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Studies in Consumption and Production of South Carolina Aquaculture Products

David Cheplick
dchepli@clemson.edu

STUDIES IN CONSUMPTION AND PRODUCTION OF SOUTH CAROLINA AQUACULTURE PRODUCTS

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by
David Samuel Cheplick
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Accepted by:
Dr. Marzieh Motallebi &
Dr. Juan Carlos Melgar, Committee Chair(s)
Dr. Michael Vassalos

ABSTRACT

Market demand for seafood products among South Carolina (SC) consumers has led to increased aquaculture production as a means of supporting the seafood supply chain across the state. Our objective is broken into four distinct parts; (1) understanding consumer's preferences and perceptions of seafood, (2) calculating their willingness to pay (WTP) for seafood products available in SC using attributes of sustainability and locality; and (3) gathering production metric and anecdotal data from SC oyster growers. Previous research assessing the market channels of seafood in South Carolina is compared to survey results. Respondents indicated that taste and quality were the most important factors considered when purchasing seafood, while production method, wild-caught or farm-raised, was the least important attribute. Using a discrete choice experiment (CE), two shellfish products available in South Carolina, oysters, and shrimp are used to measure consumers' willingness to pay for these products based on labels describing the source of origin and ecolabels relating to sustainability. Our results show that South Carolina consumers are willing to pay more for local, sustainably wild-caught clams, and shrimp, and more for local, sustainably farm-raised oysters. Lastly, interviews with SC oyster growers were conducted to understand the scale of these operations based on production metrics. This information was then utilized to assess whether implementation of an ecolabel for oyster growers to certify their production process to be sustainable.

DEDICATION

I would like to dedicate this thesis to my partner, Roshni Mangar, for all your love, support, and encouragement over these past two years. In what was supposed to be a two week break to visit you, became a one and half year journey that has been a shining light amidst the COVID-19 pandemic. I have much to learn, and you have shown me the value of hard work, a holistic mindset, and most of all, to believe in myself. I love you. This thesis is dedicated to my father, David, and my stepmother, Elizabeth Veatch, who remind me to be true to myself, and enjoy each moment along the way. To my sisters, Marissa, and Julie, who champion what it means to see every objective through from start to finish, thank you for setting an example of building success for me to follow. Lastly, I would like to dedicate my work to my mother, Linda, who's spirit of curiosity and determination will forever live on.

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CHAPTER ONE

SEAFOOD CONSUMPTION PREFERENCES AND ATTRIBUTES INFLUENCING AWARENESS OF SOUTH CAROLINA AQUACULTURE PRODUCTS

Introduction

Food fish production from aquaculture currently accounts for 53% of the global supply of seafood and since 1961, consumption of seafood has increased by 1.5% annually (United Nations Food and Agriculture Organization, 2020). In the U.S., total seafood consumption has increased 25% from 1980 to 2018 and is currently ranked as the highest seafood importing country in the world. (National Oceanic and Atmospheric Administration, 2020; USDA, 2018; FAO, 2020). A majority of the seafood that is imported to the U.S. is farm-raised, lending to the overall impact aquaculture has on the seafood supply chains in the U.S. (Shamshak et al., 2019). Due in part to the high volume of seafood imports since the 1970's, the U.S. currently faces an annual seafood trade deficit of $18 billion, with aquaculture products accounting for roughly half of that deficit (Abolofia, Asche, & Wilen, 2017; Bostock et al., 2010; Love et al., 2020).

Historically, U.S. aquaculture production constituted a double-digit share of the global market (e.g., 10% in 1951), but production has declined and only represented 1% of global output in 2016 as global expansion of aquaculture production dramatically increased (Garlock et al., 2020b). Marginal growth in gross production of U.S. aquaculture has been documented since 2010, with the situation being referred to as a "stagnation" of U.S. aquaculture (Hargreaves, 2017; van Senten & Engle, 2017). While U.S. domestic aquaculture production has seen slower growth as compared to consumer

demand since 2000, aquaculture products are now comparable in market price to wild-caught seafood, meaning a higher return on investment for aquaculture producers (Asche, Bjørndal, & Young, 2001; Verbeke et al., 2007). It is in this vein that bridging the gap between consumer's knowledge regarding seafood and their purchasing habits continues to be an objective of many state and federal agencies in addressing the production deficit that the U.S. is facing. In this study, we investigate SC coastal and inland consumer perceptions towards aquaculture products and their respective consumption across a variety of species and market outlets. To address the current gap in knowledge regarding intra-state travel relating to seafood consumption, or residents of one region of a state traveling to another region to purchase seafood products, we collected data on seafood preferences of inland residents who indicated they had traveled to a coastal county and purchased seafood (Jodice & Norman, 2020). Additionally, previous research has explored the role of how agricultural industries influences rural community development in SC based on the broader communities' support of these industries (Robinson et al., 2007). Using Principal Components Analysis (PCA), a form of data reduction across multiple similar variables, provides a method for understanding what underlying economic and social considerations influence communities support of lack of support for establishing an aquaculture industry.

The U.S. aquaculture industry appreciably contributes to domestic seafood consumption, but despite recent increases still lags worldwide production (Garlock et al., 2020a; Thong & Solgaard, 2017) and is unable to satisfy the demands of US markets (Carlucci et al., 2014; Love et al., 2020). Barriers to increasing the gross aquaculture

production in the U.S., vary depending on suitable water quality, local infrastructure, labor, and the presence of existing markets (Gibbs, 2009, Tango-Lowy & Robertson, 2005). Some of the potential reasons for the stagnation of gross aquaculture production in the U.S. include the small-scale nature of many aquaculture operations, production taking place in public waters, social opposition across a wide range of stakeholders, and the complex processes behind leasing and permitting as key reasons for the underutilization of aquaculture production in the U.S. (Knapp & Rubino, 2015; Risius, Janssen & Hamm, 2017; Whitemarsh & Palmieri, 2009). In terms of shellfish mariculture operations, regulatory costs remain a major barrier. A survey of producers on the west coast of the U.S., who collectively made up 74% of the region's gross shellfish mariculture production, found that regulatory costs associated with permitting make up 29% of the firm's operational costs (van Senten et al., 2020).

Research focused on consumer preferences and perceptions of seafood products has focused on the attributes consumers use when making purchasing decisions, segmenting the demographic and non-demographic factors that influence these decisions (Bouchard et al., 2021; Chu et al., 2010; Flaherty et al., 2019; Roheim, Sudhakaran & Durham, 2012). A systemic literature review by Carlucci et al. (2014) identified numerous factors influencing global fish consumption including the high cost of seafood products, concerns of health risks, adversity to preparing seafood and concerns over fish stock abundances among others. A survey investigating the perceptions of aquaculture products in the Northeast U.S. found that aquaculture products were perceived to be of higher food quality and safety than comparable wild harvested seafood products (Gall &

O'Dierno, 1993). Respondents from the same survey perceived aquaculture products to be more expensive than wild harvested products (Gall & O'Dierno, 1993).

Empirical surveys documenting consumers' preferences and perceptions towards seafood have sought to elucidate the patterns associated with a higher affinity towards seafood and aquaculture products, and attributes used when making seafood purchases such as labelling associated with locality and sustainability (Carlucci et al., 2017; Chu et al., 2010; Thapa, Dey & Engle, 2015). A metric that is commonly collected in seafood consumer surveys is the frequency of seafood purchases among consumers (Davidson et al., 2012; Gall & O'Dierno, 1993; Hicks, Pivarnik & McDermott, 2008). In the northeastern U.S, higher frequency of seafood purchases for in-home consumption was associated with older age groups, residence in urban or suburban areas and participation in recreational fishing activities (Herrmann et al., 1994). Following the findings of Herrmann et al. (1998) regarding population segments of recreational anglers having higher frequency of seafood consumption, Perkinson, et al. (2020) investigated seafood consumption patterns of recreational anglers in Charleston and Berkeley counties in South Carolina (SC) and found that more than 25% of respondents ate seafood twice a week or more.

Labelling schemes of seafood products and consumer's perception of where seafood is sourced continues to be a focus of consumer survey research. Specifically, surveys seek to extract empirical evidence on the impact labelling and other attributes have on consumer decision-making. Bouchard et al. (2021) surveyed consumers across the U.S. east coast and found that those who more frequently sought out labelled seafood

products, such as being farm-raised or regional identification, were more informed about aquaculture practices, older and generally had a more positive attitude towards aquaculture products. However, consumers in Hawaii reported a higher affinity for wild-caught identified seafood products (Davidson et al., 2012). While Fonner and Sylvia (2015) found that consumers in Oregon had a higher willingness to pay for seafood that displayed eco-labelling and was marketed as locally sourced.

Aquaculture along the southeastern U.S. coast is largely concentrated on shellfish mariculture production, specifically of Eastern Oyster *Crassostrea virginica*, apart from Florida where 98% of shellfish mariculture production is Hard Clams *Mercenaria mercenaria* (National Agriculture Statistics Service, 2013). The need for feedback from seafood consumers on what products they purchase, where they purchase them, and demand for alternative seafood options is evident as fledgling aquaculture operations have difficulty establishing themselves (Brayden et al., 2018; Gibbs, 2009 Whitmarsh & Palmieri, 2009). The SC aquaculture industry is embryonic: In 2018, the SC aquaculture sector was valued at slightly more than $4 million with 24 farms, which is a loss of 8 farms and 14% in revenue since 2013 (USDA, 2018). In SC, the number of freshwater aquaculture farms specializing in the production of catfish and tilapia has declined 20% since 2013, while the number of mariculture operations has increased 40% (USDA, 2018). This increase is largely occurring on farms involved in the off-bottom shellfish production of oysters (USDA, 2018).

Evaluating the demand for seafood and aquaculture products in South Carolina has been previously documented in a comprehensive economic impact report conducted

in 2008 on the market channels for seafood products in SC and the breakdown of sales of imported and exported products (Henry et al., 2008). Henry et al. (2008) provided vital information on the trends of local aquaculture production and accessibility of local aquaculture products to in-state distributors. For our purposes, we used the per-capita consumption values of various seafood products from this report as a baseline for seafood consumption in SC. It is important to provide context about baselines in seafood consumption, as supply and demand of seafood products have fluctuated substantially nationwide over the last decade. On average, Americans consumed 16.1 pounds of seafood in 2018, the highest consumption rate since 2007, hence the shirting baseline during the study by Henry et al (2008) captures a time step where average seafood consumption nationwide had decreased up until 2018 (NOAA, 2020). Using data collected by Henry, Rhodes & Eades (2008) as a baseline, our objective is to update our understanding of seafood consumption trends through empirical sampling of seafood consumers in SC.

Materials and Method

Survey

The perception towards and consumption of seafood in South Carolina focusing on aquaculture-produced species was evaluated utilizing a reputable online survey distributer, Qualtrics. Questions on the survey were pretested by select South Carolina residents, Clemson Extension, and South Carolina Sea Grant Consortium personnel, and revised as necessary. Surveys were distributed to random households across all 46 counties in South Carolina. Surveys consisted of screening, lifestyle, shopping

preference, and demographic questions. Screening questions were used to limit participants to the targeted population: SC residents 18+ years of age who consumed seafood. For simplicity both marine and freshwater species are lumped under the term seafood. A total of 1,947 respondents from all 46 counties in South Carolina matched screening criteria. Survey participants were queried about household consumption and perception of wild and raised seafood. Data on species, market outlets, and season preferences also were collected. A major portion of the survey inquired about consumer's perceptions of aquaculture in general and South Carolina's fledgling aquaculture industry in specific.

Respondents were asked to choose up to three most frequently consumed seafood products from a provided list of seafood products. This list of fish and shellfish products was comprehensive but not exhaustive, therefore seafood products representative of certain localities may not be represented among the choices available. To account for choices not represented, the survey included an "other" option as a choice. Of note, canned tuna in this survey was not differentiated between fresh, frozen and prepared products, which has been differentiated in similar surveys (Gall & O'Dierno, 1993). Shellfish options listed in the survey included bivalves such as clams, oysters, and mussels and crustaceans such as crab and shrimp. Shellfish products in this survey were not differentiated between being consumed cooked or raw, as is the case with clams and oysters on the half-shell (Murray & D'Anna, 2015).

Respondents were also asked to select up to three of the most purchased farm-raised seafood products, in addition to the three most desired farm-raised seafood

produced in SC, assuming these products were available. The option "none" was included among the choices as a proxy for respondents who would not purchase farm-raised seafood products in any capacity. The objective of this question was to assess the market potential of local aquaculture products based on possible consumer demand. Other sections in the survey include asking respondents their three most frequently visited market outlets for purchasing seafood, familiarity with seafood certification labelling, the importance of attributes when making seafood purchases, and which sources of information are preferred to obtain information about seafood. Institutional approval for conducting our consumer survey through the third-party survey platform, Qualtrics, was approved by Clemson University's Internal Review Board (IRB) in January 2020.

Principal Components Analysis

In our survey, a series of questions were posed to respondents regarding their perception of the impact that the aquaculture industry can have on economic well-being of a community, particularly rural communities. Evidence of implicit and explicit support from community members, including those involved in the food production industries, for local agricultural industries in the Lowcountry of South Carolina has the potential to retain revenue for surrounding communities (Robinson et al., 2007). In turn, collecting empirical data from South Carolina consumers of aquaculture products on their perceptions of the economic impact a local aquaculture industry can have on the broader community is an important step to assess dynamics between industry and community. The statements provided to respondents all relate to the socioeconomic impact of the aquaculture industry on surrounding communities, and therefore share common

underlying themes that make this data prime candidates for data reduction through PCA (Wold et al., 1987). Using PCA relies on overcoming several assumptions in the suitability of data inputs, in the case of assessing aquaculture on community development, through Likert scale responses. These assumptions include (1) that data should be either continuous or ordinal; (2) there must be a linear relationship between variables in the model; (3) a sufficient sample size as indicated by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, a test statistic that will be reported in our model; (4) data should be suitable for reduction and (5) no significant outliers should be present (Laerd Statistics, 2021). The purpose of asking questions revolving around the economic impact aquaculture poses for rural community development is to develop a community development index (CDI), by reducing four statements presented to respondents that are described in Table 1.1.

Table 1.1: Community development statements for principal components analysis

COMMUNITY DEVELOPMENT INDEX	DEFINITION	FULL STATEMENT
Employment	"1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree"	As an industry, aquaculture creates additional employment opportunities for residents
Entrepreneurial	" " "	Aquaculture development creates additional entrepreneurial opportunities for residents
Economic diversity	" " "	A local aquaculture industry enhances the economic diversity of a community
Broader economic impacts	" " "	Aquaculture firms provide broader economic impacts within their communities

PCA relies on comparing variance between initial variables, in our case the community development index terms that have been adapted from the full statements provided to respondents, to calculate the optimal number of reduced terms. We first start by describing the structure of the equation for covariance of the four variables in the following equation:

$$Cov\begin{pmatrix} Employment, Entrepenurial, Economic\ diversity, \\ Broader\ economic\ impacts \end{pmatrix} =$$

$$\frac{1}{n-1}\sum_{i=1}^{n}(Employment\ i - \overline{Employment})\,(Entrepenurial\ i - \overline{Entrepenurial})\,(Economic\ diversity\ i - \overline{Economic\ diversity})\,(Broader\ economic\ impact\ i - \overline{Broader\ economic\ impact})$$

In the initial data reduction process, covariances are derived for all possible pairs of initial variables, in a covariance matrix structure. The initial variables described in Table 1-A, takes the form of the variance covariance matrix that measures how each initial variable is associated with one another:

$$\begin{bmatrix} Cov(Employment,\ Employment) & Cov(Employment, Entrepenurial) \\ Cov(Employment, Economic\ diveristy) & Cov(Employment, Broader\ economic\ impact) \quad (1) \\ Cov(Entrepenurial, Employment) & Cov(Entrpenurial, Entrepenurial) \\ Cov(Entrpenurial, Economic\ diversity) & Cov(Entrpenurial,\ Broader\ economic\ impact) \quad (2) \\ Cov(Economic\ diveristy,\ Employment) & Cov(Economic\ diversity,\ Entrepenurial) \\ Cov(Economic\ diversity,\ Economic\ diversity) & \\ Cov(Economic\ diversity, Broader\ economic\ impact) & (3) \\ Cov(Broader\ economic\ impact,\ Employment) & Cov(Broader\ economic\ impact,\ Entrepenurial) \\ Cov(Broader\ economic\ impact,\ Economic\ diversity) & \\ Cov(Broader\ economic\ impact,\ Broader\ economic\ impact) & (4) \end{bmatrix}$$

Covariance matrix of statements

In determining the correlation between variables, and in turn the optimal number of principal components to retain, the direction in which the variables are dispersed, known as eigenvectors, and their associated eigenvalues measuring the variability of correlations between variables are calculated.

One of the primary limitations of this study revolves around respondents' demographics. Utilizing online survey platforms is a cost-minimization strategy for data collection, but is inherently limited by selection biases of survey companies (Wright, 2006). Primarily, two selection biases occur, online survey companies may not be able to recruit participants representative of the general population, and as such may not be able to meet target demographic groups to ensure a representative sample population. Secondly, online surveys eliminate households without access to the internet. Based on the estimates from the American Community survey (U.S. Census Bureau, 2019), 81.6% of households have broadband internet access. It is assumed that the exclusion of the population of households without Internet may result in a geographic and socioeconomic sample bias at a minimum.

Results

Sociodemographic data of survey respondents

Survey respondents resided in each county across South Carolina (Figure 1.1) and tended to be younger, well educated, and long-term state residents. A majority, 72%, resided in non-coastal counties with the seven most populous counties contributing 12% (Greenville), 9% (Charleston), 8% (Richland), 8% (Horry), 6% (Spartanburg), 6% (Lexington), and 5% (York) of all surveys collected. Sociodemographic data of survey

respondents is weighted according to American Community Survey 1-year estimates to accurately report various sociodemographic characteristics of our sample population (U.S. Census Bureau, 2019).

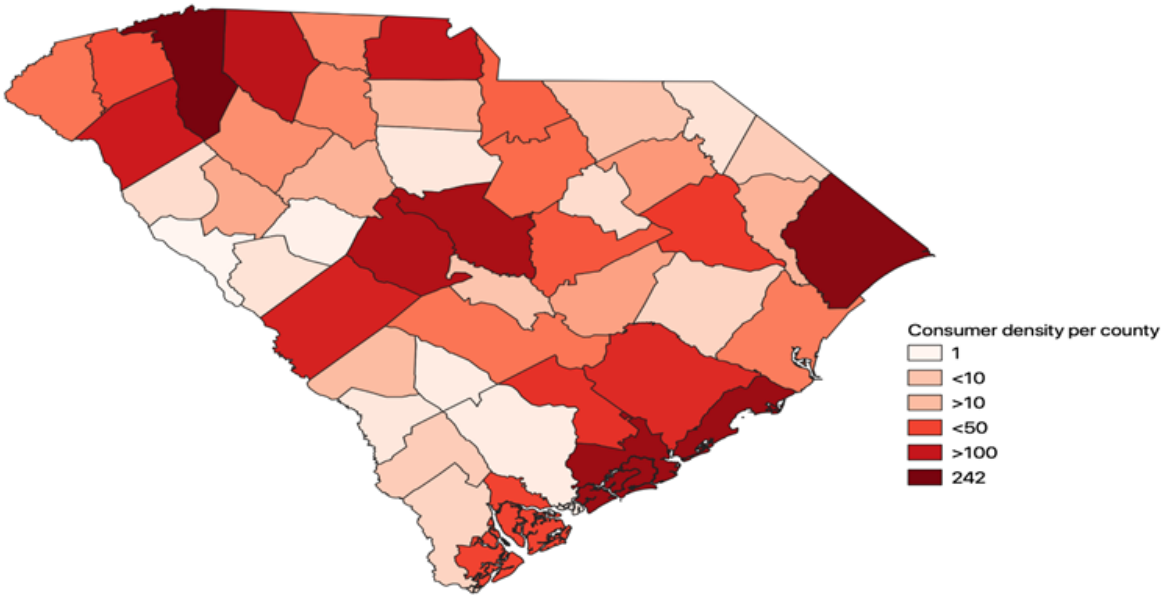

Figure 1.1: Respondent density per county

The average age of respondents was just under 44 years old and a majority, 69%, were female (Table 1.2). Average household income in 2019 was just under $65,000 and education level was 15.3 yrs. equaling between 3 to 4 years of post-secondary education. Households typically consisted of four family members including adults and were South Carolina residents for just under 19 years, highlighting that most survey participants were long-term residents of the state.

Table 1.2: Sociodemographic data of survey respondents

Variable	Definition	Obs.	Sample Average	Std. Dev.	Min.	Max.	State Average[c]
Respondent location	1 if inland, 0 if coastal county	1947	0.72	0.31	0	1	0.71
Gender	1 if male, 0 if female	1947	0.31	0.27	0	1	0.48
Age[a]	Average age in years	1947	43.6	15.82	18	100	39.9[d]
Income[a]	Average 2019 household income	1947	$65,000	$56,000	0	>$500,000	$56,277
Education[b]	Education in years	1947	15.34	1.98	9	19	13.46
Household members	Including survey respondent	1947	3.00	1.78	0	9	2.54
Residency[a]	Years residing in SC	1947	18.93	10.05	0	50	--
Race and ethnicity							
	Native American or Alaskan Native	15	0.008	--	--	--	0.004
	Asian	25	0.013	--	--	--	0.017
	Black or African American	393	0.2	--	--	--	0.26
	Hispanic or Latino	43	0.022	--	--	--	0.058
	Native Hawaiian or Pacific Islander	2	0.001	--	--	--	0.001

	White or Caucasian	1446	0.74	--	--	--	0.66
	Other	28	0.014	--	--	--	0.001
Employment							
	Employed	1208	0.62	--	--	--	0.58
	Unemployed	158	0.08	--	--	--	0.03
	Not in labor force	581	0.3	--	--	--	0.4

[a]Values are represented by using median values from categorical choices in the survey
[b]Values are represented by categorical choices, starting with Some High School and increasing to a Graduate Degree
[c]State level values are based on 2019 ACS 1-Year Estimates
[d]Age at the state level is based on individuals of 25 years or old

Seafood consumption

Frequency of seafood consumption in restaurants compared to at home varied among SC consumers (Table 1.3). 37% of respondents reported consuming seafood once a month at home, while 58% of respondents reported consuming once a month at restaurants, alluding to the higher frequency of consuming seafood at home (Table 1.3). While most species were consumed equally across seasons, oyster, crab, and shrimp consumption seasonally varied.

Table 1.3: Summary of respondent's seafood consumption frequency

Variable	Average per-capita frequency of consumption	
Frequency of seafood purchases	Prepared at home (%)	Prepared at restaurants (%)
Several times per week	18.2	8.8
Weekly	22.7	12.8

Bi-weekly	21.8	20.8
Monthly	37.3	57.6

Oyster consumption increased during winter months, and crab and shrimp consumption increased during summer months (Figure 1.2). Consumption of crab species, such as the Blue Crab, is higher among coastal residents than their inland counterparts, while inland residents who traveled to the coast and purchased crabs had the highest rate of reported consumption among respondents (Figure 1.3). We found that for consumption of aquaculture products in particular, salmon, shrimp, tilapia and catfish were the four most consumed aquaculture products (Figure 1.4). Interestingly, farm-raised shrimp is the second most consumed aquaculture product globally, followed by farm-raised salmon, farm-raised tilapia, and farm-raised catfish, in that order since 2016 (FAO, 2020).

