SHELLFISH AQUACULTURE MANAGEMENT PRIORITIES IN FLORIDA, MAINE AND NORTH CAROLINA

by

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EXECUTIVE SUMMARY

Marine shellfish aquaculture is rapidly expanding in coastal U.S. states. Common goals of the industry include supporting coastal habitat and ecosystem health, reducing pressure on wild-capture fisheries, combating food insecurity and improving nutrition, creating economic opportunities in coastal communities, and addressing the U.S. seafood trade deficit. Common challenges include an uncertain farmed shellfish market potential, conflict and negative public perceptions about aquaculture, and socio-cultural concerns around industry development. These objectives and concerns encompass the social, cultural, economic, and environmental dimensions of industry expansion. As it is unlikely that managers will be able to fulfill every opportunity and address every challenge, they will need to set management agendas that appropriately prioritize needs. Currently, there is little research on what residents both in and outside of shellfish aquaculture producing communities want industry development and management to look like or how those preferences may vary among groups. However, to make informed decisions about the trajectory of the industry, fulfill statewide responsibilities, and effectively manage growth, managers must understand how residents' priorities vary demographically, geographically, or experientially.

This project explores how residents living in Florida, Maine, and North Carolina—three states characterized by emerging and ambitious shellfish aquaculture sectors—prioritize management objectives for the industry. Therefore, this project asks 1) which shellfish aquaculture management objectives are most important to residents and 2) does prioritization of management objectives vary among demographic and other predictor variables. Managers may draw on this information to make knowledgeable decisions that will guide shellfish aquaculture development.

A large-scale (n = 1,011) survey was deployed and administered by the survey company Qualtrics in summer 2023. To understand how residents prioritize different aquaculture goals, respondents were asked to rank a series of 10 management objectives that mirror the previously described management goals and challenges. To understand how prioritization varies among groups, residents were asked about their demographics, their level of knowledge of seafood production practices, whether they fish or farm commercially or recreationally, and how frequently they have consumed seafood in the past year. Data were entered into SPSS to perform statistical analyses.

The most important management objectives for all respondents are 1) "supporting local/coastal community economic development," 2) "safeguarding the natural environment" and 3) "maintaining coastal culture and heritage." These top three objectives represent economic, environmental, and social dimensions of aquaculture development, suggesting that residents want aquaculture to fulfill multiple goals. Further, these objectives are most relevant to producing communities, indicating a statewide sentiment that shellfish aquaculture production should primarily benefit producing communities. Gender, age, frequency of seafood consumption, and community type often predicted how respondents ranked management priorities. The predictor variable "distance to the coast" was not significantly correlated with any management objectives, suggesting that there is statewide support for local benefits of shellfish aquaculture. Further, "supporting local/coastal community development" and

"protecting/maintaining coastal culture and heritage" were not significantly correlated with many predictor variables, suggesting that these are areas of broad agreement across demographics.

The results of this study allow for four conclusions. First, residents want aquaculture management and development to serve multiple needs within their communities—they want the economic, environmental, and social and cultural elements to all be considered. Second, residents think that benefits of shellfish aquaculture production should primarily be distributed to producing communities. Therefore, as managers consider how to balance statewide responsibilities with local needs, they may focus more on the local. Third, some predictor variables are more important for managers to consider while others are less so. Fourth, managers may use a survey approach to understand how to prioritize a range of objectives, setting them up to effectively manage shellfish aquaculture growth in their locality.

In future work, it would be useful to explore state-specific rather than general management priorities to enable more robust comparison between study states. It would also be useful to explore relationships between management priorities and the predictor variable race.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Current knowledge and research gaps

The rapid expansion of the marine shellfish aquaculture industry in coastal U.S. states is characterized by environmental, social, and economic benefits as well as management challenges. As managers guide the trajectory of the industry in their communities, they will grapple with questions about what values and objectives to prioritize and what tradeoffs to make. Previous research has aimed to answer these questions by studying how residents and consumers think about aquaculture (Cardoso et al., 2013; Kraly et al., 2022; Roheim et al., 2012). Much research has focused on industry impacts and preferences within producing communities—communities where aquaculture production is happening. For example, researchers in British Columbia explored how demographics, values, home setting and industry knowledge and experience shape perception of shellfish aquaculture development in producing communities (D'Anna & Murray, 2015; G. Murray & D'Anna, 2015). Still, there is little research on what residents both in and outside of producing communities want shellfish aquaculture development and management to look like and how those preferences may vary among groups. To make informed decisions about the trajectory of the industry, fulfill statewide responsibilities, and effectively manage growth, managers must understand how residents' priorities vary demographically, geographically, or experientially.

1.2 Environmental, social, and economic benefits of shellfish aquaculture

One of the reasons why proponents argue for increasing domestic shellfish aquaculture production is that it can provide a range of ecosystem services. As filter feeders, for example, shellfish take the nutrients they need from the water column, removing particulate matter and excess nitrogen during the process, thereby improving local water quality (Barrett et al., 2022). Shellfish farms may provide habitat for marine fauna; research has shown elevated diversity and abundance of marine wildlife around farm operations (Barrett et al., 2019). Further, shellfish aquaculture structures can defend coastal areas from erosion and storm surge by attenuating wave impact and stabilizing sediment (Zhu et al., 2020). As shellfish have been lost in many coastal ecosystems, restoring them through farming allows them to provide these important ecosystem services once again.

In addition to ecosystem services, shellfish aquaculture is valuable for food provisioning. As aquaculture is the fastest growing food production sector in the world, supporters position shellfish aquaculture as having the potential to contribute to sustainable food supply and food security (FAO, 2022). Shellfish farming is not energy- or feed-intensive, making it more environmentally sustainable than other forms of aquatic and terrestrial protein production (Verdegem et al., 2023). Further, greater reliance on farmed products may relieve some of the pressure on wild-capture fisheries, many of which are currently overfished (Froehlich et al., 2023). Shellfish aquaculture products are also rich in essential proteins, micronutrients, and fatty acids, positioning them to combat food and nutritional insecurity (Azra et al., 2021). To accomplish these goals, however, the shellfish aquaculture industry would need to grow significantly in the coming decades while ensuring its products are affordable and accessible (Azra et al., 2021).

