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Insights from a Survey of Texas Gulf Coast Residents on the Social Factors Contributing to Willingness to Consume and Purchase Lionfish

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Abstract: Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) are the first marine teleost to become established in the Western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Lionfish have been labeled a global conservation issue and pose major threats to local economies. To test whether commercial harvest of lionfish is a socially accepted management approach in Texas, we measured the components of an environmental behavior intention model with survey responses of Texas Gulf Coast residents (n = 420). Regression analyses of survey responses indicate that individuals were significantly more willing to consume lionfish if they had a high level of concern for the environmental problems posed by the invasive species and were more knowledgeable about the fish. Participation in an educational program that addresses lionfish was also found to be associated with greater willingness to consume lionfish among those who are moderately to highly concerned about the issue. The originality of this study is related to its contribution in identifying social factors that contribute to an individual's willingness to consume lionfish. Insights from this study demonstrate the attitudinal and behavioral mechanisms that can be addressed to increase acceptance of using consumption as a sustainable management strategy to combat marine fish invasions.

Keywords: lionfish; sustainable consumption; commercial fishery; Texas Gulf Coast; human survey; logistic regression

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1. Introduction

A biotic invasion occurs when a nonindigenous organism is introduced into a new location where the population proliferates, spreads, and persists [1]. Ecological consequences of biotic invasions can vary in scope and magnitude, while management focused on population suppression is almost always exceptionally costly [2]. Biotic invasions in the marine environment can be more challenging because of the high environmental connectivity between water bodies, in that, it is more difficult to manage a population as the spatial range and dispersion capacity increases [3].

Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) have become the first successful marine fish invaders in the Atlantic Ocean, Gulf of Mexico, and Caribbean and Mediterranean Seas [4–8], attributable to several life history and behavioral traits that are believed to facilitate their continued expansion and population growth [9]. Lionfish were first reported off the coast of Florida in the early 1980s and are widely thought to be introduced from aquaria release [8,10]. Lionfish were first reported in the northwestern Gulf of Mexico, off the coast of Texas, in 2010 [10,11] and are well known for having severe negative impacts to native reef communities [5,12–17]. In addition, lionfish also impose negative social and economic impacts to these invaded regions [18–20]. A suite of management strategies has been experimented with to suppress lionfish populations; however, and thus far, no specific policy for lionfish mitigation is in place although there are national and regional

plans aimed at the prevention, management, and control of lionfish in the United States and wider Caribbean [21,22]. One of the mitigation measures identified in both strategies advocates marketing and consumption of lionfish.

Physical removal and commercial utilization of marine invaders has been encouraged and highly prioritized among resource managers [3], especially with respect to marine and aquatic invasions [23]. There are a number of positive aspects associated with gastronomic use of invasive marine species; however, formidable barriers exist within people's consumptive habits [24], owing to their inherent conservatism in food preferences and cuisine, with a general tendency to dislike new foods [25,26]. It is broadly understood that consumer demand drives targeted fishery harvest [27]. A deeper knowledge of seafood markets and consumption preferences of a human population can be investigated through the use of surveys [28,29], in order to determine public willingness to accept the introduction of a new marine invasive fish species into the market [30]. Yet, social data and consumer preferences are inherently understudied with respect to the harvest of commercially important marine fish species [31].

The few studies that have been conducted on lionfish consumption found that there is a demand for lionfish where it has been introduced to the market in Aruba, Belize, and Mexico [30,32,33]. Other studies have calculated willingness to pay for lionfish among various consumer groups [34,35], finding that income, age, and education is positively associated with the purchase price individuals accept. While these studies are important for assessing the viability of commercial lionfish fisheries, they, similar to many studies of willingness to pay for environmental management, neglect the social factors associated with the behavior of consumption of lionfish. Thus, they miss the opportunity to identify the social mechanisms that may be leveraged to induce the behavior that the consumption management strategy depends on: the purchase and consumption of lionfish.

This study attempts to fill this gap by applying an environmental behavior intention model, put forth by Sudarmadi et al. [36], to explore how perception, knowledge, awareness, and attitude of a specific environmental problem shapes behavioral intention.