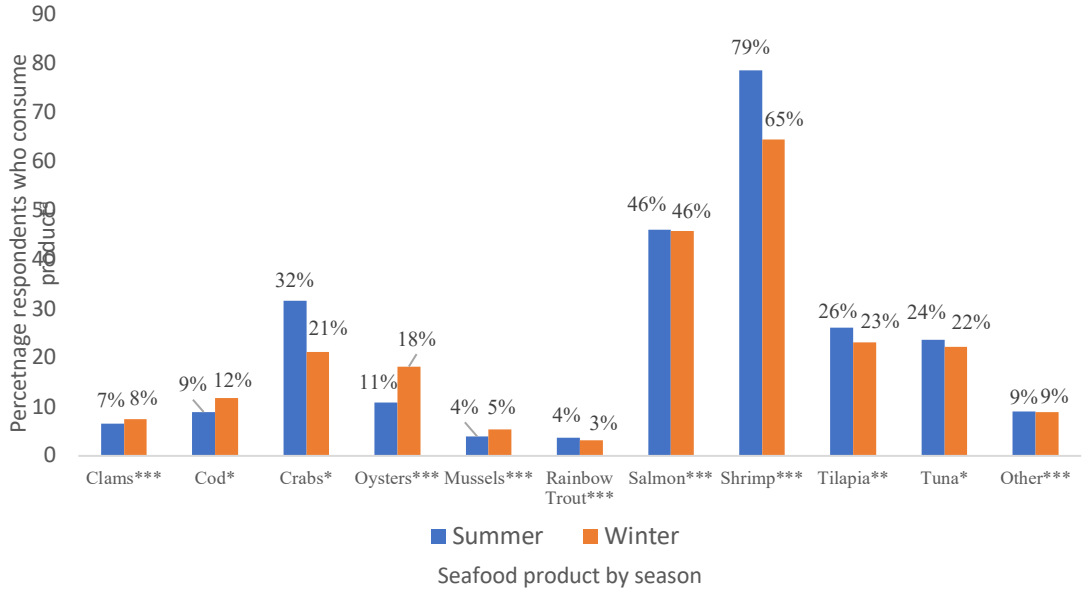

Figure 1.2: Seafood product choices by season among survey respondents

*Wild-caught seafood only

**Farm-raised seafood only

***Both wild-caught and farm-raised seafood

[a]Up to three seafood products could be selected

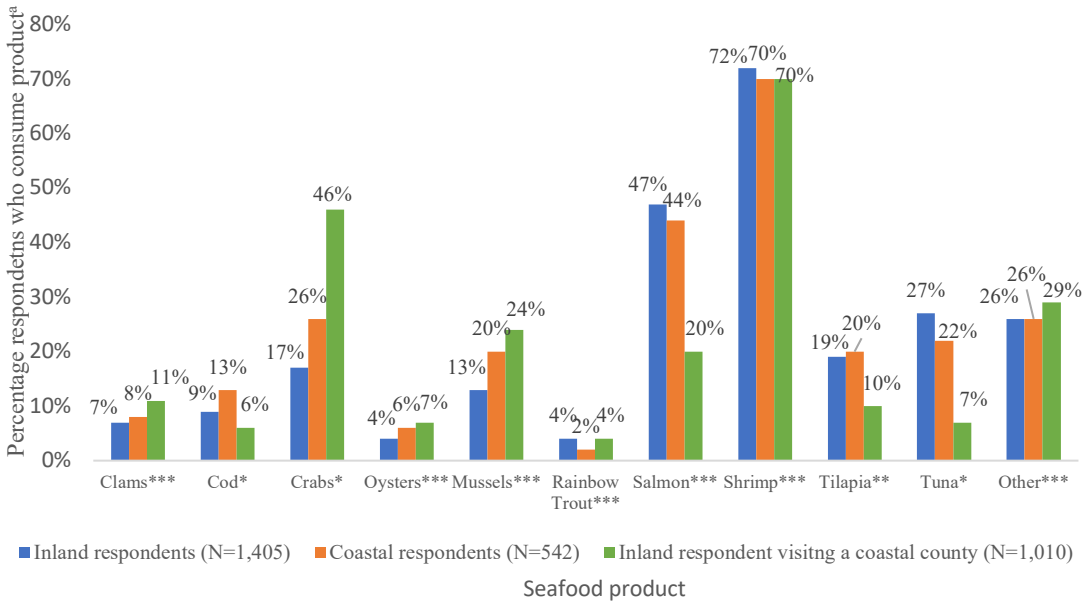

Figure 1.3: Seafood product choices by locality among survey respondents

*Represents wild-caught seafood only

***Represents both wild-caught and farm-raised seafood

[a]Up to three seafood products could be selected

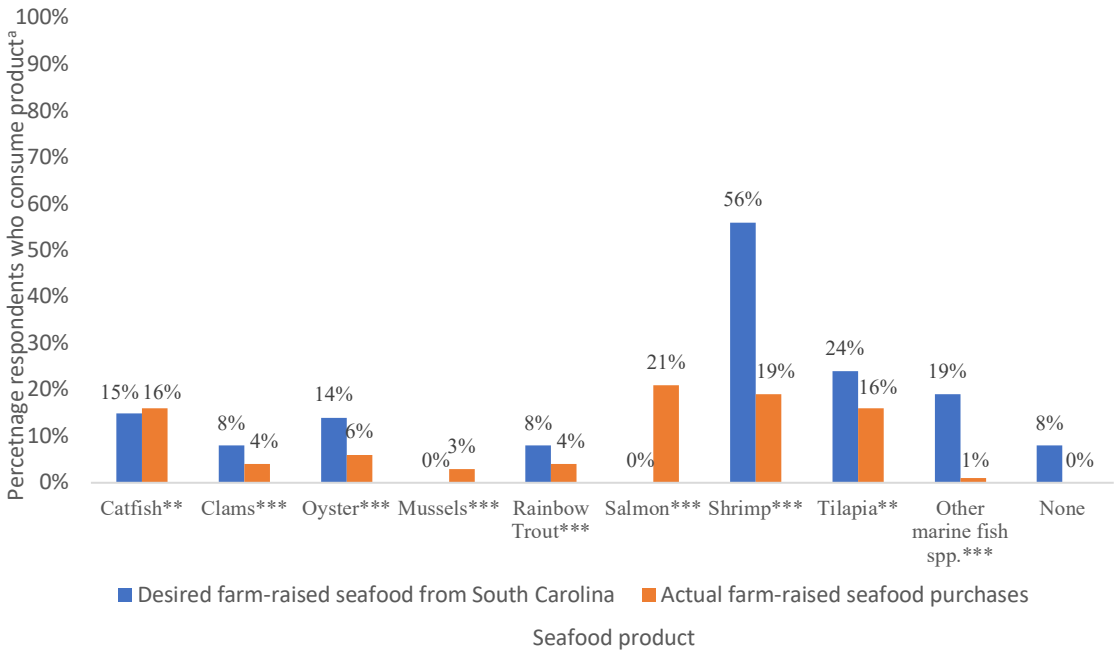

Figure 1.4: Aquaculture product choices among survey respondents
**Represents farm-raised seafood only
***Represents both wild-caught and farm-raised seafood
[a]Up to three seafood products could be selected

Market Outlet

Grocery stores are the market outlet of choice (82%) for the majority of seafood purchased for in-home consumption. The segment of inland residents who indicated they had purchased seafood while visiting a coastal county were also asked to provide the three market outlets where they purchased seafood on the coast. The purpose of this question was to compare purchasing behavior between respondents purchasing seafood near their residence as opposed to when they visit coastal communities. Among coastal and inland respondents purchasing seafood near their residence, more than 70% revealed they purchase seafood from grocery stores (Figure 1.5).

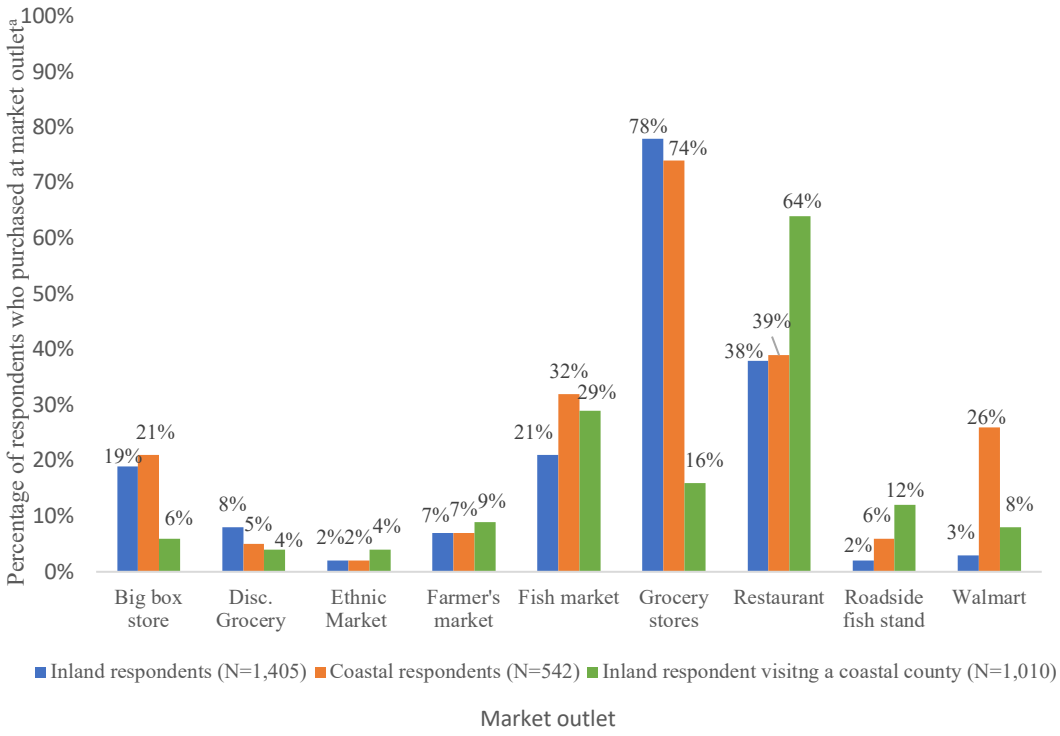

Figure 1.5: Choices of market outlet among survey respondents
[A]Up to three market outlets could be selected

A majority of inland respondents visiting a coastal county (64%) purchased seafood at restaurants, and the proportion of inland respondents visiting a coastal county who purchased seafood at grocery stores fell to 16%. Respondents reported average monthly spending of $76.00 on seafood products across all market outlets and nearly 56% of seafood purchased was cooked as opposed to raw.

Labelling

We found that 47% of respondents have purchased seafood labelled as farm-raised, 44% had not, and 9% indicated they did not know whether they had purchased seafood that was labelled as farm-raised (Table 1.4). When respondents were asked

whether they recognized any labelling signifying their seafood was farm-raised in SC, only 38% had any awareness of labelling for local farm-raised seafood. Results of seafood source recognition and labelling, including recognition of Best Aquaculture Practices (BAP) label, the Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) ecolabels shows that 57% of respondents recognized farm-raised seafood products labels, while a much smaller group of respondents recognized BAP, ASC, and MSC (Table 1.4).

Table 1.4. Summary of ecolabels for seafood and aquaculture products

Variable	Definition	Average
Recognition of aquaculture labelling organizations		
Label specifying seafood is farm-raised	(1=Yes, 0=No)	0.57
Certified SC Seafood[a]	(1=Yes, 0=No)	0.38
Best Aquaculture Practices (BAP)	(1=Yes, 0=No)	0.29
Marine Stewardship Council	(1=Yes, 0=No)	0.37
Aquaculture Stewardship Council	(1=Yes, 0=No)	0.32

[a]As of 2019, the SC Department of Agriculture created the SC Certified Seafood Program including aquaculture products

Survey respondents (68%) believed that most of the seafood they purchase was sourced either locally or domestically to the U.S. (Figure 1.6).

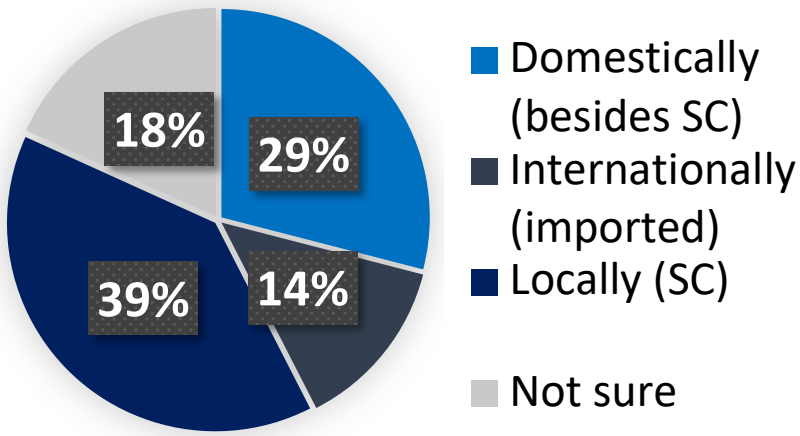

Figure 1.6: Consumer's perception of where the majority of seafood available in SC is sourced

Seafood Attributes

Taste, quality, and cost were the three most important decision-making criteria for purchasing seafood. Conversely, cooking time and whether the seafood product is farm-raised were found to be the least important factors when purchasing seafood. Table 1.5 highlights respondents were satisfied overall with the quality and variety of seafood at both grocery stores and restaurants. Respondents were familiar with the differences between farm-raised and wild-caught seafood production methods; however, they were unfamiliar with the actual species that farm-raised in South Carolina. Finally, we found that consumers were very likely to purchase local aquaculture products as evidenced by a

Likert score of 4.1, based on a 5-point Likert scale (1-very unlikely, 5-very likely). Respondents utilized local knowledge, friends, and restaurant staff most frequently for information regarding aquaculture and seafood products, while seafood websites and fisherpersons were the least frequently used sources.

Table 1.5: Summary of consumers perceptions towards seafood and marketing characteristics

Variable	Definition	Obs.	Likert Scale	Std. Dev.	Min.	Max.
Attributes for purchasing seafood	5=very important, 1=very unimportant	1947				
Cooking time			3.5	1.14	1	5
Cost/price			4.1	0.91	1	5
Farmed-raised			3.3	0.98	1	5
Location of production			3.7	0.95	1	5
Quality and/or freshness			4.6	0.81	1	5
Supporting local aquaculture			3.7	0.93	1	5
Sustainability			4.1	0.93	1	5
Taste			3.5	0.77	1	5
Market outlet satisfaction	5=very important 1=very unimportant	1947				
Quality at grocery stores			3.8	0.80	1	5
Quality at restaurants			4.0	0.78	1	5

Variety at grocery stores		3.6	0.9	1	5
Variety at restaurants		3.9	0.88	1	5
Familiarity with aquaculture products	5=very familiar 1=very unfamiliar				
Difference between wild and farm-raised seafood		3.6	1.11	1	5
Types of farm-raised seafood commonly produced in SC		2.8	1.12	1	5
Purchasing SC aquaculture products	5=very likely 1=very unlikely	4.1	0.96	1	5
Information sources	5=very frequently 1=very infrequently				
Fisherperson		3.0	1.24	1	5
Friends		3.3	1.09	1	5
Locals		3.3	1.12	1	5
Online review		3.2	1.20	1	5
Restaurant staff		3.3	1.09	1	5
Seafood retailer		3.2	1.12	1	5

Community development through principal components analysis

Principal components analysis was used to measure the correlation between the four community development statements based on respondent's Likert scores for each statement. In terms of the Likert scores reported across the four community development

statements, an average of 73% of respondents indicated they “Strongly Agree” or “Agree” with the original statements regarding the impact the aquaculture industry can have on community development (Figure 7-B). Testing for suitability of reducing variables to principal components using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy revealed an adequate sampling size for analysis (KMO = 0.811), in which a score of 0.8 or greater is deemed meritorious. Bartlett’s test of sphericity also revealed a significant finding that all initial variables are correlated, and therefore the null hypothesis of no correlation between variables can be rejected (X^2 = 3600.03, p<0.000).

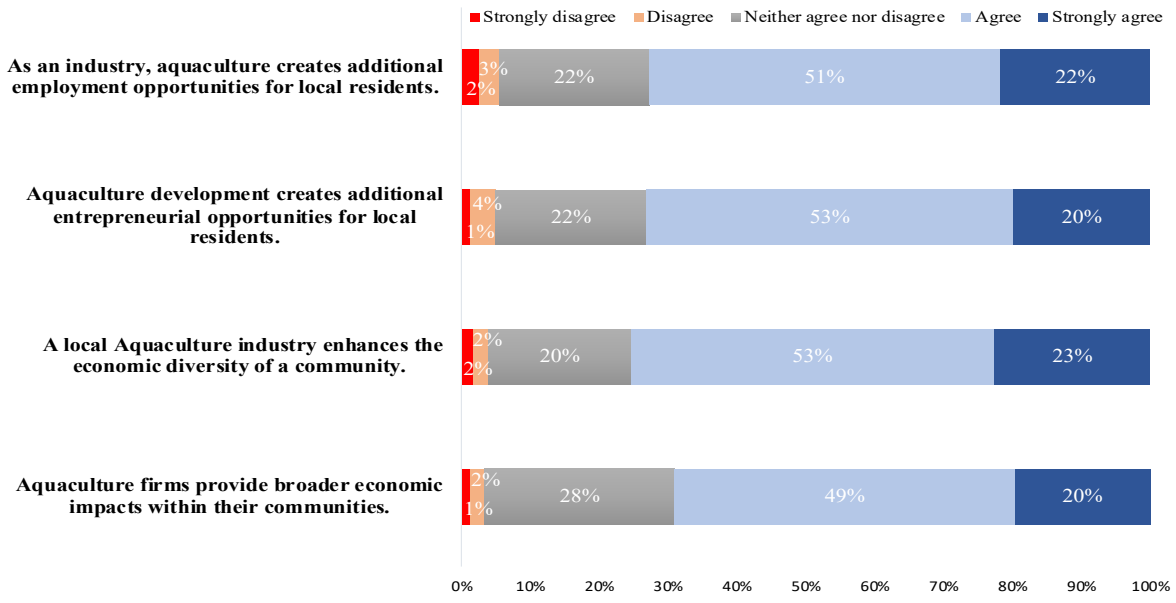

Figure 1.7: Likert scores of community development statements

Varimax rotation was preferred among these ordinal data points as this form of variable loading utilizes low and high value loading factors, thus, the range of values (1 = Strongly Disagree, 5 = Strongly Agree) is incorporated with the mid-level loading factor

(3 = Neither agree nor disagree) being ignored. Based on the graphical representation of variance explained, or the scree plot, and the total variance explained indicate that only the first principal component, employment is necessary to inform the CDI, hence additional employment opportunities in aquaculture to residents is sufficient to capture the underlying reasons for resident's support of the aquaculture industry (Figure 1.8).

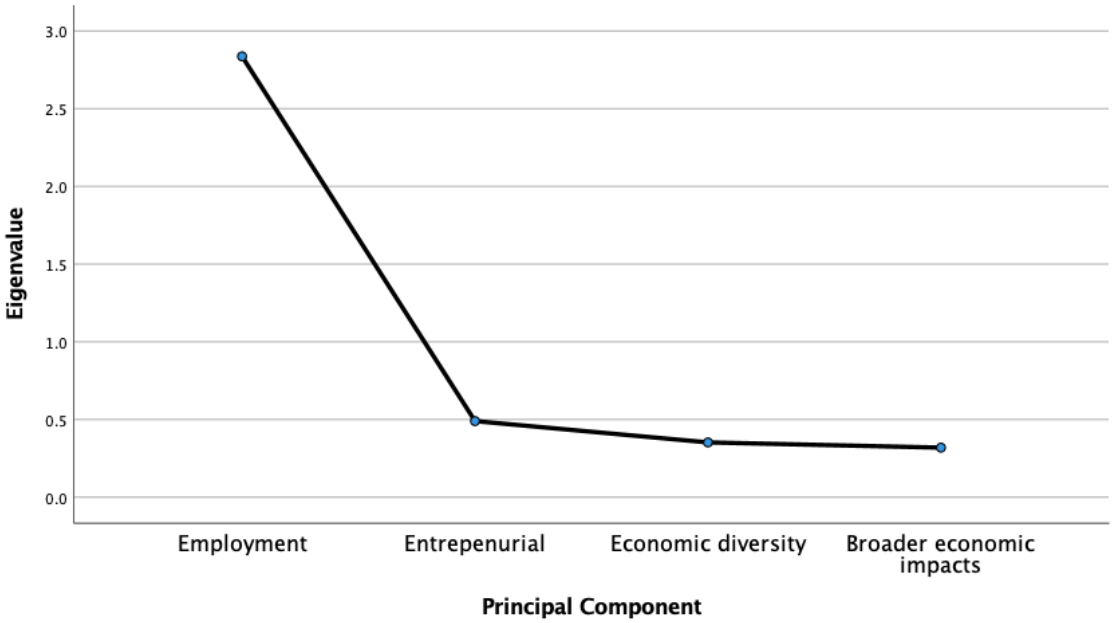

Figure 1.8: Scree plot of optimal number of community development index principal components

Information Sources

Respondents preferred to use or receive information about aquaculture products from academia, followed by state agencies, non-governmental organizations (NGO's), federal agencies and lastly, private organizations (Table 1.6).

Table 1.6: Summary of consumers preference for information regarding aquaculture products

Variable	Average
Consumer preference for obtaining information on aquaculture products	
Academia (e.g. Clemson University)	38.0%
State agencies (e.g. South Carolina Sea Grant Consortium)	24.0%
Non-governmental Organization (e.g. The Nature Conservancy)	15.0%
Federal agencies (e.g. NOAA)	14.0%
Private organization	6.0%

Discussion

In this study, we investigated South Carolinians' seafood consumption, and their perception(s) towards buying and consuming aquaculture products from SC. This research is valuable in that informs producers and aquaculture industry stakeholders about consumers' demands and preferences. Comparing national and statewide trends of seafood consumption provides evidence of the potential market for aquaculture products in SC, along with opportunities to enhance consumer's awareness of locally produced seafood in the state.

Our results found that salmon, particularly Atlantic Salmon is the most widely consumed aquaculture product, followed by shrimp. According to the National Marine Fisheries Service (NMFS) (2018), Atlantic Salmon was the most widely consumed aquaculture product, while farm-raised shrimp was the second most consumed

aquaculture product. The most consumed seafood product, regardless of production method, among U.S. consumers is shrimp and salmon, ranking first and second respectively (NMFS, 2018; USDA, 2018). Our results follow global consumption trends of farm-raised seafood products, with the proportion of respondents in our survey reporting they consume farm-raised shrimp (71%), Atlantic Salmon (46%), tilapia (20%) and catfish (16%), which are also the four most valuable farm-raised fish species by revenue behind carp species (FAO, 2020). In regard to seafood production from recirculating aquaculture systems (RAS), South Carolina has 11 RAS facilities, however, these systems do not currently support the cultivation of shrimp, which is the most desired aquaculture product among respondents (USDA, 2018). Also, mussels and salmon cannot be feasibly cultivated in SC.

Consumers may choose more frequent consumption of seafood at home given the higher cost of purchasing seafood at restaurants. This is an important signal to producers that the market for home seafood consumption is an important one for additional development and marketing as the industry grows (Hicks, Pivarnik, & McDermott, 2008). A majority of respondents purchased seafood two or more times per month for in-home consumption, and once a month at restaurants. A similar trend in restaurant purchases was observed by Hicks et al. (2008) with respondents reporting two or fewer monthly seafood purchases at restaurants, while in-home purchases took place several times per week.

Collecting empirical evidence from consumers on their consumption of seafood provides valuable insight into the market trends of seafood distribution industry, which

relies on understating the changes in products available currently, and in the past. Research by Henry et al. (2008) provides the most recent estimates of per-capita consumption of seafood among SC residents and is thus compared to the findings of this sample. Seafood consumption among SC residents is divided between inland and coastal county residents, by the aggregated groups of either finfish products, or shellfish products. In 2008, both inland and coastal SC consumers ate mostly finfish products (53%) as opposed to shellfish products (47%), while in the 2019 dataset inland respondents ate mostly finfish products (54%) and coastal respondents at mostly shellfish products (51%), the former result being more in line with the consumption trends found in Henry et al. (2008) (Table 1.7).

Table 1.7: Percentage of per-capita seafood consumption in South Carolina

Variable	Source	Per-capita seafood consumption (%)	
Respondent location		Fish	Shellfish[c]
Inland[a]	*Henry et al., 2008*[b]	53%	47%
Coastal		53%	47%
Inland	Our survey, 2020	54%	46%
Coastal		49%	51%

[a]Coastal counties in SC include Beaufort, Berkeley, Charleston, Colleton, Dorchester, Georgetown, Jaspar and Horry.
[b]Per-capita consumption by seafood type is derived from NMFS database (2008).
[c]Shelllfish in our survey include: Clams, Crabs, Mussels, Oysters and Shrimp.

Understanding the relationship of seafood purchases in the home and at market outlets was of particular importance in our survey as limited estimates exist for this type of consumer behavior in South Carolina. A majority (56%) of seafood purchased by

respondents was cooked. This value is slightly higher than the findings by Cheng and Capps (1988), who found that less than 50% of seafood purchased by Americans was already cooked. Over the last 30 years, seafood preparation at market outlets have increased with more offerings of already prepared seafood options available to consumers, particularly frozen and already cooked products (Thapa, Dey & Engle, 2015). Interestingly, our findings show that 64% of seafood consumption in SC happens at home, as compared to outside the home or at a restaurant. Respondents purchase 36% of their seafood from restaurants, which is well below the findings of other similar studies regarding seafood consumption (Brayden et al., 2018; Risius, Janssen, & Hamm, 2017).

Similar studies found overall out-of-home seafood consumption as high as 65% (Love et al., 2020). Richards (2020) estimated that in SC, more than 80% of farm-raised oysters are sold directly to restaurants, where they are marketed as half-shell quality and further explains the demand for out-of-home consumption of certain aquaculture products. A similar study by Zhang et al. (2004) on at-home and away-from-home consumption of seafood in the USA finds only 46% of respondents purchased seafood at restaurants, much lower than expected. Some studies in other U.S. locations have found that respondents purchase up to 80% of the seafood they consume at restaurants (Thapa, Dey, & Engle, 2015; Thong & Solgaard, 2017). Seafood purchases at roadside fish stands, or directly from fishermen themselves, was greatest among inland respondents visiting a coastal county (12%). This result is a sign that SC residents potentially prefer freshly caught seafood sold directly from harvesters when they are visiting the coast. Additionally, among inland respondent's seafood purchases at fish markets decreased by

8% when comparing home location purchase versus visiting a coastal county. This reveals that there may be more limited availability to fresh seafood in inland counties and that seafood markets in SC are predominantly distributed throughout coastal counties where a majority of locally sourced seafood products are purchased and consumed. This also could highlight those consumers may not be aware of where local seafood markets are in their communities and may represent a source of educational and/or market opportunities.

Our survey instrument also included a component focused on intrastate travel by inland residents to coastal counties who purchased seafood while visiting the coast. The purpose of this distinction is to investigate which seafood products are more desired by visitors of coastal counties as opposed to the inland counties they reside in, and at which market outlets inland residents visiting the coast are more likely to purchase seafood. Per capita seafood consumption between inland and coastal SC residents from our survey is compared to the values found in Henry et al. (2008) with the same eight coastal counties used to compare per-capita consumption of seafood in SC. Henry et al. (2008) found that fish accounts for 53% of seafood consumption, while shellfish comprises 47% of seafood consumption for both coastal and inland residents in 2006 (Table 3). Our survey shows similar results for inland county residents' consumption of fish (54%) and shellfish (46%) but differs with respect to coastal county residents' consumption of shellfish, which is higher than Henry et al. (2008) estimates. These results may be attributed to the increase in shellfish mariculture production in SC over the last 15 years (Jodice & Norman, 2020). The decline in grocery store seafood purchases when inland residents visit the coast

highlights the relative importance that consumers place on purchasing seafood at market outlets other than grocery stores, such as at restaurants, seafood markets, and roadside fish stands.

Similar studies have found clear distinctions in the purchasing patterns of tourists and residents of coastal counties. For instance, Jodice & Norman (2020) and Tango-Lowy & Robertson (2005) found that the main attributes of seafood consumption such as quality, taste, and price typically differ little between geographic areas, while other attributes such as preferred production method (i.e. wild-caught vs. farm-raised), and origin can vary widely between coastal and inland communities. Coastal and inland residents' differences may be related to the interactions that coastal residents have with aquaculture growers, resulting in a better understanding of the effects of aquaculture on coastal ecosystems and a greater potential for supporting producers with local purchases (Hilborn et al, 2018).

Seasonality also influenced seafood consumption trends in our survey, particularly with shellfish. The increase in consumption of oysters in winter months can be partly attributed to consumer's concern about eating oysters during summer months when water temperature is higher, which can increase the risk of shellfish poisoning due to pathogens such as *Vibrio spp.* (Børresen, 2009). Fishery closures also contribute to trends in local seafood consumption, with no seasonal closure of crab species in SC, while the fall White Shrimp commercial fishery is open from September to December and consumption of shrimp is consistently high throughout the year (SC Department of Natural Resources, 2019). However, higher consumption rates of crab species commonly

sold in SC such as Blue Crabs, were observed in the summer. This finding alludes to the demand-driven nature of Blue Crab purchases among tourists in the summer months, when the majority of Blue Crabs are sold in SC, rather than the effect of harvesting effort as a majority of landings take place from September to May (Henry et al., 2018; Jodice & Norman, 2020; SCDNR, 2019). Similar consumption trends between inland and coastal respondents were observed with salmon, with 47% and 44% of respondents, respectively, indicating they purchased salmon, while only 20% of inland respondents visiting the coast purchased salmon. Lower consumption of salmon by coastal tourists might be attributed to the relatively homogenous distribution of salmon, both farm-raised and wild-caught across the state, and therefore may be less desired than other locally caught seafood sold in coastal counties (Henry et al., 2008).