Advocates also tout the economic and social benefits of shellfish aquaculture. This industry creates jobs that are available year-round, supporting coastal community economic development. This type of development may incentivize residents to remain in their local communities, thereby supporting and maintaining working waterfront identities and instilling a sense of pride in workers (Michaelis et al., 2021). These low levels of emigration and a strong economy may significantly bolster the community resilience of farmed shellfish producing areas (Krause et al., 2020). Further, in 2018, the U.S. produced $1.5 billion in marine aquaculture products, with oysters and clams valued at $219 million and $122 million, respectively, making shellfish the most valuable marine aquaculture product (Azra et al., 2021; NOAA Fisheries, 2023).

Producing more seafood domestically through shellfish aquaculture also presents the opportunity for the U.S. to address its seafood trade deficit. As of 2020, the U.S. imports 70-85% of its seafood, leaving the nation with a $17 billion seafood trade deficit (NOAA Fisheries, 2022). Shellfish aquaculture alone could not balance this debt, but the development of the industry may allow the U.S. to import fewer shellfish aquaculture products (NOAA Fisheries, 2022).

Though shellfish aquaculture development is characterized by environmental, social, and economic benefits, there are also challenges and concerns associated with expansion of the industry. Depending on the nature of development, it may be detrimental for some residents. For example, Krause et al. (2020) found that, in Maine and in Prince Edward Island, the growth of the aquaculture industry has resulted in the loss of some family-run businesses to larger companies. A challenge of sustainably growing the industry may be balancing existing coastal community livelihoods with economic and social development.

Development of the industry may also spur conflict, affecting public support for new and existing farms. Some stakeholders may take issue with the impact of leases, including coastal aesthetics or interference with other recreational uses (Phillips, 2022). In some cases, such opposition has prevented new growing areas from being established, even if they had prior approval from governing authorities (Coastal Review Staff, 2022). Potentially, such conflicts may be mitigated by allowing shellfish aquaculture development characteristics to vary by location, depending on local public preference (Farolfi & Johnston, 2024).

1.3 Relationships between demographics and seafood preferences

Some research has been conducted on the relationships between demographics and preferences for seafood. One study observed that rates of seafood consumption are lower in communities greater 25 miles from the coast than in coastal communities (Love et al., 2020). Other researchers have discovered relationships between preferences and age (Osmond et al., 2022), gender (He et al., 2023), and income (St. Louis et al., 2023). Murray et. al (2023) found demographic and geographic variation in consumer preference for a range of aquaculture products. Still, we know very little on how these patterns may or may not translate to shellfish aquaculture. This data would give us insight into what is important to different groups, informing managers as they tailor development strategies to fit their community. Such information may also be useful to proponents of shellfish aquaculture as they develop effective messaging about the benefits of shellfish aquaculture.

1.4 Project goal

The described benefits and challenges associated with the shellfish aquaculture industry represent potential objectives for managers to pursue as they develop the industry. These objectives encompass the social, cultural, economic, and environmental dimensions of industry expansion. It is unlikely that managers will be able to fulfill every opportunity and address every challenge; instead, they will need to set management agendas that prioritize different needs. To inform this agenda-setting and fulfill statewide responsibilities, managers must understand what considerations residents across the state think are most important for shellfish aquaculture management.

The overall research goal of this project is to explore how residents living in Florida, Maine and North Carolina—three states characterized by emerging and ambitious shellfish aquaculture sectors—view the development and management of the industry. Therefore, the research objectives of this article are 1) determine which shellfish aquaculture management objectives are most important to residents, and 2) determine if and how prioritization of management objectives varies among predictor variables such as demographics, community type, behaviors and knowledge, sources of seafood information, and experience. Managers may draw on this information to make knowledgeable decisions that will guide shellfish aquaculture development.

1.5 Background and study site description

This study focuses on three states: Florida, Maine and North Carolina. The Florida shellfish aquaculture industry is dominated by hard clam (*Mercenaria mercenaria)* production, which accounts for 92% of sales as of 2018, and constitutes Florida's most profitable marine aquaculture sector (Florida Department of Agriculture and Consumer Services, Aquaculture Division, 2020). Eastern oysters (*Crassostrea virginica)* and sunray venus clams (*Macrocallista nimbosa*) comprise the remainder of the market (University of Florida, Institute of Food and Agricultural Sciences, 2021). Most production occurs on the Gulf Coast—specifically the Panhandle and Big Bend regions—though some production occurs on the Atlantic coast as well (Florida Department of Agriculture and Consumer Services, Aquaculture Division, 2020). The value of the market has greatly increased since the 1990s, when federally-funded job retraining programs facilitated the entrance of former fishermen into the industry (Florida Department of Agriculture and Consumer Services, Aquaculture Division, 2020). In 2018, clams and oysters had a sales value of $15.5 million, representing a 31% increase from 2012. Data on total economic value of the shellfish aquaculture industry in the state is limited, as the state has not conducted a Florida Aquaculture Survey since 2012; in that year, the total economic value was estimated at $38.7 million (Florida Department of Agriculture and Consumer Services, Aquaculture Division, 2020). The state guides its aquaculture development through a yearly *Florida Aquaculture Plan.*

The North Carolina shellfish aquaculture industry is dominated by Eastern oyster and hard clam production (Fodrie et al., 2018). The industry is rapidly growing in North Carolina as well; between 2011 and 2017, there was a nine-fold increase in bottom lease applications and a 12-fold increase in water column lease applications (Fodrie et al., 2018). The potential development of the industry was outlined in the *North Carolina Strategic Plan*, which sets out goals for North Carolina to become a "Napa Valley of Oysters" and grow the shellfish aquaculture industry from its 2022 economic value of $32 million to $100 million by 2030 (Fodrie et al., 2018).

The Maine shellfish aquaculture industry is slightly smaller than that of Florida and North Carolina. Production is dominated by blue mussels (*Mytilus edulis*) and Eastern oysters, though Maine has finfish and seaweed aquaculture as well (Sadusky et al., 2022). The aquaculture industry began in the state in the early 1970s and has grown significantly since then. As of 2015, the total economic benefit of the shellfish aquaculture industry was estimated to be over $15 million (Sadusky et al., 2022). As of 2019, the value of oysters was $9.7 million, making them the fourth most profitable commercial marine species in the state (Sadusky et al., 2022). The *Maine Aquaculture Roadmap 2022-2032* was created by the Maine Aquaculture Hub and outlines goals for the future of Maine's aquaculture industry.

