Highlights

- We use Q method to study perspectives about aquaculture development in Maine, USA.
- Aquaculture growth is supported, but perspectives differ about its scope and scale.
- Divergent perspectives reflect the history of ocean use in Maine.
- Perspectives have divergent views on the beneficiaries of aquaculture growth.
- Understanding perspectives on aquaculture growth is vital for long-term planning.

Abstract

As aquaculture production continues to increase worldwide, important questions are emerging about the motivations of growth and who stands to benefit. We use Q method to identify perspectives associated with marine aquaculture development in Maine, where aquaculture expansion in the United States has become a central focus. We used newspaper articles about aquaculture in Maine covering a 20-year period to inform the development of the Q study and participants included industry members, researchers, mangers, and other local experts. We identify four perspectives on aquaculture development based on the values individuals ascribe to the growth of the sector. We label these perspectives as: (1) Aquaculture Optimists, (2) Aquaculture Anchors, (3) Aquaculture Historians, and (4) Aquaculture Agnostics. Although the aquaculture sector is poised to expand in Maine, our findings suggest that there are material differences in the values associated with aquaculture growth, which may not be entirely compatible. By understanding the heterogeneity of perspectives surrounding aquaculture development in Maine, we aim to contribute to ongoing discussions about the future of aquaculture and encourage a more explicit articulation of the intended outcomes of aquaculture development and who it will serve.

Diverse perspectives on aquaculture development in Maine

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Declaration of interest

MLB and HML have no conflict of interest to declare. JSS owns and operates an oyster farm in Maine.

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1. Introduction

> *Aquaculture has the potential to enhance Maine's fishing industry. Its economic potential far exceeds the current value of the state's traditional fisheries. Its biological potential is great: the industry so far is using only a few of the numerous possible sites and species… By helping support the fishing industry, aquaculture can benefit coastal communities. Compared to traditional fisheries, aquaculture provides stable income and employment, yet is less physically taxing and dangerous.*
>
> – An Aquaculture Development Strategy for the State of Maine, 1990

It has been three decades since the Maine State Planning Office and the Maine Department of Marine Resources published *An Aquaculture Development Strategy for the State of Maine* (1), yet the messaging remains salient. Maine is experiencing a period of growth and investment in the aquaculture sector and many of the reasons that were used to promote aquaculture in the past are being raised again (2). The specific socio-economic and environmental context in Maine is, of course, unique, but aquaculture production is on the rise in the United States and worldwide, and aligns with broader narratives about blue growth and the blue economy (3–6).

Over the last three decades, from 1988 to 2018, global marine aquaculture production increased from 6.95 million tons (6.3 million tonnes) to 33.95 million tons (30.8 million tonnes) in 2018 (7). As substantial areas of "suitable" ocean space are identified for further development around the world (10), continued growth in the aquaculture sector is anticipated (7–9). Part of the appeal of aquaculture is that it intersects with the interests of a diverse cross-section of ocean

actors from multi-national corporations and private equity firms to development organizations, researchers, governments, environmental non-governmental organizations, and coastal communities (11). In practice, this has meant that a wide range of actors are investing in the aquaculture sector at the same time. In Maine, for example, there are at least 85 institutions or programs working to support aquaculture development through research, education, technical assistance or funding, as well as numerous private interests (2).

The excerpt from *An Aquaculture Development Strategy for the State of Maine* highlights several of the reasons that aquaculture is being advanced. The literature similarly points to a range of motivating factors, including: the potential for aquaculture to address global food insecurity and poverty (7,8,12–14), contribute to livelihood diversification and coastal community resilience (1,2,7), create investment opportunities (15,16) and reduce pressure on wild-capture fisheries while restoring coastal and marine habitats (17–20). While these objectives are not necessarily in conflict, they are not inherently compatible either. For example, aquaculture projects designed to maximize private investors' financial returns on investment or achieve the highest level of production efficiency (21) will not necessarily achieve community-focused objectives related to sustaining and diversifying livelihoods or enhance socioeconomic resilience (22). In many ways, aquaculture development is reminiscent of earlier work on the tradeoffs inherent in conservation and development projects (e.g., 25) and suggests that the type, scale, and distribution of aquaculture projects can influence which objectives are advanced and prioritized. As aquaculture has gained momentum, however, scholars have observed that the emphasis on sociotechnical solutions and overarching production milestones for aquaculture have consistently overshadowed efforts to define and prioritize objectives for aquaculture in particular places (24). To address this gap, research is needed to more fully understand the

motivations catalyzing aquaculture. This is not merely an academic exercise, but one that emerges from the perspective that the "success" of aquaculture is not a matter of how quickly the sector scales, but rather how closely it aligns with the underlying visions different actors have for investing and enabling it.

In this paper, we use the Q method to investigate different values actors associate with marine aquaculture to understand the heterogeneity of perspectives driving development in Maine, USA. We used a thematic analysis of Maine newspaper articles to design the Q study. In conducting this research, we specifically targeted study participants who were knowledgeable about Maine's aquaculture industry, including industry members, researchers, mangers, and other local water users. We focus on Maine for multiple reasons. First, the growth of the aquaculture industry in Maine raises questions about the balance of uses in coastal spaces. Furthermore, a systematic analysis of the values held by users of Maine's coastal marine spaces and associated with aquaculture growth in Maine has not previously been conducted. Clarifying these values has the potential to advance ongoing discussions about the future of aquaculture development in Maine and encourage a clearer articulation of the intended outcomes of aquaculture development.

2. Methods

2.1 Aquaculture in Maine

Although the United States lags behind many nations in aquaculture development, Maine is one of the epicenters for aquaculture in the country. Aquaculture in Maine started in the late 1970s, and Atlantic salmon (*Salmo salar*), blue mussels (*Mytilus edulis*), and Eastern oysters (*Crassostrea virginica*) are the largest subsectors by value and volume (25). Seaweed

aquaculture, primarily *Saccharina latissima* and *Alaria esculenta*, started in the early 2000s. Entrepreneurs and researchers in Maine are also developing sea scallop (*Placopecten magellanicus*), and quahog (*Mercenaria mercenaria*) aquaculture, as well as aquaculture for a range of other species. While the seaweed, sea scallop, and quahog sectors are relatively nascent, advocates hope they represent opportunities to diversify Maine's coastal economy (26).

By 2020, there were 179 aquaculture leases in Maine totaling 1,430 acres (578.7 ha) as well as 711 Limited Purpose Aquaculture licenses that are distributed across Maine's inshore waters. There were another 299 acres (121 ha) of leased area in review (27). Limited Purpose Aquaculture licenses allow small-scale operators to farm up to 400 ft^2 (37.2 m^2); these farms can be used to grow selected shellfish species and seaweed but not finfish (28). Of the 1,430 leased acres (578.7 ha), 550 acres (222.6 ha) were used for finfish aquaculture, 690 acres (279 ha) for shellfish, 45 acres (18 ha) for seaweed, and 145 acres (58.7 ha) for three year, non-renewable, experimental leases (max area of 4 acres or 1.6 ha) (27). Salmon aquaculture, which is concentrated in the eastern part of the state (29), is valued at approximately $74 million and represents roughly 80% of the total value of aquaculture production (25). While Maine's aquaculture industry has not yet reached achieved the milestones outlined in *An Aquaculture Development Strategy for the State of Maine,* the sector represented 13% ($88.4 million) of the total ex-vessel value of all commercial fisheries (based on 2019 data) (30). Furthermore, Maine's aquaculture sector is poised to grow significantly in the next few years (26,31).

2.2 Q method: understanding perspectives on aquaculture development

In this paper, we used the Q method to understand perspectives about aquaculture development in Maine, with a particular focus on what values people attribute to the growth of the sector. The Q method was developed by psychologists and is recognized as a useful tool for

addressing complex issues associated with natural resource use, management and planning (32–37). Studies using Q method typically involve five stages (Table 1) (38). First, a catalog of normative value statements, called a "concourse," is created about the study topic. Second, the concourse is distilled into a "Q set" that is made up of 45 to 60 statements that broadly represent the issue. Third, the study participants, or "P set," are identified. Fourth, participants organize the Q set statements into a matrix based on their agreement and disagreement with the statements. This sorting activity is coupled with an interview in which participants explain their sorting decisions. Finally, the data from the sorts are analyzed using either principal component analysis (PCA) or centroid factor analysis, and this information is combined with qualitative methods to identify and describe the dominant perspectives (38,39).

[Table 1 here]

2.3 Research design

The concourse statements were derived from a literature review of newspaper articles published in six major Maine newspapers (*The Morning Sentinel, the Kennebec Journal, The Bangor Daily News, Portland Press Herald, The Sun Journal,* and *Maine Times*). All newspapers are daily publications except the *Maine Times,* which was a weekly newspaper that stopped circulation in 2002. A total of 2,991 articles published between 1994 and 2019 were identified using the ProQuest Maine Newsstand database that include the search term "aquaculture." Of these articles, 979 articles were downloaded after reading their abstracts for relevance. The first author coded articles for value statements about aquaculture using NVivo 12 PRO (version 12.5.0) until concept saturation was reached. The final concourse resulted in 878 unique value statements and the research team distilled these statements through three rounds of thematic sorting that considered the overall balance of statements and the breadth of information

presented. This process resulted in a final Q set of 48 statements. Although the newspaper articles covered a 25 year period, many of the issues and arguments associated with aquaculture in Maine did not change substantially, making it possible to distill the large number of initial statements (n = 878) into the final Q set. Similar to the discussion in Davies and Hodge (40), perspectives about aquaculture presented in newspaper articles remained largely similar over this time period.

2.4 Research implementation

Study participants were initially identified through the authors' knowledge of the industry and then from snowball sampling (41). Participants (n = 36) included aquaculture industry members, environmental professionals, scientists, fishermen, landowners, and policymakers. The Q sorting exercise and follow up interviews (conducted by the first author) lasted between 40 minutes and two hours, with an average of approximately one hour. Interviews took place at locations across the coast of Maine between July 2019 and January 2020.