In South Carolina, the production method (i.e. capture fisheries and aquaculture) and locality of seafood are important considerations in valuation and willingness to pay (WTP). For example, in a study evaluating WTP of wild and farmed salmon, salmon labelled "wild-caught" on average sold for $15.62 per pound, whereas salmon labelled as "farm-raised" sold on average for $6.31 per pound (Bostock et al. 2010). This pattern illustrates consumer's potential preference for "wild-caught" seafood and the related market opportunities. The opposite valuation trend is observed for shellfish, specifically with farm-raised oysters where consumers preferred farm-raised oysters over wild-caught counterparts (Kecinski et al., 2017). Preference for local seafood and aquaculture products is a reoccurring theme that consumers have continued to show interest in when making food purchases (Chen et al, 2017; Grebitus et al, 2013). Similar studies along the

Atlantic coast have found that the proximity of oyster cultivation to consumers affects their willingness to pay for local products (Li et al., 2019). Jodice & Norman (2020) found that SC resident's ratings of importance for the attributes "environmentally sustainable", "wild-caught" and "harvested locally" were significantly higher than tourist ratings for the same attributes. In future studies, it will be important to examine how proximity to local aquaculture production may impact residents' willingness to pay for locally harvested products.

Education and outreach continue to be instrumental in growing awareness in the domestic aquaculture industry with consumers that would otherwise overlook the source and production method of the seafood they consume. Respondents (68%) overwhelmingly believe that seafood purchased in South Carolina is either locally sourced or domestic product of the U.S., while NMFS (2018) reports less than 20% of the seafood Americans consume is a domestic product. These results are in line with other studies that highlight the common misconception that consumers have about the source of the seafood they purchase (Barrington et al, 2010; Carlucci et al, 2017). Consumer awareness gaps appear even around the region that certain species are produced; for example, 94% of Atlantic Salmon and over 90% of various species of tropical shrimp, *Penaeid spp.,* are imported, and are often misunderstood by consumers as being domestic products (NMFS, 2018). Consumer's ability to access information regarding aquaculture products and the practices used in the industry has had a significant influence on awareness and acceptance of these products in states with strong aquaculture associations

and university-based aquaculture extension programs. They have also served as a catalyst for more financially constrained aquaculture enterprises (Swann & Morris, 2001).

As of this study, the South Carolina Department of Agriculture, in conjunction with the South Carolina Seafood Alliance and SCDNR, has developed the South Carolina Certified Seafood Program, which is designed to help consumers easily identify locally sourced seafood (SC Department of Agriculture, 2019). This program is available to wholesale dealers, distributors, retailers, and both aquaculture and shellfish mariculture permit holders; this designation certifies that their grown or landed seafood is a product of SC. This certification label includes SC certified grown seafood, which incorporates locally wild-caught seafood such as shrimp from the family *Penaeidae*, and various finfish species commonly caught in South Carolina (SCDNR, 2019). Market outlets sometimes use the text "locally-sourced" or "farm-raised" as a label on seafood signifying that the product is either farm-raised or that the product is locally sourced. Our results show that only 38% of respondents indicated they had purchased seafood with the SC Certified Seafood label, signaling that this labelling is still relatively new in its implementation among locally sourced seafood and aquaculture products.

Research has shown that education and outreach of coastal mariculture practices and promoting additional market outlets such as farmers markets and oyster trails, continues to be an effective step in promoting local, farm-raised seafood products that consumers are willing to pay a premium for (Li et al., 2019; Davidson et al., 2012; Fonner & Sylvia, 2015; Kim et al., 2020). South Carolina has recently developed its own form of and oyster trail known as the "Lowcountry oyster trail," which may be a valuable

resource for introducing the role of mariculture in the region and building environmental and economic support in coastal communities. As mariculture continues to grow in both production and accessibility along coastal counties in SC, the need for targeted surveys of rural communities where aquaculture is taking place is necessary to determine how preferences for aquaculture products may change in contrast to more urban areas of the state. Additional research exploring the preferences and perceptions towards aquaculture products among rural, urban, and underrepresented groups is imperative to better channel marketing opportunities for producers who plan to grow their markets.

Conclusion

This study is the first to elucidate South Carolina seafood consumers' consumption trends and perception towards aquaculture products through empirical reporting. Our survey findings on the preference for SC aquaculture products is in line with the national preference for species including shrimp and salmon, the two most readily available aquaculture products on the market (FAO, 2018). Taste, quality and/or freshness, and price were found to be the most important attributes when purchasing seafood, which mirrors the most important factors in consumer seafood purchasing found in other studies (Chen et al., 2017; Grebitus et al., 2013).

Our findings about respondent's perceptions towards the source of seafood and aquaculture products are important for the larger research stream. While the Certified SC Seafood Program is still in its infancy, it currently has 11 organizational members and is growing annually (Jodice & Norman, 2020). Regulating seafood-labelling related fraud

continues to be an important objective in SC and beyond, and a study on national seafood labelling found that 33% of seafood tested for its origin was inaccurately labelled, showing that a significant proportion of U.S. seafood could be geographically misrepresented (Warner et al, 2012).

In conclusion, this research provides valuable information to the broad set of stakeholders interested in aquaculture production in SC. Our results highlight there is a great potential for growth of this industry and consumers are eager to purchase local SC seafood products. Increasing awareness about the economic and environmental benefits of shellfish mariculture in SC and how this industry could benefit our rural communities by being an engine of local entrepreneurship is an area of research and outreach that should be pursued in subsequent studies.

Works Cited

Abolofia, J., Asche, F., & Wilen, J. E. 2017. The Cost of Lice: Quantifying the Impacts of Parasitic Sea Lice on Farmed Salmon. *Marine Resource Economics,* 32(3), 329-349.

Asche, F., Bjørndal, T., & Young, J. A. 2001. Market interactions for aquaculture products. *Aquaculture Economics & Management,* 5(5-6), 303-318.

Barrington, K., Ridler, N., Chopin, T., Robinson, S., & Robinson, B. 2010. Social aspects of the sustainability of integrated multi-trophic aquaculture. *Aquaculture International,* 18(2), 201-211.

Børresen, T. 2009. Understanding the Consumer's Perception of Aquaculture. *Journal of Aquatic Food Product Technology,* 18, 191-192.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I., Corner, R. 2010. Aquaculture: global status and trends. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 365(1554), 2897-2912.

Bouchard, D., Camire, M. E., Davis, C., Shaler, G., Dumont, R., Bernier, R., & Labbe, R. 2021. Attitudes toward aquaculture and seafood purchasing preferences: Evidence from a consumer survey of Atlantic States. *Aquaculture Economics & Management*, 1-28.

Brayden, W. C., Noblet, C. L., Evans, K. S., & Rickard, L. 2018. Consumer preferences for seafood attributes of wild-harveted and farm-raised products. *Aquaculture Economics & Management,* 22(3), 362-382.

Carlucci, D., Nocella, G., De Devitiis, B., Viscecchia, R., Bimbo, F., & Nardone, G. 2014. Consumer purchasing behavior towards fish and seafood products. Patterns and insights from a sample of international studies. *Appetite, 84*.

Carlucci, D., Devitiis, B. D., Nardone, G., & Santeramo, F. G. 2017. Certification Labels Versus Convenience Formats: What Drives the Market in Aquaculture Products? *Marine Resource Economics,* 32(3), 295-310.

Chen, J. Q., Haws, M. C., Fong, Q. S. W., & Leung, P. 2017. Locally Grown Oysters in Hawai‘i: Chef Preference and Local Premium? *Journal of the World Aquaculture Society,* 48(6), 972-980.

Cheng, H.-t., & Capps Jr, O. 1988. Demand Analysis of Fresh and Frozen Finfish and Shellfish in the United States. *American Journal of Agricultural Economics,* 70(3), 533-542.

Chu, J., Anderson, J. L., Asche, F., & Tudur, L. 2010. Stakeholders' Perceptions of Aquaculture and Implications for its Future: A Comparison of the U.S.A. and Norway. *Marine Resource Economics, 25*(1), 61-76.

Davidson, K., Pan, M., Hu, W., & Poerwanto, D. 2012. Consumers' willingness to pay for aquaculture fish products vs. wild-caught seafood - A case study in Hawaii. *Aquaculture Economics & Management, 16*(2), 136-154.

Engle, C. R., Kumar, G., & van Senten, J. 2020. Cost drivers and profitability of U.S. pond, raceway, and RAS aquaculture. *Journal of the World Aquaculture Society, 51*(4), 847-873.

Executive Order promoting American seafood competitiveness and economic growth. May 7th, 2020 13921, 3 C.F.R.

FAO. 2018. *The State of World Fisheries and Aquaculture 2018*. *Meeting the sustainable development goals*. Rome.

FAO. 2020. *The State of World Fisheries and Aquaculture 2020*. *Sustainability in action*. Rome.

Flaherty, M., Reid, G., Chopin, T., & Latham, E. 2019. Public attitudes towards marine aquaculture in Canada: insights from the Pacific and Atlantic coasts. *Aquaculture International, 27*(1), 9-32.

Fonner, R., & Sylvia, G. 2015. Willingness to Pay for Multiple Seafood Labels in a Niche Market. *Marine Resource Economics, 30*(1), 51-70.

Gall, K., and O'Dierno, L. 1993. Aquaculture Marketing Survey; Consumers, Retail Stores, and Food Service in New York and New Jersey. *New York Sea Grant Extension Program Press*

Garlock, T., Asche, F., Anderson, J., Bjørndal, T., Kumar, G., Lorenzen, K., Ropicki, A., Smith, M.D., Tveterås, R. 2020a. A Global Blue Revolution: Aquaculture Growth Across Regions, Species, and Countries. *Reviews in Fisheries Science & Aquaculture, 28*(1), 107-116.

Garlock, T., Nguyen, L., Anderson, J., & Musumba, M. 2020b. Market potential for Gulf of Mexico farm-raised finfish. *Aquaculture Economics & Management, 24*(2), 128-142.

Gibbs, M. 2009. Implementation barriers to establishing a sustainable coastal aquaculture sector. *Marine Policy, 33*, 83-89.

Grebitus, C., Lusk, J. L., & Nayga, R. M. 2013. Effect of distance of transportation on willingness to pay for food. *Ecological Economics,* 88, 67-75.

Hargreaves, J. 2017. The stagnation of U.S. aquaculture. *World Aquaculture* 48(1):3.

Henry, M., Rhodes, R., & Eades, D. 2008. The Flow of South Carolina Harvested Seafood Products through South Carolina Markets.

Herrmann, R., Rauniyar, G., Hanson, G., & Wang, G. 1994. Identifying Frequent Seafood Purchasers in the Northeastern U.S. *Agricultural and Resource Economics Review, 23*.

Hicks, D., Pivarnik, L., & McDermott, R. 2008. Consumer perceptions about seafood – an Internet survey. *Journal of Foodservice,* 19(4), 213-226.

Hilborn, R., Banobi, J., Hall, S. J., Pucylowski, T., & Walsworth, T. E. 2018. The environmental cost of animal source foods. *Frontiers in Ecology and the Environment,* 16(6), 329-335.

Kim, G., Jodice, L., Duffy, L., & Norman, W. 2020. Tourists' attitudes toward the benefits of mariculture: A case of decision-making in marine tourism in Southeast U.S.A. *Tourism in Marine Environments, 15*.

Knapp, G., & Rubino, M. C. 2016. The Political Economics of Marine Aquaculture in the United States. *Reviews in Fisheries Science & Aquaculture, 24*(3), 213-229.

Kecinski, M., Messer, K. D., Knapp, L., & Shirazi, Y. 2017. Consumer Preferences for Oyster Attributes: Field Experiments on Brand, Locality, and Growing Method. *Agricultural and Resource Economics Review,* 46(2), 315-337.

Jodice, L. W., & Norman, W. C. 2020. Comparing importance and confidence for production and source attributes of seafood among residents and tourists in South Carolina and Florida coastal communities. *Appetite,* 146, 104510.

Li, T., Ahsanuzzaman, A., & Messer, K. 2019. Is This Food "Local"? Evidence from a Framed Field Experiment. *Journal of Agriculutral and Resource Economics,* 45(2), 179-198.

Love, D. C., Asche, F., Conrad, Z., Young, R., Harding, J., Nussbaumer, E. M., Neff, R. 2020. Food Sources and Expenditures for Seafood in the United States. *Nutrients,* 12(6)

Murray, G., & D'Anna, L. 2015. Seeing shellfish from the seashore: The importance of values and place in perceptions of aquaculture and marine social–ecological system interactions. *Marine Policy,* 62, 125-133.

National Marine Fisheries Service. 2020. Fisheries of the United States, 2018. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2018

Petrolia, D. R., Walton, W. C., & Yehouenou, L. 2017. Is There a Market for Branded Gulf of Mexico Oysters? *Journal of Agricultural and Applied Economics, 49*(1), 45-65.

Perkinson, M.T., Faith, T.D., Vahey, G.M., Vena, J.A., & Williams, E.M. 2018. Quantifying the Seafood Consumption Patterns of Recreational Anglers in Charleston and Berkeley Counties, South Carolina, *Environmental Health Insights* 10(1)

Richards S. 2020. The South Carolina Shellfish Industry Faces a Challenging Recovery After COVID-19. Clemson (SC): Clemson Cooperative Extension, Land-Grant Press by Clemson Extension; 2020 Jun. LGP 1071.Retireved from https://lgpress.clemson.edu/publication/the-south-carolina-shellfish-industry-faces-a-challenging-recovery-after-covid-19/.

Risius, A., Janssen, M., & Hamm, U. 2017. Consumer preferences for sustainable aquaculture products: Evidence from in-depth interviews, think aloud protocols and choice experiments. *Appetite,* 113, 246-254.

Roheim, C. A., Sudhakaran, P. O., & Durham, C. A. 2012. Certification of shrimp and salmon for best aquaculture practices: Assessing consumer preferences in Rhode Island. *Aquaculture Economics & Management, 16*(3), 266-286.

Shamshak, G. L., Anderson, J. L., Asche, F., Garlock, T., & Love, D. C. 2019. U.S. seafood consumption. *Journal of the World Aquaculture Society, 50*(4), 715-727.

South Carolina Department of Natural Resources, Marine Resources Division. 2019. 2018 – 2019 Saltwater Fishing Regulations, Crab, Lobster and Shellfish, Charleston, SC

Swann, L., & Morris, J. E. 2001. *A White Paper on the status and needs of aquaculture extension outreach for the North Central Region*.

Tango-Lowy, T., & Robertson, R. A. 2005. Predisposition Toward Adoption of Open Ocean Aquaculture by Northern New England's Inshore, Commercial Fishermen. *Human Organization,* 61(3), 240-251.

Thapa, G., Dey, M. M., & Engle, C. 2015. Consumer Preferences for Live Seafood in the Northeastern Region of USA: Results from Asian Ethnic Fish Market Survey. *Aquaculture Economics & Management,* 19(2), 210-225.

Thong, N. T., & Solgaard, H. S. 2017. Consumer's food motives and seafood consumption. *Food Quality and Preference,* 56, 181-188.

U.S. Census Bureau. 2019. *2019 American Community Survey 1-Year Estimates*

U.S. Congress. 1980. National Aquaculture Act of 1980. Public Law 96-362, 94 Stat. 1198, 16 U.S.C. 2801, et seq. U.S. Congress, Washington, D.C.

U.S. Department of Agriculture. 2016. Perishable Agricultural Commodities Act of 1930. 7 U.S.C. §§ 499a-499t. Washington, D.C.

U.S. Department of Agriculture. 2018. *2017 Census of Agriculture, 2018 Census of Aquaculture.* Washington D.C.

van Senten, J., & Engle, C. R. 2017. The Costs of Regulations on US Baitfish and Sportfish Producers. *Journal of the World Aquaculture Society,* 48(3), 503-517.

van Senten, J., Engle, C. R., Hudson, B., & Conte, F. S. 2020. Regulatory costs on Pacific coast shellfish farms. *Aquaculture Economics & Management, 24*(4), 447-479.

Verbeke, W., Sioen, I., Brunsø, K., De Henauw, S., & Van Camp, J. 2007. Consumer perception versus scientific evidence of farmed and wild fish: exploratory insights from Belgium. *Aquaculture International,* 15(2), 121-136.

Warner, K., Walker, T., Lowell, B., Hirshfield, M. 2013. Oceana Study Reveals Seafood Fraud Nationwide. *Oceana,* 11.

Whitmarsh, D., & Palmieri, M. G. 2009. Social acceptability of marine aquaculture: The use of survey-based methods for eliciting public and stakeholder preferences. *Marine Policy,* 33(3), 452-457.

Wright, R. (2006). *Consumer Behaviour*: Thomson.

Zhang, X., House, L., Sureshwaran, S., & Hanson, T. 2004. At-Home And Away-From-Home Consumption Of Seafood In The United States. *Southern Agricultural Economics Association, 2004 Annual Meeting,* February, Tulsa, Oklahoma.

CHAPTER TWO

CONSUMERS WILLINGNESS TO PAY FOR SUSTAINIBILITY AND LOCALITY OF AQAUCULTURE AND FISHERIES: A CHOICE EXPERIMENT FOR SOUTH CAROLINA SHELLFISH PRODUCTS

Introduction

Over the past three decades, a notable transition of seafood production methods has been observed regarding the traditional method of harvest fisheries and the growing method of aquaculture (Food & Agriculture Organization (FAO), 2018; Hilborn et al. 2018). A report from the Global Aquaculture Alliance (GAA) in 2019 estimated that 63% of seafood will be derived from aquaculture by 2030, further indicating the need for traceability and monitoring of aquaculture operations' impacts on the surrounding environment. Growth in the aquaculture sector has helped to alleviate overfishing of wild stocks worldwide, however there is growing concern of the detrimental effects resulting from aquaculture such as effluent runoff and disease transmission, particularly in the production of shrimp *Penaeidae spp.* and Atlantic Salmon *Salmo Salar*, respectively. Atlantic Salmon is the second most successful farm raised seafood product, by value, behind shrimp (FAO 2018, Kumar and Engle 2016). As the production of both finfish and shellfish has grown considerably over the past 30 years, there has been concern among consumers as to whether the farm-raised seafood they purchase has been produced sustainably (Ayer et al., 2009; Gutierrez & Thornton, 2014; Hornborg et al., 2018; Jaffry et al., 2004; Roheim et al., 2018; Roheim & Zhang, 2018).

In response to these concerns over sustainability and traceability of seafood, the World Wildlife Fund (WWF) founded third party subsidiaries known as the Marine

Stewardship Council[1] (MSC) and the Aquaculture Stewardship Council[2] (ASC) in 1996 and 2010, respectively. The MSC is an ecolabel certification body tasked with assessing the best practice requirements set forth by the FAO for wild-caught seafood products. MSC is the most widely recognized seafood ecolabel, with over 3,300 entities worldwide certified, subsequently leading to the ASC ecolabel becoming more recognizable alongside its wild-caught certification counterpart (Bronnmann & Asche, 2016; Le Manach et al. 2020; MSC, 2019; Roebuck & Wristen, 2019; Roheim et al., 2018). Consumer's perceptions as to what they consider sustainably sourced seafood has contributed to the success of the MSC ecolabel, where previous research has focused on the attribute's consumers use when purchasing finfish, notably in Germany, Japan and the U.S. (Bronnmann & Asche, 2017; Uchida et al., 2014; Roheim et al., 2012). Roheim et al (2012) also included shrimp in their analysis elucidating consumer preferences for farm-raised seafood, however, less is known regarding consumer's preferences and willingness to pay (WTP) for bivalves such as oysters. To the best of our knowledge, the only other study to measure WTP of farmed seafood using existing ecolabels is Bronnmann and Asche (2017), who estimated WTP for salmon across German markets. Currently, no U.S. shellfish farm has become certified through ASC, and this study provides the first evidence of implementation of the ASC ecolabel on shellfish products in South Carolina markets, thus providing empirical evidence of the financial benefits of such ecolabelling schemes (ASC Bivalve Standard Version 1.1, 2019).

Another central focus of our research concerns the effect locality has on consumer's preference towards both wild-caught and farm-raised shellfish. Research

pertaining to this attribute in the U.S. and abroad is well-documented (Gall & O'Dierno, 1994; O'Dierno et al., 2008; Quagranie et al., 2008; Whitemarsh & Palmieri, 2009). Similar studies have explored wild-caught and farm-raised seafood products that are available to consumers in their study area, while less research has explored the WTP of farm-raised products within the vicinity as the respondent's location (Li et al., 2019; Grebitus et al., 2013; Lim & Hu, 2016; Onozaka et al, 2010; Vermeir & Verbeke, 2008). For example, in a stated-preference survey among South Carolina (SC) and Kentucky seafood consumers, WTP for farm-raised shrimp increased when these products were marketed as locally sourced (Soley et al., 2019). South Carolina does not currently produce farm-raised shrimp in any capacity, but engages in a harvest industry for shrimp, and as such we interpret our results for local, sustainably farm-raised shrimp as those consumers would potentially be willing to pay more for than other sources and production methods. For oysters specifically, consumers in Delaware had a higher WTP for cultivated oysters that were grown in closer proximity to where consumers live, hence the attribute of locally sourced resulting in a higher premium (Li et al., 2019.

This research focuses on the shellfish mariculture industry in SC due to its continuing growth in the state's aquaculture sector and presence in coastal communities and market outlets. There has been extensive research on the WTP of various attributes of finfish products as it pertains to both wild-caught and farm-raised production methods, however, less is known as to how various attributes affect consumer's WTP for bivalves and associated species (Bronnmann & Asche, 2017; Li et al., 2020; Petrolia et al., 2017; Risius et al., 2017; Roheim et al., 2012; Uchida et al, 2014). Our premise for measuring

the WTP of aquaculture products available in SC stems from the survey findings of Henry et al. (2008), who concluded that local seafood commanded a 20% premium over imported products at the time of their study. In this study, a common approach to investigating consumer's preferences and WTP for products involves using a choice experiment (CE) with varying levels of attributes to better understand the relative importance consumers place on factors such as cost, locality, etc.

Specifically, we conducted a CE on two seafood products, oysters, and shrimp, both of which are widely available across SC. Following McFadden & Train (2000), we measure WTP for oysters and shrimp and their associated attributes of locality, and sustainability through the MSC, or the ASC ecolabel using a mixed logit model (MLM). We use the MLM instead of the conditional logit model (CLM) to measure consumer's WTP, based on the characteristics of the choice selection, as the CLM is constrained in its inability to correlate unobserved interactions, homogeneity in taste among respondents and has fixed, rather than flexible substitutional patterns (Hensher et al., 2015). In our analysis, we segmented our study population based on those who indicated they were willing to pay a premium for SC aquaculture products, and those who recognized the ASC ecolabel. The purpose of this CE was to measure the relative value consumers place on the source labelling of shellfish available to them and the sustainability of the production practices to leverage the economic benefits of ecologically responsible aquaculture in South Carolina.

Methods and Materials

Survey Implementation

To investigate SC seafood consumption trends and preferences, the research team developed a state-wide online survey in March 2020. The survey was distributed by Qualtrics Inc. to the primary food buyers or persons who prioritize expenditures within SC households. We pre-tested the survey questionnaire with the assistance of selected SC residents, Clemson Extension personnel, SC Sea Grant personnel, and co-investigators of the project. The questionnaire consisted of a set of screening questions, questions about consumers' lifestyle characteristics, questions about seafood shopping preferences, and seafood consumers' sociodemographic traits. The screening questions in this study limited the participants who reside in SC during the time of the survey in January 2020, are one of the primary financial decision makers of their household and consume seafood products. Seafood products, for the purposes of this study, represented marine and freshwater species from South Carolina, the U.S., and other countries.

We collected 1,308 surveys from residents across all 46 counties in SC. The survey was structured into five parts, (1) perception-based questions asking whether respondents would be WTP a premium for local, aquaculture products; (2) stated reasons for why they would be willing or unwilling to pay a premium for local, aquaculture products; (3) whether respondents recognized the ASC ecolabel; (4) the choice experiment; and (5) a traditional socio-demographics section at the culmination of the survey. The perception-based questions were included to assess respondent's knowledge of seafood products available in South Carolina, providing better insight on current and future demand for

local aquaculture products that have been certified by organizations such as ASC. Following Lusk and Schroeder (2004), we included a budget constraint reminder to limit hypothetical bias in the CE. We informed respondents that results derived from this survey can be affected if they do not consider their own financial circumstances when making selections in the choice experiment.

Discrete choice experiment framework

Assuming participants in a CE will select products based on the attributes that offer the highest utility over an alternative, the typical structure of the CE incorporates varying attributes and associated attribute levels, of which price is typically included to calculate the marginal value of the product and its attributes in the choice model (Hanley et al., 1998). Two seafood products were chosen for the CE, oysters and shrimp, based on the fact that both are produced in South Carolina, where oysters are both farm-raised and wild-caught while shrimp is solely wild-caught, in addition to their relative similarity in market price (MP). Since 2013, shellfish mariculture production of Eastern Oysters *Crassostrea virginica* in South Carolina has increased by 40%, alluding to the increasing demand for these aquaculture products across the state (U.S. Department of Agriculture, 2018). Furthermore, harvest production of shrimp species caught in South Carolina, the U.S. and abroad have experienced declines over the past two decades, subsequently leading to slightly less than half of all shrimp production in the world being derived from aquaculture (FAO, 2020). Soley et al. (2018) found that consumers in SC had a notably high demand for locally sourced, farm-raised shrimp from SC, which is critical to this

studies' objective of determining which attributes have the most significant effect on consumer's WTP for shrimp.

