about mariculture

more generally. We defined these patterns as “global themes” that solidify the connections between organizing themes (Table 4). We analyzed three global themes representing major characteristics of the industry during its development: vision setting, capacity building, and adaptations and challenges, each of which contains several organizing themes that represent patterns seen within the archival data (Table 4). We created an interview guide using our archival analysis to seek a more in-depth understanding of perspectives on mariculture industry development from participants (Appendix 2).

2.3 Interviews

We conducted semi-structured interviews (Bernard 2018) with participants in Alaska mariculture in order to elicit perspectives on milestones in the development of the mariculture industry, the degree of collaboration and coordination amongst the groups involved, strengths and weaknesses of the current governance system, the distribution of industry benefits and costs, and prevailing visions for the role of mariculture in Alaska. The interview guide (Appendix 2) included open-ended questions that were intended to encourage participants to share information and insights most relevant to their experiences. The study protocol was reviewed and determined exempt by the University of Washington’s Human Subjects Division of the Institutional Review Board (study ID 00015546-MOD00021717).

Within the Gulf of Alaska, there are many different actors participating in the mariculture industry with diverse backgrounds and roles (Table 2). We took care to ensure that participants were included across geographic areas of the Gulf of Alaska with active kelp farms (i.e., Southeast Alaska, Prince William Sound, Kenai Peninsula, and Kodiak Archipelago). Initial participants were recruited through AHB's long-term professional network in the Gulf of Alaska. We identified and recruited subsequent interview participants through the archival analysis and via snowball sampling (Bernard 2018), in which interview participants recommended contacts based on relevant knowledge and experience within the nascent mariculture industry.

Interviews were conducted via videoconference between July 2024 and February 2025, as well as in person during a research trip to Juneau in August 2024. We completed 16 individual interviews and 1 group interview with a total of 19 participants (Table 5). Each interview ranged from 30-60 minutes in duration.

For the majority of the interviews, both researchers were present, with one researcher leading the discussion and one researcher asking clarifying or follow-up questions and taking hand-written notes. Some interviews were conducted by one researcher. Before the interviews began, the researchers reviewed an informed consent form with participants to explain how the data would be used and steps taken to ensure confidentiality. All interviews were recorded with the permission of participants, transcribed using automated transcription software, and manually reviewed and corrected by one of the researchers. After the completion of interviews and analysis, participants were invited to a webinar to hear a presentation of the results and provide feedback. Participants will be given the opportunity to review and provide feedback on a draft manuscript prior to journal submission.

2.4 Interview Data Analysis

We coded and analyzed interviews using both inductive and deductive coding schemes. An inductive or “bottom up” approach emphasizes themes that surface from and are directly linked to the data, allowing the researcher to code data without trying to fit the data into a preconceived analytical framework (Braun and Clarke 2006). A deductive or “top down” approach emphasizes themes that surface from testing the data against a preconceived framework, typically used when a phenomenon is generally well understood (Braun and Clarke 2006). Themes were identified at the latent level, meaning that analysis went beyond the explicit or semantic content of the data and attempted to identify underlying meaning and assumptions that shape or inform the explicit meaning of the data (Braun and Clarke 2006).

Initial coding and analysis involved applying the themes developed during archival analysis (Table 4) deductively to an initial set of interviews (n = 4) that we selected for the complexity and diversity of their data. During this process, we revised and refined our codebook inductively to more holistically reflect participant perspectives, with initial codes being transformed, edited, or broken down in order to better understand and communicate the specific nuances of interview themes. For example, we broke the code “relationship drivers” into the sub-codes “communication”, “shared vision”, “value alignment”, “money”, and “trust,” in order to better understand the nuanced forces that exert themselves upon the relationships of industry participants in different contexts.

The researchers then participated in a coding calibration session where we reviewed selected segments of interviews, compared codebook application, and reconciled any differences in their approach. Further coding was iterative, with revisions and additions to the codebook to better reflect observed patterns and themes. The lead author (LLW) performed coding using ATLAS.ti 25, with frequent discussion with the coauthor (AHB) to ensure consistency in the application of codes and interpretation of themes (Scalisi et al. 2024).

3. Results

3.1 Overview of mariculture development in Alaska since 2014

To address the first objective of this study, we explored how the mariculture industry in Alaska has evolved over the past decade from high-level visioning by a small group of industry experts to a complex system of partnerships and projects across community, regional, and statewide scales (Table 3). Participants’ initial emphasis on vision-setting evolved in response to disruptions, such as the COVID-19 pandemic, and new opportunities, such as an influx of federal grant money. Widespread perception of an untapped and scalable potential for mariculture within Alaska was evident in initial efforts by the AMTF to develop a roadmap for industry development from 2016–2018. This included a vision of U.S. leadership and global

reach and a focus on rapid commercialization and growth, with the hope being to provide economic opportunities to all Alaskans, but especially rural and Alaska Native communities (Decker et al., 2018). Industry leaders invested resources into identifying and engaging stakeholders, incentivizing new farmers, and amplifying a narrative of transformational potential at the community level related to economic development and food system resilience. The focus of these and later efforts were on identifying key areas of development that could be grown largely through coordination, establishing funding mechanisms, workforce development and training, and aligning laws and regulations to participant needs (AMTF, 2018; AMTF, 2019).

Additionally, industry proponents positioned mariculture as a way to take advantage of synergies with existing fisheries infrastructure and workforce—something which was perceived as giving Alaska a significant advantage. The Alaska Mariculture Development Plan characterized the state as having ideal qualities for mariculture development due to excellent growing conditions in the ocean, highly developed maritime industries and knowledge, and an established regulatory process for fisheries that could be drawn upon (Decker et al., 2018). Both the Administrative Order by Governor Bill Walker in 2016 to establish the AMTF, and the Administrative Order in 2018 to extend the AMTF until 2021 emphasized the diverse array of benefits that mariculture could have in Alaska across economic, environmental, cultural, industrial, and food security dimensions (Walker, 2016; Walker, 2018). The AMTF's Final Report in 2021 reinforced these narratives and carried them into the successor organizations to the AMTF—the Alaska Mariculture Alliance (AMA) and Alaska Mariculture Research & Training Center (Andersen et al., 2021).

Today, the mariculture industry in Alaska largely continues in the direction set by the Alaska Mariculture Development Plan, with a multi-faceted approach to developing the industry that relies upon simultaneous investment in scientific research, workforce development and training, product and market development, regulatory and permitting changes, and other areas.

Notably, the two entities that are most responsible for guiding the industry forward—the AMA and the Alaska Mariculture Cluster—consist of broad multi-stakeholder partnerships across the public and private sectors, significantly expanding the number of communities, organizations, and actors that are collaborating on industry development compared to during 2015–2021. Additionally, the commercial cultivation of macroalgae has largely been developed without a stable and robust market for kelp, with one company seeing success producing artisanal food products on a local and regional scale but limited buyers broadly in the industry.

3.2 Interactions among actors and governance systems

Within the Gulf of Alaska, various organizations and institutions are responsible for building demand, evaluating success, and setting the rules by which the mariculture industry operates, both formally and informally (Table 1). These groups operate at different scales and represent diverse community interests. Many of the actors within the industry (Table 2) participate through multiple modalities, often working within and across multiple organizations. Here, we address the second objective of this study by drawing from thematic analysis of both archival and interview data to highlight five major themes that relate to interactions among actors and governance systems, the outcomes of those interactions, and potential feedback into the social-ecological system. These include: (1) collaboration, coordination, and human capacity within the industry; (2) communication and policy gaps within institutions; (3) place-based needs and values of participants; (4) balancing community and commercial success as the industry looks ahead; and (5) the uncertain viability of mariculture as a livelihood diversification tool. We examine each of these themes below, drawing primarily from the semi-structured interviews with mariculture participants (Table 5). Participants are identified by the primary way in which they engage in the industry—aquatic farmer, researcher, state and federal agency staff, and community/industry leaders—however some may participate in multiple roles.

3.2.1 Collaboration, coordination, and human capacity

Participants emphasized collaboration and coordination as strengths of the industry that helped drive key milestones in development while recognizing that increased participation has amplified concerns stemming from burnout and an overreliance on grant funding. An early focus of mariculture development in the Gulf of Alaska was identifying and establishing key areas of development that can be aided through improved coordination, collaboration, and capacity building among the institutions that would guide the industry forward. Many study participants identified the creation of an extensive and broad network of partnerships within mariculture as one of the greatest successes of the industry's development so far, with one participant saying:

“I think that a major milestone for mariculture, but also just resource development in Alaska, is to get that many different—all of those groups together, forcing really difficult conversations that people just don't have, they kind of stay in their silos. But having that carrot, like, if we just work through these really tough issues, recognizing that everyone's having to be a little bit vulnerable...it's resulted now in these partnerships that didn't exist before...between industry and university system people...also tribes with state regulators” (community/industry leader, Interview 06A).

Participants identified several factors as being critical to this success, including trust, social and political capital, and a determination to self-organize. Additionally, throughout the early stages of the industry, communication and deliberative processes were built upon a generally aligned vision of mariculture's potential for coastal communities, shared goals, and a shared history and past experience of living on the Alaskan coast. Multiple participants highlighted the formation of the multi-disciplinary AMTF and Alaska Mariculture Cluster as impactful milestones that set the tone for the industry's focus on collaboration and advanced critical regulatory changes, acquired broad political buy-in for mariculture, and expanded financial and human capacity within the industry. Some participants characterized the transition of the AMTF into the AMA as being “kind of a miracle” based on volunteer hours and a lack of state funding, issues which have persisted through to the present day (community/industry leader, Interview 05). When reflecting on where the industry has come, one participant said:

“I can say that with absolute certainty that when we started this path, 12 years ago, 15 years ago, we didn't, you know, in our wildest dreams would have never contemplated that we would be where we are right now” (aquatic farmer, Interview 06C).

These two groups, particularly the AMTF and its successor organization, the AMA, made significant investments towards building human and financial capacity that helped facilitate successful coordination amongst the institutions governing the industry. These investments often involved partnerships between the public and private sector, and emphasized the establishment of positions dedicated to mariculture at state and federal agencies and within the University of Alaska system. Participants identified key positions at Alaska Sea Grant and NOAA, as well as the involvement of outside organizations such as GreenWave, as providing experts who have spearheaded workforce training and broadly mobilized extensive learning across the industry. Several participants pointed towards research partnerships that span federal, tribal, state, municipal, and farm levels—such as the Mariculture Research and Restoration Consortium and Bull Kelp Research Squad (see Table 3)—as being exemplary of the kind of successful collaboration that has largely become the norm in the industry. The ongoing championing of capacity-building in the industry can be seen in publicly communicated metrics of success which have largely revolved around participation, regulatory wins, reduced application processing time, and total industry output rather than metrics seen in analogous industries, such as farm gate or sector value (AMTF, 2017; NOAA, 2024).