2. METHODS

2.1 Survey design and deployment

A survey was deployed and administered by the survey company Qualtrics. The sample included an approximately equal number of respondents from each study state. Quotas were created for race, gender, age, community type (urban, rural, or suburban), and other measured demographics to ensure that sample sizes for each of the variables of interest were adequate and that the entire sample reflected the demographic makeup of each state to the extent possible. Respondents consented to taking the survey, were at least 18 years of age, and were residents of either Florida, Maine, or North Carolina. The survey was designed and deployed in summer 2023. We received 1,011 complete survey responses.

The survey asked respondents to answer 32 questions about their personal patterns of seafood consumption, attitudes towards farmed and wild-caught seafood, preferences for aquaculture development, demographics, and level of knowledge about seafood production. This paper zooms in on the questions about preference for aquaculture development, demographics, and level of knowledge. To understand how residents prioritize management objectives, we asked respondents to rank a series of 10 management objectives by dragging and dropping them into place from 1 to 10, with 1 being the most important and 10 being the least. This list of objectives (shown in Table 1) was developed through qualitative interviews conducted in previous research as well as through a literature review (summarized in the introduction) on what the aquaculture industry has been purported to provide. To develop our list of predictor variables (shown in Table 2), we asked residents about their demographics, their level of knowledge of seafood production practices, whether they fish or farm commercially or recreationally, and how frequently they have consumed seafood in the past year.

Table 1. List of management objectives.

Management priorities
Supporting local/coastal community economic development
Maintaining coastal culture and heritage
Supporting statewide economic development:

Safeguarding the natural environment
Protecting small and family businesses
Ensuring fair wages for seafood producers
Addressing the U.S. seafood trade deficit
Enhancing food security
Prioritizing wild-caught seafood harvest
Prioritizing farmed seafood production

Table 2. List of predictor variables.

Meta-category	**Predictor variable**
Demographic	Age
	Gender
	Income
	Education
	Political Affiliation
Community type	State
	Distance to coast
	Rural/urban/suburban
Behaviors and knowledge	Frequency of seafood consumption
	Knowledge of seafood production
	Source of information on seafood production
Experience	Person fishes or farms commercially
	Person fishes or farms recreationally

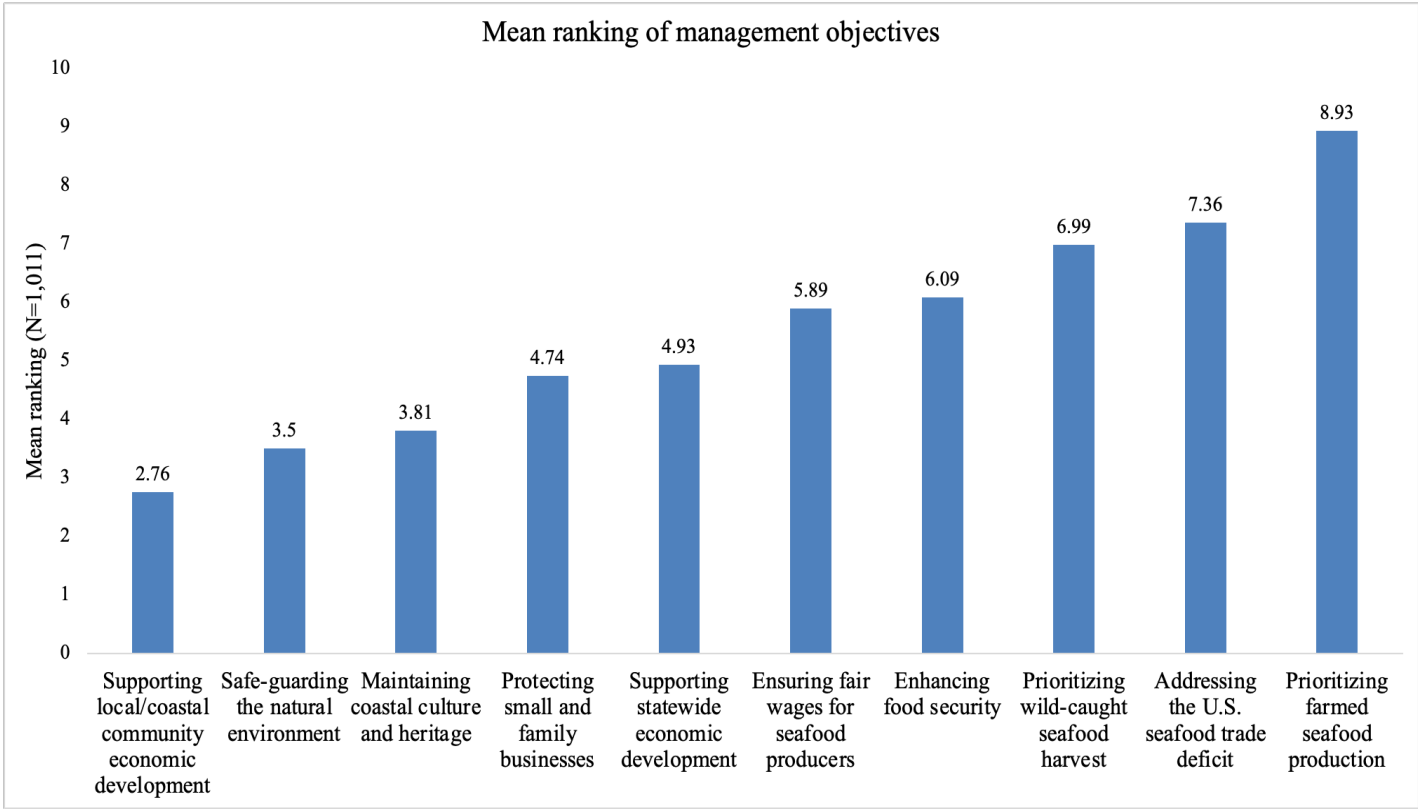
2.2 Data analysis

We entered the survey data into SPSS to perform statistical analyses. To test for relationships between management priority ranking and predictor variables, we used Spearman's rank correlation coefficient, independent samples t test, or one-way ANOVA (see Tables 3-12).