Addressing locally sourced seafood to South Carolina in our CE, we identified and included Eastern Oysters, and three species of shrimp from the family *Penaeidae,* Brown Shrimp *Farfantepenaeus aztecus*, White Shrimp *Litopenaeus setiferus*, and Pink Shrimp *L. duorarum*, collectively representing penaeid shrimp. Baseline market price per pound values were derived for these species based on harvested landings data from National Marine Fisheries Service (NMFS) in 2019, as it has been found that market prices for farm-raised and wild-caught seafood products differs, therefore we used estimates of prices for wild-caught seafood as the baseline (Henry et al., 2008). Considering the market flow of seafood available in South Carolina, Henry et al. (2008) found that 91.1% of oysters and 33.5% of shrimp caught or grown in SC are sold and consumed within the state. These findings highlight the high loyalty to in-state sales of locally produced seafood products, whereas more recent estimates of in-state seafood sales indicate that upwards of 80% of farm-raised oysters produced in SC are sold to in-state market outlets (Richards, 2020).

Based on estimates from the National Marine Fisheries Service (2018), average market price of Eastern Oysters and Penaeid Shrimp were calculated on a per pound basis. Understanding that farm-raised "single" oysters are sold on a per-individual basis, while wild-caught "cluster" oysters are sold by the bushel or pound, we include implications for having market-price per pound as our baseline for oysters in the discussion. The state(s) in which the seafood is produced was included to capture the

variation in market price of these products that are available to consumers in SC. Most oysters sold in SC are imported into the state, albeit domestically produced or products of Canada in most cases (Henry et al., 2008; Richards, 2020). We specified Penaeid Shrimp in our baseline estimates of market price as these species are locally harvested, as well as domestically in the U.S. along the eastern and gulf coasts and have a higher market price than both wild-caught and farm-raised species that have been imported (NMFS, 2018). Estimates of market prices for oysters and shrimp in our CE are shown in table 2.1.

Table 2.1: Market price estimates for Eastern Oysters and Penaeid Shrimp

Species	Definition	State of origin	Landings (lbs.) Revenue ($) NMFS price per pound ($/lbs.)[a] Empirical price per pound($/lbs.)
Eastern Oyster	Includes only Eastern Oyster *Crassostrea Virginica*	Alabama Delaware Florida Georgia Louisiana Maine Maryland Massachusetts New York North Carolina Rhode Island South Carolina Texas Virginia	18,523,958 lbs. $186,676,478 $10.08/lbs. $7.99/lbs.
Penaeid Shrimp	Includes three species Brown Shrimp *Farfantepenaeus aztecus* Pink Shrimp *Litopenaeus duorarum* White Shrimp *L. setiferus*	Florida Georgia New York North Carolina South Carolina Texas Virginia	546,438 lbs. $2,460,664 $4.50/lbs. $7.99/lbs.

[a]Price estimates were derived from 2018 NMFS market price averages for each seafood product (NMFS, 2018)

In deriving the baseline market prices of the seafood products included in the CE, consideration of practical estimates of current market price of Eastern Oysters and Penaeid Shrimp led to adjusting the price attribute to reflect current market prices in SC. Market prices for seafood products were derived from national averages of seafood valuation based on NMFS aggregated data (2018) as the source of seafood products in SC varies between in state and out-of-state. For both oysters and shrimp, this resulted in a market price of $7.99 per pound. The attributes and levels used in the CE are shown in Table 2.2

Table 2.2: Seafood product attributes and levels included in the CE

Attribute	Definition	Level
Product	Designation of seafood product shown to respondents in the CE	Oysters from in-state (Eastern Oyster) and out-of-state (species not defined sources Shrimp from in-state (Brown, Pink, and White Shrimp) and out-of-state (species not defined) sources
Source Label	Source of production for, oysters and shrimp Seafood with production in all places other than South Carolina is considered the reference	South Carolina: seafood is a product of South Carolina using the Certified SC Seafood label[4] United States: seafood is a product of all localities in the U.S. other than SC
Ecolabel	The production method and accompanying ecolabel associated with the seafood product	Aquaculture Stewardship Council: Seafood that is farm-raised and is certified by ASC to be sustainably produced Marine Stewardship Council: Seafood that is wild-caught and is certified by MSC to be sustainably caught (base)

Price	Price above and below the baseline market price of each product	Six price levels above and below MP: oysters and shrimp: ±$1, $2, & $3
ASC_Know	Respondent recognized the ASC ecolabel	1=recognized ASC ecolabel; 0=didn't recognize the ASC ecolabel (base)
Certified_SC_Seafood_Know	Respondent recognized the Certified SC Seafood label	1=recognized Certified SC Seafood label; 0=didn't recognize the Certified SC Seafood label (base)

Following Roheim et al. (2012), rather than provide a full factorial approach with all attribute levels (Hensher et al., 1998), we used a fractional factorial approach of choice samples to effectively subset attribute levels presented to consumers. In particular, the attribute ecolabel in the CE displays either the ASC or MSC ecolabel, which serves as a proxy for the production method being farm-raised and wild-caught, respectively. We coupled the production method, either farm-raised or wild-caught, with the associated ecolabel, ASC or MSC, to better reflect the labelling schemes consumers would typically observe in a market outlet. However, by doing this, we were unable to discern the utility between production method, and sustainability of said method as has been done in other studies (Bronnmann & Asche, 2017). The source of seafood products was designated as either being local to SC, evidenced by the inclusion of the Certified SC Seafood label or a domestic product of the U.S. in any other state besides SC as evidenced by a hypothetical label of U.S. product. As of 2021, both oysters and shrimp have been approved for the Certified SC Seafood label, further demonstrating the importance of evaluating the economic impact of this label among consumers (SCDA, 2021).

Varying price levels were set in combination with the main attributes of ecolabel and source for each of the three seafood products to obtain an orthogonal design of 36 pair-wise comparisons using the JMP Pro Software (JMP®, Version *15*. SAS Institute Inc., Cary, NC, 1989-2021). The price attribute varied above and below the baseline market price for each product, with three levels above, and three levels below the MP. On a price per pound basis, shrimp and oysters had the same MP. We then randomly blocked these pair-wise comparisons into two versions of each of the three seafood products, for a total of six versions with four choice sets in each version. A third option, the "status-quo", indicating that respondents would not choose either the first or second option was included to level the origin of the utility scale. An example of the choice sets for shrimp is shown in figure 2.1.

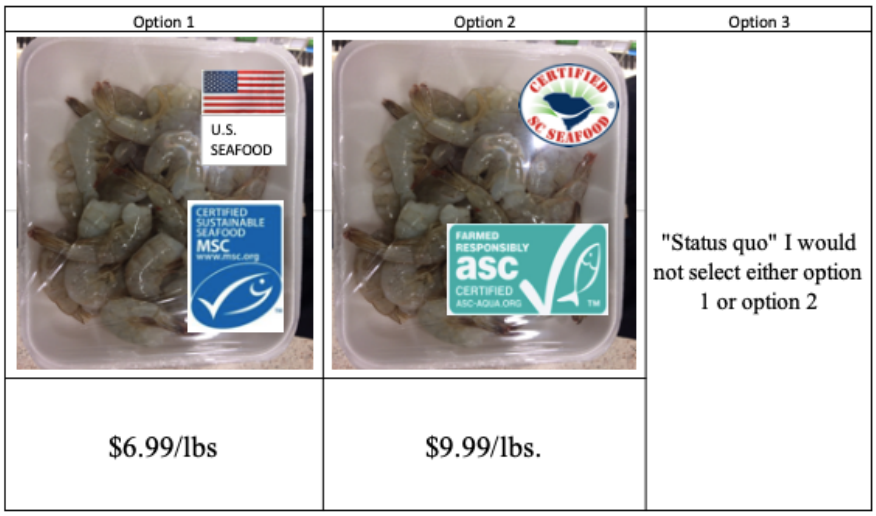

Figure 2.1: Sample choice set for shrimp

Empirical framework

Logistic regression

To assess the socioeconomic considerations of SC consumer's WTP a premium for local, aquaculture products, including clams, oysters, and shrimp, we utilized a logistic regression where WTP is a binary value of "1=Yes" if a respondent is willing to pay a premium and "0=No" if a respondent is unwilling to pay a premium for local aquaculture products. Willingness to pay a premium for local aquaculture products is defined as any price above the baseline market prices for oysters and shrimp, that is typical for SC presented in Table 1. In this model, we incorporated respondents' sociodemographic data as independent variables to predict the probability of South Carolina resident's WTP a premium for local aquaculture products. Maximum likelihood was used to determine the probability of each independent variables effect on the dependent variable, in this case WTP. Following Berkson (1944), the logistic regression equation is described below:

$$log\ [\frac{p}{(1-p)}] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_n x_n \qquad \text{eq (1)}$$

Where β_0 and β_1 represents beta coefficients that are fixed unknown parameters and *x* represents independent variables that may affect a residents' WTP a premium for local SC aquaculture products. A positive beta coefficient β_1 indicates that as *x* increases, *p*, of the log-odds increases as well. Conversely, if the beta coefficient β_1 is negative, an increasing *x* will result in a decreasing *p*.

Random utility model

The CE was structured using a random utility theory framework to assess indirect utility a survey respondent *n* makes when selecting an alternative choice *i* for the *t*-th

choice set (McFadden, 1974a; Manski, 1977). A survey respondent will select the alterative choice *i* if that choice results in greater utility when compared to seafood products in the same choice model, in the case of this choice experiment it is either clams, oysters, or shrimp. Random utility is presented as the following (McFadden, 1974):

$$U_{nit} = V(\mathrm{X}_{nit}) + \varepsilon(\mathrm{X}_{nit}) \qquad \text{eq (2)}$$

Where V_{nit} is the utility of respondent *n* choosing alternative *i* for the *t*-th choice set, $\mathrm{X}_{\mathrm{nit}}$ represents the attribute levels variable, and ε_{nit} is the error associated with the uncertainty of the utility expression. Random utility is derived from the random parameter that enables probability of respondent *n* in choice set *K* selecting alternative *i* over alternative *j* if the random utility of *i* is greater than *j.* To operationalize the model, the probability of choices using this framework is given:

$$P(i|K) = \mathrm{Prob}\big(V_{it} + \varepsilon_{it} > V_{jt} + \varepsilon_{jt}\big) \forall i \neq j \in K \quad \text{eq (3)}$$

Mixed logit model

While the conditional logit model is effective in estimating the probability of fixed explanatory variables, the assumption of independence of irrelevant alternatives (IIA) property is violated in a discrete choice experiment as preferences among individuals are assumed to be homogenous and therefore the mixed logit model is preferred. In the mixed logit model, fixed unknown parameters, β, are assumed to be random variables in which different values can vary across respondents, and therefore better captures the heterogeneity of choices among respondents (Hensher & Greene,

2003; McFadden, 1985). The mixed logit model (MLM) is represented in the following equation:

$$P_{nit} = \int \frac{e^{X_{nit}\beta}}{\sum_{k=1}^{i} e^{X_{nit}\beta}} h(\beta) d\beta \quad \text{eq (4)}$$

WTP estimation

Estimating compensating variation of willingness to pay (WTP) for each attribute in the CE can be calculated using the equation based on the principles of random utility in discrete choice experiments of McFadden (1978) and derived from the following equation from Hanemann (1984):

$$WTP = b_y^{-1} \ln \{ \frac{\sum_i e^{U_i^1}}{\sum_i e^{U_i^0}} \} \quad \text{eq (5)}$$

Where U^0 is the initial state of utility and U^1 is the alternate state of utility. The coefficient representing the price attribute, b_y, estimates the marginal utility of the function. Using this equation, WTP is estimated using the averages of explanatory variables across respondents, generating an aggregated WTP estimate for each attribute in the choice sets (Ben-Akiva et al., 1985).

While some variations of the attributes and products presented to respondents can be classified under contingent valuation, since there is no farm-raised shrimp actively being produced in South Carolina as opposed to farm-raised oysters, the purpose of our study in this circumstance is to generate estimates of WTP for currently non-marketed aquaculture products that could currently be feasibly produced in SC (Portney, 1994).

Results

Sociodemographic data

Demographic characteristics included age, years of residency in SC, education level, gender, race, and respondents' household income. A majority of respondents resided in the seven most populous counties, each with more than 100 participants per county (Greenville: 12%, Charleston: 9%, Richland: 8%, Horry: 8%, Spartanburg: 6%, Lexington: 6%, and York: 5%). Additionally, 71% of respondents reside in one of the 38 non-coastal counties. Respondents were asked to indicate their age, gender, combined annual household income in 2019, number of household members, education level, and years of residency in SC (Table 2.3). The average age among respondents was just under 44 years old, and a majority were female (69%).

Table 2.3: Sociodemographic data of survey respondents

Variable	Definition	Obs.	Sample Average	Std. Dev.	Min.	Max.	State Average[c]
Sociodemographic:							
Respondent location	(1 if inland, 0 if coas*tal)*	1308	0.71	0.30	0	1	0.71
Gender	(1 if males, 0 if female)	"	0.31	0.27	0	1	0.48
Age[a]	Average age in years	"	43.8	15.82	18	100	39.9[d]
Income[a]	Average 2019 household income ($)	"	65,989	56,500	0	>500K	56,277
Education[b]	Level of education in years	"	14.27	1.98	9	19	13.46
Household members	(including respondent)	"	3.00	1.78	0	9	2.54
Residency[a]	Numbers of years residing in SC	"	18.98	10.05	0	50	--
Race and ethnicity							
	Native American or Alaskan Natives.	11	0.008	--	--	--	0.004

Asian	14	0.011	--	--	--	0.017
Black or African American	279	0.21	--	--	--	0.26
Hispanic or Latino	28	0.02	--	--	--	0.058
Native Hawaiian or another Pacific Islander	1	0.001	--	--	--	0.001
White or Caucasian	960	0.73	--	--	--	0.66
Other	28	0.01	--	--	--	0.001
Employment						
Employed	935	0.71	--	--	--	0.58
Unemployed	255	0.19	--	--	--	0.03
Not in labor force	118	0.09	--	--	--	0.4

[a]Values are represented by using median values from categorical choices in the survey
[b]Values are represented by categorical choices, starting with Some High School and increasing to a Graduate Degree
[c]State level values are based on 2019 ACS 1-Year Estimates
[d]Age at the state level is based on individuals of 25 years or older

Average household income in 2019 was just over $65,000 and the average education level in years was 14.27, equating to between 2 and 3 years of post-secondary education. On average, respondents had two family members in their household, not including themselves and have resided in SC for just under 19 years. Additional sociodemographic questions found that most respondents are Caucasian (73%), followed by African American (21%), Hispanic or Latino (2%), Asian (1%), and other (e.g., Middle eastern, Native American, and Native Hawaiian or other Pacific Islanders) (3%). Additionally, most respondents were employed (71%), followed by unemployed (19%), and not in the labor force or retired (1%).

In comparing sample averages with those of state averages for various demographic characteristics, distribution of the percentage of respondents residing in

non-coastal counties compared to those living in one of the eight coastal counties (Beaufort Berkeley, Charleston, Colleton, Dorchester, Georgetown, Horry, and Jasper) was remarkably similar. Age, education, and number of household member among respondents as compared to the state average were also similar. A disproportionately higher number of survey respondents were female, explained in part by observations of online survey formats as opposed to other implementations, and household expenditure decision-making (Mulder et al., 2019; Saleh & Bista, 2017). Additionally, survey respondents reported higher overall average income when compared to the state average, indicating that most survey respondents reside in the seven most populous, and coincidentally the most affluent counties in terms of annual household income are evident.

Logistic regression

Logistic regression was utilized to explore factors impacting respondent's WTP a premium for local aquaculture products. WTP is a binary variable where "1=Yes" indicates a WTP a premium for local aquaculture products and "0" represents unwillingness to pay the premium. Independent variables in this model include two dummy variables, respondents who had previously purchased farm-raised seafood (purchased farm-raised = 1 and have not purchased = 0) and location of respondents based on county (coastal county = 1 and inland county = 0). Discrete numeric independent variables of age, years of residency in South Carolina, and household income in 2019 were also analyzed, in addition to the categorical education variable. For

the independent variables of age, year of residency, and income, median values are used in the model. The results of the regression analysis are presented below in Table 2.4.

Table 2.4: Logistic regression of respondent's WTP a premium for SC aquaculture products

Variable	Definition	Coefficient	SE	Marginal Effect
(Intercept)		0.154	0.23	0.508
Previously Purchased Aquaculture Products		0.343***	0.05	0.075***
Location		-0.081	0.11	-0.018
Age (years)		-0.008**	0.031	-0.002**
Years of Residency (years)		0.009*	0.005	0.002*
Household Income ($)		1.79e-06*	1.03e-06	3.93e-07*
Education		-0.033	0.037	-0.007

***p<0.01 **p<0.05, *p<0.1

Approximately two thirds (65%) of respondents were willing to pay a premium to purchase South Carolina aquaculture products. Having previously purchased aquaculture products and age were both significant in determining whether SC consumers are WTP a premium for local aquaculture products. The marginal effect of age was negative, where older respondents were less likely to pay a premium for local aquaculture products. Years of residency in SC had a positive marginal effect, indicating that the probability of WTP a premium for SC aquaculture products increases with years of residence.

Reasons for willingness to pay (WTP)

In this section we discuss the results of the stated reasons why respondents were either willing or unwilling to pay a premium for local aquaculture products. Averages of

the stated reasons are presented in Table 2.5. Most respondents (52%) who stated they were WTP a premium said "supporting in-state aquaculture producers" was the most important reason for paying the premium, while 20% reported "enhancing the South Carolina industry as a whole" was the most important factor. Among the other reasons, 16% reported that "aquaculture products from SC are fresher than other sources", and 12% indicated "aquaculture is a sustainable practice" as their most important reason for paying a premium. It is important to mention that the method of aquaculture production was not specifically addressed (e.g., recirculating aquaculture system, pond or mariculture) here. Of respondents who are not willing to pay a premium, 70% revealed that cost was the most significant barrier to paying a premium. The second most important reason for some respondents was that the source of their seafood does not matter to them (11%) and therefore, they are not willing to pay a premium. Finally, the third reason for not being willing to pay a premium was that respondents do not trust the safety of South Carolina aquaculture products (9%).

Table 2.5: Reasons for willingness and unwillingness to pay a premium for SC aquaculture products

Variable	**% of Respondents**
Reasons for willingness to pay a premium for SC aquaculture products	
Support in-state aquaculture producers	0.52
Premium in price can help enhance SC aquaculture industry	0.2
Farm-raised seafood is fresher than other sources	0.16
Aquaculture is a sustainable practice	0.12
Reasons for unwillingness to pay a premium for SC aquaculture products	
Do not have additional money to pay a premium	0.7
Source of seafood does not matter	0.11

Do not trust that SC aquaculture products are safe	0.09
Aquaculture industry in SC will not be successful	0.03
Other reason	0.07

Mixed logit model

Since standard logit model assumes preferences among respondents are homogenous, it might not necessarily show the actual decision-making strategies among a consumer. In this study, we utilized the MLM to account for respondent's unobservable preference heterogeneity of attributes in the CE. We ran two mix logit models, with the first model including the main attributes of source label, ecolabel, and price, with price being a fixed parameter that varies above and below the baseline price for each seafood product (Louviere, 1984). The second model includes all of the main attributes, in addition to interaction terms of respondents indicating they recognized seafood labelled as a local product to SC, or the Certified_SC_Seafood_Know attribute, and respondents who indicated they recognized the ASC ecolabel in a previous section of the survey, the ASC_Know attribute.

The first interaction term, Certified_SC_Seafood_Know, is a binary variable if respondents are recognized the Certified SC Seafood label for local aquaculture products. The latter interaction term serves as a proxy for respondents who are more informed as to the purpose of the ASC ecolabel, and/or aquaculture products that may fall under the guidelines of the ASC certification. We incorporated the entire sample for both models to discern whether local or non-local, and farmed shellfish displaying the ASC ecolabel or wild-caught shellfish displaying the MSC ecolabel is preferred. We follow Hole (2007)

using maximum simulated likelihood of the variables of interest, specifically the interaction terms previously described that are dummy coded with the Certified_SC_Seafood_Know variable and the ASC_know variable. The inclusion of additional explanatory variables from sociodemographic characteristics of respondents, such as respondents age or income, were not significant in the logit model parametrization, as these variables did not necessarily capture consumer heterogeneity in preliminary model fitting (Grebitus et al., 2013). The results of the MLM for oysters and shrimp are presented in Table 2.6 and Table 2.7, respectively.

Table 2.6: Mixed logit model estimates for WTP of oysters

		Base MLM			**MLM with interactions**		
Attribute	**Definition**	**Coefficient**	**SE**	**WTP**	**Coefficient**	**SE**	**WTP**
Price	$/lbs.	-0.370***	0.04		-0.378***	0.04	
Certified SC Seafood	$/lbs.	1.270***	0.11	3.43	0.948***	0.14	2.51
ASC[a]	$/lbs.	0.117	0.09	0.32	0.257***	0.12	0.68
Certified_SC_ Seafood_Know	$/lbs.				35.03	4837.3	
ASC_Know	$/lbs.				36.02	10215.9	
St. dev. of parameter estimates							
Certified SC Seafood	$/lbs.	1.416***	0.15		1.325***	0.22	
ASC[a]	$/lbs.	0.988***	0.18		0.457	0.37	
Constant	$/lbs.	4.071***	0.38		4.661***	0.60	
Certified_SC_ Seafood_Know	$/lbs.				0.821	2675.5	
ASC_Know	$/lbs.				1.221	6745.9	
Log-Likelihood			-1959.44			-921.02	

AIC	3934.88	1884.03
Observations	7,440	7,440

***p<0.01 **p<0.05, *p<0.1

[a]Aquaculture Stewardship Council (ASC) ecolabel indicates farm-raised seafood

Table 2.7: Mixed logit model estimates for WTP of shrimp

		Base MLM			MLM with interactions		
Attribute	**Definition**	**Coefficient**	**SE**	**WTP**	**Coefficient**	**SE**	**WTP**
Price	$/lbs.	-0.514***	0.04		-0.421***	0.04	
Certified SC Seafood	$/lbs.	1.298***	0.1	2.53	0.890***	0.11	2.51
ASC[a]	$/lbs.	-0.125	0.1	-0.24	-0.085	0.13	0.68
Certified_SC_ Seafood_Know	$/lbs.				39.30	853527.8	
ASC_Know	$/lbs.				38.53	964222.9	
St. dev. of parameter estimates							
Certified SC Seafood	$/lbs.	1.402***	0.14		0.782***	0.19	
ASC[a]	$/lbs.	-0.035	0.51		0.357	0.25	
Constant	$/lbs.	3.403***	0.33		3.203***	0.41	
Certified_SC_ Seafood_Know	$/lbs.				1.021	389425.1	
ASC_Know	$/lbs.				0.922	537502.7	
Log-Likelihood			-1892.28			-1000.8	
AIC			3800.55			2043.59	
Observations			7,464			7,464	

***p<0.01 **p<0.05, *p<0.1

[a]Aquaculture Stewardship Council (ASC) ecolabel indicates farm-raised seafood

Coefficients were conspicuously high for the Certified_SC_Seafood_Know and ASC_Know interaction terms in the extended models, and thus WTP estimates were not displayed. Hypothesis testing using Wald test's revealed that the null hypothesis of the MLM with interactions having a better model fit than the base MLM, and thus the additional random parameters improved the explanatory power regarding the variation in consumer's heterogeneity. The following χ^2 test statistics were calculated for the MLM with interactions for oysters; χ^2 = 34.15, ρ = <0.001, and shrimp; χ^2 = 15.67, ρ = 0.004. The price attribute in all models was significant and negative, indicating that as price increases, the likelihood of choosing the more expensive alternative decreases, which is commonly seen in similar choice experiments (Bronnmann & Asche, 2017; Roheim et al., 2012; Uchida et al., 2014).

A positive coefficient for the Certified SC Seafood label indicates that consumers prefer local oysters and shrimp. The ASC ecolabel was significant only in the extended model for oysters, where respondents indicated they are willing to pay a premium for SC aquaculture products and recognized the ASC ecolabel. The alternative specific constant in the models, or "buyno" option represents the opt-out alternative given to respondents. The statistically significant and negative coefficients of the constant variable across all models indicates that if product attributes do not affect the alternative chosen by respondents, they are less likely to choose that product, further demonstrating the heterogeneity of preferences between respondents.

Discussion

In this study, we conducted multiple levels of regression analysis beginning with the logistic regression of the factors influencing consumer's WTP a premium for local aquaculture products, and the mixed logit models for oysters and shrimp based on the choice experiment. In the logistic regression, those who have previously purchased aquaculture products may have more confidence in purchasing these types of seafood products, and the likelihood of WTP a premium for local aquaculture products could increase with prior experience of purchasing farm-raised seafood. Younger age groups were more likely to purchase farm-raised seafood products, consistent with the findings of Fernandez-Polanco & Luna, (2012), and Roheim et al. (2012) in regard to farmed shrimp. The marginal effect of income was positive and significant at the 90% confidence interval, following similar national trends of aquaculture products being purchased more frequently by individuals in higher income brackets (Quagrainie et al. 2008; Risius et al. 2017).

Our results show that location of residence, either one of the 36 inland counties, or one of the 8 coastal counties in SC, does not impact the likelihood for WTP a premium for local aquaculture products, indicating that consumers of aquaculture products may be more heterogeneously distributed across the state than previously thought. While we did not differentiate between residents and tourists of SC in the CE, a study of oyster consumers in Hawaii found that residents are more willing to pay a premium for local farm-raised oysters as opposed to tourists, and thus additional research exploring this dynamic could be useful (Chen et al., 2017). Education among respondents was assessed based on the findings of Fernandez-Polanco & Luna (2012), which indicated that support

for aquaculture increased among highly educated respondents (Fernandez-Polanco & Luna, 2012). We found that level of education (in years) does not significantly affect respondents WTP for local aquaculture products in SC

An interesting finding among the coefficient estimates for oysters shows that respondents who recognize the ASC ecolabel, are willing to pay $1.15 more per pound of farm-raised, market size oysters (3”). It has been found that consumers across the U.S. prefer farm-raised “single” oysters over their wild-caught “cluster” counterparts and do so predominantly based on taste, appearance and locality (Chen et al., 2017; Li et al, 2019; Petrolia et al., 2017). Briefly, we will discuss our decision to evaluate oysters on a price per pound basis, and how this can be interpreted for farm-raised “single” oysters. As oyster mariculture production has continued to increase nationally, so too has market accessibility to farm-raised oysters. These “single” oysters are sold individually, and at a higher price than their wild-caught “cluster” counterparts that are typically sold per pound. Total oyster mariculture production in 2018 resulted 45 million pounds of farm-raised oysters, nearly doubling the estimated 23 million pounds of wild-caught oysters (NMFS, 2018). The type of oysters available to consumers based on production are highly variable due to the market outlets typically associated with purchasing selling these products. For example, wild-caught oysters can more readily be purchased at grocery stores and associated market outlets, while farm-raised oysters are more commonly sold to restaurants and seafood purveyors.

