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What Does the Public think about Farming Seafood? Modeling Predictors of Social Support for Aquaculture Development in the U.S.

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Abstract

Understanding the factors that increase or decrease the likelihood for public support of aquaculture is critical for it to achieve its social sustainability prospects. Previous studies across the globe have identified a series of indicators linked to public support for aquaculture. We tested their validity with a national US sample and found that most were consistent with previous findings; participants who have pro-environmental views, recognize environmental benefits of aquaculture, believe that aquaculture is a source of good jobs, are more trusting of government officials, are more knowledgeable about aquaculture, eat more farmed seafood and believe that farmed seafood is safer than wild caught are more likely to support aquaculture development. Counter to our hypothesis, perceptions of use-conflict were not related to support for aquaculture. Using General Structural Equation Modelling statistical techniques, we expand on these findings to assess how individual demographic characteristics influence support directly and indirectly through our perception variables positioned as mediators. Analysis revealed that demographic characteristics influence support primarily through indirect pathways.

Keywords: Aquaculture, public perception, social acceptability, public opinion, social sustainability, policy support

1. Introduction

As climate change and overharvesting threaten wild fish stocks, marine aquaculture has become critically important for global food security (FAO 2018). Yet while the necessity of aquaculture is clear, negative perceptions of the industry have proved to be a significant barrier to growth (Mazur and Curtis 2008; Whitmarsh and Palmieri 2009; Young and Liston 2010; Young and Matthews 2010; Froehlich et al. 2021). In many cases, opposition groups have successfully slowed or even stopped development, demonstrating the importance of considering social dimensions when designing development strategies (Noakes et al. 2003; Barton and Floysand 2010; Knapp and Rubino 2016). Explanations for this opposition vary, though industry advocates often attribute resistance to either a lack of scientific understanding of the benefits and impacts of aquaculture or simply NIMBYism (not in my backyard) (Shindler et al. 2002; Ertör and Ortega-Cerdà 2015). While there is some evidence supporting these explanations (Murray et al. 2017; Cowperthwaite and Branchina 2018; Rickard et al. 2020), social acceptability research suggests that opposition is far more nuanced and is often colored by external factors (Knapp and Rubino 2016). Researchers from across the globe have identified a wide-range of indicators that likely influence perceptions of aquaculture—from environmental values to perceptions of use-conflict. This paper seeks to extend this body of work in two ways. First, we seek to create a list of empirically verified indicators shown to influence public perception of aquaculture through a systematic review of survey research exploring social acceptability of aquaculture. Second, as studies have shown that perceptions vary by place, we seek to determine the validity of such indicators in a U.S. context.

To date, only a limited number of surveys have explored public opinion of aquaculture in the United States. While three are regional (Robertson et al. 2002; Dalton and Jin 2017; Bouchard et al. 2021), to our knowledge only two national surveys have been conducted (Chu et al. 2010; Murray et al. 2017; Rickard et al. 2020). The most recent national survey was

conducted in 2017 under the Sustainable Ecological Aquaculture Network (SEANet) project at the University of Maine. (Murray et al. 2017; Rickard et al. 2020). Intending to gain insight into consumer and citizen decision making surrounding sustainable aquaculture, the SEANet survey explored a variety of topics relating to public perception of aquaculture. Due to the breadth of topics, this dataset in particular provides an opportunity to explore the indicators identified in the survey review on a national-scale. While localized studies are invaluable, looking at patterns of perceptions nationally is especially useful when creating national-level policies and development initiatives that will be applied to diverse coastal areas. To analyze this data, we apply General Structural Equation Modeling (GSEM), an analytical technique that allows us to investigate the effects of demographic characteristics and social indicators in a multi-step equation. With this technique, not only are we able to validate whether the indicators identified in the review perform in a U.S. context, but we can see whether these factors vary by social group. This analysis allows a more nuanced understanding of the social factors that influence public perceptions of aquaculture.

2. Background and Analytical Model

The extant research assessing public perceptions of aquaculture provides a roadmap for assessing how different factors affect views of the industry and farmed seafood. Using three online search engines, Academic Search Complete, Web of Science, and ProQuest, we conducted a systematic literature review of previous surveys assessing public opinions of aquaculture. We performed two separate queries within each database. The first queried included the search terms 'public perception' and 'aquaculture.' The second query included 'social acceptability' and 'aquaculture.' After reviewing the article abstracts for relevance and removing duplicates, the final list for review included 44 items.

While all 44 documents were reviewed in their entirety, for the purposes of this review, we focused on articles that included empirical public perception surveys (n=25). By focusing on survey results, we were better able to systematically search for indicators that have been statistically linked to public approval of or opposition to aquaculture. After review, we collated the data and created a list of evidenced indicators. A summarized table of this review that includes geographic scope and type of aquaculture is included as Appendix A. For a full description of methods, see Authors (forthcoming).

While surveys assessed several types of aquaculture in different countries across the globe, despite this heterogeneity, seven themes emerged as evidenced influencers of public approval: environmental values, economic values, trust in government and regulating agencies, knowledge of aquaculture, perceptions of health and safety, and perceptions of real or potential use-conflict. Informed by this analysis, we formulated eight unique hypotheses.

To test our hypotheses, we utilized a dataset from a 2017 national survey conducted by a team of researchers at the University of Maine under the Sustainable Ecological Aquaculture Network (SEANet), selecting survey items that most closely operationalized those emergent themes. Our dependent variable, *support*, is a composite measure of seven statements measuring

active support for aquaculture (see Table 1)[1]. Themes, corresponding variables and hypotheses are outlined below.

Table 1. Variable definitions and corresponding theme with codes and weighted summary statistics (n=1,210).