3. RESULTS

3.1 Mean ranking of aquaculture management objectives across all respondents

Fig. 1. Mean ranking of management objectives.



To understand how residents value different aquaculture management objectives, we asked respondents to rank their priorities for marine aquaculture management by dragging and dropping them in order from 1 to 10, with 1 being the most important and 10 being the least important. The results of this question are summarized in Fig 1, which illustrates the mean ranking across each management priority. The mean represents the average ranking across all 1,011 respondents for each objective. Fig. 1 demonstrates that the most important management objective for respondents is "supporting local/coastal community economic development," while the least important management objective is "prioritizing farmed seafood production."

3.2 Mean ranking of aquaculture management objectives across predictors

We were also interested in how these response patterns varied across predictors. The way each management objective relates to demographics is described below and shown in Tables 3-12.

Table 3. Statistical relationships between predictor variables and rank of supporting local/coastal community economic development.

Supporting local/coastal community economic development			
Demographic	Age*	rho = -0.071 p = 0.023	As age increases, respondents rank supporting local/coastal

			community economic development as more important
	Gender**	m = 2.65 f = 2.85 p = 0.096	No significant relationship
	Income*	rho = 0.039 p = 0.232	No significant relationship
	Education*	rho = 0.033 p = 0.298	No significant relationship
	Political Affiliation***	p = 0.237	No significant relationship
Community Type	State***	p = 0.093	No significant relationship
	Distance to coast*	rho = -0.026 p = 0.418	No significant relationship
	Rural/urban/suburban***	p = 0.436	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = 0.027 p = 0.395	No significant relationship
	Knowledge of seafood production*	rho = 0.057 p = 0.069	No significant relationship
Experience	Person fishes or farms commercially**	y = 2.84 n = 2.70 p = 0.242	No significant relationship
	Person fishes or farms recreationally**	y = 2.64 n = 2.78 p = 0.358	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

We found that, as age increased, respondents ranked "supporting local/coastal community economic development" as more important (rho = 0-0.071, p = 0.023).

Table 4. Statistical relationships between predictor variables and rank of safeguarding the natural environment.

Safeguarding the natural environment			
Demographic	Age*	rho = 0.035 p = 0.264	No significant relationship
	Gender**	m = 3.77 f = 3.29 p = <0.001	Female respondents rank safeguarding the natural environment as significantly more important than men do
	Income*	rho = -0.026 p = 0.421	No significant relationship
	Education*	rho = -0.062 p = 0.076	No significant relationship

	Political Affiliation***	p = 0.096	No significant relationship
Community Type	State***	p = 0.564	No significant relationship
	Distance to coast*	rho = 0.004 p = 0.902	No significant relationship
	Rural/urban/suburban***	p = 0.015	Suburban communities rank safeguarding the natural environment as significantly more important than rural communities
Behaviors and knowledge	Frequency of consumption*	rho = 0.056 p = 0.076	No significant relationship
	Knowledge of seafood production*	rho = -0.143 p = <0.001	As stated knowledge of seafood production increases, people rank safeguarding the natural environment as more important
Experience	Person fishes or farms commercially**	y = 4.09 n = 3.38 p = <0.001	Respondents who do not fish/farm commercially rank safeguarding the natural environment as significantly more important than respondents who fish/farm commercially
	Person fishes or farms recreationally**	y = 3.62 n = 3.41 p = 0.136	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

Results show that respondents who say they are more knowledgeable about seafood production ranked "safeguarding the natural environment" as more important (rho = -0.143, $p < 0.001$). Further, we found that ranking of this priority was higher with people who do not fish or farm commercially as opposed to those who do ($p < 0.001$), women as opposed to men ($p < 0.001$), and suburban communities as opposed to rural communities ($p = 0.015$).

Table 5. Statistical relationships between predictor variables and rank of maintaining coastal culture and heritage.

Maintaining coastal culture and heritage			
Demographic	Age*	rho = 0.14 p = 0.657	No significant relationship
	Gender**	m = 3.69 f = 3.98 p = 0.005	Male respondents rank maintaining coastal culture and heritage as significantly more important than female respondents

	Income*	rho = 0.000 p = 0.988	No significant relationship
	Education*	rho = 0.014 p = 0.654	No significant relationship
	Political Affiliation***	p = 0.248	No significant relationship
Community Type	State***	p = 0.386	No significant relationship
	Distance to coast*	rho = -0.010 p = 0.765	No significant relationship
	Rural/urban/suburban***	p = 0.589	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = .0.43 p = 0.169	No significant relationship
	Knowledge of seafood production*	rho = 0.068 p = .032	As stated knowledge of seafood production increases, respondents rank maintaining coastal culture and heritage as less important
Experience	Person fishes or farms commercially**	y = 3.56 n = 3.86 p = 0.099	No significant relationship
	Person fishes or farms recreationally**	y = 3.68 n = 3.90 p = 0.106	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

The mean ranking of the objective "maintaining coastal culture and heritage" was correlated with respondent knowledge of seafood production; as stated knowledge increased, respondents ranked this objective as less important (rho = 0.068, p = 0.032). This objective also correlates with gender—men rank maintaining coastal culture and heritage as significantly more important than women do (p = 0.005).

Table 6. Statistical relationships between predictor variables and rank of protecting small and family businesses.