Understanding the WTP estimate for oysters may only be applicable to those oysters that have produced through aquaculture, a post-hoc conversion of pricing is

implemented to better reflect WTP for farm-raised "single" oysters. Recent estimates of locally sourced, farmed raised oysters in SC have found that the average single oyster sells for approximately $2.65 in restaurants and other market outlets within the state (Gorstein et al., 2021). While the number of oysters per pound varies based the size and condition of the oysters, farm-raised oysters are consistently sold at a market size of 3 in. Using the units of bushels, in which one-bushel weighs approximately 45-60 pounds and contains between 100-150 oysters, roughly three oysters weigh one pound (Fresh Seafood, 2021). The baseline market price per pound of oysters was $7.99, and accounting for three oysters in a pound result in a baseline market price for single oysters at $2.67, within $0.02 of the estimated generated for SC farm-raised oysters. In the results of the extended model for oysters, where both the Certified SC Seafood label and the ASC ecolabel significantly increase WTP, respondents are WTP $0.80 more per farm-raised oyster with the Certified SC Seafood label and $0.35 per oyster with the ASC ecolabel.

The WTP estimates generated between the base MLM and extended model show that consumers had a positive preference for ASC certified farm-raised oysters in both models, a positive preference for MSC certified wild-caught shrimp in the base model, and a slightly positive preference for ASC certified farm-raised shrimp in the extended model. The latter result, while not significant, signals that prior recognition of the ASC ecolabel, slightly offsets the potentially negative perceptions consumers have of farmed shrimp. Conversely, in a similar study respondent who reported perceiving aquaculture production as negatively impacting the environment were less likely to purchase farm-

raised shrimp (Roheim et al., 2012). Our result indicates that the ASC ecolabel for farmed shrimp results in a higher WTP for these products. While the WTP estimate of the Certified SC Seafood label decreased in the extended model for both products, the WTP estimate for local, ASC certified oysters exceeds that local, non-ASC-certified oysters. Our results further explain that sustainability may play a role in consumers preference for farm-raised oysters, especially if consumers have had previous interactions with the ASC ecolabel. In the base MLM, the marginally negative sign of the ASC ecolabel attribute for shrimp means that respondents were less likely to choose options where farmed raised clams and shrimp certified with the ASC ecolabel were present, thus their WTP estimate for these products was also marginally negative.

Conclusion

This paper aims to address the gap in literature surrounding the aquaculture industry in the southeastern U.S., specifically the species currently produced and consumer's WTP for sustainability for local, farm-raised seafood. Respondents prefer locally sourced oysters and shrimp as opposed to that sourced outside of South Carolina, and in the case of oysters, farm-raised and ASC certified is preferred to wild-caught and MSC certified. According to the ASC certification guidelines, bivalve mariculture is assessed on the following criterion: biodiversity, pollution, diseases, wild seed collection and social dimensions among others (ASC Bivalve Standard V1.1, 2019). Many of these components to certification through ASC are actively implemented by oyster growers across several counties in South Carolina currently, and extensive permitting

requirements, controls for importing out-of-state and monitoring of bacterial pathogens present in oysters such as *Perkinsus marinus*, "Dermo" and *Haplosporidium nelson*, "MSX", ensures safety and sustainability of the oyster mariculture industry.

Several factors pose a limitation to obtaining certification against the ASC Bivalve Standards, including costs associated with the application and auditing process, in which the latter typically requires that businesses have been in operation for a set timeframe before seeking certification. More importantly, only two aquaculture operations are currently ASC certified in the U.S., both of which became certified in 2021, the first involved in the production Longfin Yellowtail *Seriola rivoliana* in offshore net pens, the second involved in the production of a freshwater microalgae *Schizochytrium spp.* using a recirculating aquaculture system, or RAS (NOAA, 2019; NOAA, 2020). Thus, the nascent implementation of the ASC ecolabel among U.S. aquaculture producers poses some difficulty for aquaculture operations in South Carolina to become ASC certified.

Based on these results for WTP, consumers are likely to pay a premium for local farm-raised oysters that are certified using the ASC ecolabel. In a broader context, limited market access to wild oyster stocks due to local populations declines of more than 99% of the historical abundance in SC could also play a role in the preference for farm-raised oysters (Coen et al., 1999). Consumers also prefer locally sourced shrimp and will pay slightly more for farm-raised shrimp with prior recognition of the ASC ecolabel. However, it is encouraging that local, farm-raised shrimp demands a higher price as the recirculating aquaculture system production method associated with shrimp is both

expensive and requires technical expertise of culturing practices (Chow et al., 1991; USDA, 2019).

The SC commercial shrimp industry has existed for nearly 100 years and has actively met regulatory measures of sustainable practices at the state and federal level, thus meeting MSC guidelines for certification could be possible, and the industry could benefit from implementing this labelling regime to local market outlets, (Ajuzie, 1987; Roheim et al., 2012). The findings of this study for clams and shrimp follow the trends of other similar CE involving seafood, where consumers preferred wild-caught seafood as opposed to farm-raised (Bronnmann & Asche, 2017; Uchida et al., 2014). Coupling of the product attributes in our CE, where farm-raised products were displayed with the ASC ecolabel and similarly wild-caught products with the MSC ecolabel, provides respondents with a realistic set of options in market settings and focuses on the utility generated from sustainably sourced seafood products. These results can help producers in SC better assess the benefits generated from utilizing ecolabelling regimes, and better capturing the potential economic impact generated from consumer's preferences for locally sourced, sustainably produced seafood.

Works Cited

Ajuzie, E. I. 1989. The Economic impact of South Carolinas commercial shrimp industry, 1987. *Technical report/South Carolina. Marine Resources Division (USA)*.

Aquaculture Stewardship Council 2019. ASC Bivalve Standard Version 1.1. Utrecht, The Netherlands

Ayer, N., Côté, R. P., Tyedmers, P. H., & Martin Willison, J. H. 2009. Sustainability of seafood production and consumption: an introduction to the special issue. *Journal of Cleaner Production, 17*(3), 321-324. doi:https://doi.org/10.1016/j.jclepro.2008.09.003

Ben-Akiva, M., & Lerman, S. R. 1985. *Discrete choice analysis: theory and application to travel demand*. Cambridge, MA: MIT Press.

Berkson, J. 1944. Application of the Logistic Function to Bio-Assay. *Journal of the American Statistical Association, 39*(227), 357-365. doi:10.1080/01621459.1944.10500699

Blomquist, J., Bartolino, V., & Waldo, S. 2015. Price Premiums for Providing Eco-labelled Seafood: Evidence from MSC-certified Cod in Sweden. *Journal of Agricultural Economics, 66*(3), 690-704. doi:https://doi.org/10.1111/1477-9552.12106

Boscaino, G., Sprovieri, M., Attanasio, M., Vitale, S., Giosue, C., Biondo, F.,,Bono, G. 2017. Are People Willing to Pay for Eco-Labeled Wild Seafood? An Overview. *European Journal of Sustainable Development, 6*(3), 20. doi:10.14207/ejsd.2017.v6n3p20

Bronnmann, J., & Asche, F. 2017. Sustainable Seafood From Aquaculture and Wild Fisheries: Insights From a Discrete Choice Experiment in Germany. *Ecological Economics, 142*, 113-119. doi:https://doi.org/10.1016/j.ecolecon.2017.06.005

Chen, J. Q., Haws, M. C., Fong, Q. S. W., & Leung, P. 2017. Locally Grown Oysters in Hawaii: Chef Preference and Local Premium? *Journal of the World Aquaculture Society, 48*(6), 972-980. doi:https://doi.org/10.1111/jwas.12430

Chow, S., Dougherty, M.M., Dougherty W.J., Sandifer, P.A. 1991. Spermatophore formation in the white shrimps Penaeus setiferus and P. vannamei. *Journal of Crustacean Biology 11(16)*, 201-216

Coen, L. D., Knott, D. M., Wenner, E. L., Hadley, N. H., Ringwood, A. H., & Bobo, M. Y. 1999. Intertidal oyster reef studies in South Carolina: design, sampling and experimental focus for evaluating habitat value and function. *Oyster reef habitat restoration: a synopsis and synthesis of approaches. Virginia Institute of Marine Science Press. Gloucester Point, Virginia*, 133-158.

Davidson, K., Pan, M., Hu, W., & Poerwanto, D. 2012. Consumers' Willingness to Pay for Aquaculture Fish Products Vs. Wild-Caught Seafood – A Case Study in Hawaii. *Aquaculture Economics & Management, 16*, 136-154. doi:10.1080/13657305.2012.678554

Fernández-Polanco, J., & Luna, L. 2012. Factors Affecting Consumers' Beliefs About Aquaculture. *Aquaculture Economics & Management, 16*(1), 22-39. doi:10.1080/13657305.2012.649047

Food and Agricultural Organization of the United Nations, 2018. *The State of World Fisheries and Aquaculture 2018*. *Meeting the sustainable development goals*. Rome.

Food and Agricultural Organization of the United Nations, 2020. *The State of World Fisheries and Aquaculture 2020*. *Sustainability in action*. Rome.

Gall, K., and O'Dierno, L. 1993. Aquaculture Marketing Survey; Consumers, Retail Stores, and Food Service in New York and New Jersey. *New York Sea Grant Extension Program Press*

Global Aquaculture Alliance 2019.Global Aquaculture Alliance Annual Report 2019. Portsmouth, NH. December, 2019.

Gorstein, M., Motallebi, M., Carey, R., Cheplick, D., Gaines, G., Richards, S. (2021, August 11-14). *South Carolina's first oyster mariculture industry outlook assessment* [Conference presentation]. Aquaculture America 2021, San Antonio, TX, United States https://wasblogstorage.blob.core.windows.net/meetingabstracts/AA2021AbstractBook.pdf

Grebitus, C., Lusk, J. L., & Nayga, R. M. 2013. Effect of distance of transportation on willingness to pay for food. *Ecological Economics, 88*, 67-75. doi:https://doi.org/10.1016/j.ecolecon.2013.01.006

Greene, W., & Hensher, D. 2003. A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B: Methodological, 37*(8), 681-698. Retrieved from https://EconPapers.repec.org/RePEc:eee:transb:v:37:y:2003:i:8:p:681-698

Gutierrez, A., & Thornton, T. F. 2014. Can Consumers Understand Sustainability through Seafood Eco-Labels? A U.S. and UK Case Study. *Sustainability, 6*(11). doi:10.3390/su6118195

Hanemann, M. 1984. Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses. *American Journal of Agricultural Economics, 66*(3), 332-341. Retrieved from https://EconPapers.repec.org/RePEc:oup:ajagec:v:66:y:1984:i:3:p:332-341.

Hausman, J., & McFadden, D. 1984. Specification Tests for the Multinomial Logit Model. *Econometrica, 52*(5), 1219-1240. Retrieved from https://EconPapers.repec.org/RePEc:ecm:emetrp:v:52:y:1984:i:5:p:1219-40

Henry, M., Rhodes, R., & Eades, D. 2008. The Flow of South Carolina Harvested Seafood Products through South Carolina Markets. *UCED Research Report*

Hensher, D., Louviere, J., & Swait, J. 1998. Combining sources of preference data. *Journal of Econometrics, 89*(1), 197-221. doi:https://doi.org/10.1016/S0304-4076(98)00061-X

Hicks, D., Pivarnik, L., & McDermott, R. 2008. Consumer perceptions about seafood – an Internet survey. *Journal of Foodservice, 19*(4), 213-226. doi:https://doi.org/10.1111/j.1748-0159.2008.00107.x

Hilborn, R., Banobi, J., Hall, S. J., Pucylowski, T., & Walsworth, T. E. 2018. The environmental cost of animal source foods. *Frontiers in Ecology and the Environment, 16*(6), 329-335. doi:https://doi.org/10.1002/fee.1822

Hornborg, S., Hobday, A. J., Ziegler, F., Smith, A. D. M., & Green, B. S. 2018. Shaping sustainability of seafood from capture fisheries integrating the perspectives of supply chain stakeholders through combining systems analysis tools. *ICES Journal of Marine Science, 75*(6), 1965-1974. doi:10.1093/icesjms/fsy081

Hsieh, D. A., Manski, C. F., & McFadden, D. 1985. Estimation of Response Probabilities from Augmented Retrospective Observations. *Journal of the American Statistical Association, 80*(391), 651-662. doi:10.1080/01621459.1985.10478165

Jaffry, S., Pickering, H., Ghulam, Y., Whitmarsh, D., & Wattage, P. 2004. Consumer choices for quality and sustainability labelled seafood products in the UK. *Food Policy, 29*(3), 215-228. doi:https://doi.org/10.1016/j.foodpol.2004.04.001

O'Dierno, J., Govindasamy, R., Puduri, V. S., Myers, J. J., & Islam, S. 2006. *Consumer Perceptions and Preferences for Organic Aquatic Products: Results from the Telephone Survey*. Retrieved from https://EconPapers.repec.org/RePEc:ags:rutdps:36743

Kumar, G., & Engle, C. R. 2016. Technological Advances that Led to Growth of Shrimp, Salmon, and Tilapia Farming. *Reviews in Fisheries Science & Aquaculture, 24*(2), 136-152. doi:10.1080/23308249.2015.1112357

Le Manach, F., Jacquet, J. L., Bailey, M., Jouanneau, C., & Nouvian, C. 2020. Small is beautiful, but large is certified: A comparison between fisheries the Marine Stewardship Council (MSC) features in its promotional materials and MSC-certified fisheries. *PLOS ONE, 15*(5), e0231073. doi:10.1371/journal.pone.0231073

Li, T., Ahsanuzzaman, A., & Messer, K. 2020. Is This Food "Local"? Evidence from a Framed Field Experiment. *Journal of Agricultural and Resource Economics, 45*(2), 302449. Retrieved from https://EconPapers.repec.org/RePEc:ags:jlaare:302449

Lim, K., & Hu, W. 2015. How Local Is Local? A Reflection on Canadian Local Food Labeling Policy from Consumer Preference. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 64*, n/a-n/a. doi:10.1111/cjag.12062

Louviere, J. J. 1984. Using discrete choice experiments and multinomial logit choice models to forecast trial in a competitive retail environment: A fast food restaurant illustration. *Journal of Retailing, 60*(4), 81-107.

Lusk, J. L., & Schroeder, T. C. 2004. Are Choice Experiments Incentive Compatible? A Test with Quality Differentiated Beef Steaks. *American Journal of Agricultural Economics, 86*(2), 467-482. doi:https://doi.org/10.1111/j.0092-5853.2004.00592.x

Manski, C. F. 1977. The structure of random utility models. *Theory and Decision, 8*(3), 229-254. doi:10.1007/BF00133443

Manzi, J. J., Hadley, N. H., & Maddox, M. B. 1986. Seed clam, Mercenaria mercenaria, culture in an experimental-scale upflow nursery system. *Aquaculture, 54*(4), 301-311. doi:https://doi.org/10.1016/0044-8486(86)90274-7

Marine Stewardship Council. 2020 Marine Stewardship Council Annual Report 2019-2020. *12*

Matthew, T. P., Trevor, D. F., Grace, M. V., John, E. V., & Edith, M. W. 2020. Quantifying the Seafood Consumption Patterns of Recreational Anglers in Charleston and Berkeley Counties, South Carolina. *Environmental Health Insights, 10*(1). doi:10.1177/EHI.S40668

McFadden, D. 1974a. The measurement of urban travel demand. *Journal of Public Economics, 3*(4), 303-328. doi:https://doi.org/10.1016/0047-2727(74)90003-6

McFadden, D. 1974b. Conditional logit analysis of qualitative choice behavior. *Frontiers in econometrics*, 105-142.

McFadden, D., & Train, K. 2000. Mixed MNL models for discrete response. *Journal of Applied Econometrics, 15*(5), 447-470. doi:https://doi.org/10.1002/1099-1255(200009/10)15:5<447::AID-JAE570>3.0.CO;2-1

Mulder, J., & Bruijne, M. D. 2019. Willingness of Online Respondents to Participate in Alternative Modes of Data Collection. *Survey practice, 12*, 8356.

National Marine Fisheries Service. 202. Fisheries of the United States, 2018. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2018

National Oceanic and Atmospheric Administration, 2019. Permitting and Authorization Process for Aquaculture in U.S. Federal Waters of the Gulf of Mexico, Silver Spring, MD

Petrolia, D. R., Walton, W. C., & Yehouenou, L. 2017. Is There a Market for Branded Gulf of Mexico Oysters? *Journal of Agricultural and Applied Economics, 49*(1), 45-65. doi:10.1017/aae.2016.30

Ponte, S. (2012). The Marine Stewardship Council (MSC) and the Making of a Market for 'Sustainable Fish'. *Journal of Agrarian Change, 12*, 300-315. doi:10.1111/j.1471-0366.2011.00345.x

Polymeros, K., Kaimakoudi, E., Mitsoura, A., Nikouli, E., & Mente, E. 2014. The Determinents of Consumption for Organic Aquaculture Products – Evidence from Greece. *Aquaculture Economics & Management, 18*(1), 45-59. doi:10.1080/13657305.2014.855954

Portney, P. R. 1994. The Contingent Valuation Debate: Why Economists Should Care. *Journal of Economic Perspectives, 8*(4), 3-17. doi:10.1257/jep.8.4.3

Quagrainie, K., Hart, S., & Brown, P. 2008. Consumer Acceptance of Locally Grown Food: The Case of Indiana. *Aquaculture Economics & Management, 12*(1), 54-70. doi:10.1080/13657300801962591

Richards S. 2020 The South Carolina Shellfish Industry Faces a Challenging Recovery After COVID-19. Clemson (SC): Clemson Cooperative Extension, Land-Grant Press by Clemson Extension; 2020 Jun. LGP 1071.Retireved from https://lgpress.clemson.edu/publication/the-south-carolina-shellfish-industry-faces-a-challenging-recovery-after-covid-19/.

Risius, A., Janssen, M., & Hamm, U. 2017. Consumer preferences for sustainable aquaculture products: Evidence from in-depth interviews, think aloud protocols and choice experiments. *Appetite, 113*, 246-254. doi:https://doi.org/10.1016/j.appet.2017.02.021

Roebuck, K. & Wristen, K. 2018 Global Review of the Aquaculture Stewardship Council's Salmon Standard. Technical Report. SeaChoice, September 2018.

Roheim, C., Omana Sudhakaran, P., & Durham, C. 2012. Certification of Shrimp and Salmon for Best Aquaculture Practices: Assessing Consumer Preferences in Rhode Island. *Aquaculture Economics & Management, 16*, 266-286. doi:10.1080/13657305.2012.713075

Roheim, C. A., Asche, F., & Santos, J. I. 2011. The Elusive Price Premium for Ecolabelled Products: Evidence from Seafood in the UK Market. *Journal of Agricultural Economics, 62*(3), 655-668. doi:https://doi.org/10.1111/j.1477-9552.2011.00299.x

Roheim, C. A., Bush, S. R., Asche, F., Sanchirico, J. N., & Uchida, H. 2018. Evolution and future of the sustainable seafood market. *Nature Sustainability, 1*(8), 392-398. doi:10.1038/s41893-018-0115-z

Roheim, C. A., & Zhang, D. 2018. Sustainability certification and product substitutability: Evidence from the seafood market. *Food Policy, 79*, 92-100. doi:https://doi.org/10.1016/j.foodpol.2018.06.002

Saleh, A., & Bista, K. 2017. Examining Factors Impacting Online Survey Response Rates in Educational Research: Perceptions of Graduate Students. *Journal of MultiDisciplinary Evaluation; Vol 13 No 29 (2017)*. Retrieved from https://journals.sfu.ca/jmde/index.php/jmde_1/article/view/487

Soley, G., Hu, W., & Vassalos, M. 2019. Willingness to Pay for Shrimp with Homegrown by Heroes, Community-Supported Fishery, Best Aquaculture Practices, or Local Attributes. *Journal of Agricultural and Applied Economics, 51*(4), 606-621. doi:10.1017/aae.2019.19

Sullivan, G., & Hunt, D. 1984. A Comparison of Market Channels for Commercially-Caught Catfish and Cultured Catfish in Alabama's Lower Tombigbee River Basin. *Journal of the World Mariculture Society, 15*(1-4), 391-397. doi:https://doi.org/10.1111/j.1749-7345.1984.tb00173.x

Tallis, H., Levin, P., Ruckelshaus, M., Lester, S., McLeod, K., Fluharty, D., & Halpern, B. 2010. The many faces of ecosystem-based management: Making the process work today in real places. *Marine Policy, 34*, 340-348. doi:10.1016/j.marpol.2009.08.003

Thilmany, D., Onozaka, Y., & Nurse, G. 2010. Local Food Consumers: How Motivations and Perceptions Translate to Buying Behavior. *Choices, 25*.

U.S. Census Bureau. 2019. *2019 American Community Survey 1-Year Estimates.* Washington D.C.

United States Department of Agriculture. 2019. *2017 Census of Agriculture, 2018 Census of Aquaculture. National Agricultural Statistics Service.* Washington D.C.

doi:https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Aquaculture/index.php

Vermeir, I., & Verbeke, W. 2008. Sustainable food consumption among young adults in Belgium: Theory of planned behaviour and the role of confidence and values. *Ecological Economics, 64*(3), 542-553. Retrieved from https://EconPapers.repec.org/RePEc:eee:ecolec:v:64:y:2008:i:3:p:542-553

Xuan, B. B. 2021. Consumer preference for eco-labelled aquaculture products in Vietnam. *Aquaculture, 532*, 736111. doi:https://doi.org/10.1016/j.aquaculture.2020.736111

Zeng, T., & Hill, R. 2010. Pretest Estimation in the Random Parameters Logit Model. *Advances in Econometrics, 26*, 107-136. doi:10.1108/S0731-9053(2010)0000026008

CHAPTER THREE

A MIXED METHODS APPROACH TO EVALUATING SOUTH CAORLINA'S OYSTER MARICULTURE INDUTRY

Introduction

Global human population has increased by 48%, roughly 2.5 billion people, since 1990 (United Nations Population Statistics, 2019). Over a twenty-nine-year period from 1990 to 2019, global food fish consumption has risen by 122%. To supply this growth in seafood consumption, aquaculture production of food fish has increased nearly 500%, while global capture fisheries production has increased only 14% (Food and Agriculture Organization, 2020). According to the United Nations Food and Agriculture Organization (FAO), aquaculture production now accounts for 53% of global human seafood consumption, with 171 million tons of seafood produced in 2016 (FAO, 2018). In the U.S., total seafood consumption has increased by 25% from 1980 to 2018 (National Marine Fisheries Services (NMFS), 2018) and importation of seafood products to the U.S. are estimated to exceed 80% (Bostock et al., 2010).

We refer to aquaculture as the farming of an array of aquatic organisms, including but not limited to aquatic plants and animals of freshwater and marine habitats. Aquaculture is performed in freshwater structures (e.g. ponds, raceways) and marine ecosystem (mariculture) in addition to operations that are land-based using a variety of methods (e.g. recirculating aquaculture system). Aquaculture is an ancient practice of food production dating back to 6000 B.C., when early civilizations cultivated Common Carp *Cyprinus carpio.* While freshwater fish aquaculture production remains a key

component to the food fish industry in the U.S., namely the production of tilapia and several species of catfish, there has been a shift towards shellfish mariculture, specifically of bivalves such as the Eastern Oyster *Crassotrea virginica* and the Hard Clam *Mercenaria mercenaria* in South Carolina (Clancy et al. 1991; Manzi et al. 1981; Sullivan & Hunt, 1984). The latter species been produced on a large scale in South Carolina from the 1970's. This increase has been due in part to emerging advances in sustainability through coastal ecosystems-based management (EBM), in addition to thorough efforts by federal and state agencies addressing the need for expanding the domestic shellfish mariculture industry (NOAA, Permitting and Authorization Process for Aquaculture in U.S. Federal Waters of the Gulf of Mexico, 2019; Tallis et al., 2010). It has been well documented that shellfish mariculture provides a suite of ecosystem services in habitats they are persistent in, including water filtration, suspension of sediments, habitat complexity for an array of fish an invertebrate species, and cultural ecosystem services in couple human-natural systems (Michaelis et al., 2021; Michaelis et al., 2020; Webber et al., 2020; van de Schatte et al., 2020; Carranza & zu Ermgassen, 2020; Peterson et al., 2010; Zheng et al., 2009).

Previous studies utilizing mixed methods approaches in aquatic ecosystems have explored the dynamics of fisheries involving both the sentiments of those involved in the industry and the spatial extent of fishing activities on broad scales (Collins et al., 2021). We do not include a spatial component to this research as confidentiality is a concern regarding oyster farms in SC, rather aggregated production data forms characteristics of participants and the factors influencing production of this industry at a local scale. Using

a mixed methods approach, the objective of this research is three-fold. First, using production data of the number of oysters grown, relative infrastructure based on the number of cages being used as well as operation costs generates estimates of the scale of the average oyster farm in SC during 2020, to then compare to previous years in terms of the effects of the Covid-19 pandemic on overall production. Secondly, gathering qualitative data that further describes the decisions and strategies in the production process that is then qualitatively coded according to the themes that arise, offers a more nuanced approach then simply interpreting aggregated production data to explain the current and projected capacity of these operations. Lastly, utilizing results from the choice experiment of among SC consumers of local, ASC certified oysters, where respondents who recognized the ASC ecolabel were willing to pay a premium of 8% above market price for ASC certified oysters, a benefit-cost analysis is performed to determine the economic feasibility of becoming ASC certified based on the average production metrics of SC oyster farms.

Methods and Materials

Participant recruitment

We identified oyster farm operators, all of which are currently in operation albeit at different stages in establishment, throughout coastal South Carolina in June 2020. Researchers then contacted oyster farm operators through both telephone and personal communication, and the purpose of the study was explained, and permission was requested to conduct an in-depth interview at a later date. Participants were asked where the most convenient location for the interview to be conducted would be, and interviews

were then conducted at the participant's oyster farm when appropriate. Five interviews were completed over the course of a 5-month period between October 2020 and February 2021. Institutional approval for conducting our producer interviews by trained researchers, was approved by Clemson University's Internal Review Board (IRB) in January 2020 (reference code: 2019-184). As a generalized geographic reference of the study area where interviews were conducted, a map of South Carolina and its central and southern coastal region including Charleston, Colleton, Beaufort, and Jaspar counties is displayed in Figure 3.1. It is to be noted no identifying features of participant's operations is disclosed in this map.