Despite this success however, participants generally identified far more challenges than achievements within the industry, with 442 occurrences of challenge-related codes in interview transcripts compared with 206 occurrences of achievement-related codes. This is perhaps most clear when it comes to concerns around human and financial capacity, with 12 of the 16 interviews highlighting the risk of burnout, particularly for state and federal agency staff and farmers. One participant said:

“As far as it goes with AFDF and all these organizations, it's an interesting scenario, because kelp exudes this idea of a better way, and so it attracts all these people wanting to do better. And then all of a sudden, you just throw a chunk of money in and say do

it...so I will say that like, there's no shortage of passion, but I would say there's possibility of a high rate of burnout, because people are overloaded...Like, these people are being told that they need to disperse this [grant money] in a way that creates an industry and it's just like, go, you know. There's no formula for it, especially with an industry that is so new and so different" (aquatic farmer, Interview 02).

Another participant voiced their concern for burnout, describing it as being a "top" issue currently and when discussing the Alaska Mariculture Cluster's Build Back Better funds said:

"...there is no way you can spend that much money in four years. Four years is way too [short] to develop a whole program this way. Right now we can really write very short projects and get funded, but no one wants to get more projects. Like, you try to get someone else to do this and yeah, people are getting super burned out" (researcher, Interview 07).

Participants' highlighted some negative consequences of the influx of grant funding to farmers, centering their concerns around competitiveness, accessibility, worries about instability and processing slowness at the federal level, and a general apprehension about reliance upon grant funding for livelihoods. One participant commented that:

"I think there is a lot of worry. Right now, there is a lot of funding, and that's why we can do many things...And you have all these farmers investing into putting their farms, and they can sustain themselves because there is grant money. And unfairly, in my opinion...you create a false expectation for the future at prices that are ridiculous...So it's going to be a hard hit when we get out of this wagon, and that's concerning because, you know, these are all small growers, like usually families that are investing a fair amount of money. Even though a lot comes from grants, you still have to put in a lot of money" (researcher, Interview 07).

Another participant echoed this sentiment, saying:

"We've never taken money out of our business bank account, and that's kind of one of the biggest concerns for us right now as kelp farmers. We've just been reliant on grants. Like, we luckily have been successful in getting a few grants that have really kept us going, but if we're not able to make a profit—make a real profit and not rely on grants in the next couple years—then I think we're probably going to have to bow out of the industry. But we're, we're still hopeful that it'll come to fruition" (aquatic farmer, Interview 13).

Despite nearly every participant voicing a desire to reduce or even eliminate widespread reliance on grant funding, many retained a degree of optimism about the industry's ability to do so, even in the near-term. One participant described the effort to develop markets for kelp, saying::

“So ultimately, I don't want any more grant funding. I want us to be busy growing kelp to sell into markets. That's the ultimate goal here, and so we're starting, finally, to gain market traction...[There are] two companies that are coming in, and they're interested in purchasing kelp specifically for biostimulant markets for agriculture, and we're very excited about that. What's really nice for farmers is that the price point is still very competitive. I thought, you know, at first, when we started getting into mariculture, that fertilizer would be the bottom of the tier as far as revenue, but we're really excited that it's not. And we're making some great headway there” (aquatic farmer, interview 12).

3.2.2 Communication and policy gaps between institutions and participants

Participants praised institutional achievements around adaptability, efficiency, and a commitment to working directly with industry, while highlighting communication and policy gaps related to aquatic farm siting, lease permits, and marine mammal interactions. In comparison to fisheries, study participants characterized mariculture in Alaska as relatively hands-off when it comes to policies and regulations, largely focusing on three formal institutions that govern the industry—the Alaska Department of Fish & Game (ADF&G), Alaska Department of Natural Resources (ADNR) and NOAA Fisheries (NMFS). The roles and capacity of these organizations differ; the ADF&G permitting process is led by a single staff person and ultimately up to the discretion of the ADF&G commissioner, the ADNR leasing process is led by a team of four staff, and NMFS has limited dedicated staff but contributes more broadly through the Aquaculture Opportunity Area process and consultations related to the Endangered Species Act and Marine Mammal Protection Act. The rules that govern mariculture vary in terms of formality and origin, with some rules being put in place by agencies interpreting their mandated responsibilities, and others being less clearly established—one participant described how everyone in the industry is operating on a “trust metric” and expecting each other “to do the responsible thing”, highlighting that the industry largely self-reports and self-monitors (aquatic farmer, Interview 01).

Several participants mentioned that prospective farmers rely upon existing farmers and pre-application meetings with agency staff in order to navigate complex rules related to siting, and to make informed decisions that reduce chances of conflict with other marine users and

increase chances of lease approval. Participants also highlighted concrete examples of effective communication and problem-solving from state and federal agencies, citing their ongoing efforts to update and streamline the permitting process as a bright point of the industry. When discussing the relationship between the industry and state agencies, one participant said:

“You know, [the state] can research whatever it is they want to research, but if that's not where the money is and the industry wants to go, then what's the point? Yeah, so having it be industry-driven, by processors or farmers or researchers, then [the state] will follow suit on their end. For instance, if you guys want to develop geoduck mariculture across the entire state, how does the state need to adjust statutes and regulations in order to allow for that? And what are any potential barriers or reasons why they shouldn't do that?...so with them developing what they want to do on their end, and then they come to us and say, “is this possible?” And then we'll say “not yet, but we can make it so” (agency staff, Interview 04).

Participants discussed the collaborative nature of Alaska mariculture governance, with one participant even saying that they have “been blown away” by the efforts of institutions, and expressing gratitude for everything they're doing, concluding that they're “...a surviving kelp farm because of it” (aquatic farmer, Interview 02). Another participant compared the relative efficiency and effectiveness of institutions in Alaska to other states on the West Coast:

“The last two governors have been really supportive. I think that getting that buy-in from the state is huge. Because you look around every other state, Washington in particular, getting that kind of active, proactive support—'what can we do to help this go'—is not [happening]...in California, same thing—'it's a great idea, just don't do it here.' That's the starting conversation, right?...So when you go to a place like Alaska, where not only is it not stopping you, but it's actively promoting what you're doing, that's a huge thing” (aquatic farmer, Interview 06C).

Despite these positive examples, communication challenges related to regulations and policies were among the concerns most frequently mentioned by industry participants.

Views were mixed regarding effectiveness of community and public engagement with respect to NOAA's Aquaculture Opportunity Area (AOA) process. The AOA project is a mapping effort that intends to unite spatial and relevant data to identify ideal areas for aquaculture development, with Alaska being unique in that the project is the first AOA to focus entirely on projects in state waters (NOAA, 2023). Some participants described the process as a concerted effort by NOAA to engage in proactive dialogue with industry participants. One participant

perceived this process as one in which "NOAA has put a lot of time and effort trying to have early and often engagement with tribal communities in areas overlapping with study areas or adjacent to study areas. You know, just trying to make sure that folks are aware of what they're trying to do" (agency staff, Interview 03). However, other participants identified contention around the AOA project, stemming in part from misunderstanding about the project, but also general frustration with a lack of opportunity to comment on industry development more broadly. As one participant explained:

"And we just had that big talk about the aquaculture mapping initiative being done by NOAA, and they had a meeting in Juneau where a lot of Native representatives came, and there was definitely some feeling of being ignored that was being, I think, rightfully voiced there" (researcher, Interview 01).

Participants emphasized other disconnects between Alaska Native communities and formal institutions when it came to regulations and policies. For example, one participant described values held by their community around sharing and reciprocity, noting that they should be reflected in policy. They went on to highlight particular concerns about infringement of mariculture on subsistence harvesting areas for Alaska Native communities, stating::

"So for me, in my community, I should have first right of refusal for areas that are anywhere within 25 miles of my community, because I can't get past someone else's farm. If they're, you know, if I get a big, multi-million dollar company that's got, you know, 200 or 300 acres right in front of my community, and I gotta go past them to get to my farm...so, there's quite a few different things that need to be in place. And for me, our subsistence values need to be the foundation" (community/industry leader, Interview 10).

Some participants identified weaknesses in state agency processes related to limited or restrictive opportunities for public comment. These issues ranged from those who are involved in fisheries having limited time to provide input—or missing their 30-day window to submit comments because they're out on the water the whole time—to rules that restrict who can appeal lease designations to those who submitted a public comment.

Although some participants celebrated recent legislation that increased the aquatic farm lease renewal duration to 20 years (Aquatic Farming and Hatchery Site Leases; rev. 2024), other

participants identified ways in which that regulatory change could be problematic, especially in conjunction with the AOA and other efforts that were intended to make site selection easier. These often centered around larger companies being able to purchase and own leases for several decades, and fear that those companies will make a quick profit and then abandon communities. Several participants provided an example of Alaska Native organizations self-organizing and raising financial capital to address this issue, with the “..Native Conservancy working on a Native Sea Trust to establish permits for Native kelp farmers, both now and into the future” (aquatic farmer, Interview 16).

In addition, participants noted challenges navigating several specific regulations and policies at both state and federal levels. At the state level, one noted challenge was the “50-50” rule for kelp seed—a colloquial term for a set of regulations that cover kelp broodstock sourcing and collection (Gruenthal and Habicht, 2022). One participant expressed hope that ADF&G would review its rules prohibiting gametophyte culture—a more advanced and productive seeding method developed in the Netherlands and used in Maine—saying:

“I like that the Alaska Department of Fish and Game is conducting research on seaweed genetics to basically analyze the 50-50 rule, and try to determine if there would be a negative impact by gametophyte culturing or allowing gametophyte cultures, and I think that's really necessary to examine. And I think that for this industry to really thrive, I think we're going to need gametophyte cultures to help us, you know, expand and grow the industry. And I do think that, you know, this has been proven elsewhere in the globe.” (aquatic farmer, Interview 16).

On the federal level, participants shared frustrations related to inconsistencies in monitoring requirements. One participant said:

“I permitted three commercial farms because we were trying to move away from the research model. We can't sell any of the material that's produced on a research site, so we started converting some of our research sites to commercial sites. I submitted three permits at almost the exact same time and got three different monitoring requirements. And also, they were assigned different agents within the different agencies. And so, you know, they all came up with their different rationales...and also, if you want to talk about what is harming marine mammals, you know, it's like, often interactions with humans, which you're going to have much more of if you're requiring people to go out and monitor their farms once a week” (aquatic farmer, Interview 14).