The Q sorting exercise began by obtaining participant consent, in accordance with the University of Maine Institutional Review Board rules (Application #2019-03-09). Each participant met individually with the first author to complete the sorting exercise at a time and location of their choosing. Study participants were given the Q set statements, which were printed on white index cards, and instructed to read the statements while considering the question "*What attributes do you associate with aquaculture development in Maine?"* Participants were then instructed to sort the statements into three initial piles: a pile of statements they agreed with, a pile they disagreed with, and a pile of neutral or non-relevant statements. After completing the initial sorting, participants placed the statements onto a matrix, which had a quasi-normal distribution with a ranking scale from +5 to -5 and 48 spaces for statements (Appendix Figure 1).

Participants were asked to place the statements on the matrix based on the strength of their agreement and disagreement, with +5 indicating strong agreement and -5 indicating strong disagreement. The follow-up interview started immediately after each participant finished their Q sort, and was used to clarify their thought process, the statements they agreed and disagreed with, confusing statements, and concepts that were missing from the Q set.

2.5 Analysis

2.5.1 Initial analysis

Interviews were recorded and transcribed using the online transcription program otter.ai, and the first author manually corrected the transcription. Interviews were coded using NVivo 12 PRO (version 12.5.0) to capture emergent themes about aquaculture and to contextualize the results of the Q study. For the analysis of the Q sort data, principal components analysis (PCA) and a varimax factor rotation were completed using the qmethod package in the statistical software R (version 3.6.1) (42,43). While centroid factor analysis and PCA are both accepted methods for Q method analysis, the authors chose the qmethod package and PCA following other published research (38,39,44). Although this study used PCA, it is customary in the Q method to refer to all resulting groups as factor groups, regardless of the initial method of reduction (44). Therefore, we will refer to our groups as factors instead of components.

In a Q method study, researchers define the number of groups produced by the PCA or factor analysis. This study identified four groups and after they were defined, the loadings for each participant were shown (Appendix Table 1). These loadings show the similarity between an individual participant's Q sort and each component and a significantly loading participant is included in that factor. Significant loading at the 0.01 level is calculated as $2.58 * \left(\frac{1}{\sqrt{n}}\right)$, where n

is the number of statements in the Q set (45). In addition to factor loadings, the PCA or factor analysis provides Z scores that show the relationship between factors and the Q set statements using the weighted average of the group members' responses in the Q sorting exercise (39). The Z scores are normalized into integer factor scores that show how a hypothetical person belonging to each factor would sort the Q set statements (39). Both the Z scores and the factor scores are reported in this study.

During the PCA, a threshold of 0.38 was initially used as the cutoff for significant loading onto a factor (after 37,45). However, upon examining the data we increased the threshold from 0.38 to 0.55 because "confounded" participants loading significantly onto multiple factors are removed during the analysis (38,45). We chose the value of 0.55 because it maximized the number of participants significantly loading on a single factor while minimizing the number of confounded participants (as in 38). Raising the threshold makes the factors more selective and increases the number of participants included in the final study by reducing the number of participants significantly loading onto multiple factors (45).

We used Z scores to compare the factors after defining them using PCA. The Z scores show the weighted average of each factor group's responses to each Q set statement. The Z scores were also used to define statements with strong areas of agreement and disagreement between the factors. We treated non-significant differences between Z scores as indicative of consensus statements, where all of the components sorted that statement in a similar way (38,39). Those with significant differences distinguish factors from one another. This information, as well as the qualitative interview information, was used to describe the factors.

2.5.2 Secondary PCA

After the initial analysis, we completed a second PCA and varimax rotation on the first component (as in (46)). This component explained the majority of the study variance and contained 24 participants. The first component divided into two sub-groups (n = 17, n = 7) which were supported by eigenvalues greater than 1 and a visual scree test (38,47,48). However, the two groups had a correlation of 0.68, indicating that they are different manifestations of the same perspective instead of distinct perspectives (38). As above, based on the number of statements in our Q sorting exercise (n = 48), any loading is significant at the 0.01 level if the loading is greater than 0.38 (38). Therefore, we do not present detailed results of this secondary analysis, but instead use the subgroups to add context to the first Factor Group. The eigenvalues, percentage of explained variance, and consensus and distinguishing statements are shared in Appendix Table 3.

3. Results

Our analysis revealed four distinct factor groups that explained 71% of the total study variance. The 48 Q set statements, factor group scores, factor groups Z scores, and consensus and defining statements are reported in Table 3.

Thirty-three of the 36 participants loaded significantly onto one of the four factors and were included in the final analysis. The remaining three participants loaded significantly onto multiple factors (n = 1) or did not load significantly onto any factor (n = 2) and were removed from the analysis (after 32,42,43) (Appendix Table 1). All of the aquaculture industry members loaded into the first component (Table 2). All four components included commercial fishermen (who primarily target the American lobster or softshell clams, *Mya arenaria*), waterfront

landowners, non-profit employees, government resource managers, and scientists (Table 2). Nearly all study participants, regardless of background, expressed interest and support for aquaculture development.

In the Q method, groups with only one significantly loading participant are frequently removed from the analysis. However, it is also accepted to retain single participants if they deemed as representative of a distinct and valuable perspective (see 32). In this study, the third factor (F3) had only one significantly loading participant. This participant (and factor) represent a unique perspective and therefore was included in the study (38,51). The eigenvalues in all groups were greater than one, indicating that they explain more study variance than could be expected from a single Q sort (38,47,48,52) (See Table 2). Additionally, the components passed a visual scree test and none were significantly correlated, indicating they are distinct perspectives and not subgroups of larger perspectives (38) (See Appendix Table 2).

[Table 2 here]

We describe the four distinct factor groups (hereafter "perspectives") as the: (1) aquaculture optimists (F1, n = 24), (2) aquaculture anchors (F2, n = 6), (3) aquaculture historian (F3, n = 1), and (4) aquaculture agnostics (F4, n = 2), and detail results related to each group below.

3.1 Four perspectives on aquaculture development

3.1.1 Aquaculture optimists

The optimists believe that aquaculture development in Maine is a win-win for industry members and others who live and work on Maine's coast. "I don't believe [aquaculture] will have any impact on the character of Maine's communities," explained one study participant. "If

anything, I think it will preserve it." Optimists strongly disagree that aquaculture development requires a choice between economic growth and environmental protection (Statement 46, score *-5*; hereafter only the statement number and score values are listed for brevity). Those aligned with this perspective also believe strongly that access to aquaculture should be open to all who want to participate (Statement 3, *-5*). The optimists see aquaculture as creating jobs and as an important way to diversify the economy and maintain marine infrastructure, like shoreside piers or processing plants. This working waterfront infrastructure is a critical component of Maine's marine economy, but is shrinking rapidly due to development pressure to convert marine shorefronts into other uses (53,54). Aquaculture optimists believe aquaculture will benefit working waterfront (Statement 25, *+5*) and play a valuable role in Maine's economy by providing jobs that support coastal communities (Statement 23, *+5*; Statement 15, *+3*). As one study participant explained:

> [Aquaculture] is this huge opportunity for Maine to save our working waterfront and our entire fishery industry... We're so focused on the lobster here so if there's some other ways to create a sustainable fishery in Maine, aquaculture seems to be a phenomenal way to do it.

This group tends to disagree with statements suggesting that aquaculture causes environmental harm and that there is spatial or environmental conflict associated with aquaculture growth.

Aquaculture optimists have slightly different perspectives about aquaculture's compatibility with commercial fishing and the balance between aquaculture and other uses of Maine's coast. Members of this group also varied with respect to how much they valued community participation in the aquaculture leasing process. The secondary analysis of the

aquaculture optimists revealed two sub-perspectives: industry-focused optimists (IO) and community-focused optimists (CO). The aquaculture optimists as a whole were dominated by members of Maine's aquaculture industry and supporting groups, and both subgroups included aquaculture farmers, non-profit employees, commercial fishermen, scientists, and government employees. See Appendix Table 3 for details about the two groups.

The IO strongly agreed that aquaculture is compatible with commercial fishing while the CO were relatively neutral (Statement 17, Group score *+2*, IO score *+4*, CO score *0*). Likewise, the IO strongly disagreed that aquaculture will negatively impact Maine's commercial fishing industry, but the CO only slightly disagreed (Statement 16, Group score *-4*, IO score *-5*, CO score *-2*). The IO more strongly agreed that aquaculture is environmentally sustainable (Statement 19, Group score *+3*, IO score *+5*, CO score *+1*). The two groups had different perspectives about the scale of Maine's aquaculture industry. The CO more strongly agreed that small-scale aquaculture is appropriate in Maine (Statement 11, Group score *0*, IO score *0*, CO score *4*). The IO stressed that they supported all scales of aquaculture, including large-scale aquaculture, like the developments typical in Norway or China (55). The IO pointed out the relative nature of scale, since Maine's largest farms are still small compared to spatially extensive farms in other countries. The IO were also concerned that small farms might not make enough money to survive. The CO felt more strongly that community involvement is important in aquaculture site selection (Statement 37, Group score *+1*, CO score *-1*, IO score *+5*) and that it is important to find a balance between aquaculture and other uses of Maine's coastal waters (Statement 42, Group score *+2*, IO score *+1*, CO score *+5*). As one IO explained, they worry that expanded community involvement in aquaculture would make it difficult for the industry to expand although they value community engagement:

> I don't know how vitally important is that communities have a hand, I think it's important, but you could get too many cooks in the kitchen. You got to figure out how to mitigate that and everyone having a say versus just the state making some decision. You want to include the communities for sure. But how much of a hand you want every individual community having can, there's lots and lots of communities and lots and lots of different opinions within every single community. If you let them have too much of a hand, stuff might never get done. It's kind of hard to figure out, but you want to include them.

However, one of the CO participants suggested that greater community involvement would help reduce fears about rapid growth in the industry.

> If we achieve the right balance of how communities can help to guide aquaculture, then I think that helps to address some of the concerns that are reflected elsewhere in the statements and helps with the pace question, about how fast aquaculture is growing.

3.1.2 Aquaculture anchors

The anchors are enthusiastic about aquaculture and view it as a way to support Maine's coastal economy. However, they are concerned about the potential for negative environmental impacts (Statement 34, *-4*) and want to ensure that benefits from aquaculture are anchored in coastal communities. One participant stated: "I don't think they know enough about the environmental risks to take them seriously." The anchors value community engagement in planning and participation in the aquaculture leasing process more so than the Aquaculture Optimists. Members of this group feel that aquaculture will cause changes to coastal communities (Statement 33, *+5*) and they stressed the importance of balancing trade-offs and planning for the future of Maine's coast at multiple scales, including at the estuary scale

(Statement 42, + *5*; Statement 31, +*4*). They generally agree that the current pace of aquaculture development is too fast (Statement 41, +*3*): "I don't know if [aquaculture development] is too fast. I just know that it's pretty intense right now. I don't think we're thinking about the cumulative effects."