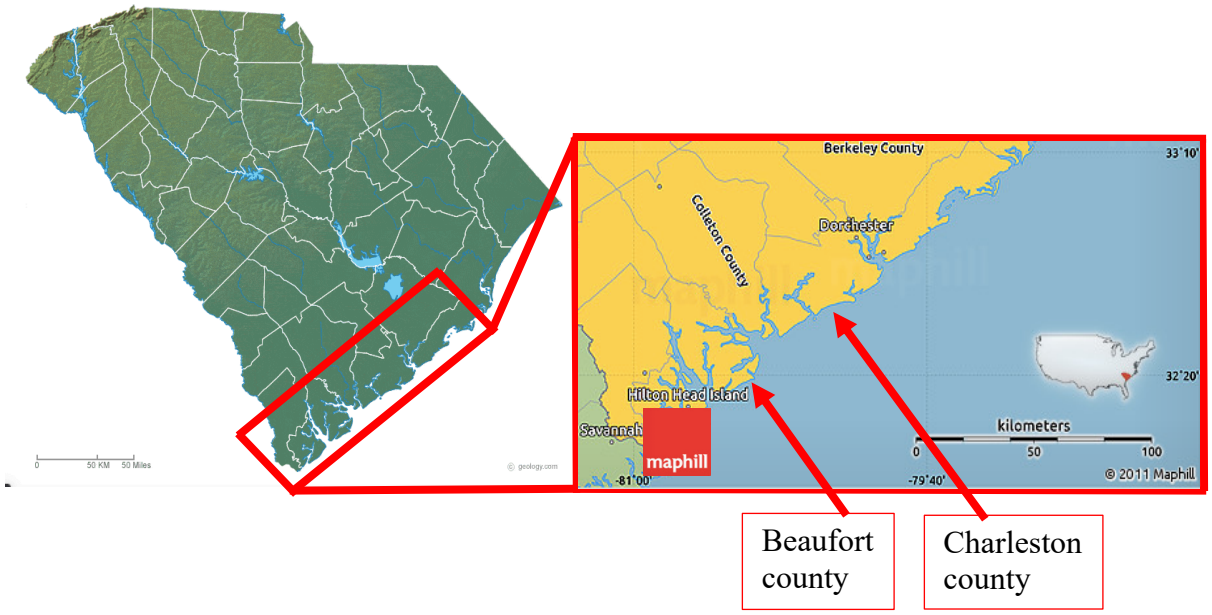

Figure 3.1: Map of South Carolina (left) and generalized study area of participants
Images courtesy of Geology.com (left) and Maphill (right)
(https://geology.com/topographic-physical-map/south-carolina.shtml)
(http://www.maphill.com/united-states/south-carolina/simple-maps/savanna-style-map/)

Oyster producer interview

The interview guide was constructed from recent literature classifying a state or region's shellfish mariculture industry involving collection of data on production metrics, operations costs, and open-ended questions on a diversity of challenges oyster farms face from seed allocation to access to market outlets (van Senten, 2019). However, limited literature on the qualitative considerations of shellfish mariculture production exists, therefore related literature on aquaculture production on other species was assessed to better understand social prioritizations in these industries (Lim et al., 2020). Finally, we utilized recommendations from South Carolina aquaculture industry experts and resource management professionals to better structure the types of questions asked as they specifically relate to South Carolina's oyster mariculture industry.

Our interview guide followed a semi-structured approach, in which the quantitative data section included questions related to production metrics and operation costs, while the qualitative section included a mix of open and closed ended questions. The 27 open and closed ended questions comprise of (1) closed-ended production metric related questions that formed descriptive statistics of participant's operations that was then aggregated for purposes of confidentiality, (2) questions elaborating on the production metric section to a further degree, including changes in the operation's production capacity both at the time of survey and in the coming two years, and (3) open-ended questions, with some containing multiple, non-hierarchical components that participants could further discuss such as oyster seed availability, permitting and market changes during the COVID-19 pandemic. To

confirm the interview guide was understood by participants, we conducted a pilot interview with one of the oyster growers, and no changes were made for the remaining interviews.

Qualitative data analysis

Interviews recorded by researchers on-site were later transcribed to word documents at a later date. Interview guides did not contain any identifying material to be answered by respondents, and any potential identifying remarks were removed prior to transcription. Interviews were then imported to the NVivo software Version 1.5 (QSR International, London, UK) to undergo data coding, classification, and analysis. We started by creating a thematic coding framework based on the interview guide and its associated questions that would inform the topical areas in the coding framework. We reviewed recent literature evaluating the social, economic, and environmental factors influencing mariculture production, as it is imperative to have current comparative baselines in an industry facing wide-ranging and complex interactions such as climate change, to support our thematic coding framework (Holden et al., 2019; Kuempel et al., 2021; Ruff et al., 2020; Theuerkauf et al., 2019). Using a deductive approach, or a concept-driven framework to create and reaffirm preexisting themes and narratives, coding was performed iteratively allowing for restructuring of parent and child codes over the course of qualitive analysis to achieve satisfactory insight within the thematic coding framework (Bryman, 2016; Saldaña & Omasta, 2016). In the coding results, selected quotes are included to provide additional context of collective responses of participants. Thematic coding follows the key criteria

presented in the interview guide, as shown in Table 3.1. describing the thematic coding framework.

Table 3.1: Thematic coding framework forming the codebook for qualitative analysis

Category	**Subgroup**	**Definition**
Factors influencing oyster mariculture production in SC	Production	Allocation of infrastructure, including *changes in the number of grow-out cages* Changes in grow-out techniques, including *frequency of air-drying grow-out cages and tumbling* Sourcing of oyster seed, including *limitations due to oyster seed availability and lifting of the moratorium on importing oyster seed from states north of South Carolina*[a] Effects of COVID-19 on production efficiency, including *estimates of seed mortality during 2020*

	Sales	Changes in sales from 2019 to 2020, including *challenges in sales during the start of the COVID-19 pandemic* Changes in sales strategies, including *non-market products*
	Industry	Collaboration between oyster growers, including *consolidated marketplaces, distribution, marketing and production* Role of state and federal agencies in aiding, including *education, funding, lobbying, and resource appropriation* Barriers for new oyster farmers, including *initial capitol, lack of guidance, permitting and seed availability* Response to COVID-19 on operation capacity, including *access to CARES Act*

[a]On April 1st, 2014, South Carolina placed a ban on importing seed north of SC, over concerns of disease transmission (SC Sea Grant Commission, 2014)

Benefit-cost analysis of SC oyster farms becoming ASC certified

The producer interviews offer important insight to the techniques and strategies SC oyster farms use to market and sell their products, in addition to the relative impact these operations pose economically and socially for the broader aquaculture industry in SC. A theme that arose from collecting data on production metrics and grower's perceptions of the challenges faced during the beginning of their operations existence concerns the

monitoring and oversight through state and federal agencies to meet regulatory requirements and ensure their operations are not damaging surrounding habitats. Preventing or mitigating negative environmental, social, or cultural perturbations to the surrounding environment is thus an assurance towards sustainability in practice, and its application to a low impact, passive form of food production, in this case the growing of oysters in marine ecosystems, is of particular interest in this study (Brown et al, 2020; Byron et al., 2011a). Ecolabelling, the labelling of products certified to be produced in a sustainable manner, has become an increasingly important apparatus at the nexus of production efficiency and sustainability. Independent third-party organizations are typically tasked with ensuring practices meet the standards of certification, and in terms of certifying the sustainability of aquaculture products, the ASC ecolabel is currently the most widely recognized ecolabel.

Determining the feasibility of implementing an ecolabelling scheme relies on empirical data from consumers of a product, in addition to the scale at which producers operate at to calculate the benefit and cost of implementation. The certification process of the ASC ecolabel is exhaustive in both the preliminary auditing process to assess whether an aquaculture operation meets the selective criteria for certification, in addition to the monitoring of required standards to maintain certification. However, this exercise in benefit-cost analysis of SC oyster farms becoming ASC certified does not include consideration of the seven principles ASC requires for shellfish operations to become certified, and thus it is only performed as a preliminary analysis of the economic

feasibility of the average SC oyster farm to implement the ASC ecolabel (ASC Bivalve Standards 1.1).

Results

Participant characteristics

In total, five oyster growers in South Carolina participated in our interview process. Compared to other states near SC, such as North Carolina, where the number of oyster farms in operation grew from eight in 2013 to thirty-three in 2018 and revenue increased over 1,700% during the same time, marginal growth has been observed in SC oyster mariculture production as evidenced by the existence of six oyster farms in 2018 (USDA, 2019). Our sample of participants is estimated to capture more than 90% of the total oyster mariculture production in SC, therefore sufficient participation was achieved for the objectives of this research. Oyster growers exhibited a wide range of production characteristics, including years in operation where one of the participants reported being in full operation for less than one year, hence a relatively wide-ranging SD (± 4.9 years).

These operations are heavily labor-intensive, yet employment remains relatively small eluding to the multifarious nature of duties exhibited between employees. Operating costs for 2020 almost entirely rely on the scale of production evidenced through the number of cages in use, where all respondents reported having less than 1,000 cages in operation. This finding characterizes the relatively minimal spatial extent of acreage and total number of oyster farms in SC. The average size of oyster mariculture off-bottom leases in SC was found to be 8.7 ac (0.03 km^2) (SCDNR, 2020). In comparison, the average oyster mariculture lease in Virginia was 24.7 ac (0.1 km^2), albeit

with 68 off-bottom oyster farms in VA, and 4 in SC as of 2018 (Beckensteiner et al., 2020; USDA, 2019). Characteristics of production among participants are reported in Table 3.2.

Table 3.2: Characteristics of sample participants from interviews

Participant characteristics[a]	**Average**	**Std. Dev.**
Years in operation	4.7 years	4.9 years
Full-time employees	3	1
Part-time employees	2.8	1.8
Contractors	1.2	2.2
Oyster seed sourcing[b]		
Percent of diploid oyster seed purchased (%)	11.2%	13.2
Percent of triploid oyster seed purchased (%)	88.8%	13.2
Price of triploid seed purchased ($ per 1,000 seed)	$78.2	124.3
Proportion of oyster seed sourced out-of-state (%)	84.0%	124.3
Production		
Market size oysters sold ($)	$250,000	$180,277.6
Percent of oysters sold wholesale for direct delivery (%)	72.3%	48.4
Price per oyster sold wholesale for direct delivery ($)	$0.81	0.25
Percent of oysters sold retail direct to customer (%)	30.3%	43.2
Price per oyster sold retail direct to customer ($)	$1.07	0.1
Percent of oyster seed that didn't make it market (%)	40%	34.6
Cages in operation	377	211.1
Investment		
Total investment as of 2020 ($)	$800,000	986,787.7
Operating costs for 2020 ($)	$181,000	98,132.6

[a]Five (5) SC-based oyster growers participated in the survey, capturing >90% of total oyster mariculture production in the state

[b]There is currently only one (1) oyster hatchery operating in SC as of 2020

Participants reported a markedly high reliance on importing oyster seed, particularly from states south of SC due in part to a moratorium on importing oyster seed north of South Carolina imposed in 2014, that resulted in the first oyster hatchery being established in the following year (SC Sea Grant Consortium, 2014; SC Sea Grant Consortium, 2016). It is important to note, that Georgia established their first oyster hatchery in 2018, leading to an additional source of oyster seed to growers in SC (Gorstein et al., 2021). From 2015 onwards, it is estimated that 50% of oyster seed used in SC was sourced from the state's first hatchery (SC Sea Grant, 2020). As of 2020, the moratorium on importing oyster north of SC has been lifted (SCDNR, 2020), and adoption of allocating oyster seed from northern states has taken affect among participants (Figure 3.2).

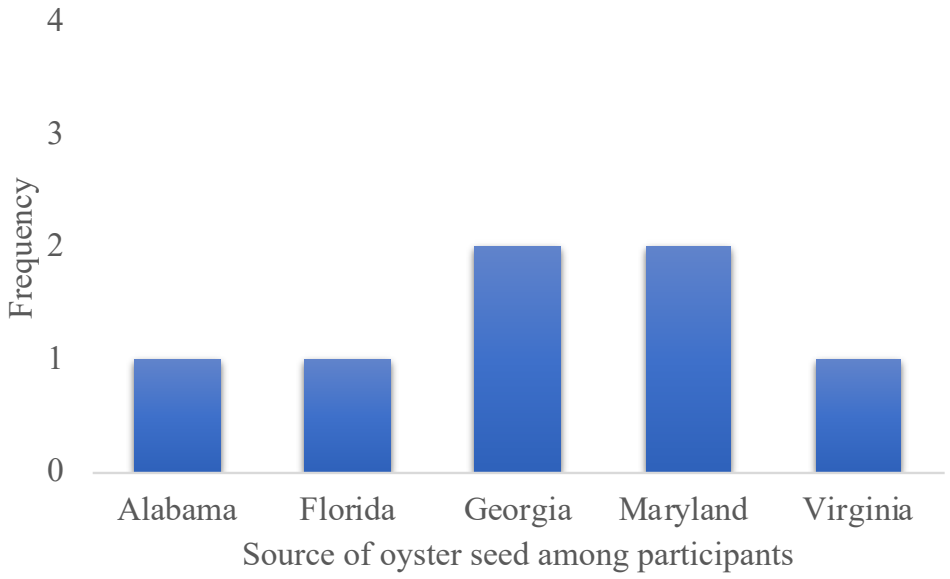

Figure 3.2: Participant's sourcing of oyster seed based on state

Qualitative responses from SC oyster growers

In the interview process, none of the participants reported any changes during broader shutdowns in mid-March to mid-May 2020 in air-drying cages as part of the grow-out process, a practice to limit biofouling of oyster shells, or tumbling of oysters to ensure they remain as singles. Oyster seed mortality was estimated to be 17% during 2020, although this estimate ranged from no seed mortality to 40% seed mortality. Total sales among participants in 2020 as compared to 2019 was estimated to have decreased by 9%, where both decreases and increases in sales during 2020 were observed. A variety of strategies for using non-market oysters (market oysters are typically between 2-3 in.) was reported during interviews, including redistributing large (+3") oysters both for replanting in surrounding habitats and discarding (40% of participants). To note, almost 90% of participants reported purchasing triploid oyster seed, inhibiting the ability to reproduce due to the inclusion of which possessing an extra set of chromosomes that inhibits their ability to reproduce, as opposed to diploid oyster seed that can reproduce (Wadsworth et al., 2019).

Funding and guidance on aspects of the permitting process was identified as a role for federal and state agencies to continue to assist oyster growers (60% of participants). Difficulty maneuvering through the permitting process was also suggested as a barrier for prospective entrants to the SC oyster mariculture industry, in addition to broader factors such as high upfront capital investment and lack of working waterfront space. Overall, the prospect of collaboration between oyster growers at any stage was not readily identified as necessary (80% of respondents), as one participant described collaboration

in this industry "*Difficult – fishermen are independent*" - *(ID02).* However, it was reported that collaboration between oyster growers in SC for introducing a centralized marketplace to sell their products could be a viable option, "*I think this is a cool idea, like what you see in the restaurant incubators + shared kitchens/Food courts*" – *(ID03)*. Qualitative results from the thematic coding framework are shown in Table 3.3.

Table 3.3: Potential variables influencing oyster mariculture production in SC based on the thematic coding framework of participants

Factor	Description	Evidence	Quote(s)
Production	Collectively, all participants identified seed availability as a major limiting factor that has been alleviated with lifting of the moratorium on importing oyster seed north of SC. However, sentiments also included doubts on the long-term viability of utilizing out-of-state oyster seed. Participants described both increases in production through the addition of grow-out cages coupled with increasing seed mortality, and a neutral effect in maintaining grow-out functions during the outset of COVID-19.	None of the participants reported changes in frequency of air-drying grow-out cages and tumbling during in 2020. Average oyster seed mortality in 2020 was estimated to be 17% and ranged from 0% to 40%. A total of 4,000 additional cages is estimated to be deployed by participants over the next two years.	*'It is unclear how seed spawned from out of state will perform. We have seen very high mortality levels (>95%) from out of state seed'(ID04)*
Sales	Number of years of establishment played a major role in operation's sales in response to the start of COVID-19, with most participants describing significantly reduced sales to restaurants as being a key	On average, participants reported a reduction of 9% in overall sales in 2020 compared to 2019. Interestingly, these	'*Covid hasn't affected us since we are so new, but I would imagine it would have seriously*

Industry	factor considering restaurant sales make up over 50% of total sales among participants. Responses to production capacity across the industry were characterized by participants adapting to restricted restaurant sales, securing monetary relief through the Paycheck Protection Program (PPP) and Cares Act, and potential stages for collaboration between growers. Participants also touched on perceptions of a lack of public awareness in their operation's activities.	estimates ranged from a reduction of 80% to an increase in 25% in overall sales during this time. Participants employed a variety of strategies for using non-market products, in which 40% indicated they had redistributed large non-market size oysters, both in surrounding habitats[a] and otherwise. Most respondents (60%) highlighted the need for state and federal agencies to provide both funding and guidance in the leasing and permitting process, and that permitting is the most significant barrier restricting new operations from establishing. Participants expressed an interest in a consolidated, centralized marketplace for oysters, however collaboration beyond this stage would not be necessary. Most participants (60%) were able to obtain loans through the Paycheck Protection Program (PPP),	*impacted sales if we started in 2019*' *(ID03)* '*In 2020, we had a surplus of big oysters, we throw them out due to COVID-19 about 100K*' *(ID01)* '*Yes. PPP was vital to keeping our crew intact. Application process for PPP was fairly simple. For CARES Act funding through DNR was more complicated*' *(ID04)* '*Encourage commercial development. S.C. is behind other states*'. *(ID02)* '*The barrier to entry with difficult permitting, the high upfront*

		however participants had more difficulty in seeking funding through CARES Act, as it was indicated that future applications of this type of relief could be streamlined.	*capital investment, and the utter lack of working waterfront has been our main obstacles. Also, lack of public understanding of what oyster farming Is all about. People Just don't know what it is and their first reaction is to oppose Something they don't understand' (ID03)*

[a]South Carolina Department of Natural Resources states that in their best management practices for shellfish mariculture that only those permitted to release out-of-state sourced oysters in SC waters have the authority to do so.

Benefit cost analysis of SC oyster farms becoming ASC certified

To accurately calculate the feasibility of ASC certification of the average oyster farm in SC, estimates of the costs of initial certification were collected from currently ASC certified oyster farms. These farms had become ASC certified between 2019 and 2021, alluding to the relatively recent implementation of bivalve mariculture within the ASC certification framework (ASC Bivalve Standard 1.1). The average initial cost for ASC certification of oyster farms was estimated to be $22,800, with estimates being converted from euros to U.S. dollars using the conversation rate at the time of certification for these

farms (Huitres Geay; Huitres Favier E.A.R.L; Jersey Oyster Company, personal communication, October 28th, 2021). Aggregating production metrics from interview participants provided the necessary components of benefit-cost analysis in relation to the cost of ASC certification based on currently certified oyster farms.

Results from the benefit-cost analysis provide encouraging prospects for the average SC oyster farm to become ASC certified with minimal upfront capital necessary to adopt this ecolabel. Based on the aggregated production metrics of participants oyster operations in 2020, it is estimated that 99% of the initial cost to be certified through ASC is met by the premium SC consumers are willing to pay for ASC certified oysters (Figure 3.3). The basis for this estimate considers only production data among SC oyster farms in 2020, in which the Covid-19 pandemic posed multiple disruptions in participant's ability to sell their products and from issues appropriating oyster seed due to the moratorium of importing out-of-state oyster seed north of South Carolina, which had been lifted immediately before completing interviews. The results of this benefit-cost analysis capture production during an atypical economic and market cycle, and thus provides insight as to how adopting an ecolabel could offset the economic impacts of future market disruptions.

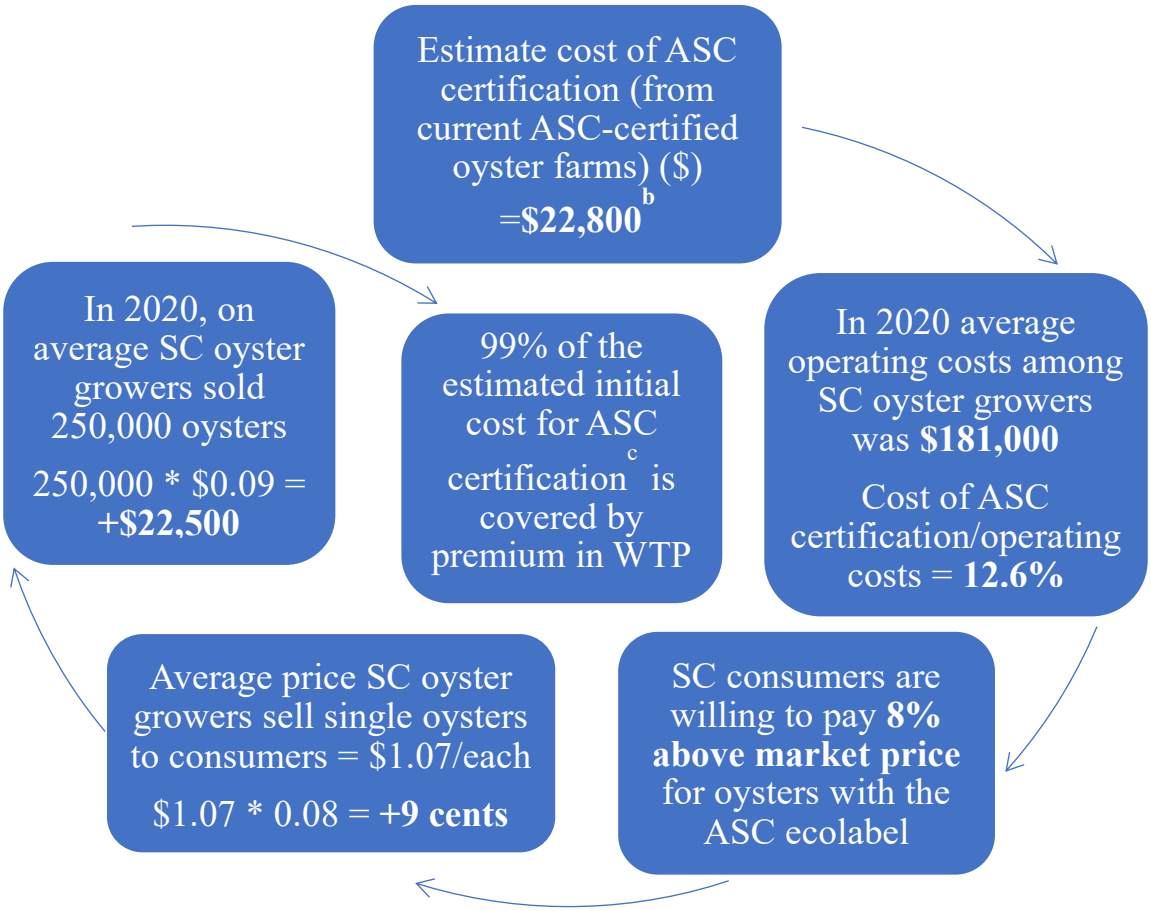

Figure 3.3: Benefit-cost analysis for implementation of ASC ecolabel

Discussion

The mixed-method approach has increasingly been implemented in socio-economic and ecological systems (Collins et al., 2021; Hattam et al., 2015; Oleson et al., 2015; Fetters et al., 2013; Driscoll et al., 2007). The dichotomy of incorporating quantitative or qualitive data in study design has been met by a growing area of research approaching social and ecological systems through a mix of both types of data (Johnson & Onwuegbuzie, 2004). Tashakkori & Teddlie (2003) state that using quantitative and

qualitive data in framework of a single study qualifies as a mixed method approach, while Johnson et al. (2007) defines mixed methods approach by the incorporation of quantitative and qualitative data together, typically through assigning quantitative values to qualitative data, such as transforming nominal data to ordinal data. For the purposes of this study, we consider the inclusion of both quantitative and qualitative data in evaluating the dynamic nature of local aquaculture production as a mixed methods approach, however we acknowledge that this approach has formed post-hoc of the data collection phase.

As qualitive data collection and analysis was a core aspect of this study, it is evident that other studies exploring factors influencing aquaculture production share somewhat limited similarities. This includes the types of questions asked based on specific challenges being faced, which is entirely dependent of the location of production, species involved, stocking densities and many other variables (Lim et al., 2020). Results from the qualitative analysis offer several novel implications to draw upon the oyster mariculture industry in SC. While participant characteristics varied in both production and sentiments regarding challenges they face, a common finding between participants emerged in addressing strategies and steps taken during the start of the COVID-19 was apparent. An overarching impact between participants indicated greatly reduced restaurant sales, a primary market of an estimated 90% of all single oysters produced in SC, and difficulty seeking relief funding through CARES Act (Richards, 2020). These findings are not unique among oyster growers, a study comprising of approximately 18% of all aquaculture producers according to 2018 Census of Aquaculture (USDA, 2019)

reported that 90% of respondents had been impacted by COVID-19, and that 84% had experienced loss of sales in the first quarter of 2020 (van Senten, Engle & Smith, 2020).

Our results indicate a mixed response as to how sales were affected by COVID-19 in 2020, where both increases and decrease in sales were reported. Participants who became operational immediately preceding or proceeding the start of the COVID-19 pandemic reported lower losses of revenue during 2020 as they had not produced any market size oysters yet, and their initial crop would not be ready for market until 12-18 months later, the typical time it takes for single oysters to mature in SC (SCDNR, 2019). van Senten et al. (2020) found that sixty percent of aquaculture producers surveyed reported that holding market-ready product at their facilities due to losses in sales would make it less marketable. This finding includes producers of finfish that rely on supplementary feeds during the grow-out process, while bivalves rely solely on the surrounding environment for feeding, and both categories of products face shortages of space as the grow-out process continues. Oysters grown in off-bottom cages in particular face increased likelihood of disease and sub-optimal growth when stocked at high densities and when space becomes limited due to large size (Casas et al., 2017). Our results show oyster growers were forced to discard a substantial number of non-market size oysters, in one instance over 100,000 oysters were lost in 2020, potentially due to limitations in space and difficulty selling these non-market products.