NOAA consultations related to whale entanglements (Marine Mammal Protection Act of 1972, 2018) were also identified as a challenge. Several participants mentioned needing to “educate” federal agencies about the perceived threats that kelp farms pose to whales, expressing that federal agencies were being too precautionary when it came to whale entanglements and that there was a lack of evidence that kelp farms threaten whale livelihoods given farm and gear design:

“I’ve had to work, and we’ve been working with the AMA to educate NOAA on how farms are constructed. Now I mean, obviously the last thing we want to do is catch a whale and have our gear destroyed and our crop ripped out of the water. That would be terrible! Plus, I mean, no one wants to hurt whales. We’re not here to do that. Just—how [kelp farms] are constructed safely and that all the lines are held under tension. And so unlike a loose line on a crab pot and a buoy just floating around there, there isn’t the risk of it wrapping around the fluke of a whale and dragging it around, right? Our farms are just different, so we had a lot of pushback there initially” (aquatic farmer, Interview 12).

3.2.3 Place-based needs and values of participants

Study participants emphasized that coastal identities form the foundation of a shared vision for mariculture development across institutions and industry participants, but that the specific pathways to achieving those visions are intensively place-based, making building consensus difficult. Strategic discussions around sustainable and equitable growth have occurred throughout the development of the industry, usually centered around a goal of engaging with, encouraging investment from, and providing benefits to rural and Alaska Native communities, as well as representing the interests of all Alaskans. Participants highlighted how norms, leadership, and the importance of mariculture within the industry are informed by a generally shared goal of stabilizing economies of coastal and rural communities facing numerous pressures, such as declining opportunities for fishery participation, as well as cascading effects of climate change. Community needs identified by participants ranged from creating jobs for youth “because so many of the young people in that already tiny community are, you know, leaving or wanting to leave” (community/industry leader, Interview 06A), to the need for something to offset seasonal industries like tourism, especially during the winter, and

“supplement people’s income and also just provide a reason for people to, like, stay throughout the year” (aquatic farmer, Interview 14). Participants also generally described the creation of jobs or supplemental income through mariculture as a way to go beyond the desire for money, and focus more on cultivating a feeling of local opportunity, resilience, and coastal identity year-round.

Study participants expressed hope that mariculture could address specific issues in their communities, with one study participant explaining how mariculture could restore economic sovereignty and exemplify how to integrate Alaska Native values into an industry that is largely focused on commercial growth:

“I was looking for some kind of an industry for people here that wasn't just big industry, and something that could be done without the use of major power. So, you know, you got to the boats, they were on their own power, the ocean is doing the work. So, kind of a no-brainer, you know, of a next step for people in my area. And then the other attraction was that it was here in our waters, and it's something visceral that we could start, we could grow, and it was up to us. You know, in the salmon [and] finfish fisheries, you're kind of dependent on what goes on in the whole world. So it was more about trying to reclaim economic power in our community that we could, and things we could control.

You know, we just had a shrimp and halibut and salmon giveaway from some of the things that we've done—we do this on a regular basis. Why can't other communities do this? I'm not just saying that, you know, ‘okay, I'm awesome, this is what I do in my community.’ I think this is what every community should do. You fill freezers before you take their money. You make sure people have food, you make sure they have what they need, and then you start making money. I know that's not the thought around the world, but it could be” (community/industry leader, Interview 10).

Study participants highlighted several successful partnerships involving Alaska Native communities, centered on addressing place-based community needs—such as food access and food safety issues—and often facilitated by regional organizations such as Alutiiq Pride Marine Institute (APMI), the Native Conservancy, and Kodiak Archipelago Leadership Institute (KALI).

Study participants also emphasized the need to think of future generations when discussing natural resource industries and economic livelihoods in coastal communities, with mariculture providing an industry that elicits a feeling of growth, opportunity, and excitement. As one participant said when discussing their vision for mariculture:

“...the giant industry, I don't know that's even what anyone wants, but keeping people working, keeping people at home. We're working to fund a [floating upweller system] for an oyster operation there, because so many of the young people in that already tiny community are leaving or wanting to leave because there's no future, necessarily, or there's nothing to do. And so having an oyster operation means that the young people might stay in their communities and that's a success that we hope to see.”
(community/industry leader, Interview 06A)

Another participant echoed this, adding that providing economic stability to their community in the face of decreased fishing opportunities was a source of motivation and, at times, pressure:

“I never imagined that my little idea years ago would create 15 jobs last year for a month. You know, that's huge to me. I never...that's not why I got into it in the beginning, but like, when you start to become a bigger part of your community, and you start to care about where you live, and your kids start to try to dive into that workforce, it's, man, it's scary. It really is” (aquatic farmer, Interview 09).

While study participants generally agreed upon the potential of mariculture at a regional or statewide level, many participants emphasized significant challenges related to consensus-building at the local level, highlighted regional and community differences, and voiced concern around the number of voices in the room. These issues were most apparent when discussing the inclusion of Alaska Native communities in the industry, with participants highlighting that trust and communication play a critical role in establishing the relationships necessary for meaningful inclusion and participation. As one participant put it:

“I think that there is good spirit and good intentions. I don't think that we know how to do it—and I'm gonna say ‘we’ putting me in the non-native people. And I have collected a lot of stories from a lot of people around that idea, so I'm gonna try to tease it [out]. So we can start with the AMA and say the one seat for Natives. And that already gives you a perspective of what that inclusion and benefit to rural communities mean, right? You know, you have your rep who's supposed to know you all and get along with all of you. I think there was a lot—there is good intention to reach out, but there is such mistrust...there's only a handful of people that can do that. And, Alaska is huge and every single community has their own opinion about which way to go.” (researcher, Interview 07).

Several participants identified that some communities may have specific goals and needs for mariculture development that are not easily aligned with regional and industry-wide goals, such as increasing the scale and potential profitability of operations. One participant said:

“...the goals aren't necessarily the same. Like the goals of like maximizing production and like making money aren't necessarily like what...is being sought... Sometimes that

perspective gets lost in the general narrative of, like, how do we grow the industry? How do we scale, scale, scale? And it can feel...you know, people can feel very defensive in terms of like, you know, we're being overlooked or not listened to, or what have you" (aquatic farmer, Interview 15).

Other concerns were raised that outside interests would develop the industry while taking advantage of communities who would not realize the financial benefits of development, and without prioritizing community-driven outcomes. As one study participant commented,

"...we've had people come here for kelp and mariculture, and we could have went to work years ago, but nobody had a business plan that would work. It was just using us as sherpas to get up the mountain. And no, nowhere in there were we going to prosper with them. And these are our communities. I mean, there's a lot of people that feel like they have ownership over someone else, and we're going to have that fight until the end of the world, I think. But still, this is where I live. This is where we grew up...so it's just, yeah, we've had people come in, and I haven't [seen] what they would pay our people, if they would take our people with them as they start to prosper" (community leader, Interview 10).

That same study participant mentioned that farmer cooperatives could help to retain autonomy over what happens in their communities, and that they can "see something that can work for everyone, but greed or not is going to dictate how that turns out—there are big, big companies coming up here, looking here" (community leader, Interview 10). In addition to farmer cooperatives, several participants highlighted the potential for beneficial outcomes of shellfish mariculture—including clam gardens—on community food sovereignty, food safety concerns related to paralytic shellfish poisoning, and bolstering traditional foodways and access for subsistence harvest. Some participants identified a lack of research in this space, both in Alaska and more broadly, and expressed a desire for better understanding of the impacts of harmful algal blooms and climate change on mariculture as priorities. Additionally, a handful of participants identified that rural communities often have other concerns and needs, such as energy costs, health care, housing, and that there is limited capacity to get involved in standing up a brand new industry unless it helps address those as well. One study participant described communities they work with as "kelp curious" (aquatic farmer, Interview 14), but that the

experimental and high-risk nature of kelp mariculture right now was holding people back from getting too involved, a sentiment that other study participants echoed.

3.2.4 Looking ahead: balancing community and commercial success

Participants largely agreed that mariculture has the potential to serve as a needed and powerful catalyst for both economic and community development, but emphasized a tension between community success and the widespread, scalable, rapid commercial success that is driving the industry forward.

Several study participants grounded mariculture's connection to both community and economic development in terms of offsetting declining fishing opportunity and providing a catalyst to areas affected by fishery and/or processor closures, with some participants framing it as a necessary development for communities to survive. One participant described their vision for mariculture as a way to:

“...remediate the effects of ocean acidification and possibly climate change, whether that be cyclical or something that's happening...to help remediate that is number one, while serving the communities that will be most affected by these changes in a number of ways. To help with loss of hours for workforce, loss of opportunity for fishermen through fisheries, loss of crew through opportunities on fishing vessels. And I think it opens a lot of education doors as well that reconnects us with the coast that we live on. I think that's my dream. To see all those things work in harmony, and to keep our way of life. To keep Alaska why I moved here, and why I stayed” (aquatic farmer, Interview 09).

Another participant shared a similar sentiment after discussing how some coastal communities in Alaska were facing existential threats from processor closures:

“I'm a community person, that's what I care about, and so I care about small communities in Alaska existing and surviving, and I hope that mariculture can help with that. And I think it can, I think it already is, particularly shellfish farming” (community/industry leader, Interview 05).

Many participants grounded their perspectives on mariculture in the context of community success. For example, one participant pointed towards successful industries elsewhere, such as Washington State's shellfish industry and its farmers benefiting greatly from owning fee title to tidelands used for production, and added that:

“...mariculture, like all agriculture, is intensely local, it has to be done by people who live in the community. And success, to me, is if we can establish an industry that is sustainable, diversified and broadly across the state, where it can exist and be profitable without the stimulus funding in place, then that’s a win” (aquatic farmer, Interview 06C).

Another participant echoed that sentiment and said they’ve observed a widespread desire to keep mariculture “kind of in the hands of the common people,” as compared to large-scale farms owned by large processors or companies, and adding that:

“...if there were some breakthrough, and, you know, somebody cracked the nut and found some very valuable stuff out of seaweed, I’m sure that the large companies are not going to hesitate to get right into it, but I think they’re hoping that the small guys are building their own footprint right now and trying to get a jump on things” (researcher, Interview 11).

Although several participants expressed a hesitancy or opposition to investment from large companies, many also acknowledged that investment from larger companies is likely a requirement to overcome challenges with marketing and processing, and achieve the broad economic goals of development, with one participant saying:

“...there is fear that if you bring huge investment or investors, this is going to be like the same story of the canneries, but...you have to run the numbers. You have to get away from that fantasy that this is going to be a mom and pop for kelp—we have to grow massive amounts, and we’re not going to be able to do that if we don’t bring big investors” (researcher Interview 07).

Finding a way to reconcile regional, scaled commercialization with diverse definitions of success across coastal communities is a key challenge identified by participants. When discussing the investments stemming from the Build Back Better grant funding, one participant said:

“...while the scope of this project is an industry, and so much of the rural communities aren’t really necessarily looking for anything that large, I think they will benefit from the infrastructure, the supply chains, the pieces of the industry that benefit coastal Alaska, they’ll be able to benefit indirectly from that, and that’s good. If they want to participate directly that’s okay too, but I think there’s areas where, especially for things like animal feed and fertilizer, soil amendments, that there is a sweet spot for scalable bulk commodities to be processed and shipped” (community/industry leader, Interview 06B).