The anchors strongly disagree that the current regulatory process hampers this growth, while the other groups did not feel strongly about the influence of regulation on the growth of Maine's aquaculture industry (Statement 43, -*4*). Anchors are also concerned about potential conflicts between aquaculture and commercial fishing that could have negative implications for commercial fishing, such as displacement from active fishing areas (Statement 16, +*3*). One participant, who was a commercial fisherman, stated: "There's leases that I used to lobster fish in and I can't anymore because they're leases." They feel that aquaculture could benefit Maine's coastal economy and support smaller-scale operations. While concerned about the distribution of benefits and potential environmental costs of aquaculture, this group is not opposed to aquaculture development in Maine. Members of this group see the opposition to aquaculture as including more diverse members than coastal landowners alone (Statement 2, -*5*).

Anchors are unique because they are less likely to agree that aquaculture is an important part of the coastal economy than those who hold the other perspectives (Statement 23, -*1*) (Table 3), and they are concerned that people or companies from out of state will purchase existing farms (Statement 32, +*2*). They agree with the aquaculture agnostics (see below) that aquaculture causes significant changes to coastal waters (Statement 33, +*5*). They also agree with the aquaculture historians (see below) about the potential and realized issue of spatial conflicts between aquaculture and commercial fishing (Statement 16, +*3*) and that more proactive planning for aquaculture development is needed (Statement 31, +*4*).

3.1.3 Aquaculture historian

The historian sees the potential of further marine aquaculture development in Maine, but is cautious about the associated socioeconomic benefits that it affords coastal communities. This perspective is informed by the history of salmon aquaculture in eastern Maine, and the narrative that this development, which started in the 1990s, would bring prosperity to eastern Maine (29,56). The historian is consequently skeptical about aquaculture's benefits for Maine's commercial fishing sector and coastal communities (Statement 17, *-5*; Statement 8, *-4*). They prefer small-scale aquaculture (Statement 11, *+4*), support further consideration of the fit of aquaculture relative to other uses of Maine's ocean commons (Statement 31, *+4*), and are concerned about the transferability of farms (Statement 4, *+5*). The historian is more likely to disagree with statements that described aquaculture as providing economic benefits to Maine's coastal communities (Statement 40, *-1*; Statement 32, *-3*; Statement 25, *-2*). They agree that aquaculture lowers the value of waterfront homes (Statement 13, *+4*) and that the environmental risks are being taken seriously (Statement 34, *+2*), but they think aquaculture is not environmentally sustainable and that the risks are still too great for development to proceed in the current fashion (Statement 19, *-5*). Uniquely, the historian believes that only commercial fishermen should be allowed to participate in aquaculture (Statement 3, *+5*). The historian agrees that there is room for aquaculture growth within Maine's working waterfront but is concerned with the current leasing process and feels it needs to better serve existing uses of the coast, including commercial fishing (Statement 16, *+3*; Statement 24, *+3*). They described one lease applicant in their local area as being inconsiderate of other users:

> [The aquaculture lease applicant] didn't take into consideration all of the lobster fishermen that fish traps around these sites presently… to be able to come right in and

just take over. It wasn't the right way to go about it. Now, if they'd done it a different way, it would never have been an issue.

3.1.4 Aquaculture agnostics

The agnostics have mixed feelings about the impact of aquaculture on Maine's coast. They see aquaculture as benefiting aquaculture industry members but believe that further growth will involve economic and spatial tradeoffs between aquaculture farmers and other users of Maine's coast, like commercial fishermen (Statement 18, *-4*). Agnostics also believe that increased aquaculture development will reduce available space in Maine's coastal waters for commercial fishing (Statement 16, *+4*), displacing fisheries and other marine uses of Maine's coast while having limited benefits for coastal residents generally. One participant described a lease near them and worried about future growth:

> We've got lobster traps all around there and it's going to take space away. It's one of those situations that one little acre block isn't going to really hurt anybody. You can move traps around, but it's a kind of slippery slope that you have to watch. One year, then there's another one, then they expand that one and all of a sudden, a lot of the bottom is not used traditionally, and that's one of my issues with aquaculture is it gives the traditional land use to one person.

Another participant described crowding that they have experienced because of the growth of aquaculture in their local area: "This is a very popular river for recreational boating and, being a sailor myself, I do enjoy sailing these waters and it's restricting in some places, how much sailing is possible where these leases are so sizeable."

Aquaculture agnostics believe that aquaculture has potential to diversify Maine's coastal economy and provide employment opportunities (Statement 14, *+5*; Statement 15, *+3*; Statement 16, *+4*), and they strongly agree that aquaculture will change how coastal ocean spaces are used (Statement 33, *+5*). Agnostics think that aquaculture will help sustain working waterfronts (Statement 22, *+3*), but are less likely to agree that the economic opportunities are valuable (Statement 27, *+1*) or fit with Maine's existing working waterfront (Statement 24, *0*). Agnostics think aquaculture creates conflict (Statement 47, *-5*), and that concern about growth is reasonable (Statement 35, *-5*). They support further planning about how the industry fits with other uses of Maine's coastal waters (Statement 42, *+4*). They are unsure if marine aquaculture in Maine is environmentally sustainable and are concerned about its potential negative environmental impacts (Statement 19, *0*; Statement 34, *-2*).

3.2 Areas of consensus and disagreement

Individuals across the four groups all felt relatively neutral that regulatory uncertainty lowers investment in Maine's aquaculture industry (Statement 28). Many participants were unsure about the effects of current state-level regulations: some felt that the industry is aided by low levels of regulation; and others felt that lower investment and slower growth benefitted the industry by preventing long-term damage from conflict associated with overly rapid growth. Members of the four groups also agreed that aquaculture is polarized (Statement 12), provides opportunities to local residents (Statement 27), and that climate change will impact the industry long term (Statement 48). They disagreed whether or not aquaculture offers diversification opportunities to residents of coastal communities, and whether the industry has a negative impact or is complementary to Maine's commercial fishing industry (Statements 14, 16, 17). They also disagreed whether or not aquaculture causes far-reaching changes to coastal marine spaces

(statement 33). Consensus and disagreement statements are shown in Figure 2 and Table 3. All groups slightly disagreed that climate change will reduce aquaculture in Maine in the future and its impact on Maine's economy (Statement 48). While most participants expressed concern about climate change, including disease risk and ocean acidification, they felt that aquaculture would fare better than Maine's commercial fishing industry. Aquaculture farmers can grow different species and have already demonstrated their ability to adapt to changing conditions (57). Also, shellfish experience increased growth in warmer waters, expanding the amount of suitable space and improving yields. Aquaculture optimists in particular felt that climate change impacts highlight the importance of aquaculture in supporting Maine's coastal economy and providing economic diversity in the face of uncertainty for wild-caught fisheries. Two participants recognized the potential for aquaculture to support Maine's coastal communities:

> I think that there will be impacts of climate change that will hurt individual parts of aquaculture like ocean acidification hurting oyster or mussel production. I also think that the onset of climate change will mean that the importance and therefore the social capacity for aquaculture will grow.

> Assuming that climate change causes significant problems for wild fisheries, I think the impact of aquaculture on local economies in Maine will actually increase because if your main breadwinner goes out the door, you'd better have something on standby that can help take over. Otherwise, all the communities are just going to disappear and break apart and you won't have a working waterfront intact anymore.

Another participant commented that climate change may have benefits for species cultured in Maine, like oysters and mussels:

I think climate change is going to create disruption in wild stocks, it's going to create the opportunity for some species to grow more quickly in the waters off Maine. Sadly, to me, there are some benefits to climate change. There are far more disadvantages on a global scale, but for aquaculture, for oysters in particular, they're going to grow faster as waters get warmer.

[Figure 1 here]

[Table 3 here]

Discussion

Like other forms of ocean development, aquaculture creates a complex set of interactions among humans and coastal marine environments and involves tradeoffs. Understanding the perspectives that different people hold about aquaculture development can help to clarify these tradeoffs.

4.1 Diverse perspectives on aquaculture development

Using the Q method, this paper aims to understand the different values people associate with aquaculture development in Maine. We identified four distinct perspectives: (1) aquaculture optimists, (2) aquaculture anchors, (3) aquaculture historian, and (4) aquaculture agnostics (Figure 3). Importantly, all groups agreed that further aquaculture development is beneficial. But they did not agree about *who* would benefit, the magnitude of development, or what tradeoffs are associated with growth. In general, two groups – the aquaculture anchors and the aquaculture agnostics – focused on aquaculture's impact on coastal communities in the larger context of Maine's marine economy and other uses of the coastal marine environment. In contrast, the aquaculture optimists emphasized the economic benefits of aquaculture and were less worried

about environmental impacts; they believed that aquaculture growth would have widely distributed benefits and few costs for coastal residents, commercial fishermen, and other users of Maine's coastal waters. The aquaculture historian focused on the interactions between the aquaculture and commercial fishing sectors and was concerned about negative impacts of further aquaculture development on coastal communities and the environment. Beyond the differences across the four perspectives, we also found that there were two sub-perspectives within the aquaculture optimists group. We analyzed the aquaculture optimists using a second PCA and varimax rotation because the group was large and contained all participants who were identified as members of Maine's aquaculture industry. This analysis revealed two sub-perspectives within the optimists, the industry-focused optimists (IO) and the community-focused optimists (CO). Although these two groups were not significantly different from one another, they illuminate differences within the overarching optimist perspective.

There was only one consensus statement (Statement 28) and one defining statement (Statement 14). The groups all felt neutral about whether regulatory uncertainty lowers investment in the aquaculture industry (Figure 2). Many participants commented that they didn't know enough about the status of investment into Maine's aquaculture industry to respond, and others felt that investment was not relevant to the shellfish and seaweed aquaculture industries, which are primarily owner-operator and have low startup costs. The groups all had significantly different responses about whether aquaculture offers the state's fishing industry much needed economic and species diversification (Statement 14). Both the optimists and agnostics agreed with this statement and many optimists mentioned in the follow-up interview that they agreed strongly but prioritized other statements because the shape of the Q sort allowed fewer places for statements of strong agreement and disagreement. The historian felt neutral about that statement

and the anchors disagreed. Reasons for disagreement included the fact that most participants in Maine's aquaculture industry grow either salmon, mussels, or oysters, but rarely more than one. Also, the overall benefit of aquaculture to the fishing industry was questioned.