Protecting small and family businesses			
Demographic	Age*	rho = 0.009 p = 0.785	No significant relationship
	Gender**	m = 4.90 f = 4.61 p = .035	Female respondents rank protecting small and family businesses as significantly more important than male respondents
	Income*	rho = -0.045 p = 0.167	No significant relationship
	Education*	rho = -0.014	No significant relationship

		p = 0.654	
	Political Affiliation***	p = 0.009	Republicans rank protecting small and family businesses as significantly more important than Democrats do
Community Type	State***	p = 0.011	Maine residents rank protecting small and family businesses as significantly more important than Florida residents do
	Distance to coast*	rho = 0.048 p = 0.128	No significant relationship
	Rural/urban/suburban***	p = 0.002	Rural communities rank protecting small and family businesses as significantly more important than urban communities do
Behaviors and knowledge	Frequency of consumption*	rho = 0.046 p = 0.145	No significant relationship
	Knowledge of seafood production*	rho = 0.014 p = 0.652	No significant relationship
Experience	Person fishes or farms commercially**	y = 4.66 n = 4.75 p = 0.583	No significant relationship
	Person fishes or farms recreationally**	y = 4.61 n = 4.84 p = 0.095	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

Four demographic variables were significantly related to the mean ranking of "protecting small and family businesses": gender, state of residence, community type, and political party. We found that women rank this priority as significantly more important than men do ($p = 0.035$), respondents from Maine value this priority significantly more than respondents from Florida ($p = 0.011$), rural communities value this priority more than urban communities ($p = 0.002$), and that republicans value this priority more than democrats ($p = 0.009$).

Table 7. Statistical relationships between predictor variables and rank of supporting statewide economic development.

Supporting statewide economic development			
Demographic	Age*	rho = 0.087 p = 0.006	As age increases, respondents rank supporting statewide economic development as less important
	Gender**	m = 4.59	Men rank supporting statewide

		f = 5.17 p = <0.001	economic development significantly more important than female respondents
	Income*	rho = 0.073 p = 0.023	As income increases, respondents rank supporting statewide economic development as less important
	Education*	rho = 0.058 p = 0.066	No significant relationship
	Political Affiliation***	p = 0.200	No significant relationship
Community Type	State***	p = 0.799	No significant relationship
	Distance to coast*	rho = -0.021 p = 0.504	No significant relationship
	Rural/urban/suburban***	p = 0.585	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = 0.092 p = 0.004	As frequency of consumption increases, respondents rank supporting statewide economic development as less important
	Knowledge of seafood production*	rho = 0.074 p = 0.019	As stated knowledge of seafood production increases, people rank supporting statewide economic development as less important
Experience	Person fishes or farms commercially**	y = 4.64 n = 4.97 p = 0.057	No significant relationship
	Person fishes or farms recreationally**	y = 4.86 n = 4.96 p = 0.439	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

As age (rho = 0.087, p = 0.006), income (rho = 0.073, p = 0.023), frequency of seafood consumption (rho = 0.092, p = 0.004), and knowledge of seafood production (rho = 0.074, p = 0.019) increase, respondents rank the objective "supporting statewide economic development" as less important. There are also gendered differences, as men rank this objective as significantly more important than women (p < .001).

Table 8. Statistical relationships between predictor variables and rank of ensuring fair wages for seafood producers.

Ensuring fair wages for seafood producers			
Demographic	Age*	rho = 0.093 p = 0.003	As age increases, respondents rank ensuring fair wages for seafood producers as less

			important
	Gender**	m = 6.03 f = 5.81 p = 0.075	No significant relationship
	Income*	rho = 0.042 p = 0.193	No significant relationship
	Education*	rho = 0.052 p = 0.102	No significant relationship
	Political Affiliation***	p = 0.185	No significant relationship
Community Type	State***	p < 0.001	Maine residents rank ensuring fair wages for seafood producers as signifincatly more important than for Florida residents and North Carolina residents
	Distance to coast*	rho = -0.030 p = 0.340	No significant relationship
	Rural/urban/suburban***	p = 0.925	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = 0.085 p = 0.007	As frequency of consumption increases, respondents rank ensuring fair wages for seafood producers as less important
	Knowledge of seafood production*	rho = -0.097 p = 0.002	As stated knowledge of seafood production increases, respondents rank ensuring fair wages for seafood producers as more important
Experience	Person fishes or farms commercially**	y = 4.66 n = 4.75 p = 0.583	No significant relationship
	Person fishes or farms recreationally**	y = 5.89 n = 5.92 p = 0.768	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

The mean ranking of the objective "ensuring fair wages for seafood producers" was correlated with multiple predictor variables. Increases in age (rho = 0.093, p = 0.003) and frequency of seafood consumption (rho = 0.085, p = 0.007) were correlated with a lower ranking of this priority. Conversely, respondents who say they are more knowledgeable about seafood production think that ensuring fair wages for seafood producers is more important (rho = -0.097, p = 0.002). Interestingly, we found that residents of Maine represent an outlier in how they ranked this priority—for this demographic, ensuring fair wages for seafood producers is significantly more important than for residents of Florida and of North Carolina (p < 0.001).

Table 9. Statistical relationships between predictor variables and rank of enhancing food security.

Enhancing food security			
Demographic	Age*	rho = -0.021 p = 0.502	No significant relationship
	Gender**	m = 6.39 f = 5.85 p = 0.002	Female respondents rank enhancing food security as significantly more important than male respondents
	Income*	rho = -0.034 p = 0.290	No significant relationship
	Education*	rho = -0.026 p = 0.414	No significant relationship
	Political Affiliation***	p = 0.934	No significant relationship
Community Type	State***	p = <0.001	Florida residents rank enhancing food security are significantly more important than Maine residents
	Distance to coast*	rho = 0.030 p = 0.353	No significant relationship
	Rural/urban/suburban***	p = 0.088	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = -0.005 p = 0.874	No significant relationship
	Knowledge of seafood production*	rho = -0.122 p = < 0.001	As stated knowledge of seafood production increases, respondents rank enhancing food security as more important
Experience	Person fishes or farms commercially**	y = 6.59 n = 5.98 p = 0.009	Respondents who do not fish or farm commercially rank enhancing food security as significantly more important than people who fish or farm commercially
	Person fishes or farms recreationally**	y = 6.30 n = 5.93 p = 0.37	Respondents who do not fish or farm recreationally rank enhancing food security as significantly more important than respondents who do fish or farm recreationally

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

There was a strong relationship between the management objective "enhancing food security"

and stated knowledge of seafood production; as respondents' knowledge increased, they ranked this priority as more important (rho = -0.122, $p < 0.001$). We also found that respondents who do not fish or farm recreationally rank "enhancing food security" as significantly more important than people who do these activities ($p = 0.037$). Similarly, people who do not fish or farm commercially rank "enhancing food security" as significantly more important than people who do ($p = 0.009$). Interestingly, women value this priority more highly than men do ($p = 0.002$), and residents of Florida value this priority more highly than residents of Maine ($p < 0.001$).