One participant reflected more broadly on mariculture as an opportunity to shift economic development away from extractive industries and potentially repair some past harms:

“And there was need and desire. One of the reasons that I feel so strongly about mariculture is I grew up in the timber industry and the seafood industry—so much of the

economic activity in Alaska since colonialization has been focused on the extraction of natural resources. I mean, from, you know, from the Russians coming for gold and furs to oil, all of these things, you know really powerful economic engines, but they are all extraction based. And this was a paradigm shift. This was something that [had] almost unlimited capacity...well, not capacity, unlimited opportunity when you think about the infrastructure, the water, the people, the skill sets, the species that are here that we can cultivate. They are all part of, you know, kind of that mosaic to change the paradigm of what's possible in Alaska. And that's what really intrigued me. You know, the opportunity to—you know it seems cliché—but be the change you want to see” (aquatic farmer, Interview 06C).

Although many participants acknowledged the delineation and tension between community and commercial success, there was nearly universal desire for mariculture to maintain space for both forms of success as it develops. While there is not necessarily consensus on the best path forward, a few participants detailed specific examples of projects where mariculture may be turning the tide towards more commercial success without sacrificing community success, largely stemming from place-based, community-oriented partnerships. One participant (aquatic farmer, Interview 12) highlighted a diversity of projects that they were excited about: hydroponics farming that was contributing to food security; a grant-funded project to establish a clam garden in an Alaska Native community; community leases in Alaska Native communities, and the scaling up of farming infrastructure in Metlakatla; four buyers being secured in the Kodiak Archipelago for seaweed for the upcoming harvest; and a bright outlook for the biostimulant market for agriculture use, including a price point that could potentially be competitive for farmers compared to food products and a stabilization method for that product that could work well for rural communities.

3.2.5 Uncertain viability as a livelihood diversification tool

Study participants expressed optimism for the future economic potential of kelp farming and mariculture, but emphasized significant challenges in meeting economic goals that have perpetuated risk and vulnerability for industry participants, and undermined its viability as a livelihood diversification tool for commercial fisheries. Organizations like the AMTF and AMA

initially envisioned mariculture as a livelihood diversification tool that could complement fishery participation (especially given the seasonality of salmon fishing in Alaska), as well as take advantage of synergies with existing fisheries infrastructure and experience, giving Alaska a perceived advantage in both the pace and success of industry development.

In our archival analysis, many strategic documents, press releases, and early discussions of the AMTF highlighted a narrative of untapped growth and economic potential for the industry, a goal of fully utilizing maritime resources and vast quantities of coastline, and a vision of an industry that would stretch from the smallest communities to the largest ports. Some documents even articulated a vision for Alaska to not only be a national leader in mariculture, but a key player globally (e.g., Rinker et al., 2021). Additionally, expectations for exponential growth and enormous economic potential were clearly laid out in economic analyses and projections of industry growth, particularly as it relates to seaweed (e.g., Northern Economics Inc., 2015; McKinley Research Group, LLC, 2022), with an ambitious goal of the entire mariculture industry reaching a value of \$100 million by 2040.

Participants highlighted several challenges in meeting that goal, including the COVID-19 pandemic, but centered around an uncertain domestic market for kelp in the U.S., underdeveloped processing infrastructure that lacks established best practices, and challenges around energy, transportation, and shipping unique to Alaska. One participant described the consequences of these challenges, saying that the industry has “hit pause” on kelp farming for a while. Notably, one participant explained how Alaska’s overall decrease in kelp production since 2023 was misleading, since you can hold a lease for a certain period of time without growing anything, stating that if all leases were in full production, Alaska could likely produce “just shy of eleven million pounds,” (aquatic farmer, Interview 12), which would be a nearly 2800% increase in production for the state compared to the 2023 harvest (Alaska Department of Fish & Game, 2025). Other participants described how kelp farmers were considering potential shifts in their cultivars, such as: shellfish production; exploring relatively niche species of kelp, such as dragon

kelp, giant kelp, and split kelp; and bull kelp, which several participants highlighted as having high potential since it is not a widely grown species in the United States and globally.

Participants also highlighted that the question of industry scale remains unanswered and has cascading implications for the production side of the industry, especially considering that many participants voiced motivations for entering the industry related to small-scale, regenerative food production. In the words of one study participant:

“...that’s a big push and pull in the whole, you know, the whole scene is that, you know, do we want Cargill, you know, do we want to make pig feed? Do we want to make, you know, Barnacle stuff? What do we want to do? That’s still a question, and I think we want to do all of it, you know, ultimately” (community/industry leader, Interview 05).

Another participant pointed out that:

“...we have, like, always assumed that there is demand when that is actually not true...I think there has just been, like, this notion that if we grow a whole lot of it, we can sell it, so I think that has been an inaccurate framing of thinking about like developing an organic, real customer base, as opposed to trying to like create—balloon this huge industry, and then they will come” (aquatic farmer, interview 15).

Several study participants also expressed concern about mariculture’s potential as a livelihood diversification tool, highlighting how unrealistic expectations around kelp farming can perpetuate economic risk and vulnerability. For example, many participants dispelled narratives about the ease of mariculture (e.g. that you can “set it and forget it”), detailing the immense amount of work and challenges that go into making kelp farming “work” economically at this point in time. Additionally, participants spoke about how projections of rapid and exponential growth early in industry development that were widely spread motivated people to enter into an industry that could largely be characterized as at an experimental stage. One participant described this rush to join the industry as “...a huge boom, everybody jumped on the bandwagon, and they found out that nobody would buy it, or people bought very little of it” (agency staff, Interview 04), while another described the vulnerability of the kelp industry due to it being “90% reliant on grants” (researcher, Interview 07). Another participant described the

precarious situation this economic environment has placed new entrants to the kelp farming industry in, saying:

“...it still seems like until there's an actual profit, I mean, there people are still risking a lot to get involved, and so I guess it just hasn't—it's not a proven business plan in Alaska. Like a small [kelp] farmer hasn't proven to be profitable in a way that can, like, sustain a whole family, you know what I mean? So it's like, until we can prove that it's profitable, you can put the opportunities and the federal funding out there as much as you want, but people know that that's temporary. It's like, sure, yeah, that might get you started, but it's not going to pay for your fuel costs and your boat maintenance in five years. And so, unless you already have a boat and you're already a commercial fisherman, it's, yeah, it's not equitable in terms of opportunities. Like, I don't feel it's ethical right now to encourage other young people or young families to get involved, because we haven't made a dime.” (aquatic farmer, Interview 13).

Study participants also discussed mariculture in the context of economic uncertainty within the seafood system as a whole in Alaska, which is dominated by wild capture fisheries, and which mariculture is envisioned as supporting by offering alternative livelihoods. One participant detailed “the loss of fishing permits, and [fishing] opportunity to rural communities throughout Alaska, [which] hit Alaska Native communities particularly hard” and that they see mariculture as “a way to take people that already had skills and ties to working on the water and put those to use” (aquatic farmer, Interview 12). They also shared their experience as a salmon fisherman in the industry, saying “...the story of Alaska salmon being fully sustainable and all this stuff is kind of, as you know, if you know, know the industry, it's not necessarily true. We've had some huge declines in catches, and then especially our set net group has seen a lot of issues with seafood processors wanting to consolidate...and plants have been mothballed by their current owners” concluding by saying “we're in trouble in the fishing industry” (aquatic farmer, Interview 12).

4. Discussion

Within the context of climate-driven ecological and economic pressures on coastal communities, exploring the outcomes of marine aquaculture using a social-ecological systems framework can contribute to policymaking that bolsters communities' ability to respond to

external threats or change (Johnson et al., 2019). This work examines the complex challenges and opportunities that arise from interactions between industry participants and the formal and informal institutions that shape the direction of aquaculture development. We also contribute to a growing body of research examining how the strategic and rapid development of aquaculture in the United States has incorporated concepts like sustainable and equitable growth. We provide insight into the importance of meaningful communication, and the alignment of local community and broader industry goals in natural resource industries. Study participants highlighted how institutions and industry leaders can better integrate place-based needs and values into industry development to work towards equitable and beneficial outcomes for rural communities and Indigenous peoples. Study participants identified areas of immediate concern for kelp farming, including an overreliance on grant funding within the context of general market uncertainty, but also lauded mariculture's immense value in building relationships, and remained optimistic about its economic potential in both the short and long term. This study highlights the work, knowledge, and determination that farmers, communities, NGOs, and agency staff are putting towards making mariculture a viable industry that realizes its full potential.

4.1 Impact of mariculture on community and individual livelihoods

Our work builds on other research to highlight how rapid commercial growth of the mariculture industry in Alaska is broadly envisioned by both institutions and participants to play a crucial economic role in the state moving forward, especially as it relates to addressing livelihood concerns in fisheries (Miller, 2021). Other states have attempted to use mariculture to complement or even supplement fisheries income with mixed success (Stoll et al., 2019; Cleaver et al., 2018), with other research highlighting gaps in understanding between aquaculture policymakers, institutions, and participants leading to unintended and detrimental outcomes (Krause et al., 2015). There is evidence to suggest that the ability of seaweed farming to diversify

livelihoods is highly context dependent, and perhaps best suited to places where alternative forms of livelihood are dwindling, or where aquaculture is implemented primarily as a supplement to fisheries income (Spillias et al., 2023; Eggertsen & Halling, 2020).

In the context of coastal Alaska, the opportunities provided by kelp farming align well with community needs, as several participants voiced concerns about increasing economic pressures, loss of fishing opportunity, and consolidation within fisheries leading to the closing of critical infrastructure that supported towns. Study participants also spoke about mariculture as a paradigm shift away from extreme reliance upon industries that are perceived by some as “boom or bust” (aquatic farmer, Interview 14) and “extractive” (aquatic farmer, Interview 06C). Mariculture was also recognized as providing opportunities during non-fishing seasons (aquatic farmer, Interview 14). Many participants characterized the potential of mariculture as a way to preserve and maintain the cultural dimensions of coastal communities, ranging from reconnecting with nature to maintaining a population during the winter to bolstering food security for Alaska Native communities by reducing exposure to paralytic shellfish poisoning. However, more research is needed to understand whether Alaska is facing similar challenges to other states in terms of fisher participation and livelihood diversification, and the degree to which gaps between institutions and participants are contributing to detrimental outcomes.

4.2 Commercial versus community success in mariculture development

Study participants discussed how there were two kinds of success in the industry: community success and commercial success. Participants described community success as being largely focused on addressing specific place-based needs and community-driven goals for mariculture such as food security and livelihood diversification. On the other hand, participants described commercial success as being largely focused on the techno-industrial aspects of the industry such as improving seed supply, farming and processing technology, product

development, and commercial scalability of kelp farming for bulk commodities such as animal feed and biostimulants.