Excluding the statement that defined all groups (Statement 14), the optimists had the most defining statements (9, 16, 31, 39, 46). These statements involved the environmental sustainability of aquaculture (Statements 9, 39, 46) and the interactions between aquaculture and commercial fishing (Statement 16). The optimists were unique because they felt strongly that aquaculture is environmentally sustainable and did not think aquaculture would have negative impacts on the commercial fishing industry. They also were less likely to agree that planning for the future expansion of aquaculture is important (Statement 31). The anchors were defined by two other statements (23, 32), and the agnostics by one (Statement 29). The anchors slightly disagreed that aquaculture is an important and compatible part of Maine's coastal economy (Statement 23) and agreed that there is a risk that farms will be bought out by foreign companies (Statement 32). They are more concerned about the long-term trajectory of the industry than the other groups. The agnostics were distinguished by their disagreement that Maine's aquaculture production could help offset the U.S. seafood trade deficit. No group agreed with this statement but the agnostics felt that Maine's industry was too small to make a difference relative to the large amount of seafood trade in the U.S. The historian had no defining statement other than the one that defined all groups (Statement 14).

[Figure 2 here]

4.2 Reflections on the research design

The goal of this study was to bring attention to the diverse perspectives associated with aquaculture development in Maine in a structured way to explain as much individual variation as possible. One strength of Q method is that the analysis process is designed to identify these broader perspectives (36). However, Q method does not enable researchers to quantify the frequency of a given perspective in a specific population. Therefore, it is difficult to know how representative any of the four perspectives are in Maine without further research. To understand the relative proportion of each perspective, future research could include a structured survey and interviews with a representative set of informants. Alternatively, the Q study could be repeated in more geographically defined areas in the state. With a more geographically constrained Q study, one could draw conclusions about the connection among the identified perspectives and geography. We have reason to believe this may be important, since one participant loaded significantly in both the aquaculture anchors and aquaculture historian perspectives, and although they were removed from the analysis, that participant and the remaining historian lived in eastern Maine and were more familiar with salmon aquaculture than most other study participants (38,51). Further, we interviewed fewer people from eastern Maine (which hosts all salmon aquaculture in the state), and thus we may have under-sampled with respect to this perspective.

Another potential limitation of our study is that it was designed to examine all marine aquaculture in Maine, but the differences associated with different types of aquaculture complicated our results and need further examination. Salmon aquaculture is an example of intensive aquaculture, where fish are actively fed and also receive treatments to mitigate disease risks and other factors that impact yield (58). In contrast, extensive aquaculture, employed by most shellfish and seaweed farms in Maine, requires much less startup capital and labor-

intensive inputs like feed (26). Some study participants did not see a material difference between intensive and extensive aquaculture, while others explicitly stated that they felt differently about the two, especially with respect to their sustainability and environmental impacts. For example, in the follow-up interviews, the two eastern Maine participants commented that they focused on salmon aquaculture during the sorting exercise. They were the only participants to articulate a focus on salmon aquaculture. The remaining participants focused on shellfish and seaweed aquaculture (n = 15), grouped shellfish, seaweed, and salmon aquaculture together (n = 16), or did not specify their focus (n = 3). Six participants explicitly mentioned that they thought differently about salmon aquaculture versus shellfish and seaweed aquaculture, while one argued that distinguishing between shellfish, seaweed, and salmon aquaculture is misleading and an inaccurate way to describe the industry.

Although we did not detect a clear connection among the participants' perspectives and their geographic frame of reference or demographic traits, these themes demand further study. Not only are within-state differences in social-ecological context widely recognized in Maine (e.g., 54,55) but recent global scale analyses highlight the importance of recognizing and analyzing these differences for managing aquaculture in marine environments (e.g.,11,56). However, these differences are rarely mentioned in discussions about aquaculture in Maine.

The expansive nature of our Q set, extending over 25 years of newspaper articles, also provides the foundation for another complementary set of inquiry. Discourse analysis, informed by rhetoric and communications sciences, could be used to investigate if and how the discourse related to aquaculture in Maine has changed through time. That temporal analysis was beyond the scope of this study, but certainly one that could be productive to explore in the future, both in the context of aquaculture as well as other place-based natural resource management issues.

4.3 Lessons from Maine

As aquaculture continues to grow in Maine, decision makers and other stakeholders will need to consider the global nature of seafood trade. Seafood markets are highly integrated and changes in global markets, even outside of the seafood sector, could have unintended consequences in Maine (e.g., 57,58). The salmon aquaculture industry is globally integrated but the shellfish and seaweed industries are relatively local in terms of their distribution and supply chains, in comparison (26). However, social and economic shifts could still affect these industries by changing demand or perspectives about the industry. One statement (#29) mentioned the influence of global trade on Maine aquaculture; study participants were largely neutral about it. The participants that did comment about global trade indicated that they didn't know enough to respond or didn't feel it was relevant to the shellfish aquaculture industry. These results suggest that actors operating at the local or state geographic scale may be attuned to different socioeconomic dynamics than those focused on global scale analyses. In future studies, particularly those designed to inform place-based policy and management, it would be wise to attend to these distinctions.

Our results showed that people associated with Maine's aquaculture industry have different perspectives the industry's role and the best path in the future. They also had different perspectives about the sustainability of salmon, shellfish, and seaweed aquaculture. Narratives about Maine's aquaculture industry and its interaction with other uses frequently do not account for nuances about the type of aquaculture. Researchers using the Q method to study aquaculture should consider attitudes about intensive versus extensive aquaculture and potential regional differences when selecting study participants. Focusing on a single species or region could help avoid assumptions and different perspectives about the sustainability and role of aquaculture.

Maine manages aquaculture at the state level and this scale might fail to account for regional differences in perspectives, if they do exist. There are definite tradeoffs associated with local-scale natural resource management (as in Maine's softshell clam fishery, in which each coastal town manages those resources) (64). We are not arguing for local-scale management of aquaculture, but people are more likely to interact with aquaculture at a relatively small scale and local perspectives need to be considered when discussing the future of the industry, even if management takes place at a statewide scale.

The process of establishing aquaculture farms changes the use of ocean spaces: farmers lease marine space in order to develop their farms, while the ocean as a whole is often treated as a common pool resource with limited property rights (65–67). Balancing different types of property rights and uses of the ocean will be critical to ensure fairness and equity (66,68,69). Dialogue and policy development regarding aquaculture will be more effective and durable if placed in this broader context, e.g., recognizing benefits of ecosystem-based management and spatial planning (70,71).

Maine is also experiencing aquaculture growth in tandem with other marine resource use issues, like increases in development and tourism, changing abundance of lobsters, and developing industries like offshore wind. Aquaculture is only one aspect of Maine's marine economy, and while understanding perspectives about the industry can help improve discussions about its future, these other activities are also important. Changes in other parts of Maine's marine economy may influence perspectives about aquaculture, and future research will need to consider the overlap of different activities in crowded and changing marine spaces. Aquaculture is a common part of global discussions about blue growth, but all aspects will need to be considered to plan for future uses of marine spaces. However, learning about one aspect of blue

growth, like aquaculture, can help clarify places where further research is needed and shows the nuance that is present within a single state. As blue growth strategies grow in importance, understanding local applications will be critical to ensure they achieve desired outcomes.

4.4 Moving beyond growth

In this paper, we use the Q method to elucidate perspectives about aquaculture development and the motivations for growth. We identified four perspectives as well as areas of agreement and disagreement, thereby establishing a baseline understanding that can be used to inform further research and policy development. These perspectives can be used to help track progress related to economic, community development, and environmental sustainability goals. Further work is needed to understand the frequency of these perspectives and how they are linked with geography, demography, and other important social and environmental contextual factors in Maine and beyond. Likewise, perspectives about intensive and extensive aquaculture will need further clarification when discussing the future of Maine's aquaculture industry.

The four perspectives represent different visions about the role of aquaculture development and its value for Maine, and different interpretations of how coastal ocean spaces should be used. Study participants from all groups stressed that Maine's coastal waters are managed by the State for the public benefit. However, the question of *how* and *how much* ocean space should be used for aquaculture was contentious. Articulating perspectives about aquaculture growth in Maine is important for answering questions like these and encouraging clear and open discussions about the industry and its role within the complex social-ecological systems of the Maine coast.

Maine's coastal environment and the communities and economies that depend on it are valued for many reasons, including but not limited to farmed seafood production. As the marine aquaculture industry grows in Maine and in other coastal areas throughout the world, conflict regarding aquaculture and other coastal marine activities will likely continue. Answers to important questions like "*How much aquaculture is too much?*" or "*Where should farms be located?*" depend not only on technical assessments informed by the ecological and other biophysical sciences, but also on the values that people hold in particular places and the narratives and visions that they articulate at the individual and community scale. The aquaculture anchors, historian, and agnostics are not entirely satisfied with Maine's current aquaculture regulatory process and would likely support changes that prioritize balance among uses and alter the site selection process. The aquaculture optimists also support balancing uses of Maine's coastal waters, but do not feel that regulatory changes are required to achieve these goals. Clarifying the diverse perspectives that shape answers to questions like these, such as through the scholarship presented here, will help encourage further dialogue and also may facilitate development of policy that mitigates conflict among divergent perspectives and the individuals who hold them. These findings also could serve as the basis for monitoring the long-term success of aquaculture development in Maine.

Discussions about aquaculture development in Maine will continue, and as other forms of blue growth develop in the state, those discussions will grow as well. Policy goals may ultimately be more effectively achieved through the use of more integrated, ecosystem-based regulations than currently exist in Maine. However, such discussions take time and are contingent on social and political path dependencies (72–77). Many demands are being placed on Maine's coastal waters, both for blue growth development as well as for recreation, residential,

and tourism uses. Aquaculture and other elements of blue growth could provide many benefits to Maine's marine economy and its marine resource-dependent coastal communities. Addressing the potential conflicts between existing and new development and finding ways to support development while including and considering the varied perspectives of people in coastal communities is a critical part of ensuring that these industries succeed and bring benefits to Maine and other areas that are experiencing ocean development.