Endogenous Variables:

Support: Composite score of seven statements measuring active support. Scores were additive (mean 26.0, SD 7.3) "For each statement below, please indicate how likely you are to engage in the following." Reponses, ranging from 1 (strongly disagree) to 6 (strongly agree).

a. Support policies that fund research on aquaculture.
b. Support policies that expand aquaculture operations in the U.S.
c. Support policies that expand aquaculture operations outside of the U.S.
d. Buy aquaculture products.
e. Look for aquaculture products when I purchase seafood.
f. Seek more information on aquaculture.
g. Learn more about the issues surrounding aquaculture.

Theme: Environmental Values

EnvFragility: Factor score variable that includes the following survey items (mean .02, SD 1.0): "What is your general opinion of the state of the environment? For each statement below, please tell us how you feel"

a. Almost everything we do in modern life harms the environment.
b. Nature would be at peace and in harmony if only human beings would leave it alone.
c. Any change humans cause in nature – no matter how scientific – is likely to make things worse.
d. Economic growth always harms the environment.

EnvProgress: Factor score variable that includes the following survey items (mean .01, SD 1.0): "What is your general opinion of the state of the environment? For each statement below, please tell us how you feel"

a. We worry too much about the future of the environment, and not enough about prices and jobs today.
b. People worry too much about human progress harming the environment.

HelpWild: "Aquaculture is a good way to relieve pressure on wild fish populations and other marine species." Strongly disagree (coded 1, 3%), disagree (coded 2, 4%), slightly disagree (coded 3, 9%), don't know (coded 4, 30%), slightly agree (coded 5, 30%), agree (coded 6, 36%), strongly agree (18%).

Theme: Economic Values

Economy: "The aquaculture industry supports U.S. communities by providing a source of local jobs." Strongly disagree (coded 1, 2%), disagree (coded 2, 3%), somewhat disagree (coded 3, 7%), don't know (coded 4, 14%), somewhat agree (coded 5, 29%), agree (coded 6, 34%), strongly agree (coded 7, 11%).

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[1] To assess internal consistency of the composite measure *support*, we conducted a principal component factor analysis. All seven items loaded onto one dimension, explaining 69% of the combined variance. Using the resulting factor score variable (supportF) in place of the additive composite variable did not change analytical outcomes.

Theme: Trust in Government and Regulating Agencies

TrustGovernment "Government officials are a possible source of information about aquaculture. Considering what you know, please click on the number (1–6) between the two phrases that best describes your feelings about information from government officials." Following Rickard et al. 2020, responses for each statement pair, ranging from 1–6, were averaged to create a credibility index (mean 3.1, SD 1.2).

a. Cannot be trusted (1)—can be trusted (6)
b. Is inaccurate (1)—is accurate (6)
c. Is not fair (1)—is fair (6)
d. Does not tell the whole story (1)—tells the whole story 6)

Theme: Knowledge of Aquaculture

Knowledge: "Please estimate your current knowledge of marine aquaculture on a 0–100 scale, where 0 means knowing nothing and 100 means knowing everything you can possibly know about the topic. How much do you think you currently know?" (mean 16.5, SD 19.3)

Theme: Perceptions of Health and Safety

Safety "Farm-raised seafood is safer to eat than wild-caught seafood." Strongly disagree (coded 1, 5%), disagree (coded 2, 9%), slightly disagree (coded 3, 21%), don't know (coded 4, 31%), slightly agree (coded 5, 22%), agree (coded 6, 9%), strongly agree (3%).

Theme: Experience

EatFarmed "Have you consumed aquaculture-raised seafood?" Definitely have not consumed (coded 1, 9%), probably have not consumed (coded 2, 5%), don't know (coded 3, 27%), probably have consumed (coded 4, 31%), definitely have consumed (coded 5, 28%).

Theme: Use Conflict

Recreation: "In coastal areas, aquaculture operations can interfere with recreational activities (e.g., swimming, boating)." Strongly disagree (coded 1, 3%), disagree (coded 2, 7%), slightly disagree (coded 3, 16%), don't know (coded 4, 17%), slightly agree (coded 5, 34%), agree (coded 6, 19%), strongly agree (coded 7, 4%).

Exogenous Variables:

Age (weighted mean 47.5 years, SD 17.4 years, range 18–85 years)

Gender: Male (coded 1, 48.3%) Female (coded 2, 51.7%)

Education: <HS (coded 1, 11.8%), HS (coded 2, 29%), Some college (coded 3, 28.5%), Bachelors or higher (coded 4, 30.8%)

Race: White, non-Hispanic (coded 1, 64.4%), Non-white (coded 2, 35.6%)

Income: 21 groups ranging from <$,5000 (coded 1) to >$250,000 (coded 21)

Ideology: "When it comes to social issues, you generally consider yourself to be:" and "When it comes to fiscal issues, you generally consider yourself to be:" (Very liberal (1) to Very conservative (7). Following Rickard et al. 2020, both items were averaged to create *ideology*, mean 4.4, SD 1.4).

Region: New England (coded 1, 4.5%); Mid-Atlantic (coded 2, 13.5%), East-North Central (coded 3, 15.2%), West-North Central (coded 4, 5.9%), South Atlantic (coded 5, 21.9%), East-South Central (coded 6, 4.9%), West-South Central (coded 7, 10.6%), Mountain (coded 8, 7.6%), Pacific (coded 9, 16%).