The relative infancy of the oyster mariculture industry in SC contributes to the overall trend of private ventures operating in coastal areas along the southeastern U.S. A growing concern about the availability of working waterfront space, or areas with direct

access to marine waterways for activities like fishing and tourism, has led some operations to pursue leases of coastal habitat for the purpose of culturing shellfish (Beckensteiner et al., 2020). This shift in permanent infrastructure such as docks, to shellfish farms using off-bottom cages is being observed across all four of the Atlantic southeast states. In Florida, large scale production of Hard Clams *Mercenaria mercenaria* accounts for 98% of total shellfish mariculture production (Botta et al., 2021). These operations use different production techniques and equipment than oyster mariculture, and ASC has not certified any operation growing clam species as of 2021 (ASC Bivalve Standard Version 1.1). Georgia established the state's first oyster seed hatchery in 2018 but has not participated in commercial oyster mariculture production as of 2021, alluding to the compounding regulatory and economic factors necessary to facilitate the start of this industry. North Carolina is the most established in terms of oyster mariculture production in the southeast U.S., with a total of thirty-three oyster farms in operation and generating revenue of over $1.2 million in 2018 (USDA, 2018). The relative similarity in scale of oyster farms in North Carolina, where one farm reported a lease of 16 acres, and the average lease in SC is just under 10 acres, provides context on the economic impact of responsibly expanding the oyster mariculture in SC moving forward.

Limitations

We acknowledge several shortcomings regarding drawing conclusions about the presently changing landscape of oyster mariculture production in SC using primary qualitative data, and the dynamic nature of aquaculture production on a national level through secondary census data. Firstly, we drew comparisons to related shellfish

producer interview guides with an understanding of what the most prominent factors and challenges oyster mariculture operations are currently facing, with industry specific expert intervention. There is on-going debate as to whether the coding of qualitative data is in fact a reasonable approach as coding infers assigning magnitude and frequency to qualitive data, which is a quantitative approach (Creswell, 2013). Taking a deductive approach to qualitatively coding interview responses is subject to less variability in the formation of the thematic coding framework derived, and therefore coding was performed by only one trained researcher. However, like inductive or data-driven approaches, coding is an iterative process that decreases observational bias when performed by two more trained researchers. Hence, the qualitative coding described in this study should be taken in context of the scope of inference that can be generated in a semi-structured, in-depth interview incorporating questions that may have a limited number of reasonable responses.

Secondly, we acknowledge the possibility of overlooking thematically important narratives or data points not included in our thematic coding framework, considering data that is unique or infrequently mentioned may be integral to studies' qualitative findings (Saldaña, 2016). Lastly, we provide results from the clustering analysis as an exercise in presenting aquaculture and the subset of oyster mariculture production variation in two discrete time steps. We acknowledge that secondary production data of these two discrete time steps derived from the 2018 USDA Census of Aquaculture can only provide limited insight as to how a singular facet of production within a much broader industry behaves in a stochastic system without datum between the time-steps.

Conclusion

Our interview-based approach for empirical evidence of both standard production metrics such as revenue, employment, and investment, coupled with qualitative social data provides a more nuanced set of insights into the nascent oyster mariculture industry in SC than traditional census categorization. This is particularly evident in response to the COVID-19 pandemic, affecting global food production systems and supply chains, in addition to regional and local scale operations and on-going research on the impacts to oyster mariculture production will continue to uncover vulnerabilities in this growing industry (Richards & Motallebi, 2021; van Senten et al., 2021).

This study has three key implications for a quickly growing sector of coastal entrepreneurial development that is intended to create a more complete picture of factors influencing implementation and operationalizing of oyster mariculture production. Firstly, our results of participant characteristics present a small (n=5), yet representative organizational presence among SC oyster growers with a wide-ranging level of operational experience and production capacity, and similarities in the challenges regarding appropriation of oyster seed and resources necessary for permitting applications. As South Carolina continues to shift from on-bottom culturing methods of oysters to using equipment within the water-column, greater emphasis has been placed on understanding both environmental and social carrying capacity as it relates to surrounding habitats and stakeholders in South Carolina, an area of research that is vital to creating a holistic interface for future management of this industry (Jodice et al., 2015; Byron et al., 2013; Byron et al., 2011a.; Byron et al., 2011b.).

Secondly, empirical evidence of production practices, responses to environmental and social perturbations, and interactions within the broader oyster mariculture industry gleaned from interview participants provides invaluable input for developing strategies that promote local food production initiatives with consideration of ecological, social, and cultural sustainability (Brown et al., 2020; D'anna & Murray, 2015; Samuel-Fitwi et al., 2012; Shumway, 2011). Lastly, adoption of the ASC ecolabel can increase consumers' willingness to pay for local, certified sustainable oysters in just the first year of certification and can promote an already growing initiative among bivalve mariculture producers to ensure that the production process is sustainable.

Works Cited

Alleway, H. K., Gillies, C. L., Bishop, M. J., Gentry, R. R., Theuerkauf, S. J., & Jones, R. 2019. The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature. *BioScience, 69*(1), 59-68. doi:10.1093/biosci/biy137

Aquaculture Stewarship Council, 2020. ASC Bivalve Standard Version 1.1. Retrived from: https://www.asc-aqua.org/wp-content/uploads/2019/03/ASC-Bivalve-Standard_v1.1_Final.pdf

Beckensteiner, J., Kaplan, D. M., & Scheld, A. M. 2020. Barriers to Eastern Oyster Aquaculture Expansion in Virginia. *Frontiers in Marine Science, 7*(53). doi:10.3389/fmars.2020.00053

Botta, R., Court, C. D., Ropicki, A., & Camp, E. V. 2021. Evaluating the regional economic contributions of US aquaculture: Case study of Florida's shellfish aquaculture industry. *Aquaculture Economics & Management, 25*(2), 223-244.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I., Corner, R. 2010. Aquaculture: global status and trends. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 2897-2912.

Brown, A. R., Webber, J., Zonneveld, S., Carless, D., Jackson, B., Artioli, Y., Miller, P.I., Holmyard, J., Baker-Austin, C., Kershaw, S. 2020. Stakeholder perspectives on the importance of water quality and other constraints for sustainable mariculture. *Environmental Science & Policy, 114*, 506-518.

Bryman, A. 2016. *Social research methods*: Oxford university press.

Byron, C., Bengtson, D., Costa-Pierce, B., & Calanni, J. 2011a. Integrating science into management: ecological carrying capacity of bivalve shellfish aquaculture. *Marine Policy, 35*(3), 363-370.

Byron, C., Link, J., Costa-Pierce, B., & Bengtson, D. 2011b. Calculating ecological carrying capacity of shellfish aquaculture using mass-balance modeling: Narragansett Bay, Rhode Island. *Ecological Modelling, 222*(10), 1743-1755.

Byron, C. J., & Costa-Pierce, B. A. 2013. Carrying capacity tools for use in the implementation of an ecosystems approach to aquaculture. *Site selection and carrying capacities for inland and coastal aquaculture*, 87-101.

Carranza, A., & zu Ermgassen, P. S. E. 2020. A Global Overview of Restorative Shellfish Mariculture. *Frontiers in Marine Science, 7*(722). doi:10.3389/fmars.2020.00722

Casas, S., Walton, W., Chaplin, G., Rikard, S., Supan, J., & La Peyre, J. 2017. Performance of oysters selected for dermo resistance compared to wild oysters in northern Gulf of Mexico estuaries. *Aquaculture Environment Interactions, 9*, 169-180. Retrieved from https://www.int-res.com/abstracts/aei/v9/p169-180/

Collins, C., Nuno, A., Benaragama, A., Broderick, A., Wijesundara, I., Wijetunge, D., & Letessier, T. B. 2021. Ocean-scale footprint of a highly mobile fishing fleet: Social-ecological drivers of fleet behaviour and evidence of illegal fishing. *People and Nature, 3*(3), 740-755. doi:https://doi.org/10.1002/pan3.10213

Creswell, J. W. 2013. Steps in conducting a scholarly mixed methods study.

D'Anna, L. M., & Murray, G. D. 2015. Perceptions of shellfish aquaculture in British Columbia and implications for well-being in marine social-ecological systems. *Ecology and Society, 20*(1).

Driscoll, D. L., Appiah-Yeboah, A., Salib, P., & Rupert, D. J. 2007. Merging qualitative and quantitative data in mixed methods research: How to and why not.

Dumbauld, B. R., Ruesink, J. L., & Rumrill, S. S. 2009. The ecological role of bivalve shellfish aquaculture in the estuarine environment: A review with application to oyster and clam culture in West Coast (USA) estuaries. *Aquaculture, 290*(3), 196-223. doi:https://doi.org/10.1016/j.aquaculture.2009.02.033

Food and Agricultural Organization of the United Nations, 2018. *The State of World Fisheries and Aquaculture 2018*. *Meeting the sustainable development goals*. Rome.

Food and Agricultural Organization of the United Nations, 2020. *The State of World Fisheries and Aquaculture 2020*. *Sustainability in action*. Rome.

Fetters, M. D., Curry, L. A., & Creswell, J. W. 2013. Achieving integration in mixed methods designs—principles and practices. *Health services research, 48*(6pt2), 2134-2156.

Gorstein, M., Motallebi, M., Carey, R., Cheplick, D., Gaines, G., Richards, S. (2021, August 11-14). *South Carolina's first oyster mariculture industry outlook assessment* [Conference presentation]. Aquaculture America 2021, San Antonio, TX, United States. Retirved from: https://wasblobstorage.blob.core.windows.net/meetingabstracts/AA2021AbstractBook.pdf

Hattam, C., Böhnke-Henrichs, A., Börger, T., Burdon, D., Hadjimichael, M., Delaney, A., Atkins, J.P., Garrard, S., Austen, M. C. 2015. Integrating methods for ecosystem service assessment and valuation: mixed methods or mixed messages? *Ecological Economics, 120*, 126-138.

Holden, J. J., Collicutt, B., Covernton, G., Cox, K. D., Lancaster, D., Dudas, S. E., Ban, N.C., Jacob, A. L. 2019. Synergies on the coast: Challenges facing shellfish aquaculture development on the central and north coast of British Columbia. *Marine Policy, 101*, 108-117. doi:https://doi.org/10.1016/j.marpol.2019.01.001

Janssen, P., Walther, C., & Lüdeke, M. 2012. *Cluster Analysis to Understand Socio-Ecological Systems: A Guideline* (Vol. 126).

Jodice, L. W., Norman, W. C., Davis, J., Coskun, G., & Kang, S. 2015. *Perceptions of marine aquaculture in coastal tourist destinations in the US Southeastern region*. Retrieved from http://media.clemson.edu/cbshs/prtm/research/Mariculture.pdf

Johnson, R. B., & Onwuegbuzie, A. J. 2004. Mixed methods research: A research paradigm whose time has come. *Educational researcher, 33*(7), 14-26.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. 2007. Toward a definition of mixed methods research. *Journal of mixed methods research, 1*(2), 112-133.

Kankainen, M., Setälä, J., Berrill, I. K., Ruohonen, K., Noble, C., & Schneider, O. 2012. How To Measure The Economic Impacts of Changes In Growth, Feed Efficiency and Survival in Aquaculture. *Aquaculture Economics & Management, 16*(4), 341-364. doi:10.1080/13657305.2012.729247

Kuempel, C. D., Froehlich, H. E., & Halpern, B. S. 2021. An informed thought experiment exploring the potential for a paradigm shift in aquatic food production. *Ocean & Coastal Management, 206*, 105574. doi:https://doi.org/10.1016/j.ocecoaman.2021.105574

Manlosa, A. O., Hornidge, A.-K., & Schlüter, A. 2021. Aquaculture-capture fisheries nexus under Covid-19: impacts, diversity, and social-ecological resilience. *Maritime Studies, 20*(1), 75-85. doi:10.1007/s40152-021-00213-6

Michaelis, A. K., Walton, W. C., Webster, D. W., & Shaffer, L. J. 2020. The role of ecosystem services in the decision to grow oysters: A Maryland case study. *Aquaculture, 529*, 735633.

Michaelis, A. K., Walton, W. C., Webster, D. W., & Shaffer, L. J. 2021. Cultural ecosystem services enabled through work with shellfish. *Marine Policy, 132*, 104689.

National Marine Fisheries Service. 2020. Fisheries of the United States, 2018. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2018

Newaj-Fyzul, A., Al-Harbi, A. H., & Austin, B. 2014. Review: Developments in the use of probiotics for disease control in aquaculture. *Aquaculture, 431*, 1-11. doi:https://doi.org/10.1016/j.aquaculture.2013.08.026

Oleson, K. L., Barnes, M., Brander, L. M., Oliver, T. A., van Beek, I., Zafindrasilivonona, B., & van Beukering, P. 2015. Cultural bequest values for ecosystem service flows among indigenous fishers: A discrete choice experiment validated with mixed methods. *Ecological Economics, 114*, 104-116.

Oyinlola, M. A., Reygondeau, G., Wabnitz, C. C. C., Troell, M., & Cheung, W. W. L. 2018. Global estimation of areas with suitable environmental conditions for mariculture species. *PLOS ONE, 13*(1), e0191086. doi:10.1371/journal.pone.0191086

Petersen, C., Costa-Pierce, B., Dumbauld, B., Friedman, C., Hoffmann, E., Kite-Powell, H., Manahan, D.T., O'Beirn, F., Paine, R.T., Thompson, P. M. 2010. *Ecosystem concepts for sustainable bivalve mariculture*: The National Academies Press.

Proestou, D. A., Vinyard, B. T., Corbett, R. J., Piesz, J., Allen, S. K., Small, J. M., Li, C., Liu, M., DeBrosse, G., Guo, X., Rawsom, P., Gómez-Chiarri, M. 2016. Performance of selectively-bred lines of eastern oyster, Crassostrea virginica, across eastern US estuaries. *Aquaculture, 464*, 17-27. doi:https://doi.org/10.1016/j.aquaculture.2016.06.012

R Core Team. 2020. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Retrieved from http://www.r-project.org/index.html

Richards, S. 2020. Impacts of COVID-19 restaurant closures on South Carolina's shellfish industry (LGP 1070). Clemson Cooperative Extension, Land-Grant Press. https://lgpress.clemson.edu/publication/impacts-of-covid-19- restaurant-closures-on-south-carolinas-shellfish-industry/

Richards, S., & Motallebi, M. 2021. New survey shows COVID-19's impacts on South Carolina oyster farmers and offers hope for recovery. *Journal of Agriculture, Food Systems, and Community Development, 10*(2), 1–4-1–4.

Ruff, E. O., Gentry, R. R., & Lester, S. E. 2020. Understanding the role of socioeconomic and governance conditions in country-level marine aquaculture production. *Environmental Research Letters, 15*(10), 1040a1048.

Saldaña, J. 2016. The Coding Manuel for Qualitative Researchers, London, UK, 368pp.

Saldaña, J., & Omasta, M. 2016. *Qualitative research: Analyzing life*: Sage Publications.

Samuel-Fitwi, B., Wuertz, S., Schroeder, J. P., & Schulz, C. 2012. Sustainability assessment tools to support aquaculture development. *Journal of Cleaner Production, 32*, 183-192.

Shumway, S. E. 2011. *Shellfish aquaculture and the environment*: John Wiley & Sons.

Smith, W. G. 2018. Evaluating socioeconomic dimensions for a resilient shellfish mariculture industry in Humboldt Bay: Assessing the strengths, vulnerabilities, and potential of Humboldt's expanding industry.

South Carolina Department of Natural Resources, Marine Resources Division. 2019. 2018 – 2019 Saltwater Fishing Regulations, Crab, Lobster and Shellfish, Charleston, SC

Tashakkori, A., & Teddlie, C. 2003. Issues and dilemmas in teaching research methods courses in social and behavioural sciences: US perspective. *International journal of social research methodology, 6*(1), 61-77.

Theuerkauf, S. J., Morris, J. A., Jr., Waters, T. J., Wickliffe, L. C., Alleway, H. K., & Jones, R. C. 2019. A global spatial analysis reveals where marine aquaculture can benefit nature and people. *PLOS ONE, 14*(10), e0222282. doi:10.1371/journal.pone.0222282

United States Department of Agriculture. 2019. *2017 Census of Agriculture, 2018 Census of Aquaculture.* Washington D.C: National Agricultural Statistics Service, USDA. Retrievedfrom https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Aquaculture/Aqua.pdf

van der Schatte Olivier, A., Jones, L., Vay, L. L., Christie, M., Wilson, J., & Malham, S. K. 2020. A global review of the ecosystem services provided by bivalve aquaculture. *Reviews in Aquaculture, 12*(1), 3-25.

Van Senten, J., Engle, C., Parker, M., & Webster, D. 2019. Analysis of the Economic Benefits of the Maryland Shellfish Aquaculture Industry. *Final Project Report, 31*.

van Senten, J., Engle, C. R., & Smith, M. A. 2021. Effects of COVID-19 on U.S. Aquaculture Farms. *Applied Economic Perspectives and Policy, 43*(1), 355-367. doi:https://doi.org/10.1002/aepp.13140

Wadsworth, P., Wilson, A. E., & Walton, W. C. 2019. A meta-analysis of growth rate in diploid and triploid oysters. *Aquaculture, 499*, 9-16.

Webber, J. L., Tyler, C. R., Carless, D., Jackson, B., Tingley, D., Stewart-Sinclair, P., Artioli, Y., Torres, R., Galli, G., Miller, P. I. 2021. Impacts of land use on water quality and the viability of bivalve shellfish mariculture in the UK: A case study and review for SW England. *Environmental Science & Policy, 126*, 122-131.

Yáñez, J. M., Newman, S., & Houston, R. D. 2015. Genomics in aquaculture to better understand species biology and accelerate genetic progress. *Frontiers in Genetics, 6*(128). doi:10.3389/fgene.2015.00128

Zheng, W., Shi, H., Chen, S., & Zhu, M. 2009. Benefit and cost analysis of mariculture

APPENDICES

Appendix A

Seafood Consumer Survey Instrument

Aquaculture Consumer Survey

Start of Block: Cover letter

South Carolina aquaculture futures -Evaluating socioeconomic potentials for rural communities and limitations for entrepreneurs

KEY INFORMATION ABOUT THE RESEARCH STUDY
Voluntary Consent: Dr. Marzieh Motallebi is inviting you to volunteer for a research study. Marzieh Motallebi is an assistant professor at Clemson University conducting the study with Dr. Lori Dickes, Dr. Michael Vassalos, and Dr. Kenneth Robinson. You may choose not to take part and you may choose to stop taking part at any time. You will not be punished in any way if you decide not to be in the study or to stop taking part in the study.

Study Purpose: The purpose of this research is to understand the value on which stakeholders place on the importance of aquaculture production of various species produced and consumed in SC. We are gathering information from SC residents as to whether they consume local seafood products and their willingness to pay for local aquaculture products.

Activities and Procedures: Your part in the study will be to respond to the survey and to provide us with your valuable insights regarding with local aquaculture consumption and aquaculture production barriers in SC.

Participation Time: It will take you about 15-20 minutes to be in this study.

Risks and Discomforts: We do not know of any risks or discomforts to you in this research study.

Possible Benefits: We do not know of any way you would benefit directly from taking part in this study. However, this research will help us understand SC aquaculture consumers' perception towards consuming local products. We will also disseminate the result of this study through our workshops and publications.

PROTECTION OF PRIVACY AND CONFIDENTIALITY: The results of this study may be published in scientific journals, professional publications, or educational

presentations. You will not be identified in any publications or presentations. We are not requesting any contact information on the survey. The information collected during the study could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from the participants or legally authorized representative.

CONTACT INFORMATION: If you have any questions or concerns about your rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-0636 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC's toll-free number, 866-297-3071. The Clemson IRB will not be able to answer some study-specific questions. However, you may contact the Clemson IRB if the research staff cannot be reached or if you wish to speak with someone other than the research staff. If you have any study related questions or if any problems arise, please contact Marzieh Motallebi at Baruch Institute of Coastal Ecology and Forest Sciences Clemson University at 843-546-1013, Ext 223 or e-mail: mmotall@clemson.edu.

CONSENT By participating in the study, you indicate that you have read the information written above, been allowed to ask any questions, and you are voluntarily choosing to take part in this research. You do not give up any legal rights by taking part in this research study.

Page Break

End of Block: Cover letter

Start of Block: Baseline Information on Consumer Preferences

1 Do you currently live in South Carolina?

- ○ Yes (28)
- ○ No (29)

Skip To: End of Block If Do you currently live in South Carolina? = No

Skip To: 2 If Do you currently live in South Carolina? = Yes

Display This Question:

If Do you currently live in South Carolina? = Yes

2 What county do you live in?

▼ Abbeville (1) ... Other (47)

Page Break

3 Are you one of the "finance decision makers" of your household?
(*finance decision maker - the one who controls the household budget and decides prioritization of regular household expenditures)*

- ○ Yes (24)
- ○ No (25)

Skip To: End of Block If Are you one of the "finance decision makers" of your household? (finance decision maker - the on... = No

Page Break

4 Do people in your household consume seafood products?
(*Seafood products are meant to represent all products from both marine and freshwater habitats*. For brevity, we consider seafood to encompass both marine and freshwater products for the rest of the survey).

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If Does your household consume seafood and/or associated products? (Seafood and associated products is = No

5 How frequently do you purchase seafood products (Wild-caught and farm-raised)?

	Once a day (1)	Several times a week (2)	Once a week (3)	Once every 2 weeks (4)	Once a month (5)
Prepared at home (29)	○	○	○	○	○
Prepared at restaurants (30)	○	○	○	○	○

6 Generally, what percentage of the seafood products your household purchases are **raw** compared to **cooked**?

	0 10 20 30 40 50 60 70 80 90 100
Percentage (%) ()	

7 Where does your household purchase the **majority** of your uncooked seafood products for in-home preparation?

- ○ Grocery stores (1)
- ○ Other sources (e.g. fish markets, roadside fish stands) (2)
- ○ I do not buy uncooked seafood products (4)

8 On average, about how much **per month** does your household spend on seafood products? Please use the sliding bar to assign a dollar amount.

0 30 60 90 120 150 180 210 240 270 300

In dollars ($) ()	

Page Break

9 Where would you normally purchase seafood products? **Select at least one and up to three most frequent.**

- ☐ Big Box Stores (e.g. Costco) (2)
- ☐ Discount Grocery (e.g. Save-a-lot) (4)
- ☐ Ethnic Market (e.g Oriental Market) (6)
- ☐ Farmer's Market (7)
- ☐ Fish Market (8)
- ☐ Grocery Store (Aldi, Bi-Lo, Food Lion, Kroger, Publix, Safeway, Trader Joes, Whole Foods) (14)
- ☐ Restaurant (16)
- ☐ Roadside Fish Stand (19)
- ☐ Walmart (20)
- ☐ Other (21) _____

Page Break

10 What types of seafood products does your household normally purchase during the **summer** months (May-September)? **Select at least one and up to three most frequent.**

- [ ] Clams (1)
- [ ] Cod/Pollack/Hake (2)
- [ ] Crabs (e.g. Blue Crab, Stone Crab) (4)
- [ ] Oysters (5)
- [ ] Mussels (6)
- [ ] Rainbow Trout (7)
- [ ] Salmon (8)
- [ ] Shrimp (9)
- [ ] Tilapia (10)
- [ ] Tuna (12)
- [ ] Other saltwater fish species (e.g. Flounder, Mahi Mahi etc.) (13)
- [ ] Other (14) _____

Page Break

11 What types of seafood products does your household purchase during the **winter** months (October-April)? **Select at least one and up to three most frequent.**

- [ ] Clams (1)
- [ ] Cod/Pollack/Hake (2)
- [ ] Crabs (e.g. Blue Crab, Stone Crab) (4)
- [ ] Oysters (5)
- [ ] Mussels (6)
- [ ] Rainbow Trout (7)
- [ ] Salmon (8)
- [ ] Shrimp (9)
- [ ] Tilapia (10)
- [ ] Tuna (12)
- [ ] Other saltwater fish species (e.g. Flounder, Mahi Mahi etc.) (14)
- [ ] Other (15) _____

Page Break

12 Approximately what percentage of total seafood products consumed by you or your household is purchased at **food service establishments** (e.g. restaurants, fast food)?