While this research focuses on aquaculture development in Maine, the aquaculture sector is growing worldwide, raising important questions about the motivations of growth and who it will benefit. As growth continues, research focused on these different motivations will be needed because there will ultimately be tradeoffs that may affect the scale, geography, species, and governance structure of aquaculture in particular places. By understanding the heterogeneity of perspectives surrounding aquaculture development, we aim to contribute to ongoing discussions about the future of aquaculture and encourage a more explicit articulation of the intended outcomes of aquaculture development and who it will benefit.

References

1. An aquaculture development strategy for the State of Maine. Maine State Planning Office, Maine Department of Marine Resources; 1990.

2. Stoll JS, Leslie HM, Britsch ML, Cleaver CM. Evaluating aquaculture as a diversification strategy for Maine's commercial fishing sector in the face of change. Mar Policy. 2019 Sep;107:103583.

3. Voyer M, Quirk G, McIlgorm A, Azmi K. Shades of blue: what do competing interpretations of the Blue Economy mean for oceans governance? J Environ Policy Plan. 2018 Sep 3;20(5):595–616.

4. WWF. Principles for a sustainable blue economy [Internet]. WWF Baltic Ecoregion Programme; 2018 [cited 2020 Jul 31]. Available from: https://wwf.panda.org/?247477/Principles-for-a-Sustainable-Blue-Economy

5. FAO. Achieving blue growth: Building vibrant fisheries and aquaculture communities. Food and Agriculture Orginzation of the United Nations; 2018.

6. Bennett NJ, Blythe J, White CS, Campero C. Blue growth and blue justice: Ten risks and solutions for the ocean economy. Mar Policy. 2021 Mar;125:104387.

7. FAO. The State of World Fisheries and Aquaculture 2020. Sustainability in action. [Internet]. Rome: FAO; 2020 [cited 2021 Feb 16]. Available from: http://www.fao.org/documents/card/en/c/ca9229en

8. Costello C, Cao L, Gelcich S, Cisneros-Mata MÁ, Free CM, Froehlich HE, et al. The future of food from the sea. Nature. 2020 Dec 3;588(7836):95–100.

9. Garlock T, Asche F, Anderson J, Bjørndal T, Kumar G, Lorenzen K, et al. A Global Blue Revolution: Aquaculture Growth Across Regions, Species, and Countries. Rev Fish Sci Aquac. 2020 Jan 2;28(1):107–16.

10. Gentry RR, Froehlich HE, Grimm D, Kareiva P, Parke M, Rust M, et al. Mapping the global potential for marine aquaculture. Nat Ecol Evol. 2017 Aug 14;1(9):1317.

11. Silver JJ, Gray NJ, Campbell LM, Fairbanks LW, Gruby RL. Blue Economy and Competing Discourses in International Oceans Governance. J Environ Dev. 2015 Jun;24(2):135–60.

12. Smith MD, Roheim CA, Crowder LB, Halpern BS, Turnipseed M, Anderson JL, et al. Sustainability and Global Seafood. Science. 2010 Feb 12;327(5967):784–6.

13. Gephart JA, Golden CD, Asche F, Belton B, Brugere C, Froehlich HE, et al. Scenarios for Global Aquaculture and Its Role in Human Nutrition. Rev Fish Sci Aquac. 2021 Jan 2;29(1):122–38.

14. Troell M, Naylor RL, Metian M, Beveridge M, Tyedmers PH, Folke C, et al. Does aquaculture add resilience to the global food system? Proc Natl Acad Sci. 2014 Sep 16;111(37):13257–63.

15. Marshall J. Landlords, leaseholders & sweat equity: changing property regimes in aquaculture. Mar Policy. 2001 Sep 1;25(5):335–52.

16. Bavinck M, Berkes F, Charles A, Dias ACE, Doubleday N, Nayak P, et al. The impact of coastal grabbing on community conservation – a global reconnaissance. Marit Stud. 2017 Dec;16(1):8.

17. Naylor RL, Goldburg RJ, Mooney H, Beveridge M, Clay J, Folke C, et al. Nature's Subsidies to Shrimp and Salmon Farming. Science. 1998 Oct 30;282(5390):883–4.

18. Froehlich HE, Gentry RR, Halpern BS. Conservation aquaculture: Shifting the narrative and paradigm of aquaculture's role in resource management. Biol Conserv. 2017 Nov 1;215(Supplement C):162–8.

19. Le Gouvello R, Hochart L-E, Laffoley D, Simard F, Andrade C, Angel D, et al. Aquaculture and marine protected areas: Potential opportunities and synergies. Aquat Conserv Mar Freshw Ecosyst. 2017 Sep;27:138–50.

20. Gentry R, Alleway H, Bishop M, Gillies C, Waters T, Jones R. Exploring the potential for marine aquaculture to contribute to ecosystem services. Rev Aquac. 2019 Feb 1;

21. Campbell LM, Fairbanks L, Murray G, Stoll JS, D'Anna L, Bingham J. From Blue Economy to Blue Communities: reorienting aquaculture expansion for community wellbeing. Mar Policy. 2021 Feb;124:104361.

22. Groesbeck AS, Rowell K, Lepofsky D, Salomon AK. Ancient Clam Gardens Increased Shellfish Production: Adaptive Strategies from the Past Can Inform Food Security Today. Thrush S, editor. PLoS ONE. 2014 Mar 11;9(3):e91235.

23. Benjaminsen TA, Bryceson I. Conservation, green/blue grabbing and accumulation by dispossession in Tanzania. J Peasant Stud. 2012 Apr;39(2):335–55.

24. Krause G, Brugere C, Diedrich A, Ebeling MW, Ferse SCA, Mikkelsen E, et al. A revolution without people? Closing the people–policy gap in aquaculture development. Aquaculture. 2015 Oct 1;447:44–55.

25. Maine Department of Marine Resources. Aquaculture Harvest Data [Internet]. 2020 [cited 2020 Feb 19]. Available from: https://www.maine.gov/dmr/aquaculture/harvestdata/index.html

26. Cole A, Langston A, Davis C. Maine Aquaculture Economic Impact Report. Aquaculture Research Institute; 2016.

27. MDMR. Maine Department of Marine Resources Open Data [Internet]. 2020 [cited 2020 Aug 4]. Available from: https://dmr-maine.opendata.arcgis.com/

28. Aquaculture Lease Regulations [Internet]. Department of Marine Resources - Procedural Rules; 2020. Available from: https://www.maine.gov/dmr/laws-regulations/regulations/documents/Chapter2_08292020.pdf

29. Kelso D. Aquarian transitions: Technological change, environmental uncertainty, and salmon production on North America's Pacific Coast [Doctoral Dissertation]. University of California, Berkeley; 2000.

30. Maine Department of Marine Resources. Preliminary 2019 Commercial Maine Landings by Ex-vessel Value [Internet]. 2020. Available from: https://www.maine.gov/dmr/commercial-fishing/landings/documents/ValueBySpecies.Pie.Graph.pdf

31. The Hale Group, LTD. Maine Farmed Shellfish Market Analysis. 2016.

32. Carr LM. Seeking stakeholder consensus within Ireland's conflicted salmon aquaculture space. Mar Policy. 2019 Jan 1;99:201–12.

33. Lewison RL, Johnson AF, Verutes GM. Embracing Complexity and Complexity-Awareness in Marine Megafauna Conservation and Research. Front Mar Sci [Internet]. 2018 Jun 26 [cited 2019 Mar 7]; Available from: http%3A%2F%2Flink.galegroup.com%2Fapps%2Fdoc%2FA544453160%2FAONE%3Fu%3Dmaine_orono%26sid%3DAONE%26xid%3Dadfdbe29

34. Rudell PN. Human Perceptions and Attitudes Regarding Geoduck Aquaculture in Puget Sound, Washington: A Q Methodology Approach. University of Washington; 2012.

35. Stephenson W. The Study of Behavior: Q-technique and its Methodology. Chicago, IL, US: University of Chicago Press; 1953.

36. Swedeen P. Post-normal science in practice: A Q study of the potential for sustainable forestry in Washington State, USA. Ecol Econ. 2006 May 1;57(2):190–208.

37. Murray G. Measuring what we value: The utility of mixed methods approaches for incorporating values into marine social-ecological system management. Mar Policy. 2016;73:61–8.

38. Watts S, Stenner P. Doing Q Methodological Research: Theory, Method and Interpretation. SAGE Publications; 2012. 238 p.

39. Zabala A, Sandbrook C, Mukherjee N. When and how to use Q methodology to understand perspectives in conservation research. Conserv Biol. 2018;32(5):1185–94.

40. Davies BB, Hodge ID. Shifting environmental perspectives in agriculture: Repeated Q analysis and the stability of preference structures. Ecol Econ. 2012 Nov;83:51–7.

41. Bernard HR. Research methods in anthropology: Qualitative and quantitative approaches. 6th ed. Rowman & Littlefield; 2018.

42. Zabala A. qmethod: A package to explore human perspectives using Q methodology. R J. 2014;6(2):163–73.

43. RStudio Team. RStudio: Integrated Development for R [Internet]. RStudio, Inc.; 2016. Available from: http://www.rstudio.com/

44. Zabala A, Pascual U. Bootstrapping Q Methodology to Improve the Understanding of Human Perspectives. Xia Y, editor. PLOS ONE. 2016 Feb 4;11(2):e0148087.

45. Watts S, Stenner P. Doing Q methodology: theory, method and interpretation. Qual Res Psychol. 2005;2:67–91.

46. Carr LM, Heyman WD. "It's About Seeing What's Actually Out There": Quantifying fishers' ecological knowledge and biases in a small-scale commercial fishery as a path toward co-management. Ocean Coast Manag. 2012 Dec;69:118–32.

47. Kaiser HF. The application of electronic computer to factor analysis. Educ Psychol Meas. 1960;20(1):141–51.

48. Guttman L. Some necessary conditions for common-factor analysis. Psychometrika. 1954;19:149–61.

49. Giannoulis C, Botetzagias I, Skanavis C. Newspaper Reporters' Priorities and Beliefs About Environmental Journalism: An Application of Q-Methodology. Sci Commun. 2010 Dec;32(4):425–66.