3.1 *Environmental Values*

Previous studies have linked environmental values with opposition to aquaculture development. Specifically, those who are more concerned with environmental impacts tend to be less supportive (Whitmarsh and Palmieri 2009; Chu et al. 2010; Dalton and Jin 2017; Hynes et al. 2018; Krovel et al. 2019). While most surveys inquired about environmental concerns by asking participants about their perception of 'environmental harm' caused by aquaculture operations, other surveys included more marine-specific questions about concern over the displacement of wild fish stocks (Chu et al. 2010) or impacts on the beauty of the coastal environment (Dalton et al. 2017). Both types of questions yielded similar results. Public support for aquaculture was also linked with environmental views more generally, with one study finding that participants with higher scores on a New Ecological Paradigm (NEP) measure, which gauges pro-environmental views, were significantly less likely to support shellfish aquaculture (Murray and D'Anna 2015). Lastly, Whitmarsh and Palmieri (2009, 2011) explored the relationship between pro-environment and pro-economy views, which are frequently juxtaposed. In their analysis, they found that those who favored aquaculture expansion were those who minimized environmental impacts and prioritized maximizing economic benefits.

Though these results are reflective of several qualitative studies showing that opposition to aquaculture is often driven by environmental concern (Young and Liston 2010; Young and Matthews 2010; Billing 2018), the relationship between environmental views and public sentiment of aquaculture is likely more complex. For example, participants in several surveys acknowledged environmental benefits of aquaculture—mainly, the relief of pressure on wild fish populations (Freeman et al. 2012; Alexander et al. 2016; Murray et al. 2017; Flaherty et al. 2018), though these perceptions were not investigated as predictors of public sentiment. Further, a recent study by Rickard et al. (2020) drawing from the SEANet survey shows a positive relationship between perceptions of environmental fragility and support for aquaculture. They also investigated whether participants who favored economic progress despite environmental harm were more supportive and found no relationship.

Considering the importance and complexity of this theme, we included three environment variables. Consistent with previous research (Dietz, Stern and Guagnano 1998; Rickard et al. 2020), we created two variables through a principal component factor analysis of a series of six questions assessing participants' environmental values. Responses loaded onto two factors—one measuring progress verses environment *(progress),* and the second measuring perceptions of environmental fragility *(fragility).* Our hypotheses for both variables are based on findings by Rickard et al. (2020), though they diverge from previous research. This analysis seeks to confirm whether or not the relationship between *fragility* and *support* holds in our 7-category model. The third variable, *helpwild,* assesses whether perceptions of environmental benefits of aquaculture influence public sentiment. *Helpwild* measures the extent to which participants agreed that aquaculture helps restore wild stocks (*helpwild).* Teasing out which views are tied to support is key to developing policy and information campaigns that addresses public concerns that drive opposition within the US.

H1: Beliefs favoring progress despite environmental harm will have no effect on support for aquaculture development(a); those who believe in the fragility of nature will be more supportive of aquaculture development(b); those who believe that aquaculture helps restore wild stocks will be more supportive of aquaculture development(c).

3.2 *Economic Values*

Economic benefits such as tax revenue and job creation are often cited as a major advantage of aquaculture development and survey research confirms that those who recognize economic benefits tend to be more supportive. Specifically, those who agree that aquaculture increases economic growth, boosts tax revenue and creates jobs are more supportive of development (Murray and D'Anna 2015; Dalton and Jin 2017; Krovel et al. 2019). Considering previous research illustrates that job creation is one of the most cited economic benefits of aquaculture development (Whitmarsh and Palmieri 2009; Freeman et al. 2012; Murray and D'Anna 2015; Murray et al. 2017; Alexander et al. 2018; Flaherty et al. 2018; Hynes et al. 2018), we included an item that asked participants the extent to which they agree that aquaculture is a good source of local jobs (*economy*) to assess whether this view is predictive of support for aquaculture development within the United States.

H2: Respondents who believe that aquaculture is a source of local jobs will be more likely to support aquaculture development.

3.3 *Trust in Government and Regulating Agencies*

Previous survey research has shown that confidence in governing bodies and trust in government officials can increase support of aquaculture operations (Mazur and Curtis 2006; Rickard et al. 2020). The SEANet survey included a set of questions measuring trust in government-provided information. Using a series of four statements, participants were instructed to select a number from 1(representing low levels of trust) to 6(high levels of trust) on whether they trusted information from government officials and whether they believed that information was accurate, fair, or complete. Following Rickard et al. 2020, we averaged these scores to create the variable *trustgovernment* to gauge whether level of trust influences public support for aquaculture. Considering development initiatives are often launched by government agencies, this relationship is especially important to consider.

H3: Respondents who believe that information from government officials can be trusted, is accurate, fair and complete will be more likely to support aquaculture development.

3.4 *Knowledge*

Studies consistently show that public understanding of aquaculture is limited (Mazur and Curtis 2006; Mazur and Curtis 2008; Freeman et al. 2012; Alexander et al. 2016; Murray et al. 2017). This was also found within the US (Robertson et al. 2002; Murray et al. 2017). While three studies show that participants with higher levels of knowledge are more supportive of aquaculture (Robertson et al. 2002; Thomas et al. 2018; Rickard et al. 2020; Bouchard et al. 2021), a fourth showed no association (Murray and D'Anna 2015). This is a key area of inquiry, considering public perceptions can be shaped by strategic awareness initiatives. To assess whether knowledge level is linked to support within the US, we included the survey measure in our model that asked participants to estimate their level of knowledge of marine aquaculture from 0 (knowing nothing at all) to 100 (knowing everything there is to know).

H4: Respondents who believe they are more knowledgeable about aquaculture will be more supportive of development.

3.5 *Perceptions of Farmed Seafood Safety*

Perceptions of consumer safety of farmed seafood also appears to play a role in public acceptance of aquaculture. While these perceptions varied by place, two studies connected perceptions with support, finding that participants who believed that farmed seafood was safe or

healthy were more likely to support aquaculture development (Chu et al. 2010; Dalton and Jin 2017). We considered this issue using a survey item that gauged the extent to which participants agreed that farm-raised seafood is safer than wild-caught.