Aquaculture research is often centered around one side of this dichotomy. Research oriented towards commercial success has discussed how aquaculture can address large-scale issues such as U.S. seafood import deficits and supply gaps, growing global demand for seafood (Froehlich et al., 2021; Froehlich et al., 2019; Costello et al., 2020; Gephart et al., 2021; Helvey et al., 2017) or provide large-scale benefits such as carbon mitigation and ecosystem services (Duarte et al., 2017; Krause-Jensen et al., 2018; Theuerkauf et al., 2012). Research oriented towards community success has explored how an overemphasis on economic success can dilute, or even reduce, benefits to communities (Campbell et al., 2021), the importance of understanding and uplifting local decision-making and capacity (Diana et al., 2013; Britsch et al., 2021; Cumming et al., 2022), and integrating the wellbeing-oriented aspects of regenerative frameworks into aquaculture (Loring, 2023).

Study participants navigated this “either, or” dynamic in aquaculture by expressing an explicit desire for future investments in the industry to make room for both types of success. They highlighted the need to prioritize the types of improvements that will lead to economic viability for small-scale farmers—such as using gametophyte culture to improve seed supply and facilitating healthy partnerships with “big” industry (researcher, Interview 07; community/industry leader, Interview 10)—without sacrificing the types of projects that are more focused on issues like food sovereignty and ensuring that benefits and participation stay local. Participants also generally pushed back on the narrative that processing plus products equals economic success, highlighting the importance of social drivers of economic success, such as meaningful inclusion of Alaska Native and rural communities and equitable access.

4.3 Aligning institutional goals and actions with community needs

Participants stressed communication as one of the most important relationship drivers within the mariculture industry in Alaska, citing it as a critical element of successful collaboration and coordination, while recognizing breakdowns in communication as a major driver of regulation and policy challenges. Building an understanding of fisher leadership, behaviors, values, and motivations can lead to better policy outcomes, particularly around diversification (Beaudreau et al., 2018; Stoll, 2017), and addressing social capital and cultivating interactions with managers can build stewardship capacity within fisheries (Scalisi et al., 2024). Additionally, research into perceptions of aquaculture amongst the general public has revealed widespread uncertainty and complexity, and the importance of establishing pathways to understanding community desires and goals (D'Anna and Murray, 2015; Fong et al., 2024; Britsch et al., 2021). In this way, proactive, purposeful, and effective communication between institutions and participants is essential in order to achieve broadly-held goals and underpins successful, sustainable industry development.

Although many participants seemed certain that mariculture would continue to grow as an industry in Alaska, questions were raised about whether it would do so in a sustainable and equitable manner. Central to this question was the degree and manner in which Alaska Native communities would have a voice in how the industry develops, and whether Indigenous values would shape policy and regulatory frameworks (such as whether Alaska Native communities would acquire the first right of refusal to permits near their land).

Participants highlighted alternative ownership structures, such as farmer cooperatives, as a way to achieve a dual goal of structurally supporting both commercial and community success, as well as building the kind of social capital amongst rural and Alaska Native communities that could allow them to better advocate for beneficial outcomes. These types of approaches would not be without precedent in mariculture. Mussel farmers in Ireland (Cush and Varley, 2013) have employed both formal and informal methods of cooperation, Atlantic Sea Farms has seen success in kelp farming in New England with a unique business model that

directly supplies farmers with training and seed, and guarantees purchase of their kelp (Atlantic Sea Farms, 2025), and the Moana Project in New Zealand represents a true integration of Indigenous values and language into a public-private partnership that will drive seafood industry governance (Moana Project, 2024). As Campbell and colleagues put it: “...policy initiatives like these acknowledge the importance and agency of communities in the development of and participation in governance processes and outcomes appropriate for their interests and place-based human-environment systems” (Campbell et al., 2021, p. 3).

4.4 Differences and social dynamics between kelp and shellfish farming

Study participants stressed that an important distinction within mariculture is that commercial seaweed farming only began in 2017, while commercial shellfish farming has been occurring in the state for close to half a century. Shellfish farmers have their own industry organization, the Alaska Shellfish Grower’s Association, which was founded in the 1980s and is part of the AMA and AMC, but also participates in broader shellfish-focused industry governance such as the Pacific Coast Shellfish Grower’s Association and Pacific Shellfish Institute. A key distinction that surfaced during the archival analysis and which was emphasized by many study participants was a delineation between the needs of seaweed farmers and shellfish farmers, with one study participant even characterizing the industry as being “like we have two worlds...we have shellfish and seaweed, and shellfish is doing just fine, thank you” (industry leader, Interview 5). Future research on the outcomes of mariculture development and community needs should take care to explore, identify, and evaluate differences between participants depending upon the species they cultivate and the length of the time they have been participating, particularly as kelp farmers look to shift towards shellfish or integrate shellfish into their business models in order to increase economic security.

4.5. Conclusions

Although study participants reinforced that mariculture has the potential to diversify coastal livelihoods and stabilize communities amidst growing pressures and changes, participants expressed a nearly universal concern around the high degree of difficulty, risk, and vulnerability that currently comes with participation. Participants recognized the benefits of the influx of grant money with the Build Back Better funds, particularly in how it has provided income to farmers and facilitated innovative, multi-stakeholder, cross-disciplinary partnerships. However, nearly all study participants acknowledged that the funding has come with significant limitations, to the degree that several participants expressed skepticism that all of the grant money would be spent during the grant period. Other participants questioned what sort of off-ramps will come after the availability of funds ends in 2026, with one farmer suggesting that the USDA needs to view aquaculture as agriculture and support it, concluding that “without further funding, I really don’t see seaweed farming really getting off the ground ever, you know?” (aquatic farmer, Interview 16).

Other studies have suggested that robust governmental support and strong economic incentives to de-risk participation in mariculture are critical to the industry’s future success (Rubino 2023; LaPointe, 2013). The federal government has recognized aquaculture as essential to developing a climate-smart, sustainable food system, identifying sustainable development of the industry as a national priority (Rubino, 2024). However, study participants identified funding as a consistent challenge throughout industry development, even during times when the industry had explicit state support with the Alaska Mariculture Task Force, or federal support with the Build Back Better program funds. To realize the broad-reaching and immense potential of the industry to support economic livelihoods, state and federal governments must take calculated, sustainable steps towards long-term economic support of industry development, and importantly, aquatic farmer livelihoods.

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Figure 1. Social-ecological systems framework used to examine dynamic relationships among actors and the governance system for Gulf of Alaska mariculture. Adapted from Johnson et al. 2019.

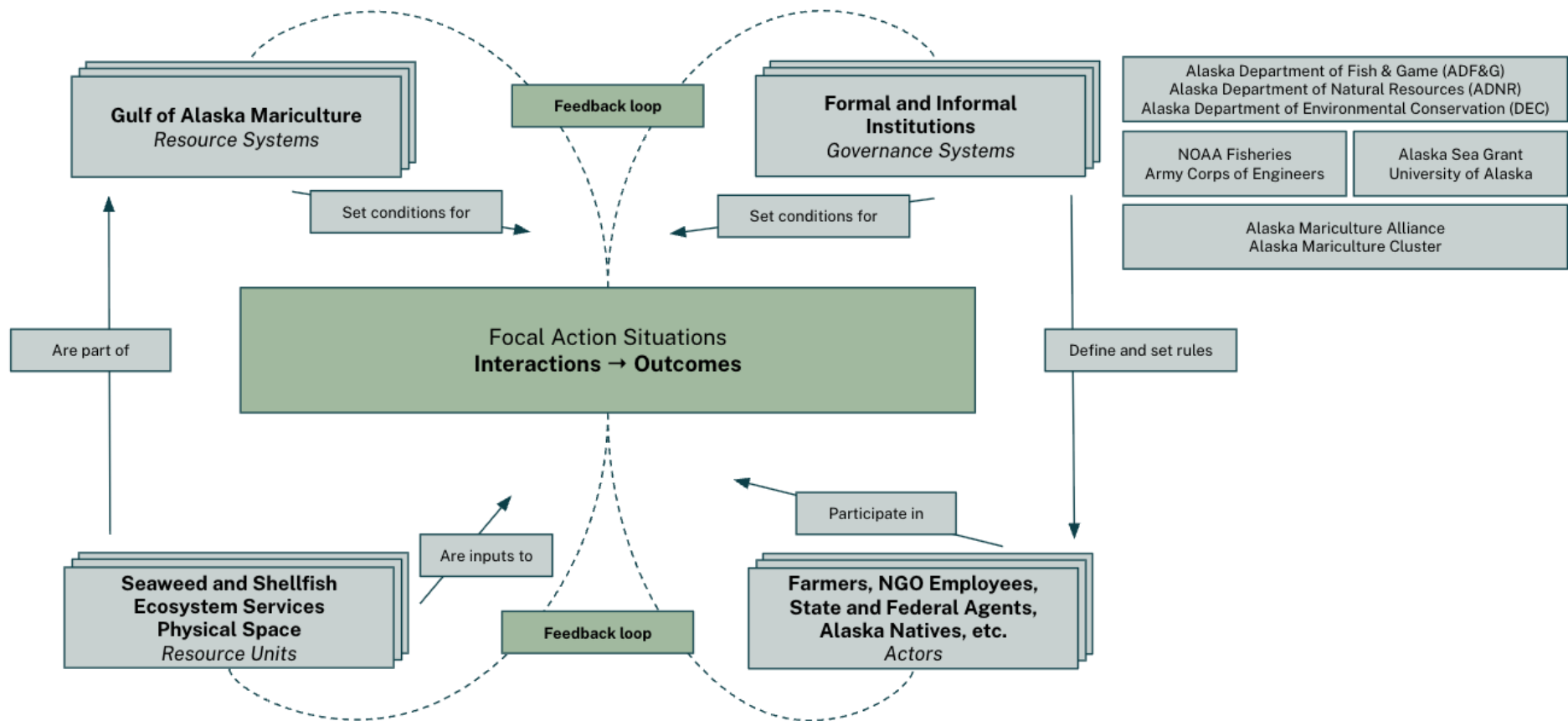


Table 1. Governance systems within the Gulf of Alaska social-ecological system.

Name	Organization type	Role*
Alaska Department of Fish and Game (ADF&G)	State agency	Responsible for aquatic farm permitting and enforcing state regulations around operational activities (such as genetics concerns with hatcheries or interactions with fisheries)
Alaska Department of Natural Resources (ADNR)	State agency	Responsible for reviewing and approving proposed subaquatic land leases and enforcing relevant state regulations
Alaska Department of Environmental Conservation (ADEC)	State agency	Responsible for enforcing food safety and water quality regulations
Army Corps of Engineers (Army Corps)	Federal agency	Responsible for enforcing federal regulations related to the Clean Water Act (CWA)
NOAA Fisheries (NMFS)	Federal agency	Consults with Army Corps and state agencies and enforces federal regulations related to the Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA). Oversees the federal Aquaculture Opportunity Area (AOA) project within Alaska state waters.
U.S. Economic Development Administration (EDA)	Federal agency	Responsible for administering and creating regulations related to its Build Back Better (BBB) grant award
U.S. Department of Energy	Federal agency	Has funded research projects in the industry through their Advanced Research Projects Agency-Energy (ARPA-E) program, a wing of the DOE that is focused on disruption within the energy landscape, and have collaborated with farmers and researchers on everything from early explorations of macroalgae as a biofuel to scaling culturing techniques.