50. MacDonald PA, Murray G, Patterson M. Considering social values in the seafood sector using the Q-method. Mar Policy. 2015 Feb;52:68–76.

51. Duffy KP, Rickard LN, Grosswiler P. Routine Influences on Aquaculture News Selection: A Q Method Study With New England Journalists. Sci Commun. 2019 Oct;41(5):602–32.

52. Kaiser HF. A second generation Little Jiffy. Psychometrika. 1970;35(4):401–17.

53. Conover S, Rowan H, Snyder RB, Platt D, Leavitt B, Ralston P. The Last 20 Miles - Mapping Maine's Working Waterfront. Island Institute; 2007.

54. Coombs M. The state of Maine's working waterfront. Maine Coast Fishermen's Association; 2020.

55. Naylor RL, Hardy RW, Buschmann AH, Bush SR, Cao L, Klinger DH, et al. A 20-year retrospective review of global aquaculture. Nature. 2021 Mar 25;591(7851):551–63.

56. Governor's Task Force. Governor's Task Force on the Planning and Development of Marine Aquaculture in Maine - Executive Summary of Final Report. Mar Resour Doc [Internet]. 2004 Jan 30; Available from: https://digitalmaine.com/dmr_docs/8

57. Arnold S. For Mook Sea Farm, "Problems are the raw material for innovation" [Internet]. 2020 [cited 2021 Mar 22]. Available from: https://www.islandinstitute.org/2020/06/09/for-mook-sea-farm-problems-are-the-raw-material-for-innovation/

58. FAO, editor. The state of world fisheries and aquaculture: Meeting the sustainable development goals [Internet]. Rome; 2018. 210 p. (The state of world fisheries and aquaculture). Available from: http://www.fao.org/3/I9540EN/i9540en.pdf

59. Deese H. Waypoints: Community indicators for Maine's coast and islands [Internet]. Island Institute, Rockland, ME; 2017. Available from: https://www.islandinstitute.org/stories/waypoints/waypoints-community-indicators/

60. Cucuzza M, Stoll JS, Leslie HM. Comprehensive plans as tools for enhancing coastal community resilience. J Environ Plan Manag. 2020 Sep 18;63(11):2022–41.

61. Froehlich HE, Gentry RR, Rust MB, Grimm D, Halpern BS. Public Perceptions of Aquaculture: Evaluating Spatiotemporal Patterns of Sentiment around the World. PLOS ONE. 2017 Jan 3;12(1):e0169281.

62. Stoll JS, Harrison HL, De Sousa E, Callaway D, Collier M, Harrell K, et al. Alternative seafood networks during COVID-19: Implications for resilience and sustainability [Internet]. EcoEvoRxiv; 2021 [cited 2021 Mar 22]. Available from: https://osf.io/kuzwq

63. Love DC, Allison EH, Asche F, Belton B, Cottrell RS, Froehlich HE, et al. Emerging COVID-19 impacts, responses, and lessons for building resilience in the seafood system. Glob Food Secur. 2021 Mar;28:100494.

64. Maine/New Hampshire Sea Grant College Program. The Maine clam handbook. Maine/New Hampshire Sea Grant College Program; 1998. 85 p.

65. Christy FT Jr. Property Rights in the World Ocean. Nat Resour J. 1975;15(4):695–712.

66. Crowder LB, Osherenko G, Young OR, Airame S, Norse EA, Baron N, et al. Resolving Mismatches in U.S. Ocean Governance. Science. 2006 Aug 4;313(5787):617–8.

67. Ostrom E, Burger J, Field CB, Norgaard RB, Policansky D. Revisiting the commons: Local lessons, global challenges. Science. 1999 Apr 9;284:278–82.

68. Bennett NJ. Navigating a just and inclusive path towards sustainable oceans. Mar Policy. 2018 Nov;97:139–46.

69. Bennett NJ, Cisneros-Montemayor AM, Blythe J, Silver JJ, Singh G, Andrews N, et al. Towards a sustainable and equitable blue economy. Nat Sustain. 2019 Nov;2(11):991–3.

70. Foley MM, Armsby MH, Prahler EE, Caldwell MR, Erickson AL, Kittinger JN, et al. Improving Ocean Management through the Use of Ecological Principles and Integrated Ecosystem Assessments. BioScience. 2013 Aug;63(8):619–31.

71. McLeod K, Leslie HM. Ecosystem-Based Management for the Oceans. Island Press; 2009. 393 p.

72. Stoll JS, Beitl CM, Wilson JA. How access to Maine's fisheries has changed over a quarter century: The cumulative effects of licensing on resilience. Glob Environ Change. 2016 Mar 1;37:79–91.

73. Kelly C, Ellis G, Flannery W. Conceptualising change in marine governance: Learning from Transition Management. Mar Policy. 2018 Sep;95:24–35.

74. McCay BJ. Emergence of institutions for the commons: Contexts, situations, and events. In: The drama of the commons. National Academy Press; 2002. p. 361–402.

75. Pew Oceans Commission. America's living oceans: Charting a course for sea change. Summary Report [Internet]. Pew Oceans Commission, Arlington, Virginia; 2003. Available from: https://www.pewtrusts.org/-/media/assets/2003/06/02/poc_summary.pdf

76. U.S. Commission on Ocean Policy. An ocean blueprint for the 21st century: Final report [Internet]. U.S. Commission on Ocean Policy, Washington, DC; 2004. Available from: https://govinfo.library.unt.edu/oceancommission/documents/full_color_rpt/000_ocean_full_report.pdf

77. NOAA. NOAA Fisheries Ecosystem-Based Fisheries Management Road Map [Internet]. National Oceanic and Atmospheric Administration; 2016. Available from: https://www.fisheries.noaa.gov/resource/document/ecosystem-based-fisheries-management-road-map

Appendix 1

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Figure 1

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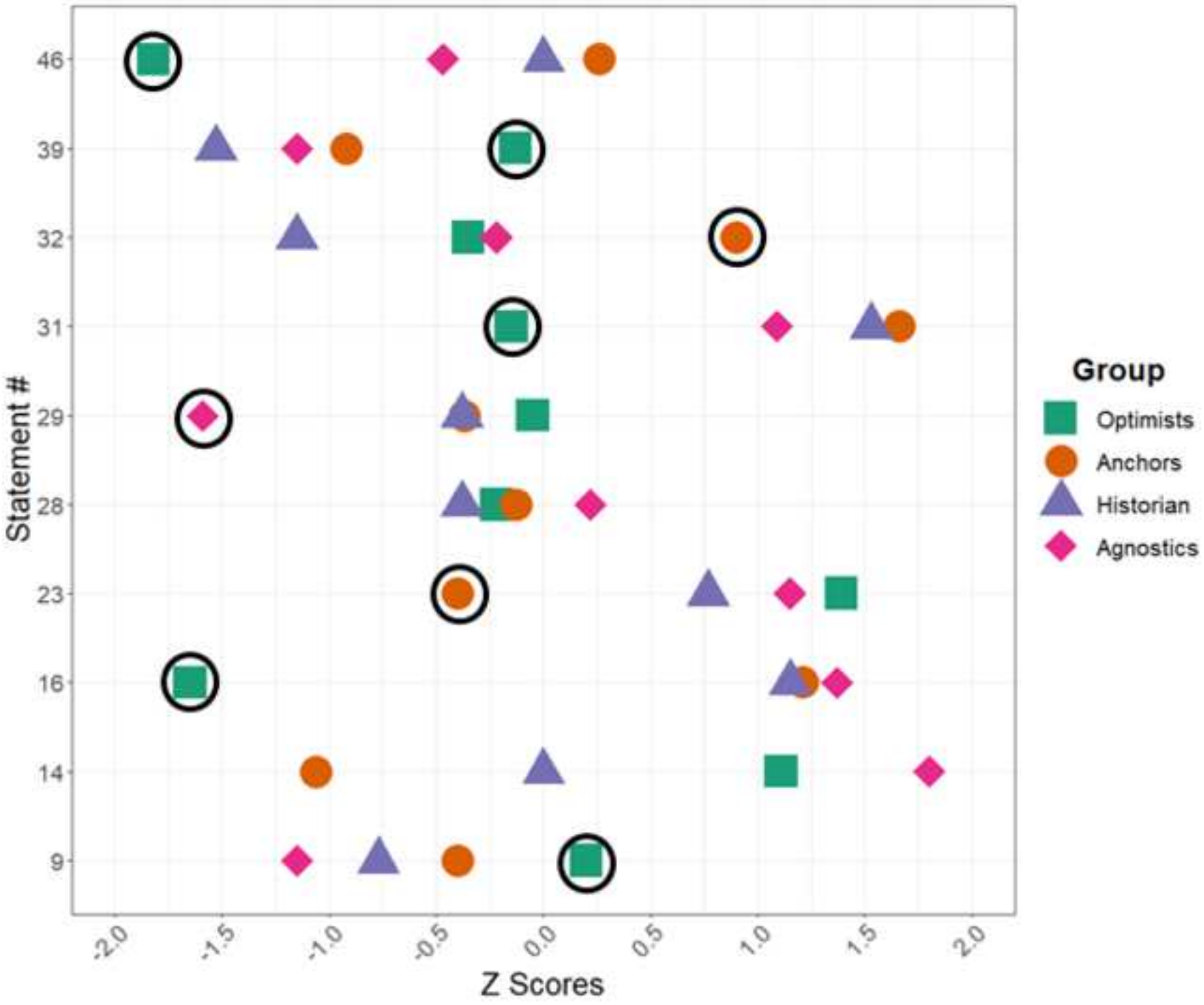
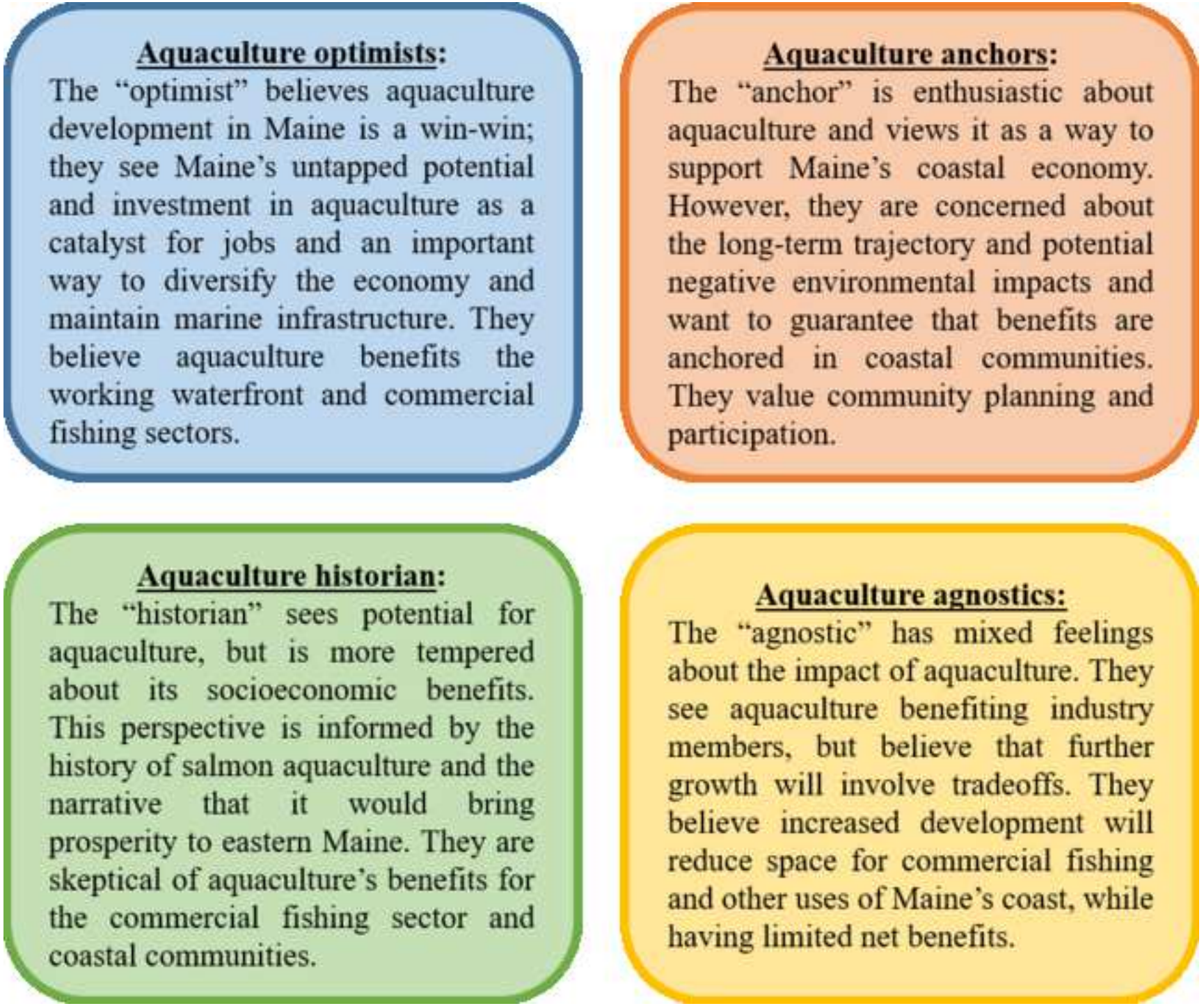