H5: Respondents who believe that farm-raised seafood is safer than wild-caught seafood will be more likely to support aquaculture.

3.6 *Experience*

Scholars have also suggested that the public's experience with aquaculture, including proximity to farms, engagement with farmers, and consumption of farmed seafoods might influence support for widening the industry. However, the direction of the experience—support relationship appears to depend on the characterization of that experience. For example, surveys conducted in places where the public has witnessed negative impacts from aquaculture operations will have lower support (Murray and D'Anna 2015). This demonstrates the importance of place-specific research (Mazur and Curtis 2008; Murray and D'Anna 2015; Dalton and Jin 2017; Hynes et al. 2018; Thomas et al. 2018). While this relationship likely varies across the US, it is useful to have a national approximation when designing policy that will be broadly applied to wide-ranging areas. Though assessing only one dimension of 'experience,' we selected a SEANET survey item that asked about awareness of consumption, considering consumption is the primary avenue of exposure. Specifically, the question asked whether respondents had consumed aquaculture products. Respondents were provided with a scale from 1(definitely have not consumed) to 5(definitely have consumed). We expect a positive relationship.

H6: Respondents who are more certain that they have consumed aquaculture products will be more likely to support aquaculture.

3.7 Use Conflict

Lastly, concerns over interference with competing uses of marine areas also appears to influence support, though there is no clear consensus among researchers as to the direction of this relationship (Dalton et al. 2017; Thomas et al. 2018; Krovel et al. 2019; Sinner et al. 2020). This is likely to due to variation in the type of 'competing use' as well as place-based variability. For example, fishing-dependent communities may be less likely to approve of incoming aquaculture operations if residents suspect that these activities would encroach on fishing areas. Participants from areas with less dependence on coastal resources may be less concerned about incoming industry. Further, surveys varied in what 'competing use' they addressed. While some asked about competing coastal activities, others asked more specific questions about conflict with boating or swimming (Shafer et al. 2010; Dalton and Jin 2017; Krovel et al. 2019). The SEANet survey included one question that asked participants the extent to which they agreed that aquaculture interferes with other recreational activities. Though this question does not address the most contentious conflict among resource users—use conflict between competing economic activities, it does allow us to consider how perceived competition with recreational activities may influence support for aquaculture.

H7: Respondents who agree that aquaculture will interfere with recreational activities will be less likely to support aquaculture development.

3.8 *Demographic Characteristics*

In addition to the seven themes found in the literature, we included a series of demographic variables in our model to investigate whether perceptions of aquaculture are patterned by group. Such information could be critical for tailoring policies and management efforts. To date, researchers have found varying links between gender, age, education level, income level, geography, and measures of support for aquaculture (Mazur and Curtis 2008; Fernandez-Polanco et al. 2012; Safford and Hamilton 2012; Murray and D'Anna 2015; Alexander et al. 2016; Hynes et al. 2018; Outiero et al. 2018; Krovel et al. 2019). Females appear to be more concerned with aquaculture impacts (Mazur and Curtis 2006; Hynes et al. 2018; Thomas et al. 2018), though there are mixed results for the relationship with age. Younger people seem to be more concerned about environmental affects, which could negatively influence support for aquaculture (Mazur and Curtis 2006; Hynes et al. 2018; Outiero et al. 2018). Older individuals were found to be more supportive in two studies (Murray et al. 2017; Krovel et al. 2019) but were also less likely to see economic benefits (Alexander et al. 2016) or think that development was important (Safford and Hamilton 2012). A handful of studies suggest that more highly educated people are more supportive of aquaculture (Fernandez-Polanco et al. 2012; Safford and Hamilton 2012; Murray et al. 2017), though additional studies found no relationship (Outiero et al. 2018; Krovel et al. 2019). Local and regional variation has been found in several studies, with perceptions varying by exposure to and experience with aquaculture (Hamilton and Safford 2015; Dalton and jin 2017; Thomas et al. 2018; Hynes et al. 2018). Lastly, the effects of income, political party and race are less often included in statistical models, leaving this question open for investigation.

H8: Participants who are male, older, and more educated will be more supportive of aquaculture development.

3. Methods

3.1 Analytical Approach

Figure 1 is a conceptual path diagram representing our structural equation model (SEM) design. However, classical SEM analysis assumes that endogenous variables are continuous and linearly related. Because several of our endogenous variables are ordinal, we utilized the generalized structural equation modeling (GSEM) procedures of Stata v.16 (StataCorp 2019), which permits nonlinear specifications such as (in this case) ordered logit regression, within a structural equation framework for a more flexible approach. SEM and GSEM models permit tests of intervening or mediating effects, involving variables that are causally subsequent to exogenous factors such as age and gender, but more general and prior to the dependent variables of interest—in this case, support for aquaculture. They also provide insight on the indirect effects of exogenous variables, operating through mediating factors. This analytical approach offers a more nuanced understanding of the way our independent variables influence support.