Table 10. Statistical relationships between predictor variables and rank of prioritizing wild-caught seafood harvest.

Prioritizing wild-caught seafood harvest			
Demographic	Age*	rho = -0.144 p = <0.001	As age increases, respondents rank prioritizing wild-caught seafood harvest as more important
	Gender**	m = 6.91 f = 7.06 p = 0.394	No significant relationship
	Income*	rho = -0.037 p = 0.245	No significant relationship
	Education*	rho = -0.024 p = 0.452	No significant relationship
	Political Affiliation***	p = 0.429	No significant relationship
Community Type	State***	p = 0.792	No significant relationship
	Distance to coast*	rho = 0.042 p = 0.188	No significant relationship
	Rural/urban/suburban***	p = 0.384	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = -0.154 p = < 0.001	As frequency of seafood consumption increases, respondents rank prioritizing wild-caught seafood harvest as more important
	Knowledge of seafood production*	rho = 0.072 p = 0.021	As stated knowledge of seafood production increases, respondents rank prioritizing wild-caught seafood harvest as less important
Experience	Person fishes or farms commercially**	y = 7.01 n = 6.99 p = 0.948	No significant relationship
	Person fishes or farms recreationally**	y = 7.03 n = 6.96 p = 0.718	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

Mean ranking of "prioritizing wild-caught seafood harvest" increased with increases in age (rho = -0.144, $p < 0.001$) and frequency of seafood consumption within the past year (rho = -0.154, $p < 0.001$). Both relationships are very strong. However, as stated knowledge of seafood production increased, respondents ranked this objective as less important (rho = 0.072, $p = 0.021$).

Table 11. Statistical relationships between predictor variables and rank of addressing the U.S. seafood trade deficit.

Addressing the U.S. seafood trade deficit			
Demographic	Age*	rho = 0.112 p = < 0.001	As age increases, respondents rank addressing the U.S. seafood trade deficit as less important
	Gender**	m = 7.20 f = 7.49 p = 0.020	Male respondents rank addressing the U.S. seafood trade deficit as significantly more important than female respondents
	Income*	rho = 0.074 p = 0.021	As income increases, respondents rank addressing the U.S. seafood trade deficit as less important
	Education*	rho = 0.109 p = < 0.001	As education level increases, respondents rank addressing the U.S. seafood trade deficit as less important
	Political Affiliation***	p = 0.089	No significant relationship
Community Type	State***	p = 0.018	No significant relationship
	Distance to coast*	rho = -0.009 p = 0.766	No significant relationship
	Rural/urban/suburban***	p = 0.187	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = 0.044 p = 0.163	No significant relationship
	Knowledge of seafood production*	rho = 0.056 p = 0.074	No significant relationship
Experience	Person fishes or farms commercially**	y = 7.09 n = 7.42 p = 0.039	Respondents who fish/farm commercially rank addressing the U.S. seafood trade deficit as significantly more important than people who do not fish/farm commercially
	Person fishes or farms recreationally**	y = 7.29 n = 7.42 p = 0.298	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

As age, income, and education level increased, "addressing the U.S. seafood trade deficit" became less important (rho = 0.112, p < 0.001; rho = 0.074, p = 0.021; rho = 0.109, p < 0.001). Further, we found that people who fish or farm commercially rank "addressing the U.S. seafood trade deficit" as more important than people who do not fish or farm commercially (p = 0.039), and that men ranked this priority as significantly more important than women did (p = 0.020).

Table 12. Statistical relationships between predictor variables and rank of prioritizing farmed seafood production.

Prioritizing farmed seafood production			
Demographic	Age*	rho = -0.011 p = 0.719	No significant relationship
	Gender**	m = 8.87 f = 8.89 p = 0.538	No significant relationship
	Income*	rho = -0.068 p = 0.035	As income increases, respondents rank prioritizing farmed seafood production as more important
	Education*	rho = -0.079 p = 0.013	As education level increases, respondents rank prioritizing farmed seafood production as more important
	Political Affiliation***	p = 0.103	No significant relationship
Community Type	State***	p = 0.006	Florida residents rank prioritizing farmed seafood production as significantly more important than Maine residents
	Distance to coast*	rho = -0.028 p = 0.379	No significant relationship
	Rural/urban/suburban***	p = 0.233	No significant relationship
Behaviors and knowledge	Frequency of consumption*	rho = -0.081 p = 0.010	As frequency of seafood consumption increases, respondents rank prioritizing farmed seafood production as more important
	Knowledge of seafood production*	rho = 0.063 p = 0.046	As stated knowledge of seafood production increases, people rank prioritizing farmed seafood production as less important
Experience	Person fishes or farms commercially**	y = 8.84 n = 8.95 p = 0.522	No significant relationship

	Person fishes or farms recreationally**	y = 8.89 n = 8.86 p = 0.581	No significant relationship

* tested using Spearman's rank correlation coefficient

** tested using independent samples t-test

*** tested using one-way ANOVA

Respondent ranking of "prioritizing farmed seafood production" was correlated with several predictor variables. As income, education level, and frequency of seafood consumption increased, people ranked "prioritizing farmed seafood production" as more important (rho = -0.068, $p < 0.035$; rho = -0.079, $p = 0.013$; rho = -0.081, $p = 0.010$). However, as stated knowledge of seafood production increased, respondents ranked this priority as less important (rho = 0.063, $p = 0.046$).

3.3 Sources of marine aquaculture information

Table 13. How frequently residents get information on marine aquaculture from sources.