Figure 2



Appendix Figure 1

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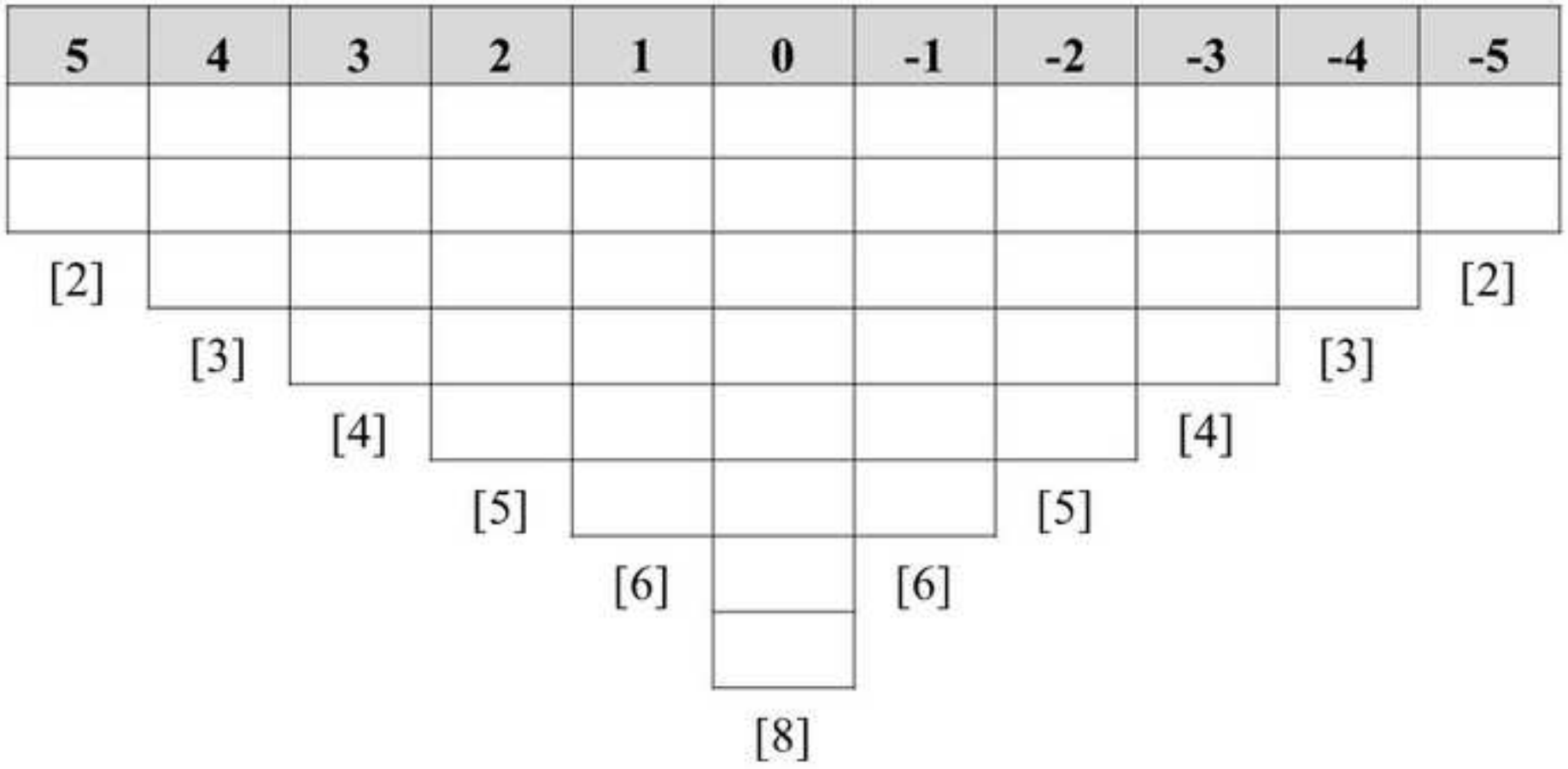

Figure 1: Distinguishing and consensus statements for the four factors based on their statement Z scores. In cases where one group's response is significantly different, or distinguishing, the group is circled. Statement 14 distinguished all groups and statement 28 was a consensus statement. Distinguishing and consensus statements are also marked in Table 3.

Figure 2: Summary of four perspectives about aquaculture in Maine

Appendix Figure 1: Matrix for the Q method sorting exercise. The numbers in the shaded bar at the top indicate the ranking score, from most strongly agree (5) to most strongly disagree (-5). The bracketed numbers below each column indicate how many Q set cards may be placed in that column.

Stage	Description	Implementation
1	Concourse	We downloaded 979 newspaper articles and coded a random subset, of the articles (n = 124) until saturation was achieved. The concourse included 878 statements.
2	Q set	We categorized statements thematically and distilled them using an iterative process to create broadly representative list of statements (n = 48) about aquaculture in Maine.
3	Participant selection	We used purposive and snowball sampling to identify a diverse range of individuals with knowledge about aquaculture in Maine (n = 36).
4	Q sort and debrief	Study participants sorted the Q set and then participated in follow-up interviews about the sorting process.
5	Analysis	We used Principal Component Analysis of the Q sorts to identify groups and a thematic analysis of the interviews to interpret the results.

Table 1: Summary of the five steps of the Q method.

	F1	**F2**	**F3**	**F4**
Number of Q sorts	24	6	1	2
Eigenvalues	15.13	5.83	2.41	2.24
Percentage of explained variance	42.02	16.19	6.70	6.21
Average age of participants (years)	50	61	Removed to preserve confidentiality	63
Occupations	Non-profit employees, fishermen, aquaculture farmers, harbormasters, scientists, government resource managers, waterfront residents	Non-profit employees, government resource managers, fishermen, waterfront residents, waterfront business owners (excluding aquaculture)		Fishermen, government resource managers, waterfront business owners (excluding aquaculture), waterfront residents

Table 2: Summary of study participants.