0 10 20 30 40 50 60 70 80 90 100

Percentage (%) ()	

Page Break

Display This Question:

If What county do you live in? != Beaufort

And What county do you live in? != Berkeley

And What county do you live in? != Charleston

And What county do you live in? != Colleton

And What county do you live in? != Dorchester

And What county do you live in? != Georgetown

And What county do you live in? != Horry

And What county do you live in? != Jasper

13 Have you or your household purchased seafood while traveling to one of the coastal counties in SC? (e.g Beaufort, Berkeley, Charleston, Colleton, Dorchester, Georgetown, Horry, Jasper)

- ○ Yes (1)
- ○ No (2)
- ○ I have not traveled to one of the coastal counties in SC (4)

Skip To: End of Block If Have you or your household purchased seafood while traveling to one of the coastal counties in SC... = No

Skip To: End of Block If Have you or your household purchased seafood while traveling to one of the coastal counties in SC... = I have not traveled to one of the coastal counties in SC

Page Break

Display This Question:

If What county do you live in? != Beaufort

And What county do you live in? != Berkeley

And What county do you live in? != Charleston

And What county do you live in? != Colleton

And What county do you live in? != Dorchester

And What county do you live in? != Georgetown

And What county do you live in? != Horry

And What county do you live in? != Jasper

14 Where did you purchase your seafood products while visiting one of the coastal counties? **(Select at least one and up to three most frequent)**

- ☐ Big Box Stores (e.g. Costco) (1)
- ☐ Discount Grocery (e.g. Save-a-lot) (2)
- ☐ Ethnic Market (e.g Oriental Market) (3)
- ☐ Farmer's Market (4)
- ☐ Fish Market (5)
- ☐ Grocery Store (Aldi, Bi-Lo, Food Lion, Kroger, Publix, Safeway, Trader Joes, Whole Foods) (6)
- ☐ Restaurant (7)
- ☐ Roadside Fish Stand (8)
- ☐ Walmart (9)
- ☐ Other (10) _____

Page Break

Display This Question:

If What county do you live in? != Beaufort

And What county do you live in? != Berkeley

And What county do you live in? != Charleston

And What county do you live in? != Colleton

And What county do you live in? != Dorchester

And What county do you live in? != Georgetown

And What county do you live in? != Horry

And What county do you live in? != Jasper

15 What types of seafood products did you or your household purchase when visiting one of the coastal counties? **(Select at least one and up to three most frequent)**

- ☐ Clams (1)
- ☐ Cod/Pollack/Hake (2)
- ☐ Crabs (e.g. Blue Crab, Stone Crab) (3)
- ☐ Oysters (4)
- ☐ Mussels (5)
- ☐ Rainbow Trout (6)
- ☐ Salmon (7)
- ☐ Shrimp (8)
- ☐ Tilapia (9)
- ☐ Tuna (10)
- ☐ Other saltwater fish species (e.g. Flounder, Mahi-Mahi etc.) (12)
- ☐ Other (13) _____

End of Block: Baseline Information on Consumer Preferences

Start of Block: Knowledge, Awareness, Perception Baseline

16 Please select how familiar you are with the concepts in the following statements.

	Very unfamiliar (1)	Unfamiliar (2)	Neither familiar nor unfamiliar (3)	Familiar (5)	Very familiar (6)
Difference between a wild-caught seafood product as compared to a farm-raised seafood product? (4)	○	○	○	○	○
The types of farm-raised seafood products commonly produced in South Carolina? (6)	○	○	○	○	○

17 In your opinion, where do you think most seafood products in South Carolina come from?

- ○ Locally (SC) (1)
- ○ Domestically (besides SC) (11)
- ○ Internationally (imported) (14)
- ○ Not sure (15)

Page Break

18 Please rate your satisfaction of the quality (taste, freshness etc.) and variety (different types) of seafood products:

	Very dissatisfied (23)	Dissatisfied (24)	Neither satisfied nor dissatisfied (25)	Satisfied (26)	Very satisfied (27)
The ***quality*** of seafood products available at **grocery stores**. (1)	○	○	○	○	○
The ***quality*** of seafood products available at **restaurants**. (2)	○	○	○	○	○
The ***variety*** of seafood products available at **grocery stores**. (3)	○	○	○	○	○
The ***variety*** of seafood products available at **restaurants**. (5)	○	○	○	○	○

19 Please rate your confidence that seafood products are being accurately labeled as farm-raised:

	Very unconfident (1)	Unconfident (2)	Neither confident nor unconfident (3)	Confident (4)	Very confident (5)
The ***labeling*** of seafood products (location and whether it is farm-raised) at **grocery stores**. (1)	○	○	○	○	○
The ***labeling*** of seafood products (location and whether it is farm-raised) at **restaurant** (2)	○	○	○	○	○

Page Break

20
Please identify your strength of agreement with the following statements related to community development provided by the aquaculture industry.

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
As an industry, aquaculture creates additional employment opportunities for local residents. (1)	○	○	○	○	○
Aquaculture development creates additional entrepreneurial opportunities for local residents. (5)	○	○	○	○	○
A local Aquaculture industry enhances the economic diversity of a community. (6)	○	○	○	○	○
Aquaculture firms provide broader economic impacts within their communities. (7)	○	○	○	○	○

Page Break

21 When purchasing seafood products, how important is each attribute to you?

	Very unimportant (1)	Unimportant (2)	Neither important nor unimportant (3)	Important (4)	Very important (5)
Cooking time (2)	○	○	○	○	○
Cost (5)	○	○	○	○	○
Location of production (6)	○	○	○	○	○
Quality and/or freshness (9)	○	○	○	○	○
Supporting local aquaculture producers (10)	○	○	○	○	○
Sustainability of production process (11)	○	○	○	○	○
Taste (12)	○	○	○	○	○
That the seafood product is farm-raised (13)	○	○	○	○	○

Page Break

22 Please provide an answer to the following questions.

	No (1)	Yes (2)
Have you or your household noticed labels specifying if seafood products are **from South Carolina**? (1)	○	○
Have you or your household noticed labeling specifying if seafood products are **farm-raised**? (2)	○	○
Do you recognize the **Best Aquaculture Product (BAP)** label/certification on seafood products? (4)	○	○
Do you recognize the **Marine Stewardship Council (MSC)** label/certification on seafood products? (5)	○	○
Do you recognize the **Aquaculture Stewardship Council (ASC)** label/certification on seafood? (7)	○	○

End of Block: Knowledge, Awareness, Perception Baseline

Start of Block: Informational

I1 Aquaculture in coastal states is comprised of both land-based and aquatic-based practices. The following video below provides more information about aquaculture across the U.S. Please watch the entire video as this will help in answering questions in the survey going forward.

V1

Video courtesy of NOAA

Q330 Timing
First Click (1)
Last Click (2)
Page Submit (3)
Click Count (4)

Page Break

23 Is **wild-caught** seafood considered to be **farm-raised?**

- ○ Yes (1)
- ○ No (2)

Page Break

24 How likely would you be willing to purchase farm-raised seafood products from **South Carolina**

- ○ Very unlikely (1)
- ○ unlikely (2)
- ○ Neither likely nor unlikely (3)
- ○ Likely (18)
- ○ Very likely (19)

End of Block: Informational

Start of Block: Consumer preferences of aquaculture

Consumer preferences The following section focuses specifically on farm-raised seafood products.

Page Break

25 Have you or your household purchased seafood products that have been labeled as farm-raised?

- ○ Yes (1)
- ○ No (2)
- ○ I don't know (I have not paid attention) (3)

Page Break

Display This Question:

If Have you or your household purchased seafood products that have been labeled as farm-raised? = Yes

26 What types of **farm-raised seafood products** have people in your household purchased? **Select at least one and up to three most frequent** (If "none" is selected, please only choose "none" and no other option)

- ☐ Catfish (1)
- ☐ Clams (2)
- ☐ Oysters (4)
- ☐ Mussels (5)
- ☐ Rainbow Trout (6)
- ☐ Salmon (7)
- ☐ Shrimp (8)
- ☐ Tilapia (9)
- ☐ ⊗ None (10)
- ☐ Other seafood products that have been deemed farm-raised (Please describe) (11) _____

Page Break

27 What types of **farm-raised seafood products** produced in **South Carolina** you would like to see more of in the market? **Select at least one and up to three most desired products if made available** (If "none" is selected, please only choose "none" and no other option)

- ☐ Catfish (1)
- ☐ Clams (2)
- ☐ Oysters (4)
- ☐ Rainbow Trout (5)
- ☐ Saltwater fish (6)
- ☐ Shrimp (7)
- ☐ Tilapia (8)
- ☐ ⊗ None (9)
- ☐ Other seafood products that have been deemed farm-raised (Please describe) (10) _____

Page Break

Display This Question:

If What county do you live in? != Abbeville

And What county do you live in? != Aiken

And What county do you live in? != Allendale

And What county do you live in? != Anderson

And What county do you live in? != Bamberg

And What county do you live in? != Barnwell

And What county do you live in? != Calhoun

And What county do you live in? != Cherokee

And What county do you live in? != Chester

And What county do you live in? != Chesterfield

And What county do you live in? != Clarendon

And What county do you live in? != Darlington

And What county do you live in? != Dillon

And What county do you live in? != Edgefield

And What county do you live in? != Fairfield

And What county do you live in? != Florence

And What county do you live in? != Greenville

And What county do you live in? != Greenwood

And What county do you live in? != Hampton

And What county do you live in? != Kershaw

And What county do you live in? != Lancaster

And What county do you live in? != Laurens

And What county do you live in? != Lee

And What county do you live in? != Lexington

And What county do you live in? != Marion

And What county do you live in? != Marlboro

And What county do you live in? != McCormick

And What county do you live in? != Newberry

And What county do you live in? != Oconee

And What county do you live in? != Orangeburg

And What county do you live in? != Pickens

And What county do you live in? != Richland

And What county do you live in? != Saluda

And What county do you live in? != Spartanburg

And What county do you live in? != Sumter

And What county do you live in? != Union

And What county do you live in? != Williamsburg

And What county do you live in? != York

And What county do you live in? != Other

28 If an aquaculture producer were to start growing shellfish (Clams or Oysters) using floating cages along a river or tributary you or your household uses for recreational purposes (e.g. fishing, swimming, boating), how affected or unaffected would you be?

- ○ Very unaffacted (1)
- ○ Unaffected (2)
- ○ Neither affected nor unaffected (3)
- ○ Affected (4)
- ○ Very affected (5)

ID 2 When you are seeking more information about a seafood product, how frequently do you rely on the following sources of information?

	Very infrequently (1)	Infrequently (2)	Neither frequently nor infrequently (3)	Frequently (4)	Very frequently (5)
Seafood retailer (1)	○	○	○	○	○
Restaurant server (2)	○	○	○	○	○
Friends (3)	○	○	○	○	○
Fisherman (4)	○	○	○	○	○
Locals (e.g. people I meet in a coastal area while visiting) (5)	○	○	○	○	○
Seafood websites (e.g. aquaculture company) (6)	○	○	○	○	○
Online reviews (7)	○	○	○	○	○

ID 3 How would you want to learn more about aquaculture products?

- ○ Academia (e.g. Clemson University, Univ. of South Carolina) (1)
- ○ Non-government organization (The Nature Conservancy) (2)
- ○ State government agencies (e.g. SCDNR, SC Sea Grant) (3)
- ○ Federal government agencies (USDA, NOAA) (4)
- ○ Private organizations (5)
- ○ Others, please specify (6)

_____

End of Block: Institutional design

Start of Block: Profile

Profile Finally, as we are about to end the survey, please let us know more about yourself.

1 What is your sex?

- ○ Male (1)
- ○ Female (2)

2 Please tell us your age group

- ○ 18 - 25 years old (4)
- ○ 26 - 35 years old (5)
- ○ 36 - 45 years old (6)
- ○ 46 - 55 years old (7)
- ○ 56 - 65 years old (8)
- ○ 66 - 75 years old (9)
- ○ Older than 76 years old (10)

3 What is your marital status?

- ○ Married (1)
- ○ Widowed (2)
- ○ Divorced (3)
- ○ Separated (4)
- ○ Never married (single) (5)

4 Are you White, Black, or African-American, American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific Islander, or some other race?

- ○ White (1)
- ○ Black or African American (2)
- ○ American Indian or Alaska Native (3)
- ○ Asian (4)
- ○ Native Hawaiian or Pacific Islander (5)
- ○ Hispanic or Latino (6)
- ○ Some other race (please specify) (9)

_____

5 Which of the following categories best describes your employment status?

- ○ Employed full time (working 40 or more hours per week) (1)
- ○ Employed part time (working 1 - 39 hours per week) (2)
- ○ Unemployed looking for work (3)
- ○ Unemployed not looking for work (4)
- ○ Retired (5)
- ○ Student (6)
- ○ Disabled (7)

6 What is your occupation?

- ○ Food industry (1)
- ○ Business (2)
- ○ Healthcare (3)
- ○ Engineering or technical profession (4)
- ○ Education (5)
- ○ Sales and marketing (6)
- ○ Legal (7)
- ○ IT occupations (8)
- ○ Administrative (9)
- ○ Farming or fishing (10)
- ○ Construction (11)
- ○ Other (13) _____

7 How many people live in your household?

_____

8 How long have you lived in South Carolina?

- ○ Less than one (1) year (12)
- ○ 1 - 5 years (13)
- ○ 6 - 10 years (14)
- ○ More than 10 years (15)

9 What is the highest level of school you have completed or the highest degree you have received?

- ○ Less than high school degree (1)
- ○ High school degree or equivalent (e.g. GED) (2)
- ○ Some college but no degree (3)
- ○ 2 year degree (4)
- ○ 4 year degree (5)
- ○ Professional degree (6)
- ○ Graduate degree (7)

10 How much total combined income did all members of your HOUSEHOLD earn in 2019?

This includes money from jobs; net income from business, farm, or rent; pensions; dividends; interest; social security payments; and any other money income received by members of your HOUSEHOLD that are EIGHTEEN (18) years of age or older.

Please report the total amount of money earned - do not subtract the amount you paid in taxes or any deductions listed on your tax return.

- ○ Less than $10,000 (11)
- ○ $10,000 - $19,999 (12)
- ○ $20,000 - $29,999 (13)
- ○ $30,000 - $39,999 (14)
- ○ $40,000 - $49,999 (15)
- ○ $50,000 - $59,999 (16)
- ○ $60,000 - $69,999 (17)
- ○ $70,000 - $79,999 (18)
- ○ $80,000 - $89,999 (19)
- ○ $90,000 - $99,999 (20)
- ○ $100,000 - $149,999 (21)
- ○ More than $150,000 (22)

Page Break

End Thank you for participating in this survey. Your answers are very helpful and rest assured that they will be kept confidential. We would like to reiterate that all information that you have contributed to this survey is confidential and that the survey is purely hypothetical. The results of this survey will be used only for the intended research towards aquaculture in South Carolina as conducted by Clemson University.

End of Block: Profile

Appendix B

Choice Experiment for Oysters

Version 1

CM 1 Having heard or read about what aquaculture is, the issues regarding accessibility of seafood products, as well as the characteristics of the aquaculture industry in South Carolina, this survey wants to find out what consumers will be willing to pay in regard to having access to farm-raised seafood products grown in SC. In 2014, South Carolina Department of Natural Resources ruled that all out-of-state oyster seed north of North Carolina was deemed illegal to import into SC over concerns of disease transmission to local oyster populations. Subsequently, the years following saw declines of up to 70% in SC farm-raised oysters according to South Carolina Department of Natural Resources. Since this regulation, SC oyster growers have seen demand for their products soar while finding it nearly impossible to grow enough oysters to meet this demand. Therefore, most oysters are now imported from out-of-state to meet the SC demand. Considering the challenges oyster growers in SC have faced, we are seeking to know how much consumers are willing to pay for oysters grown in SC.

Page Break

CM 2 In the next series of questions, you will be given a set of options to choose from considering different combination of attributes towards oysters in SC. When choosing, remember that the **average price in the market for unshucked oysters currently is $7.99/lb**.

Please choose the option that best reflects your preference considering it might affect your current household budget.

Also, please consider that you are choosing only for your household, therefore **do not choose by considering what would be best for your community**.

Finally, past studies have found that many people say **YES** to a hypothetical survey, such as this one, but they would not be willing to pay when faced by the actual situation. Therefore, we request for you to answer this survey as if you are in an actual situation.

Page Break

CM 3 Would you be willing to pay a premium for a **South Carolina** farm-raised seafood product?

- ○ Yes (26)
- ○ No (27)

Skip To: CM 4a If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = Yes

Skip To: CM 4b If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = No

Display This Question:

If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = Yes

CM 4a Please rank your reason why you chose to say **YES** to the previous question (Please drag up or down the items to rank according to your preference with 1 being the best on top and 4 being at the bottom least)

_____ I want to support in-state producers of farm-raised seafood products (1)
_____ I believe the premium in price can help in the enhancement of SC aquaculture production (2)
_____ I believe the aquaculture of seafood products is a sustainable practice (3)
_____ I believe farm-raised seafood products are fresher than other sources (4)

Display This Question:

If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = No

CM 4b Please check your main reason why you chose **NO**

- ☐ I do not care about the source of seafood products (1)
- ☐ I do not think aquaculture production can be successful in South Carolina (2)
- ☐ I do not trust that aquaculture products in South Carolina are safe (4)
- ☐ I do not have additional money to pay for the premium (5)
- ☐ Other reason (6) _____

End of Block: The Choice Model

Start of Block: Choice set: Oysters

CM 4c In the following sets of options, oysters designating they are a product of **SOUTH CAROLINA** will display the Certified SC Seafood label as follows:

Oysters designating they are **U.S.** products (**other than SC**) will display the U.S. Seafood label as follows:

Oysters designating they have been **WILD-CAUGHT** will display the Marine Stewardship Council (MSC) Label as follows:

Oysters designating they have been **FARM-RAISED** will display the Aquaculture Stewardship Council (ASC) label as follows:

Page Break

1 Given the set of choices with corresponding prices of oysters available to consumers, which option will you select for the following choice sets?

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$8.99/lbs	$6.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

2

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$4.99/lbs	$9.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (4)

Page Break

3

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$10.99/lbs	$10.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

4

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$9.99/lbs	$6.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

End of Block: Choice set: Oysters

Start of Block: Institutional design

ID 1 Thank you for completing the survey up to this point. We will ask few more questions as we approach the last part of the survey...

Version 2

CM 4c In the following sets of options, oysters designating they are a product of **SOUTH CAROLINA** will display the Certified SC Seafood label as follows:

Oysters designating they are **U.S.** products (**other than SC**) will display the U.S. Seafood label as follows:

Oysters designating they have been **WILD-CAUGHT** will display the Marine Stewardship Council (MSC) Label as follows:

Oysters designating they have been **FARM-RAISED** will display the Aquaculture Stewardship Council (ASC) label as follows:

Page Break

1 Given the set of choices with corresponding prices of oysters available to consumers, which option will you select for the following choice sets?

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$4.99/lbs	$5.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

2

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$4.99/lbs	$4.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (4)

Page Break

3

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$10.99/lbs	$5.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

4

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$9.99/lbs	$10.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

End of Block: Choice set: Oysters

Start of Block: Institutional design

ID 1 Thank you for completing the survey up to this point. We will ask few more questions as we approach the last part of the survey...

Appendix C

Choice Experiment for Shrimp

Version 1

CM 1 Having heard or read about what aquaculture is, the issues regarding accessibility of seafood products, as well as the characteristics of the aquaculture industry in South Carolina, this survey wants to find out what consumers will be willing to pay in regard to having access to farm-raised seafood products grown in SC.
Shrimp production in South Carolina has focused primarily on the trawling of Brown and White Shrimp over the past 100 years. While this fishery has historically seen significant yields of both species during this time, recent developments in shrimp farming capability in other regions of the world have created a surging demand for these products at much cheaper prices. In addition to the unequal supply of U.S. produced shrimp compared to those produced abroad, it has been difficult for shrimp farmers domestically to produce shrimp at the scales needed to balance this dynamic due to the significant costs associated with building facilities for recirculating aquaculture systems (known as RAS), that produce shrimp in land-based settings and do not circulate any water from outside sources.
Considering the challenges shrimp growers in SC have faced, we are seeking to know how much consumers are willing to pay for shrimp grown in SC.

Page Break

CM 2 In the next series of questions, you will be given a set of options to choose from considering different combination of attributes towards shrimp in SC. When choosing, remember that the **average price in the market for unshelled shrimp currently is $7.99/lb**.

Please choose the option that best reflects your preference considering it might affect your current household budget.

Also, please consider that you are choosing only for your household, therefore **do not choose by considering what would be best for your community**.

Finally, past studies have found that many people say **YES** to a hypothetical survey, such as this one, but they would not be willing to pay when faced by the actual situation. Therefore, we request for you to answer this survey as if you are in an actual situation.

Page Break

CM 3 Would you be willing to pay a premium for a **South Carolina** farm-raised seafood product?

- ○ Yes (26)
- ○ No (27)

Skip To: CM 4a If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = Yes

Skip To: CM 4b If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = No

Display This Question:

If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = Yes

CM 4a Please rank your reason why you chose to say **YES** to the previous question (Please drag up or down the items to rank according to your preference with 1 being the best on top and 4 being at the bottom least)

_____ I want to support in-state producers of farm-raised seafood products (1)
_____ I believe the premium in price can help in the enhancement of SC aquaculture production (2)
_____ I believe the aquaculture of seafood products is a sustainable practice (3)
_____ I believe farm-raised seafood products are fresher than other sources (4)

Display This Question:

If Would you be willing to pay a premium for a South Carolina farm-raised seafood product? = No

CM 4b Please check your main reason why you chose **NO**

- ☐ I do not care about the source of seafood products (1)
- ☐ I do not think aquaculture production can be successful in South Carolina (2)
- ☐ I do not trust that aquaculture products in South Carolina are safe (4)
- ☐ I do not have additional money to pay for the premium (5)
- ☐ Other reason (6) _____

End of Block: The Choice Model

Start of Block: Choice set: Shrimp

CM 4c In the following sets of options, shrimp designating they are a product of **SOUTH CAROLINA** will display the Certified SC Seafood label as follows:

Shrimp designating they are **U.S.** products (**other than SC**) will display the U.S. Seafood label as follows:

Shrimp designating they have been **WILD-CAUGHT** will display the Marine Stewardship Council (MSC) Label as follows:

Shrimp designating they have been **FARM-RAISED** will display the Aquaculture Stewardship Council (ASC) label as follows:

Page Break

1 Given the set of choices with corresponding prices of shrimp available to consumers, which option will you select for the following choice sets?

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$4.99/lbs	$9.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

2

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$10.99/lbs	$6.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (4)

Page Break

3

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$4.99/lbs	$5.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

4

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$10.99/lbs	$8.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

End of Block: Choice set: Shrimp

Start of Block: Institutional design

ID 1 Thank you for completing the survey up to this point. We will ask few more questions as we approach the last part of the survey...

Version 2

1 Given the set of choices with corresponding prices of shrimp available to consumers, which option will you select for the following choice sets?

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$10.99/lbs	$8.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

2

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$4.99/lbs	$4.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (4)

Page Break

3

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$6.99/lbs	$9.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

Page Break

4

Option 1	Option 2	Option 3
		"Status quo" I would not select either option 1 or option 2
$8.99/lbs	$6.99/lbs.	

- ○ Option 1 (1)
- ○ Option 2 (2)
- ○ Option 3 (3)

End of Block: Choice set: Shrimp

Start of Block: Institutional design

ID 1 Thank you for completing the survey up to this point. We will ask few more questions as we approach the last part of the survey...

Appendix D

Oyster Mariculture Producer Interview

Oyster Mariculture Producer Interview Questions

Confidentiality Statement:
We are conducting a survey to form an oyster mariculture industry outlook in the state of South Carolina. Participants are encouraged to provide honest and accurate information regarding operational costs and production output. Survey duration will vary, as there is a section covering open-ended questions, however we do not anticipate the duration of this questionnaire to exceed 30 minutes. Records of participation in this research project will be kept confidential. Results will be reported in a summarized manner in such a way that no individual can be identified. Taking part in this research study is voluntary. We encourage you to participate in the survey. Each and every single response is valued and appreciated. If you decide not to take part, or if you stop participating at any time, your decision will not result in any penalty or loss of benefits to which you may otherwise be entitled. If you withdraw from the study, the answers you provide will not be used.

Goal: measure total economic contribution of oyster mariculture in SC, including direct, indirect, and induced effects.

1. Do you cultivate aquaculture oysters?
    a. Yes (If yes, go to Q2)

2. How long has your operation been in business (in years)-____years

3. Do you cultivate single oysters?
    a. Yes (If yes, go to Q4).

4. Please describe some of the characteristics of your **2019** commercial single oyster aquaculture cultivation.
    a. Number of oyster seed planted on your farm in 2019 _____
        i. % diploid _____%
        ii. % triploid _____%
    b. Average price of triploid seed purchased ($ per 1,000) ____
    c. Percent of planted seed sourced from out of state _____%
    d. Primary state of importing oyster seed (If not SC)_____
    e. Market sized (3” and above) oysters sold _____
        i. % wholesale/distributor _____%
        ii. % wholesale/direct delivery _____%

iii. % retail/direct to consumer _____%

f. Average price per market oyster
   i. Wholesale/distributor price $___
   ii. Wholesale/direct delivery price $_
   iii. Retail/direct to consumer price $_____

g. Total number of (3" and above) oysters sold in 2019? _____

5. How many cages is your operation currently using? _____

6. Did you re-sell oyster seed in 2019 (i.e. did you sell seed that you did not produce)?

   a. No (If no, go to Q9)

7. Selling seed
   a. Number of seed sold _____
   b. Average price of seed sold ($ per 1,000) $_____

8. What percent of your purchased seed did not make it to market in 2019?_____%

9. How did you use and/or sell undersized size oysters in 2019?
   a. Find a market use (fried recipes, etc.)
   b. Personal consumption
   c. Use for reef habitat building
   d. Planted in surrounding environment
   e. Other (please describe): _____

<u>We would like to ask about operational costs of your production</u>

10. Number of full-time employees _____
11. Number of part time employees _____
12. Number of contractors _____
13. To date, how much have you invested in your business? _____
14. Total operating expenses incurred for business operation in 2019 _____

15. Across the following expense categories, please approximate the percent of total expenses that were spent in each category for business operation in 2019. This information will remain completely confidential, will only be used for purposes of aggregation and averaging.

Category	Percentage (0-100%)
Labor	
Seed	
Vessel Fuel	
Gear and equipment for harvest (cages, bags, anchors, sorting table, baskets, containers, rope/twine/wire, protective clothing, etc.)	
Maintenance/repairs	
Shipping/freight	
Regulatory costs (Permitting/Lease fee/Compliance cost)	
Insurance/Bonds	
Interest (loans, credit cards, etc.)	
Utilities (electric, non-vessel fuel, gas/propane, internet, etc.)	
Advertising	
Administrative costs (distribution of owner's salary)	
Taxes	
Vessel	
Other	

Perception-Based Section

16. Did you change any production practices due to COVID-19 shutdown (Mid-March to Mid-May)?
    a. Frequency of air drying your cages ____
    b. Frequency of tumbling oysters _____
    c. Other _____

17. Do you have an estimate of the current season's seed mortality since March 2020 (0-100%)

18. How do you expect sales change (in percent) in 2020 to compare to 2019?

19. Since the moratorium on oyster seed north of SC has been lifted, how has accessibility to oyster seed changed for you?

20. Has your operation been limited in the past by the availability of oyster seed?

21. Does your operation plan to increase production in terms of the number of cages in next two years?

-Yes

-No

If yes, by how many cages?

Open discussion

How can federal or state agencies help you to enhance your operations and improve your sales (e.g. funding, education resources)

Do you think collaboration amongst growers at any of the following steps would be beneficial to the oyster maricultural industry as a whole? If yes, how?

-Production (i.e., lease sharing):

-Distribution

-Marketing (i.e. consolidating farm's information in a website)

-Public seafood marketplace

Please describe how the recent lifting of the ban on out-of-state seed north of SC has affected your operation's current or future outlook.

Please describe the top three challenges your operation has faced since the occurrence of Covid-19 (since March 2020)

Did your operation seek compensation from the CARES Act? If yes, please describe how helpful the compensation was in maintaining your operations? Please describe whether this process was easy or difficult?

For potential growers, what is the most challenging element of entering the shellfish industry in SC?

1- Lack of guidance through the process

2- Permitting

3- High production cost
4- Lack of seed availability

If there was one thing that the state or your growers association could assist you with to be successful, what would that be?