Sources of marine aquaculture information		
Television	Never	30.7%
	Occasionally	49.4%
	Frequently	20.0%
Online news	Never	25.3%
	Occasionally	55.1%
	Frequently	19.6%
Friends	Never	46.2%
	Occasionally	39.9%
	Frequently	13.9%
Grocery stores	Never	42.7%
	Occasionally	44.7%
	Frequently	12.6%
Local government	Never	57.8%
	Occasionally	35.4%
	Frequently	6.8%
State government	Never	54.0%
	Occasionally	39.4%
	Frequently	6.6%
Newspaper	Never	54.6%
	Occasionally	37.5%
	Frequently	6.1%
Seafood information cards	Never	63.8%

	Occasionally	30.3%
	Frequently	5.9%
University reports	Never	68.0%
	Occasionally	26.3%
	Frequently	5.7%
Industry	Never	71.4%
	Occasionally	24.2%
	Frequently	4.4%

The top three sources from which residents most frequently got information on marine aquaculture are: 1) television (20.0%), 2) online news (19.6%) and 3) friends (13.9%). Respondents least frequently got information from industry (4.4%).

4. DISCUSSION

4.1 Rankings of aquaculture management priorities

Respondents ranked supporting "local/coastal community economic development," "safeguarding the natural environment," and "maintaining coastal culture and heritage" as the top three most important shellfish aquaculture management objectives. These results may suggest a sentiment that managers should prioritize objectives that directly impact producing areas. "Supporting local/coastal community development" was ranked first while "supporting statewide economic development" was ranked fifth, indicating that respondents may think that the economic benefits of shellfish aquaculture production should be distributed to the producing areas. Further, "safe-guarding the natural environment" was ranked second, suggesting that respondents in geographic locations across the states value protecting a coastal environment that they do not necessarily interact with. "Maintaining coastal culture and heritage" was ranked third, which might suggest that even respondents who do not live on the coast think that protecting the social landscape of producing areas should be prioritized. Conversely, the fact that these priorities were ranked so highly may indicate hesitant or negative views towards the development of the shellfish aquaculture industry—it may be that residents are concerned that expansion could degrade the environment, harm the economy, and threaten local ways of life and culture, so they want to ensure protection against these processes.

Respondents demonstrated a preference for "prioritizing wild-caught seafood harvest" (mean = 6.99) over "prioritizing farmed seafood harvest" (mean = 8.93), in alignment with other research that has compared preference for the two production methods (Cardoso et al., 2013; Roheim et al., 2012). This preference for prioritizing wild-caught over farm-raised products raises questions about the market potential for farmed products. For example, can North Carolina truly grow its farmed shellfish market from $30 million to $100 million by 2030 if state residents do not think that this objective should be prioritized? On the other hand, these results may illustrate a potential gap between what residents say they want and what their purchasing behavior is, a phenomenon described in D'Anna and Murray (2015).

4.2 Relationships between ranking of management priorities and predictors variables
As described, previous research has shown some connection between demographic, geographic, and experiential variables, and resident feeling toward marine shellfish aquaculture production. These results expand on that body of work.

"Safeguarding the natural environment" is of particular importance to women, suburban (rather than rural) communities, people who say they are more knowledgeable about seafood production, and people who do not fish/farm commercially. The fact that female respondents value "safeguarding the natural environment" more than male respondents aligns with previous research—women are more likely to be concerned about climate change and the environment (Pearson et al., 2017). In terms of the difference in prioritization between suburban and rural communities, it may be that rural communities—which often face greater economic challenges and higher rates of poverty than developed areas (Hibbard & Lurie, 2013)—are more focused on management concerns that relate to economic development rather than environmental protection.

We found that "protecting small and family businesses" is significantly more important for respondents from Maine, rural respondents, women, and Republicans. Culture and population may be shaping the way that respondents rank this objective. Maine is a small, rural state that takes great pride in its maritime industry, history, and working waterfronts (Coombs, 2020). Maine's cultural uniqueness may explain why it is an outlier here. However, it is important to note that "protecting small and family businesses" was ranked fourth out of the ten objectives, suggesting that it is important to respondents across demographics, even though there are some groups of respondents for whom it is particularly important.

"Supporting statewide economic development" was ranked as significantly less important for older respondents, higher income respondents, respondents who have eaten seafood more frequently in the past year, and respondents who say they are more knowledgeable about seafood production. Though it is difficult to explain these results, it may be that, in terms of income, wealthier respondents do not feel that they would benefit as much from statewide economic development, as they are already financially secure. Respondents whose stated knowledge of seafood production processes is higher may believe that the distribution of economic benefits should be focused on coastal communities, rather than the entire state. This may be true for the other demographic groups as well, but for reasons that remain unclear. Interestingly, we found that "supporting local/coastal economic development" was more important to older residents, in contrast to the pattern observed for "supporting statewide economic development."

Like the patterns found for the objective "protecting small and family businesses," respondents from Maine ranked "ensuring fair wages for seafood producers" as significantly more important than respondents from Florida and from North Carolina. This may also be explained by Maine's close cultural ties to the maritime industry and to working waterfronts. It is unclear why older respondents and people who consume seafood more often rank this priority as less important. Interestingly, this objective was not significantly correlated with rankings from respondents who fish or farm commercially.

We found that women, people who fish or farm recreationally (as opposed to those who do not), people who say they are more knowledgeable about seafood production, and people from Florida (as opposed to people from Maine) think that "enhancing food security" is more important. As studies have shown that food insecurity disproportionately affects women, it follows that women would rank this priority higher than men (Broussard, 2019). It is unclear why people who fish or farm recreationally rank this priority higher than those who do not, or why there is not also a significant relationship between this priority and people who fish or farm commercially. As with other priorities that are significantly related to the knowledge of seafood production predictor variable, it is impossible to say what knowledge respondents may be drawing upon when they answer this question; potentially, people with greater knowledge recognize the potential that farmed products can play in addressing food security, or that their knowledge results in greater concern that this potential may not be fulfilled without adequate prioritization, but this is speculation. Potentially, the difference between Maine and Florida could be attributed to the fact that Florida is a more food insufficient state; however, the difference in food insufficiency rates is small (only about 2%) (United States Census Bureau, 2023). It may just be that the survey sample happened to include more food-insecure people from Florida than it did from Maine, as this demographic was not accounted for when creating quotas.