Alaska Mariculture Alliance (AMA)	NGO	Successor to the Alaska Mariculture Task Force; private non-profit industry-led coalition to catalyze and guide industry development
Alaska Mariculture Cluster (AMC)	NGO	Public-private industry-led coalition; created as a broad multi-stakeholder partnership to pursue a \$49M grant through the U.S. EDA
Alaska Sea Grant	University	Collaboration between the Federal government and the University of Alaska System
University of Alaska System	University	Directly partners with both farms and other organizations to facilitate research projects within the industry, from hatchery research and commercial hatchery production to product development and species diversification and viability. Integrates mariculture into seafood technical programs that provide pathways for professional participation in the industry.
Tribal-Led NGOs	NGO	Includes organizations such as The Native Conservancy, Spruce Root, Alutiiq Pride Marine Institute (APMI) and the Chugach Regional Resources Commission (CRRC), as well as others, dedicated to representing the interests of Alaska Native communities in natural resources management, including as it relates to the development of the mariculture industry. Activities may include community engagement, research, advocacy, and more.
Regional NGOs	NGO	Regional NGOs include nonprofits such as the Aleutian Pribilof Island Community Development Association (APICDA), as well as government-affiliated nonprofits such as regional economic and community development organizations. These include Southeast Conference (the lead entity for distributing BBB grant funds), as well as the Kenai Peninsula and Prince William Sound Economic Development Districts. Also included are organizations such as the Prince William Sound Science Center, a place-based institute that conducts research and educational programming.
External NGOs	NGO	Organizations such as GreenWave, the World Wildlife Fund, the Woods Hole Oceanographic Institute, Blue Evolution, and Ecotrust have provided everything from funding for research and community engagement to hands-on trainings and educational materials, as well as exploring pathways for rural and Alaska Native community participation. Some have directly partnered with farmers to facilitate the creation of seaweed hatchery

		infrastructure, purchase and processing of seaweed, and/or exploring seaweed product development.
Alaska Native Communities	Tribal Communities	The participation of Alaska Native communities often involves coordination and partnership with Alaska Native Corporations, Tribes, and Villages. There are also efforts to conduct general community engagement with Alaska Native community members. It's important to note that no formal government-to-government consultation regarding mariculture has occurred in Alaska, although it may occur as part of NOAA's Aquaculture Opportunity Area project.
Cities	Coastal Communities	Alaskan communities, towns, and cities may participate more formally in the industry, often through membership in the Alaska Mariculture Alliance, or partnering with other groups to facilitate and administer grants within their area.

*Many organizations participate through holding membership in the Alaska Mariculture Alliance and contribute to governance discussions.

Table 2. Actors within the Gulf of Alaska mariculture social-ecological system.

Name	Description	Role
Aquatic farmers	Includes those who actively hold an aquatic farming lease, and/or participate in the industry at least partly through cultivation of macroalgae or shellfish.	Many farmers participate in the industry in ways that extend beyond their farm boundaries, either through collaboration on research projects or through actual employment with industry organizations.
Researchers	Includes university extension staff, university researchers, as well as professional scientists working for science centers.	Collaborate with public and private partners to conduct scientific research related to mariculture.
State and Federal agency staff	Includes staff at state and federal agencies.	Review and approve proposed aquatic farms; enforce state and federal regulations; respond to monitoring and statute-related concerns.
Community leaders	Includes Tribal governmental staff, Tribal-led NGO staff, Alaska Native corporation staff, and individuals who participate in the industry via local economic development organizations.	Advocate for mariculture industry development in a manner consistent with represented community needs; apply for funding for specific projects.
Industry leader	Includes staff from local, regional, national, and international nonprofit organizations with an environmental or industry perspective.	Advocate for mariculture industry development across a broad range of needs; coordinate industry and workforce development; administer funding; partner with other organizations.
Private companies	Includes staff at private companies and corporations that are operating within the mariculture industry, but not actively participating in farming; may or may not be based in Alaska.	Invest in partnerships that build capacity within Alaskan mariculture, such as hatchery infrastructure; purchase and/or distribute aquatic farm outputs (seaweed and shellfish); create mariculture-related products for consumer markets.

Table 3. Alaskan mariculture development timeline. Key events outline important and related milestones in the development of the mariculture industry, with a focus on the cultivation of seaweed. The initial year indicates the first year that the event (or one of its components) occurred. Events with only an initial year are ongoing.

Years	Key events
2014–2022	Funding from NOAA enables the creation of the Alaska Mariculture Initiative (AMI) by the Alaska Fisheries Development Foundation, beginning with economic analyses (Northern Economics, 2015) of industry potential.
2016–2021	Creation of the Alaska Mariculture Task Force (AMTF) by order (Walker, 2016) of the Governor of Alaska legitimizes mariculture, and emphasizes a narrative of immense opportunity and potential across social, cultural, and economic dimensions.
2016–	Beginning of the expansion of the federal government's role in supporting aquaculture in Alaska through exploratory workshops (Biga et al., 2020), research partnerships (von Ketiz, 2016; Rinker et al., 2021) and eventually a comprehensive siting and mapping assessment , NOAA's Aquaculture Opportunity Area effort (NOAA, 2023)
2016–	The first commercial seaweed hatchery begins operating in Alaska (Keller, 2018). Hatchery seed production quickly expanded both in the number of hatcheries and their capabilities, largely supporting their respective region, with some partnering with specific farms early on.
2017–	Commercial harvesting of seaweed begins in Alaska (Alaska Mariculture Task Force, 2017). The Mariculture Task Force releases growth indicators that celebrate the first commercial harvest of seaweed in Alaska, as well as over 1,000 acres of new seaweed and oyster farms being applied for. For seaweed farming, success continues to be statistically measured in both permit applications and output rather than economic value (NOAA, 2024) though the industry saw its first decline in production in 2023 (Alaska Department of Fish & Game, 2025), likely due in large part to challenges with processing and market development.
2017–	Alaska State Legislature proposes the Mariculture Revolving Loan Fund (Mariculture Revolving Loan Fund, 2024) a funding source for those who already hold farming or shellfish and aquatic plant hatchery permits, and begins a string of related legislation in the State of Alaska Congress.
2018–2021	Creation of the Alaska Mariculture Development Plan (Decker et al., 2018), a comprehensive model for developing the industry, and the culmination of three years of research and strategizing within the AMTF and its

Years	Key events
	associated advisory councils. The AMTF is extended for another three years. Shortly after its creation, it is supplemented by the Alaska Mariculture 5-Year Plan (Alaska Mariculture Task Force, 2019) an action plan that identifies key achievements needed to advance the plan prior to the planned sunseting of the AMTF.
2019–	Addressing capacity needs identified in the Alaska Mariculture Development Plan, establishment of key positions within Alaska Sea Grant, NOAA, and the University of Alaska system (Alaska Mariculture Task Force, 2019) focused on mariculture coordination and research.
2021–	The Final Report to Governor Dunleavy (Andersen et al., 2021) reported on the progress of the industry towards meeting its goals and action plan set in 2017 and 2018, and coincided with the replacement of the AMTF with the Alaska Mariculture Alliance , an industry-led non-profit organization dedicated to developing and supporting the industry.
2021–	Creation of research centers, consortiums, and partnerships based in Alaska, including the Mariculture Research and Restoration Consortium (Prince William Sound Science Center, 2025), the Alaska Mariculture Research and Training Center (Alaska Mariculture Research & Training Center, 2025a), the Bull Kelp Research Squad (Alaska Mariculture Research & Training Center, 2025b), and others.
2021–	NOAA announces Alaska as the third region (NOAA, 2023), after the Gulf of Mexico and California, to be selected for its Aquaculture Opportunity Area mapping effort . This project intends to unite spatial and relevant data to identify ideal areas for aquaculture development, with Alaska being unique in that the project is the only one to focus entirely on projects in state waters, and the only project to exclude finfish aquaculture since it is illegal by state statute.
2021–2023	As the industry faces economic challenges, various organizations undergo large research efforts and release reports on seaweed processing (McKinley Research Group, LLC, 2022a), seaweed branding and marketing (Rising Tide Communications, 2022), and revisions to earlier “expansion scenarios” (McKinley Research Group, LLC, 2022b). The “chicken or egg” scenario becomes common terminology describing market growth being dependent upon and limited by emerging markets (Rinker et al., 2021; Kite-Powell et al., 2022).
2022–	The first Alaska Mariculture Conference is held (University of Alaska, 2025), now an annual conference intended to serve as a nexus of farmers, researchers, industry, and agencies. An increase in webinars, training, workshops, research groups, and on-farm research signals an increase and focus on supporting existing farmers and sharing knowledge with prospective industry participants.

Years	Key events
2022–2026	Receipt and implementation of the U.S. Economic Development Administration’s Build Back Better regional challenge grant (NOAA, 2022), a ~\$49 million award intended to catalyze nearly every aspect of the industry. The grant is administered by the Alaska Mariculture Cluster (Alaska Mariculture Cluster, 2025a), a coalition of public, private, and Alaska Native organizations, led by the Southeast Conference.
2023–	Using funding from the Build Back Better grant, the Alaska Mariculture Cluster partners with several regional organizations to create the Mariculture Liaison program (Alaska Mariculture Alliance, 2022; Alaska Mariculture Cluster, 2025b). Liaisons serve underserved, rural, and Alaska Native communities, address concerns around access to funding, and support mariculture development in a way that prioritizes local/regional needs.

Table 4. Themes from archival review and analysis of digital content across the development of Alaskan mariculture since 2015. Global themes encompass and summarize the organizing themes into a singular characteristic of the industry. Organizing themes summarize the contours and patterns of basic themes, which are keywords and phrases that serve as individual characteristics of data.

Global themes	Organizing themes
Vision setting	Scope, scale, and pace of industry development
	Sustainable & equitable growth
	Industry governance and coordination
	Coastal community needs and opportunities
Capacity building	Expanding human and financial capacity
	Addressing regulatory and permitting gaps
Adaptations and challenges	Operational infrastructure, product and market development, and species diversification
	Social cohesion: collaboration, conflict, and relationship drivers
	Dynamic alignment of narratives and expectations

Table 5. Study participants and demographic data. Participants are identified by the primary way in which they engage in the industry, though some may participate in multiple roles.