Using data drawn from an original survey of Texas Gulf Coast residents, regression analyses are estimated to assess the association of knowledge of lionfish, concern for lionfish impacts, and willingness to support control of lionfish with the likelihood of willingness to purchase and consume lionfish. The association of previous exposure to lionfish education and outreach efforts with willingness to consume lionfish is also examined, and education experience is interacted with knowledge, concern, and attitudes about control to evaluate how the association of these social factors with willingness to consume lionfish differs among individuals with and without lionfish education.

These analyses contribute to the limited studies empirically addressing the social dimensions related to invasive species management [37]. This study also contributes to the literature on willingness to pay for environmental protection and invasive species control by focusing social factors—knowledge, concern, and attitudes about management—that may be targeted and changed in efforts to boost the desired environmental behavior. Furthermore, this study empirically tests the relationship of environmental education program participation with the desired environmental behavior, whereas previous research has largely speculated on the association of environmental education with willingness to pay for environmental management.

2. Literature Review and Conceptual Framework

2.1. Willingness to Pay for Environmental Management

Assessment of willingness to pay (WTP) for environmental protection determines if certain management strategies are economically feasible. This is critical when financial resources supporting environmental protection programs are scarce [37,38] and when economic viability determines the success of the strategy [35]. For example, WTP for lionfish must exceed the production costs of a commercial lionfish fishery to be economically viable, assuming that there is sufficient and sustained demand to create an ecological difference.

Studies of WTP for environmental protection tend to focus on individual-level measures of socioeconomic status. A range of analyses have found individuals with higher incomes and education are more willing to pay for seaweed control in Ghana [38], protection of fish resources in coastal Italy [39], control of pine invasion in Chile [37], and lionfish as a seafood product in Florida and the United States Virgin Islands [34,35].

While WTP studies illuminate how much and which users are willing to contribute toward environmental protection and thus are important for the financing of specific management strategies, they often neglect the social dynamics at play. Determining that WTP for lionfish is comparable to other reef or white fish [34,35] offers critical information for assessing the economic viability of commercial lionfish fisheries. Nonetheless, it does not address the social factors associated with consumption management strategy that may be leveraged to improve the likelihood of successful implementation. The finding, however, that WTP increases with information on the severity of the environmental threat posed by lionfish [34] points to a social factor that can be manipulated to the benefit of management.

Similarly, analyses that have highlighted the influence of climate change attitudes, interest in nature, knowledge of invasive species, and sense of place on WTP [39,40] offer insights into relevant social factors for environmental protection and invasive species management. Yet, most WTP studies lack consideration of social factors beyond demographic characteristics. Fewer analyses address social factors in a way that can translate into public interventions, such as environmental education that may encourage pro-environmental behavior [39].

Few studies in the economic literature have empirically evaluated local communities' willingness to contribute monetarily to protect marine resources [41,42], and more specifically, fishery resources [39]. Less research has focused their efforts on quantifying a consumer's willingness to pay for resources to manage an invasive species or repair damages to the environment [43,44]. A greater disparity in the literature exists in identifying social factors that influence willingness to pay for invasive species management [37,40,45], especially in the context of commercial harvest [30,46].

2.2. Environmental Behavior Intention Model

Sudarmadi and colleagues [36] offer a conceptual model for understanding the association of social factors with behavior intentions in the context of environmental policy. Individual environmental perception, knowledge, awareness, and attitude mutually influence behavioral intention (Figure 1). Perceptions of environmental problems involve the "ability to perceive environmental issues in the real world" [36]. For example, identifying water pollution from industry in a local body of water is a perception. Knowledge of environmental problems reflects individual understanding of the cumulative body of facts on an environmental issue, for example, having knowledge of the health impacts of water pollution. Awareness of environmental problems entails the sensitivity individuals have for an environmental issue, including their level of concern about the issue. For example, considering water pollution a serious problem demonstrates awareness. Attitude to environmental problems entails motivation to improve and protect the environment. For example, considering the issue of water pollution to be a problem that requires government intervention.