We found that older respondents, higher-income respondents, and respondents with higher levels of education ranked "addressing the U.S. seafood trade deficit" as less important, while men and people who do not fish or farm commercially ranked the objective as more important. It could be that respondents who fish or farm commercially perceive that their livelihood or income would be improved by addressing the trade deficit and through more domestic seafood production. Further, as the vast majority of commercial fishers or farmers in the three study states are men (McClenachan & Moulton, 2022; Posadas, 2018; Stemle & Wiegand, 2017), these two demographics might make sense as explained together: commercial fishers, who are most often men, view "addressing the U.S. seafood trade deficit" as more important. It is unclear how age, income, and education level are related to this objective.

We found that people with higher income, higher levels of education, and higher frequencies of seafood consumption ranked "prioritizing farmed seafood production" as more important. It is unclear why these patterns exist. We also found that respondents who say they are more knowledgeable about seafood production ranked this priority as less important. It is impossible to know what these respondents are accounting for in this response pattern. Interestingly, we found that respondents with higher levels of stated knowledge also ranked "prioritizing wild-caught seafood harvest" as less important. Potentially, respondents are not weighing these priorities against each other as heavily as they are weighing them against other priorities—respondents may just find both objectives to be relatively unimportant, as shown in the results from Fig 1. It is also possible that many respondents are not aware of the positive benefits of farmed shellfish culture or that respondents are especially wary of the perceived negative consequences of the development of the industry. Also notable is that people from Florida ranked this objective as significantly more important than people from Maine. This may indicate that Florida residents are more eager to develop their aquaculture industries than respondents from Maine due to any number of reasons, such as positive perceptions of the environmental or economic benefits of the industry or positive messaging about aquaculture development from different information sources.

Though high in the overall rankings, the objectives “supporting local/coastal community development,” “protecting/maintaining coastal culture and heritage,” and “prioritizing wild-caught seafood harvest" were not significantly correlated with many predictor variables. This suggests that prioritization of these objectives is relatively consistent across demographics, with the few exceptions of some significant relationships. “Supporting local/coastal community development” and “protecting/maintaining coastal culture and heritage” were both objectives that ranked in the top three most important. It appears that residents broadly agree that these two objectives should be prioritized in management agendas.

Because previous research has drawn connections between proximity to the coast, resident attitude toward aquaculture, and consumer preference for aquaculture (Cardoso et al., 2013; D’Anna & Murray, 2015; G. D. Murray et al., 2023; G. Murray & D’Anna, 2015), it was surprising that the predictor variable “distance to the coast” did not show any significant relationships with the ranking of any management objectives. Potentially, in these states, “distance to the coast” is more influential on seafood purchasing behaviors than it is on preferences for aquaculture management objectives.

4.3 Sources of marine aquaculture information

Because of the degree of variation across predictor variables, it was difficult to determine how demographic, geographic, and experiential characteristics were connected to the sources from which respondents got information on marine aquaculture. However, we did find that residents most frequently get information from television, online news, and friends. As managers and proponents think about messaging and communication efforts, they may want to consider how they can distribute news through television and online news.

5. CONCLUSION

This study set out to understand how residents in Florida, Maine, and North Carolina prioritize ten aquaculture management objectives, and how prioritization patterns vary across predictor variables related to demographics, community type, behaviors and knowledge, sources of seafood information, and experience. The top three most important management objectives are 1) supporting local/coastal community economic development, 2) safeguarding the natural environment, and 3) maintaining coastal culture and heritage. This pattern suggests that residents think benefits from aquaculture production should primarily be distributed to the producing communities. Further, these top-ranking objectives range from economic to environmental to social concerns, illustrating that residents want aquaculture management to serve multiple needs within their communities.

This study found that “prioritizing farmed seafood production” was the least important priority on average across all predictor groups, indicating that managers may need to find ways to raise demand for shellfish aquaculture products to reach ambitious goals for industry expansion. This may be especially true in the state of Maine, as Maine respondents ranked this priority as significantly less important than residents of Florida. Further differences between states suggest that aquaculture development and management strategies will be most effective if they vary in accordance with local priorities. Other demographic differences suggest that managers should be attentive to the character of their community while developing the shellfish aquaculture industry

in their localities. Lastly, the results suggest that some predictor variables are more important for managers to consider while others are less so, and that managers may use a survey approach to understand how to prioritize a range of complicated management objectives in their community.

One limitation of this work is that the management priorities are informed from a wide body of literature, meaning that they may be completely reflective of what managers are currently prioritizing in our study states. Therefore, future work may research state-specific management priorities to enable more robust comparison. Further, future studies may explore relationships between management priorities and the predictor variable race. With time constraints, we were not able to analyze this variable, though we think notable relationships may be present.

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APPENDIX

Predictor variables categories used in survey questions

Meta-category	Predictor variable	Categories
Demographic	Age	18 - 24
		25 - 34
		25 - 44
		45 - 54
		55 or older
		Prefer not to answer
	Gender	Male
		Female
		Non-binary/third gender
	Income	Less than $20,000
		$20,000 - $34,999
		$35,000 - $49,999
		$50,000 - $74,999
		$75,000 - $99,999
		$100,000 - $149,999
		$150,000 or more
		Prefer not to answer
	Education	Less than high school
		High school graduate
		Some college
		2-year degree
		4-year degree
		Professional degree

		Doctorate
		Prefer not to answer
	Political Affiliation	Democrat
		Republican
		Independent
		Prefer not to answer
Community type	State	Florida
		Maine
		North Carolina
	Distance to coast	I live right beside the water
		1 - 5 miles
		6 - 10 miles
		11 - 25 miles
		26 - 50 miles
		51 - 99 miles
		100 miles or father
		Prefer not to answer
	Community type	Rural
		Urban
		Suburban
Behaviors and knowledge	Frequency of seafood consumption	Never
		Once in the past year
		A few times in the past year
		Once a month
		A few times every month
		Once a week

		More than once a week
	Knowledge of seafood production	Extremely knowledgeable
		Very knowledgeable
		Moderately knowledgeable
		Somewhat knowledgeable
		Not knowledgeable at all
	Source of marine aquaculture information	Newspaper
		Online news
		Television
		Friends
		Local government
		State government
		Seafood information cards
		Grocery stores
		University reports
		Industry trade groups
		Other
Experience	Person fishes or farms commercially	Fish
		Farm
		Both
		Neither
	Person fishes or farms recreationally	Fish
		Farm
		Both
		Neither