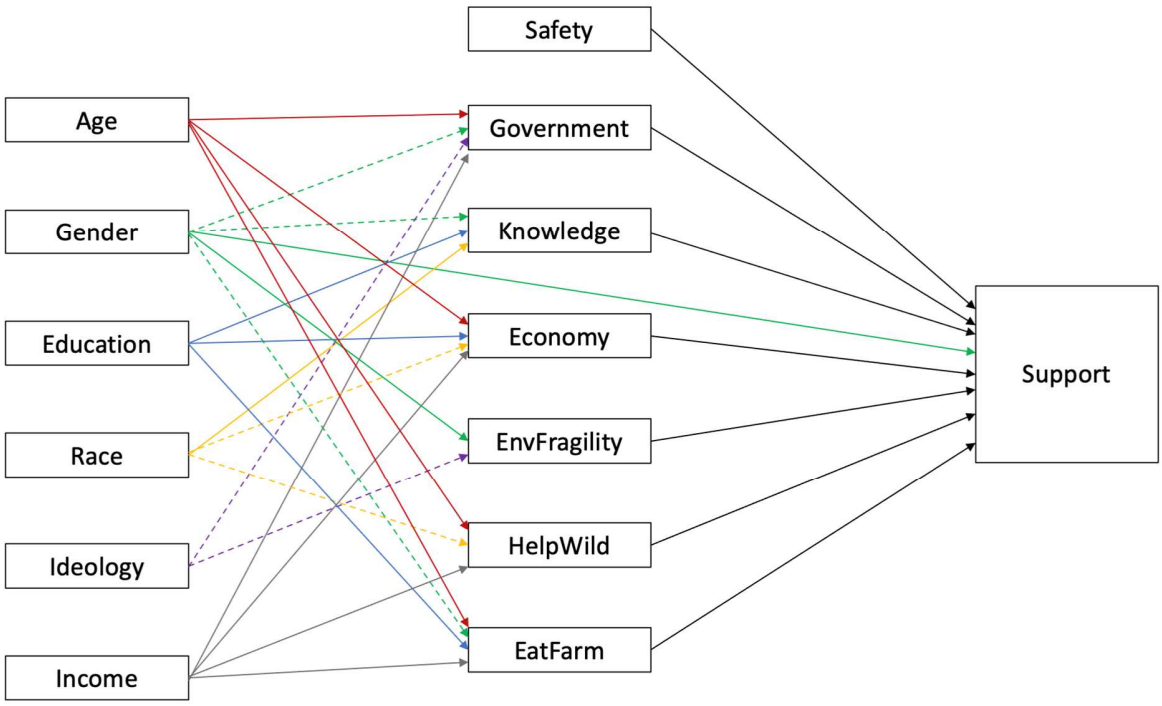

Figure 1. Path diagram showing relationships from demographic factors, through a set of general views on environmental and related topics, to support for aquaculture (*support*). Solid lines represent statistically significant positive relationships, while dotted lines represent statistically significant negative relationships, based on the analysis in Table 2.

3.2 Survey data and sample

The SEANet study, conducted in January 2017, was designed by the SEANet Theme 4: *Human Dimensions of Sustainable Aquaculture* research team at the University of Maine. The survey itself was administered by the GfK Group using a sample from KnowledgePanel®, an online probability-based, representative web panel. The sample was drawn from a target population of English-speaking, non-institutionalized adults age 18 and over living in the United States. Out of 2125 sampled, 1210 participants completed the survey. While the raw distribution of KnowledgePanel® closely represents the population of US adults, results were weighted to the demographic benchmarks set by the most recent Current Population Survey using probability proportional to size (PPS) methodology. In a concluding step, final weights were calculated using an iterative proportional fitting procedure.

3.2 Path Model

To begin answering our research question, we position the thematic variables outlined above as intervening variables between individual demographic characteristics (*age, gender, education, race, income* and *ideology*) and support of aquaculture. Figure 1 visualizes this model as a path diagram, with arrows representing results from the analysis in Table 2. The arrows indicate causal direction for both exogenous and endogenous variables. Only relationships that pass

criteria for statistical significance ($p < 0.05$) are shown. Solid lines indicate a significant positive relationship, while dotted lines represent negative. The thematic variable *recreation,* and the demographic variable *region* were omitted as they were not significant predictors in the final model.

3.3 Results

Figure 2 visualizes the bivariate relationships between intervening variables and *support*, showing the mean score for *support* broken down by participant response to each thematic variable. Adjusted Wald tests showed that all relationships, aside from *EnvProgress,* were statistically significant. Because of this, the graphic for *EnvProgress* was omitted. Figure 2a and 2b show that both *envfragility* and *helpwild* are positively related to *support.* Participants who believe the environment is fragile and those who believed that aquaculture helps to relieve pressure on wild fish populations were more likely to support aquaculture (H1b, H1c). As expected, *economy* is also positively associated with support for aquaculture (H2), with those who agree that aquaculture is a good source of local jobs being more supportive. Also as anticipated, those who trust government officials as a source of information about aquaculture are more likely to be supportive (H3). Higher levels of knowledge (*knowledge)*, the belief that farmed seafood is safer than wild seafood (*safety)* and those that are certain that they have consumed aquaculture products (*eatfarmed)* are also predictive of support (H4, H5 and H6). Lastly, bivariate analysis revealed that contrary to H7, participants who believed that aquaculture operations can interfere with recreation (*recreation)* were surprisingly more supportive of aquaculture activity. However, when controls were added in the full GSEM model, *recreation* lost all predictive power showing that this result is likely spurious.