Table 3

#	Statements	Factor Scores				Z Scores			
		F1	F2	F3	F4	F1	F2	F3	F4
1	Tax-incentive programs intended to bring aquaculture development to Maine will minimize the benefits to local communities	-2	1	2	-3	-0.93	0.22	0.77	-1.13
2	Waterfront landowners are the only people opposed to aquaculture	-3	-5	-2	-3	-1.24	-1.82	-0.77	-1.19
3	The ability to participate in aquaculture should be reserved for commercial fishermen	-5	-3	5	-4	-1.92	-1.14	1.92	-1.8
4	The large maximum size and transferability of aquaculture leases makes them attractive to sell	-1	2	5	0	-0.5	0.83	1.92	0.02
5	The noise from aquaculture operations makes them undesirable to be around	-3	1	-3	1	-1.04	0.69	-1.15	0.22
6	Once established, local aquaculture farms gain acceptance with time	1	-1	1	-2	0.58	-0.52	0.38	-0.51
7	Maine's proximity to major US consumer markets benefits the aquaculture industry	1	0	1	-2	0.53	-0.03	0.38	-0.67
8	Maine is an excellent place for aquaculture because it has clean, cold waters and a wide open coastline	2	2	-4	-1	0.93	0.83	-1.53	-0.24
9	*Producing food using aquaculture contributes to a lower carbon profile than other food production methods (D1)*	*0**	*-1*	*-2*	*-3*	*0.2*	*-0.4*	*-0.77*	*-1.15*
10	Aquaculture is a sustainable way for Mainers to make a living	2	-2	-1	2	1.03	-0.66	-0.38	0.95
11	Small-scale aquaculture is appropriate for Maine	0	3	4	-1	0.46	1.16	1.53	-0.42
12	Aquaculture is a polarized topic in Maine	0	2	0	2	-0.03	1.03	0	0.95
13	The presence of aquaculture lowers the value of waterfront homes	-3	-1	4	3	-1.32	-0.3	1.53	1.15
14	***Aquaculture offers the state's fishing industry much needed economic and species diversification (Distinguishes all)***	***3****	***-3****	***0****	***5****	***1.11***	***-1.06***	***0***	***1.8***
15	Aquaculture provides an opportunity for people to work in Maine's marine economy	3	0	1	3	1.18	-0.06	0.38	1.19
16	*Increasing the amount of aquaculture in Maine will negatively impact the ability of commercial fishermen to fish by pushing them out of traditional fishing grounds (D1)*	*-4****	*3*	*3*	*4*	*-1.65*	*1.21*	*1.15*	*1.37*
17	Aquaculture is complementary to commercial fishing, not a threat	2	-3	-5	0	1	-1.04	-1.92	-0.02
18	Aquaculture has a presence in Maine, but the question of who it will benefit remains unanswered	-1	2	0	-4	-0.58	0.9	0	-1.35
19	Aquaculture is environmentally sustainable	3	-2	-5	0	1.04	-0.66	-1.92	-0.2
20	Aquaculture is a solution to overfishing because it helps augment wild capture fisheries	0	-2	-2	-2	-0.16	-0.67	-0.77	-0.51
21	Aquaculture allows for a consistent supply of local, high-quality seafood	1	0	1	4	0.68	-0.3	0.38	1.35
22	We need new fisheries and creative methods of fishing to sustain the industry and the infrastructure, and aquaculture is one way to do this	4	0	2	3	1.31	-0.14	0.77	1.13
23	*Aquaculture is an important and compatible element in Maine's diverse coastal economy (D2)*	*5*	*-1**	*2*	*3*	*1.39*	*-0.4*	*0.77*	*1.15*
24	There is room for growth in aquaculture at a scope and scale that fits with Maine's working waterfront	4	1	3	0	1.35	0.27	1.15	0.02
25	Aquaculture helps preserve Maine's working waterfronts	5	-2	-2	2	1.69	-0.62	-0.77	0.69
26	Aquaculture is one of the most promising sectors in Maine's economy	1	-2	0	-2	0.66	-0.79	0	-0.66
27	Aquaculture provides valuable economic opportunities for local residents	3	1	1	1	1.14	0.04	0.38	0.24
28	***Regulatory uncertainty lowers investment in the aquaculture industry.*** [C]	***-1***	***0***	***-1***	***1***	***-0.22***	***-0.13***	***-0.38***	***0.22***
29	*Increasing aquaculture production in Maine will help lower the US seafood trade deficit (D4)*	*0*	*-1*	*-1*	*-4**	*-0.05*	*-0.37*	*-0.38*	*-1.59*

30	Aquaculture is an efficient and sustainable way to feed a growing human population	1	0	-3	1	0.49	-0.23	-1.15	0.67
31	*We need to further consider how much of a particular body of water is to be taken from the public and given to an individual or corporation for commercial use in the future (D1)*	*0***	*4*	*4*	*2*	*-0.15*	*1.66*	*1.53*	*1.09*
32	*Aquaculture is a way to provide economic support to Maine's coastal communities, but there is a risk that farms will be bought out by foreign companies (D2)*	*-1*	*2***	*-3*	*-1*	*-0.35*	*0.9*	*-1.15*	*-0.22*
33	Aquaculture causes far-reaching changes to common access waters	-4	5	-4	5	-1.43	1.86	-1.53	1.84
34	The potential environmental risks posed by aquaculture are being taken seriously	0	-4	2	-2	0.19	-1.51	0.77	-0.69
35	Concerns about the excessive expansion of aquaculture in the future are generally unfounded	-1	-4	-1	-5	-0.41	-1.67	-0.38	-2.04
36	Aquaculture has the potential to drastically alter the character of Maine's coastal communities	-2	4	3	2	-0.98	1.54	1.15	0.73
37	It is vitally important that communities have a hand in guiding the future of aquaculture	1	4	3	0	0.49	1.62	1.15	0.04
38	The Department of Marine Resources' siting criteria do not account enough for adjacent farms and the cumulative impact of aquaculture	-2	3	0	-2	-0.74	1.07	0	-1.11
39	*The early days of aquaculture were marked by trial and error, and little regard for the local environment and community impacts. That and other objectionable practices have changed (D1)*	*0***	*-3*	*-4*	*-3*	*-0.13*	*-0.92*	*-1.53*	*-1.15*
40	Aquaculture is good for Maine's economy, not only for farmers but for local restaurants and tourism businesses too	4	0	-1	1	1.23	0.02	-0.38	0.66
41	The rate of growth of the aquaculture industry is too fast	-3	3	2	-1	-1.27	1.52	0.77	-0.22
42	It has become more important than ever to find a balance between existing and new uses of our ocean while also protecting everything it has to offer for future generations	2	5	0	4	0.98	1.68	0	1.35
43	Maine's aquaculture regulatory process is hampering the growth of the industry	-1	-4	0	1	-0.68	-1.4	0	0.22
44	Maine's coastal communities need to decide whether to gear up for the economic growth of aquaculture or to retain the qualities of wild-caught fisheries	-4	1	-3	0	-1.55	0.28	-1.15	-0.02
45	Much of the concern about aquaculture stems from misunderstandings about the application and companies, as well as a lack of knowledge about aquaculture in general	2	-1	1	1	0.96	-0.57	0.38	0.4
46	*Aquaculture production requires a choice between economic growth and environmental protection (D1)*	*-5****	*1*	*0*	*-1*	*-1.82*	*0.26*	*0*	*-0.47*
47	There are very few conflicts between aquaculture farms and other water users	-2	-5	-1	-5	-0.72	-1.86	-0.38	-1.84
48	The effects of climate change will reduce the long-term impact of Maine's aquaculture industry on the economy	-2	0	-2	-1	-0.78	-0.3	-0.77	-0.24

Table 3: Factor scores and Z scores for each statement. Participants agreed most strongly with statements scored 5, and most strongly disagreed with statements scored -5. The Z scores are the standardized weighted average of the scores that group members gave to a statement, and the factor scores translate the Z scores into the format used in the original Q sort. Distinguishing statements are indicated by italics and in parentheses. The consensus statement (28) and the statement that distinguished all factors (14) are bolded.

Asterisks indicate the strength of significance. * = 0.5, ** = 0.01, *** <0.01. F1: Aquaculture Optimists, F2: Aquaculture Anchors, F3: Aquaculture Historian, F4: Aquaculture Agnostics.

Participant #	F1	F2	F3	F4
AQ02	***0.81**	0.3	-0.02	0.17
AQ07	0.39	0.4	0.48	0.32
AQ09	***0.68**	0.38	0.16	0.25
AQ11	-0.02	***0.74**	0.46	-0.02
AQ14	-0.06	***0.86**	0	0
AQ16	***0.86**	-0.16	0.23	0.19
AQ17	***0.78**	0.09	0.07	-0.29
AQ18	***0.8**	-0.01	-0.09	0.27
AQ20	***0.75**	-0.14	-0.14	-0.07
AQ22	***0.85**	0.17	0.09	0.01
AQ23	***0.72**	-0.4	-0.31	0.23
AQ28	***0.64**	0.52	0.15	-0.07
AQ34	0.19	***0.75**	0.02	0.13
AQ35	***0.82**	-0.19	0.16	0.04
AQ37	-0.33	*0.56*	*0.55*	-0.01
AQ38	***0.77**	0.15	-0.35	0.09
AQ41	0.17	0.13	-0.12	***0.68**
AQ43	***0.71**	-0.3	-0.41	-0.03
AQ44	0.54	0.47	0.41	0.26
AQ45	***0.78**	0.06	-0.12	0.35
AQ58	***0.75**	-0.38	-0.11	0.2
AQ59	-0.42	***0.64**	0.07	0.33
AQ60	-0.17	***0.77**	0.28	0.31
AQ63	0.21	0.41	0.28	***0.7**
AQ64	***0.7**	0.23	0.2	-0.15
AQ67	***0.71**	-0.32	-0.17	0.32
AQ70	-0.2	***0.78**	-0.02	0
AQ72	***0.71**	-0.17	-0.12	0.02
AQ73	***0.84**	-0.13	-0.02	0.28
AQ74	***0.85**	-0.27	-0.06	-0.05
AQ80	***0.74**	-0.04	0.08	0.25
AQ83	-0.07	0.13	***0.79**	-0.05
AQ94	***0.83**	-0.08	0.1	-0.04
AQ95	***0.78**	-0.17	-0.12	0.21
AQ97	***0.83**	-0.06	-0.12	0.06
AQ99	***0.7**	0.31	-0.04	0.22

Table 1: Factor loadings of all participants. Significant loading ($p < 0.01$) is indicated by * and the column is bolded. The confounded participant is shown in italics.

	F1	F2	F3	F4
F1	1	-0.15	-0.1	0.31
F2		1	0.24	0.38
F3			1	0.11
F4				1

Table 2: Correlation between factor z-scores. Significant correlations are >0.38 at the $p < 0.01$ level.

	Component 1a (IO)	Component 1b (CO)
Number of Q sorts	17	7
Eigenvalues	9.58	6.89
Percentage of explained variance	39.91	28.69
Average age of participants (years)	48.41	53.43
Occupations	Non-profit employees, fishermen, aquaculture farmers, harbormasters, scientists, government resource managers, waterfront residents, waterfront business owners.	Non-profit employees, fishermen, aquaculture farmers, harbormasters, scientists, government resource managers, waterfront residents, waterfront business owners.

Table 3: Summary of secondary analysis of Factor 1

Melissa L. Britsch: Conceptualization, Formal analysis, Investigation, Writing – Original Draft. **Heather M. Leslie:** Writing – Review & Editing, Funding Acquisition. **Joshua S. Stoll:** Formal analysis, Writing – Review & Editing, Funding acquisition.