Region	Number of Participants
Southeast Alaska	11
Southcentral Gulf of Alaska (Prince William Sound and Kenai Peninsula)	5
Kodiak Archipelago	3
Role	
Aquatic farmers	8
Researchers	3
State and federal agency staff	3
Community / Industry leaders	5

Appendix 1: Archival Data Collection

We began our data collection by doing an advanced search across University of Washington and Google databases using the key words “kelp,” “seaweed,” “mariculture,” “aquaculture,” and “Alaska” to identify key agencies and organizations involved in mariculture in Alaska. We then applied principles of purposive sampling to search directly on key informant organizations’ websites and digital archives, using the same set of keywords but dropping the place indicator of “Alaska.” Many documents, reports, and meeting minutes had hyperlinks to other datum, or referenced specific external documents that we then located. In an effort to document analogous or parallel efforts to aquaculture by Alaska Native peoples, we expanded key words on relevant websites to include “climate,” “farm,” and “food.”

We also attended several webinars related to NOAA Fisheries Aquaculture Opportunity Area efforts and their Future of Aquaculture series of listening sessions, and recorded participant observations.

Once data were reviewed and identified as being relevant to mariculture, they were assigned inclusion or exclusion criteria and archived accordingly. Data assigned inclusion criteria were then reviewed further and assigned a summary, potential codes (initial themes observed), and notes for future qualitative analysis.

Inclusion criteria were split into four categories: “content,” “document,” “literature review,” and “TBD.” Content criteria were assigned when a datum required detailed review of specific content, such as direct quotes, detailed dialogue, or explicit conveyance of individual/group perspectives on mariculture. Document criteria were assigned when a datum required cursory review of broad content that offered implicit conveyance of organizational perspectives, such as technical reports and general summaries of meetings. Literature review criteria were assigned when datum contained primarily high-level information useful to establishing a timeline or temporal context around mariculture development in Alaska, or were

scientific literature. TBD criteria were used when datum fit more than one category, and required discussion amongst the authors to determine the appropriate level of analysis.

Exclusion criteria were broadly defined as content that either did not clearly contain content that explicitly or implicitly conveyed perspectives on mariculture development, or did not provide relevant contextual information to mariculture development. Data that were completely unrelated to mariculture and/or analogs (mining, fisheries, coastal food systems, etc.) were not collected, and were not assigned any criteria.

Table A.1.

Criterion Type	Criterion Code	Category	Criterion Description
Inclusion	C1	Content	Direct quotes
Inclusion	C2	Content	Detailed dialogue (e.g. extended and detailed summaries of meetings)
Inclusion	C3	Content	Descriptive information that conveys group and/or individual perspectives about mariculture
Inclusion	D1	Document	Primarily technical in nature (e.g. technical report from agency; analysis of forage fish abundance in kelp farms)
Inclusion	D2	Document	High-level overviews of dialogue (e.g. concise and general summaries of meetings)
Inclusion	D3	Document	High-level information that conveys organizational perspectives or priorities regarding mariculture
Inclusion	L1	Literature Review	Information that is useful to establish a timeline or context about the evolution of mariculture in Alaska
Inclusion	L2	Literature Review	Scientific research related to mariculture
Inclusion	T1	TBD	Meets criteria in more than one category
Exclusion	E1	Exclusion	Information which does not convey group or individual perspectives on mariculture, and offers little to no relevant context-setting

Appendix 2: Interview Guide

This interview protocol is a guide for the interviewer, who will conduct verbal, in-person interviews with participants in a semi-structured format. Participants will not have to provide written answers to questions.

Reminders for interviewer: Summarize the consent form for them and allow time to look it over (includes project overview, confidentiality information, and tells them about how long the interview should take). Allow time for questions. Ask them for oral consent. Ask for consent to audio record. If yes, start audio recorder and state date and interview #.

Part 1. Background and experience

1. We're interested in your experience with mariculture in the Gulf of Alaska. [Ask about all relevant experience. Ask about years in mariculture and/or adjacent industries (such as fisheries).]

- a. Aquaculture / Mariculture
 - a. What type (farming, wild-harvest, hatcheries, processing)
 - b. How long (and motivation for entering industry)
 - c. Role in livelihood (full-time, part-time, etc.)
 - d. What region(s)
- b. Research and/or management
- c. Fishing
 - a. Commercial fishing
 - b. Sport fishing / Personal use
 - c. Subsistence
- d. Other (please specify)

Part 2. Industry footprint

2. What do you see as the most important milestones in the development of the Alaska mariculture industry to date?

- a. Do you feel like where the industry is today matches where you expected it to be ten years ago?
- b. How impactful have the actions of government and coordinating groups been?

3. There are many people and organizations involved in the Alaska mariculture industry—how would you describe the degree of collaboration and coordination among groups?

- a. Does it feel like some groups or organizations have a larger voice than others?
- b. Are there any groups or people who haven't had a voice at the table? Do you have any thoughts or feelings on why they haven't?
- c. Do you feel like there's alignment (or misalignment) between the goals or values of different participants?
- d. How would you describe the role of knowledge and information sharing in the industry?

4a. [Non-Agency] What are some of the strengths and weaknesses of the way mariculture is being managed currently?

4b. [Agency] How could you or your organization's work be better supported?

Part 3. Perceptions of mariculture

5. What is your vision for mariculture in Alaska?

- a. Do you feel like others share that vision?
- b. What do you see as the biggest challenges to realize that vision?
- c. Is there a role that you think mariculture should play in Alaska? Does it seem likely to fill that role? Why or why not?

6. One of the stated goals in development of the mariculture industry is to provide benefits to rural and Alaska Native communities—what progress do you see towards that goal? What still needs to be done?

- a. Do you feel confident that those communities will stand to benefit from the industry moving forward? Why or why not?
- b. Another intended benefit is as an off-season form of income for those working in fisheries—do you feel confident that those communities will benefit from the industry moving forward?

7. There's a healthy debate about the benefits and drawbacks to mariculture that seems to have created a "fact or fiction" atmosphere, especially as it relates to seaweed—are there any aspects of the industry that are receiving too much or too little attention?

- a. Are there any that are falling short of their promise?

Appendix 3: Codebook

Code Group	Code Group Definition
Perception: Goals	Question #5: "What is your vision for mariculture in Alaska?" Descriptions of hopes and goals for the industry's future in Alaska; Question #6: "One of the stated goals in development of the mariculture industry is to provide benefits to rural and Alaska Native communities—what progress do you see towards that goal? What still needs to be done?"; Other descriptions of whether or not native, rural, fishing, or coastal communities stand to benefit from mariculture.
Perception: Risks	Question #5: "What is your vision for mariculture in Alaska?" Descriptions of fears about the future of the industry in Alaska and aspects of the industry that add risk / concern.
Mariculture: Roles	Question #5: "What is your vision for mariculture in Alaska?" Descriptions of the role that mariculture should play—such as providing benefits to specific groups of people, addressing past wrongs, etc.
Mariculture: Pathways	Descriptions of existing or potential strategies that would address existing pain points and challenges, continue success seen so far, or prevent fears from being realized.
Mariculture: Narratives	Question #7: "Are there any aspects of the industry that are receiving too much or too little attention?" Descriptions of the narratives related to mariculture in terms of expectations, expected benefits or characteristics, etc.
Cohesion: Collaboration	Question #3: "How would you describe the degree of collaboration and coordination among groups?" Descriptions of how collaboration, partnerships, and relationships have or have not worked, or faced tension, within the industry.
Cohesion: Conflict	Question #3: "How would you describe the degree of collaboration and coordination among groups?" Descriptions of how collaboration, partnerships, and relationships have or have not worked, or faced tension, within the industry.
Cohesion: Relationship Drivers	Catch-all category that captures important drivers of relationships, both positive and negative, between participants and institutions involved in the industry.
Achievements	Descriptions of "wins" or successes so far in the development of the mariculture industry, across the industry, organizational, and personal scale.
Challenges	Question #4: "How could you or your organization's work be better supported?" Catch all category for challenges to industry

	development; pain points for industry participants; future needs for participants across every role.
Participants	Descriptions of who is participating in mariculture, and what their role is. Alaska Natives, Fishermen, Researchers, and State & Federal Agencies.

Code Group	Code Name	Code Definition
Achievements	Coordination	Achievements that revolve around bringing people together; increasing or enabling coordination across participants, groups, and government agencies.
Achievements	Data / Research	Achievements related to improving access to data and/or research and researchers.
Achievements	Funding	Achievements related to improving access to funding, whether at the industry or individual level.
Achievements	Human Capacity	Achievements related to improving human capacity, either through increased support for existing participants, or by hiring and creating new positions focused on mariculture.
Achievements	Improved Efficiency / Efficacy	Achievements related to improving efficiency, such as improving turnaround time for lease applications, improved on-farm growing strategies, etc.
Achievements	Industry Recognition / Validation	Achievements related to gaining recognition and/or validation from government, investors, etc.
Achievements	Infrastructure	Achievements related to improving infrastructure (such as access to processing or drying infrastructure), or farm infrastructure such as gear, buoys, a single-farm dryer, and related issues.
Achievements	Markets	Achievements related to improving access to markets, whether through increasing demand for current markets or expanding into new markets.
Achievements	Preserving Subsistence / Traditional Use	Achievements that involve preserving or attempting to preserve subsistence access and/or traditional use.
Achievements	Regulations	Achievements related to improving regulations, whether at the state or federal level.
Achievements	Resiliency	Achievements characterized by resiliency in the face of challenges—continuing to develop and improve the industry despite issues around capacity, time, energy, profitability, etc.
Challenges	Consensus-Building	Descriptions of challenges related to differences between participant groups, communities, and/or regions in their interest

		in participating in mariculture, goals related to mariculture benefits, and/or values surrounding mariculture.
Challenges	COVID-19 Disruption	Issues and interruptions to the industry resulting from the COVID-19 pandemic.
Challenges	Data / Research	Challenges related to a lack of access to data and/or research or researchers.
Challenges	Food Product Development	Viability of food as the main product vector for seaweed in Alaska; value of different food products; strategies for producing food products successfully.
Challenges	Funding	Challenges related to a lack of access to funding, a lack of ability to spend available funds, or other issues such as restrictions/limits on funding or decisions on who receives funding.
Challenges	Human Capacity	Challenges related to a lack of human capacity, such as limited time and energy, burnout, a lack of experts or inability to retain them, etc.
Challenges	Infrastructure	Challenges related to infrastructure more broadly (such as regional processing or drying infrastructure) or farm infrastructure such as gear, buoys, a single-farm dryer, and related issues.
Challenges	Livelihood Feasibility	Challenges related to supporting oneself with the income from a kelp farm; commentary on the feasibility of supporting oneself with a kelp farm.
Challenges	Markets	Challenges related to a lack of access to markets, resulting from issues around lack of demand for products, transportation challenges, lack of infrastructure necessary to enter certain markets, global competition, etc.
Challenges	Non-Food Product Development	Viability of alternative products to food, such as pharmaceuticals, biofuels, bioplastics, or biomining. Strategies around developing or pivoting to alternatives, and perspectives on why the focus remains on food.
Challenges	Preserving Subsistence / Traditional Use	Challenges that involve a failure or struggle to preserve or attempt to preserve subsistence access and/or traditional use.
Challenges	Regulations & Policies	Challenges related to regulations, both at the state and/or federal level.
Challenges	Species Diversification	Discussion of impacts resulting from a lack of species diversity (such as ignoring oysters or red seaweed), or impacts resulting from broadening species diversity (such as industry research centered on dragon kelp, bull kelp, etc.), with a focus on profitability, product development, efficacy for industry and market development, etc.