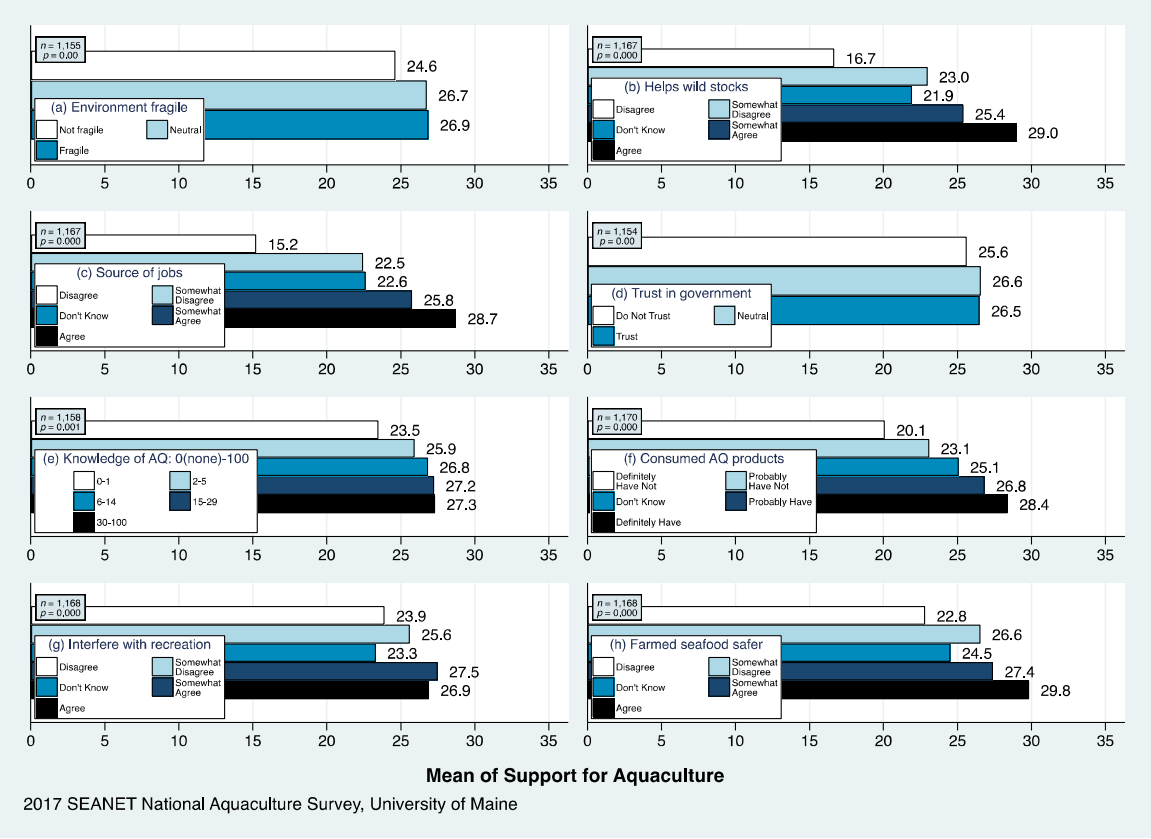

Figure 2. Weighted mean of support for aquaculture broken down by participant views on thematic variables.

While these bivariate visualizations are helpful for understanding the basic direction of these relationships, multivariate analysis allows us to estimate the independent effects of each variable while adjusting for the effects of the other variables included in the model. Using GSEM, we are also able to position demographic characteristics as exogenous variables preceding our set of topical variables in order to gauge both direct and indirect effects on support. These indirect effects are masked in standard logistic regression. Detailed results for the GSEM model are outlined in Table 2.

Table 2. Statistically significant coefficients and standard errors from a generalized structural equation model (GSEM) using probability-weighted ordered logistic regression (n=1,178).

Effect on	**From**	**Coefficient**	**Standard Error**
EnvFragility			
	Gender (F)	.149*	.060
	Ideology (Con)	–.191***	.025
EnvProgress			
	Education	–.042*	.017

	Race	–.245**	.071
	Ideology (NW)	.281***	.023
HelpWild			
	Age	.010***	.003
	Race (NW)	–.389***	.104
	Income	.023*	.011
Economy			
	Age	.010***	.002
	Education	.056*	.024
	Race (NW)	–.364***	.098
	Income	.035**	.010
TrustGovernment			
	Age	.007***	.002
	Gender (F)	–.186*	.074
	Income	.020*	.009
	Ideology (Con)	–.115***	.031
Knowledge			
	Gender (F)	–3.757**	1.237
	Education	.839*	.407
	Race (NW)	4.015**	1.515
EatFarmed			
	Age	.007**	.002
	Gender (F)	–.268***	.071
	Education	.092***	.019
	Income	.025**	.008
Recreation			
	Education	.061*	.024
Support			
	Gender (F)	.834*	.401
	EnvFragility	.775**	.232
	HelpWild	1.328***	.211
	Economy	1.262***	.214
	TrustGovernment	.471*	.215
	Knowledge	.027*	.011
	EatFarmed	1.199***	.205
	Safety	.464**	.163

*p<.05, **p<.01, ***p<.001

Results confirmed H1 through H6. While we did not find a relationship between *recreation* and support, this non-finding is certainly not conclusive. It is likely that the non-association is because *recreation* does not capture the breadth of competing uses. Lastly, contrary to our hypothesis, we did not find a direct relationship between age, education and support (H8). The only demographic characteristic predictive of support was gender. While several previous surveys elsewhere found that women were more concerned with aquaculture development, counter to our hypothesis, U.S. women were significantly more supportive.

In addition to identifying direct predictors of support, GSEM also allows simultaneous evaluation of direct and indirect effects of multiple interrelated variables while assuming causal order. This extends the results of our hypotheses to evaluate which groups hold which perceptions, which in turn influences sentiment. Following the path model shown in Figure 1, Table 2 outlines the significant effects from our set of demographic variables on each endogenous variable, and the effects of each intervening variable on our dependent variable. The table includes both β coefficients and standard error for each equation. Non-significant relationships (p values greater than .05) were excluded from the table for simplification.

As Table 2 describes, *gender* and *ideology* have significant, direct effects on *EnvFragility*. Women and people with more liberal political views are more likely to hold beliefs of environmental fragility. In turn, those who are concerned with environmental fragility are more supportive of aquaculture (p <.001). Those with lower levels of education, whites and political conservatives are more likely to prefer progress despite environmental risk (*envprogress)*, yet this view is not predictive of support for aquaculture. For the final environment variable, *helpwild,* older, white, high-income participants are more likely to agree that aquaculture is a good way to relieve pressure on wild fish populations. *Age, education, race* and *income* are predictive of participant's perceptions of aquaculture's ability to produce jobs. Specifically, older people, highly educated people, whites and those with higher income are more likely to believe that aquaculture is a good source of local jobs (p <.001). Subsequently, those with positive views on aquaculture's ability to produce jobs are more likely to be supportive. Looking at which demographic characteristics predict *trustgovernment*, we see that older people, men, people with higher income and those who identify as more liberal tend to believe that aquaculture information provided by government officials can be trusted, is accurate and fair, and tells the whole story. In turn, this group is significantly more supportive of aquaculture (p <.05).

Knowledge is also directly influenced by certain demographic characteristics. Men, those with higher educations, and non-whites perceive that they know more about aquaculture. Those who believe they are knowledgeable about aquaculture are significantly more supportive (p <.01). *Age, gender, education* and *income* are predictive of whether participants are aware that they have eaten farmed seafood products. Older individuals, men, those with higher education and higher income are significantly more likely to have consumed—or be aware that they have consumed aquaculture products. Subsequently, consumption of farmed seafood is a strong predictor of support (p <.001). Lastly, those who are more highly educated are more likely to believe that aquaculture interferes with recreational activities, though this belief is not related to support.

Interestingly, we found that *safety* is unrelated to demographic characteristics in our model, making it an exogenous variable rather than intervening. Participants who believe that aquaculture products are safer than wild-caught seafood are significantly more likely to support aquaculture (p <.01), and this does not vary by demographic group.

Discussion & Conclusion

Considering the importance of aquaculture for global food security, it is essential to have an understanding of social factors that can influence public perception. This is especially true for an industry that has faced considerable public opposition. Through a systematic review of prior survey research investigating public perceptions of aquaculture, we identified seven themes that influence approval of development and formulated hypotheses as to how these relationships would play out in a U.S. context. We then investigated the validity of these potential indicators

with a U.S. sample and found support for most of the hypothesized relationships. Participants who are concerned with ecosystem fragility, believe that aquaculture helps to restore wild fish stocks, believe that aquaculture is a source of good jobs, are more trusting of government officials, are more knowledgeable about aquaculture, eat more farmed seafood and believe that farmed seafood is safer than wild caught are more likely to support aquaculture development. We did not find support for H7, measuring use-conflict. Using GSEM statistical techniques, we were also able to assess how individual demographic characteristics influence support directly and indirectly through mediating perception variables. Analysis revealed that demographic characteristics effect support primarily through indirect pathways. Gender was the only demographic characteristic directly related to support, with females holding more positive sentiment.

These findings have several implications for ocean and coastal development and policymaking., First and foremost, public perception research identifying issues of importance surrounding aquaculture development could guide more socially sustainable growth. For example, our results confirm that people are more supportive of aquaculture when they recognize environmental and economic benefits. Maintaining rigorous regulatory standards for environmental stewardship and seafood safety, expanding opportunities for low-input, net positive operations, and incentivizing new businesses to hire local, year-round employees are strategies that would likely improve social sustainability.

However, most notably these findings provide guidance for developing strategic knowledge campaigns or raising public awareness about aquaculture. It is well known that public understanding of aquaculture is limited (Robertson et al. 2002; Mazur and Curtis 2006; Freeman et al. 2012; Alexander et al. 2016; Murray et al. 2017). Echoing others, our analysis shows that enhanced knowledge of aquaculture is associated with support (Robertson et al. 2002; Thomas et al. 2018; Rickard et al. 2020). Further, increased experience with aquaculture—in this case, through consumption, is also positively associated with support. Thus, initiatives aiming to raise awareness of farmed seafood could enhance support for coastal aquaculture development. However, considering levels of knowledge and awareness vary by social group, targeted initiatives may be most effective. Women, participants with lower levels of education, and whites rated their knowledge lowest. Similarly, women and less educated participants were less confident that they had consumed aquaculture products. Campaigns aiming to foster awareness in these groups would likely have more impact than initiatives designed for broader audiences.

Additionally, our results show that certain groups are less likely to trust information about aquaculture provided by government officials. Two of these groups—women and those with lower levels of education, overlap with the target groups above. As many individuals have misgivings about information from government, our efforts to inform the public about aquaculture may need to engage non-governmental organizations and key private sector actors such as supermarkets. Our results suggest broadening outreach and targeting key groups could be beneficial.

Relatedly, laws and regulations could play an important role in bolstering approval. In 2005, a law passed that required seafood sold in stores be labeled as wild-caught or farm raised (C.O.O.L. §60.300). Though the law has faced criticism (Mullins 2010), expanding labeling in stores to contain more information about growing methods and making that information highly visible could increase awareness. This strategy could be particularly effective for increasing knowledge among women, considering they continue to be the primary shoppers in most households (Pew Research Center 2019). Further, the source of this information would be

coming from food purveyors rather than government officials, potentially increasing receptiveness among women and those with lower levels of education.