Cohesion: Collaboration	Collaboration: Complement/Supplement to Fisheries	Mariculture is a natural complement to fisheries due to seasonal timing, workload, required gear/equipment/knowledge, etc.; mariculture can help supplement or diversify fishermen livelihoods; characterization of a complementary relationship rather than a conflicting one.
Cohesion: Collaboration	Collaboration: Culture / Community	Descriptions of mariculture and/or its core outputs (seaweed and oysters) facilitating connection to others via cultural use, an Alaskan or coastal way of life, building community, etc.
Cohesion: Collaboration	Collaboration: Inclusivity / Open	Usage of words such as openness, collaboration, cooperation, sharing, and related vocabulary that indicates an "inclusive" culture and atmosphere within the mariculture industry.
Cohesion: Collaboration	Collaboration: Uniting Voices / Building Common Ground	Perception that mariculture is bringing people together, or has the potential to bring people together in a way that's unique.
Cohesion: Conflict	Conflict: Exclusivity / Secretiveness	Characterization of the mariculture industry as one where knowledge is guarded/closely held/reserved for certain groups or types of people; where certain groups or types of people entering into the industry are not welcome (such as large organizations, those living outside of Alaska, etc.)
Cohesion: Conflict	Conflict: Marine Use (External)	Descriptions of conflict or potential conflict pertaining to use of marine areas besides mariculture, such as for fishing, recreational usage, traditional harvesting, etc.
Cohesion: Conflict	Conflict: Marine Use (Internal)	Descriptions of conflict or potential conflict pertaining to use of marine areas within mariculture, such as between those who farm oysters, kelp, geoduck, etc.
Cohesion: Conflict	Conflict: Roles	Conflict either concerning or stemming from the role that various groups, such as government agencies, university researchers, industry groups, advocacy groups, etc. play in the industry
Cohesion: Conflict	Conflict: Tension with the Past	Tension stemming from past mistrust / other industries, such as with large processors, fisheries management, etc.; descriptions of a divide within mariculture between those who've been involved for a long time, and those who have joined the industry recently (old school vs new school).
Cohesion: Conflict	Conflict: Too Many Voices / Competing Goals & Visions	Characterization of the mariculture industry as having too many voices, competing or incompatible goals and visions for the industry, competing or incompatible views of how to

		achieve goals, etc.
Cohesion: Relationship Drivers	Relationship Drivers: Communication	Descriptions of participants' communication and/or lack thereof how it drives relationships.
Cohesion: Relationship Drivers	Relationship Drivers: Shared Vision	Descriptions of shared and/or disparate visions for the past, present, or future of mariculture, and how it drives relationships.
Cohesion: Relationship Drivers	Relationship Drivers: Value Alignment	Descriptions of value alignment and/or misalignment and how it drives relationships.
Cohesion: Relationship Drivers	Relationship Drivers: Money	Descriptions of how financial incentives / disincentives drive relationships.
Cohesion: Relationship Drivers	Relationship Drivers: Trust	Descriptions of how trust and/or a lack of trust drives relationships.
Mariculture: Narratives	Narratives: Physical Impact of Farms	Opinions, beliefs, and statements that speak to the physical impact of farms on the environment, whether that's being spatially disruptive to human activities, being an eyesore, or disturbing the ecosystem itself, etc.
Mariculture: Narratives	Narratives: Climate Change / OA Mitigation	Descriptions of benefits—hopeful, perceived, or real—related to mariculture as a method for removing and/or sequestering carbon; mitigating the effects of climate change; or serving a critical role in addressing climate change.
Mariculture: Narratives	Narratives: Ecosystem Services	Descriptions of benefits—hopeful, perceived, or real—related to ecosystem services, such as improving the environment around the farm, increasing biodiversity, restoring or regenerating ecosystems, etc.
Mariculture: Narratives	Narratives: Expected Difficulty	Descriptions related to the relative difficulty of farming seaweed, such as the prevalent "set it and forget it" mindset, the amount of time and energy put into the farm to make it work, etc.
Mariculture: Narratives	Narratives: Expected Economic Opportunity	Descriptions of expectations around the scale/impact of economic opportunities for those who are interested in getting involved in mariculture.
Mariculture: Narratives	Narratives: Expected Growth	Descriptions of expectations around the speed/pace of growth in the industry; potentially including references to initial and/or ongoing projections of growth.
Mariculture: Narratives	Narratives: Buzz / Hype	Opinions, beliefs, and statements that speak to how mariculture is receiving buzz and hype; may or may not refer to a divide between old school and new school, or oysters and kelp.
Mariculture: Narratives	Narratives: Advantages / Relationship with Fisheries	Opinions, beliefs, and statements that speak to the mindset of mariculture interacting with Alaska's fisheries, especially as it concerns assumed advantages such as infrastructure, existing capacity or understanding, etc.
Mariculture:	Narratives: Paradigm	Opinions, beliefs, and statements that speak to

Narratives	Shift	the mindset of mariculture serving as a potential paradigm shift for the state, whether that's moving on from failing industries, representing new ways of doing things, creating opportunities where fewer now exist, etc.
Mariculture: Narratives	Narratives: Provide Community Resilience	Opinions, beliefs, and statements that speak to the mindset of mariculture being beneficial for community resilience, survival and strength.
Mariculture: Narratives	Narratives: Sustainable Food Production	Descriptions of benefits—hopeful, perceived, or real—related to mariculture serving as a sustainable, non-harmful, non-invasive method of food production, especially in comparison with other food industries and/or methods.
Mariculture: Pathways	Pathways: Diversify / Integrate Mariculture	Expand mariculture to include more products (such as oysters, red seaweed, etc.), and/or integrate mariculture into existing economy (have it complement fisheries rather than replace it). Farmers may or may not participate in other industries.
Mariculture: Pathways	Pathways: Increased Network Strength	Increased strength of the connections between participants via increased support (strengthening existing connections), opening new avenues of connection, or maintaining connections long-term (via funding).
Mariculture: Pathways	Pathways: Increase Speed / Scale	The industry moving too slowly and lagging behind; missed opportunities; the need for a "large" company or investor to come in and catalyze the industry by building infrastructure, slingshotting product demand, etc.
Mariculture: Pathways	Pathways: Decrease or Maintain Speed / Scale	A desire to slow the industry down; a sense of things moving too quickly, mistakes being made, decisions happening that will have irreversible consequences.
Mariculture: Pathways	Pathways: Improved Data Richness / Availability	A desire to increase the richness / resolution of data related to mariculture, either for use making policies and regulations, or for use by mariculture participants.
Mariculture: Roles	Roles: Environmental Impacts	Vision for mariculture includes hopes around the positive environmental impacts of the mariculture industry.
Mariculture: Roles	Roles: Learn From / Repair Past Mistakes	Vision for mariculture that includes recognizing an opportunity for learning from the past and repairing past mistakes, especially as it relates to the fishing industry.
Mariculture: Roles	Roles: Economic / Community Development	Vision for mariculture that includes a focus on building careers for the future, moving Alaska into the industries of tomorrow, and economic or community development. May or may not reference moving away from dying or declining industries.
Mariculture: Roles	Roles: Solve / Improve	Vision for mariculture that includes

	Problems	solution-oriented views, such as utilizing a workforce that's otherwise underutilized or sent home, making mining of minerals more sustainable, etc.
Participants	Alaska Natives / Tribes	Descriptions of Alaska Natives & tribes and their participation in the mariculture industry.
Participants	Fishermen	Descriptions of fishermen and their participation in the mariculture industry.
Participants	Researchers	Descriptions of researchers and their participation / role in the mariculture industry.
Participants	State & Federal Agencies	Descriptions of state and federal agencies and their participation / role in the mariculture industry.
Perception: Goals	Goals: Inclusivity and Equity	Vision for mariculture that includes an attitude of inclusivity and equity, especially as it concerns Alaska Native communities.
Perception: Goals	Goals: Increased / Deepened Collaboration	Vision for mariculture that includes important forms of cooperation and collaboration, risk and profit sharing, farmer cooperatives, etc.
Perception: Goals	Goals: Provide Cultural / Food Security	Vision for mariculture that includes providing food or cultural security—especially as it relates to subsistence harvest—to communities in Alaska.
Perception: Goals	Goals: Provide Economic Security	Vision for mariculture that includes providing economic security to communities in Alaska.
Perception: Goals	Goals: Industry and Regional Focus	Vision for mariculture that includes a focus on regional or state-wide benefits, growing the industry at scale, etc.
Perception: Goals	Goals: Local and Community Focus	Vision for mariculture that includes a focus on local benefits, providing for communities, etc.
Perception: Risks	Risks: Big Industry / Outside Investment	Vision for mariculture that includes fears of big industry or outside investment disrupting some of the achievements so far, steering the industry in the wrong direction, or incentivizing rapid and perhaps thoughtless growth. This may or may not include references to past mistakes that have been seen in the fishing industry.
Perception: Risks	Risks: Burnout	Vision for mariculture that includes fears around the people who are carrying the industry forward right now experiencing burnout or frustration at continued efforts to make it work.
Perception: Risks	Risks: Social-Ecological Concern	Vision for mariculture that includes fears around the negative impacts of the mariculture industry on the social-ecological system.
Perception: Risks	Risks: Finfish Farming	Vision for mariculture that includes fears or negative perceptions of finfish farming, both in terms of a future that includes finfish farming, mariculture only being viable if it includes

		finfish farming, or the impact that negative public perception of finfish farming has on other forms of mariculture/aquaculture.
Perception: Risks	Risks: Disconnects / Social Gaps	Vision for mariculture that includes fears or concerns around a disconnect between communities or participants as the industry grows, or around communities or specific groups of people being left behind.
Perception: Risks	Risks: Longevity	Vision for mariculture that includes fears around the longevity or long-term viability of the industry.
Perception: Risks	Risks: Misinformation / Unrealistic Expectations	Vision for mariculture that includes fears around misinformation or unrealistic expectations in the industry. This includes both negative misinformation (aquaculture is harmful) and positive misinformation (aquaculture will save the planet).