Findings from our study also add to our understanding of the way environmental values influence perceptions of aquaculture. While the environment is often centerpiece to local conflicts, our results validate recent findings showing that nationally, pro-environmentalists tend to support aquaculture development and that supporters are not more or less likely to value progress despite environmental harms (Rickard et al. 2020). This complicates a common narrative that links environmental activism to anti-aquaculture sentiment—a link that is likely strengthened by high-profile opposition cases where well-resourced groups and environmental NGOs combat development on an environmental platform. While these cases provide insight into specific environmental concerns, this analysis shows that more broadly, pro-environmentalists are supportive of aquaculture. Further, our results confirm that the recognition of specific environmental benefits of aquaculture is a strong predictor of support and that older individuals, whites and those with higher incomes are more likely to recognize benefits. Campaigns aiming to increase awareness of the environmental benefits of aquaculture—specifically the reduction of pressure on wild stocks, may be more effective in bolstering support if tailored to younger, non-white, lower income individuals.

Lastly, this study demonstrates the value of quantitative analytical techniques as a policy resource as they provide a rigorous method for identifying broader patterns of perceptions and can give the general public a voice. Integrating such broader perspectives with locally-situated stakeholder engagement may be key to crafting socially sustainable coastal management policy. Additionally, GSEM in particular allows researchers to identify direct and indirect effects following a causal model, thus identifying factors that might otherwise have been overlooked despite their importance. Here, GSEM allowed us to position perception measures as intervening variables between demographic characteristics and support. With this path model, we were able to identify which groups were most likely to hold perceptions that were predictive of support for aquaculture, thus providing insight into how to create more targeted outreach and engagement initiatives.

However, quantitative analysis on this scale also has limitations. While there are clear benefits to looking at broader patterns—especially when crafting policies that will be applied uniformly across states, it is important to note that quantitative analysis on this scale can miss local variation. Considering experience with aquaculture can shape perceptions of support, certain communities may be more or less supportive of aquaculture due to local interaction with aquaculture operations or impacts from neighboring farms. A second major limitation to this analysis is the lack of specificity of aquaculture type. Survey items from this questionnaire asked participants about aquaculture generally, despite there being various cultivation methods for various species. These methods differ significantly in size and environmental impact. Net-pen operations, for example, can be highly intensive and can present several environmental risks like the escape of non-native species, disease transmission to wild populations and impacts from fish waste. On the other hand, shellfish aquaculture requires limited inputs and has been shown to improve water quality. Other technologies such as land-based recirculating aquaculture systems can raise concerns over effluent or fish welfare. However, despite this real complexity, scholars have found that in addition to limited awareness of aquaculture generally, knowledge of differences between types of aquaculture is also limited (Robertson et al. 2002; Alexander et al. 2016; Thomas et al. 2018). It is likely that this is true in the U.S., thus the public's conception of aquaculture may be homogenous despite these real differences. While more research is needed to

investigate the extent to which perceptions vary by aquaculture type, this analysis shows that support is socially patterned nonetheless, demonstrating the utility of a generalized measure of aquaculture support.

Overcoming negative perceptions of the industry is key if aquaculture is to reach its full potential in the U.S. Considering policy and development initiatives are often national in scale, research intending to better understand public opinion of aquaculture nationally is key. Collated from research in other parts of the world, this paper tests the validity of a series of evidenced predictive indicators of approval for aquaculture in a U.S. context, finding support for six of seven variables. Further, this analysis incorporates demographic variables that could inform strategic information campaigns. While more research is certainly needed, this analysis confirms that environmental benefits, economic benefits and the safety of aquaculture are important factors in public sentiment and that those who eat more farmed seafood, who trust regulating agencies and who are more knowledgeable are more supportive. Armed with this information, policy-makers and industry advocates will be better able to develop a socially sustainable industry that garners support by addressing concerns.

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APPENDIX A

Study	Aquaculture Type	Geographic Scope	Environment	Economy	Knowledge	Use Conflict	Experience	Govt. & Regulation	Health & Safety
Alexander et al. 2016	IMT	Multinational: Ireland, Israel, Italy, Norway, UK	■		■				
Alexander et al. 2018	IMT	Multinational: Ireland, Israel, Italy, Norway, UK	■		■				
Bouchard et al. 2021	Finfish, Shellfish, Sea	Regional: Atlantic States, USA			■				

	Vegetables								
Chu et al. 2010	All	Cross-national: Norway, USA							
Claret et al. 2014	Finfish	Regional: Spain							
Dalton and Jin 2017	Shellfish	Regional: 3 coastal regions, RI, USA							
Fernandez-Polanco and Luna 2012	All	National: Spain							
Flaherty et al. 2018	Mariculture	Regional: coastal Vancouver Island & CA Maritime							
Freeman et al. 2012	Mariculture	Multinational: Israel, Germany							
Hynes et al. 2018	Finfish	Cross-national: Norway, Ireland							
Krovel et al. 2019	Finfish	National & local, Norway							
Mazur and Curtis 2006	Finfish, shellfish	Regional: Australia							
Mazur and Curtis 2008	Finfish, shellfish	Regional: Australia							
Murray and D'Anna 2015	Shellfish	Local: Baynes Sound (Vancouver & Denman Isl)							
Murray et al. 2017	All	National: USA							
Outeiro et al. 2018	Finfish	National: Chile (tourists)							
Rickard et al. 2020	All	National: USA							

Robertson et al. 2002	Offshore	Local: Hampden Beach, USA			■				
Safford and Hamilton 2012	All	Regional: Hancock & Washington County, ME, USA	■	■					
Shafer et al.2010	All	Local: Banks Peninsula and Christianchurch, New Zealand				■	■		
Sinner et al. 2020	All	National: New Zealand	■	■	■	■	■		
Thomas et al. 2018	Seaweed, mussel, finfish	Regional: Sweden, west coast	■	■	■	■	■		
Whitmarsh and Palmieri 2009	Salmon	Regional: Scotland	■	■					
Whitmarsh and Palmieri 2011	Salmon	Regional: Scotland	■			■	■		
Whitmarsh and Wattage 2006	Salmon	Regional: Scotland	■	■					■