Individual environmental perceptions, knowledge, awareness, and attitudes are affected by exposure to environmental education. Education helps to "develop skills and attitudes necessary to understand and appreciate the interrelatedness of humans, their culture and their biophysical surroundings" [36]. The expectation is that environmental education—formal and informal—increase perception, knowledge, awareness, and attitudes to motivate change in behavior.

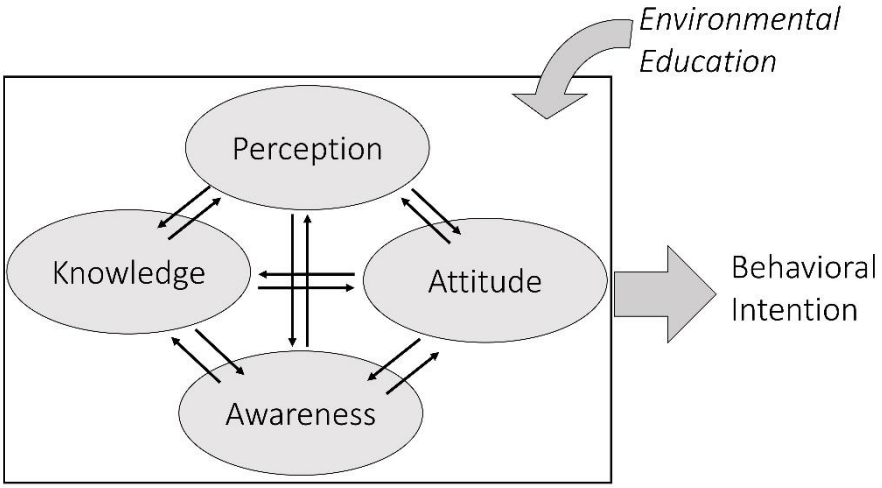

Figure 1. Environmental behavior intention model. Adapted from Sudarmadi et al. [36].

The commercial harvest of lionfish as a management approach relies on individual behavior in the form of consumption of lionfish. The environmental behavior intention model provides the framework to evaluate the social factors of an individual perception, knowledge, awareness, and attitude of lionfish and how this is associated with the behavior desired from the consumption management strategy. Furthermore, this model connects environmental education with these social factors to assess how education may indirectly influence the behavior of consumption of lionfish. Conceptualizing environmental education as "a necessary cognitive 'pre-condition' of responsible behavior and action" is in line with studies of invasive species control [37]. Furthermore, inclusion of environmental education as an explanatory factor in the conceptual model allows for empirical testing of the effect of education on behavioral intentions. Previous work on willingness to pay for environmental protection and invasive species control has largely speculated, but not tested, the influence of education on behavior [37,39]. Beyond education, we acknowledge there may be other factors (e.g., altruism) affecting environmental behavior intention that are not captured by this conceptual model. However, we chose to directly apply the environmental behavior intention model put forth by Sudarmadi et al. [36]; future work may be aimed at revising and expanding it.

3. Materials and Methods

3.1. Social Survey Design and Study Area

A survey was developed and launched to Texas Gulf Coast county residents in July 2018. An 18-item survey instrument was generated to quantitatively measure perceptions about the willingness to buy and consume lionfish. Specifically, questions were designed to assess: (1) willingness to purchase and eat lionfish, (2) perception of environmental problems, (3) knowledge of lionfish and the environmental problems they cause, (4) level of concern for lionfish impacts, (5) level of support for control efforts, and (6) exposure to lionfish education and outreach efforts (Table S1). This survey provides the first and most comprehensive evaluation of social factors that impact an individual's willingness to consume lionfish in Texas.

The sample area included the entire Texas coastal zone, spanning 367 miles of coastline, to include the 19 counties designated by the National Oceanic and Atmospheric Administration as part of the Coastal Zone Management program: Aransas, Brazoria, Calhoun, Cameron, Chambers, Galveston, Harris, Jackson, Jefferson, Kenedy, Kleberg, Liberty, Matagorda, Nueces, Orange, Refugio, San Patricio, Victoria, and Willacy [47] (Figure 2).

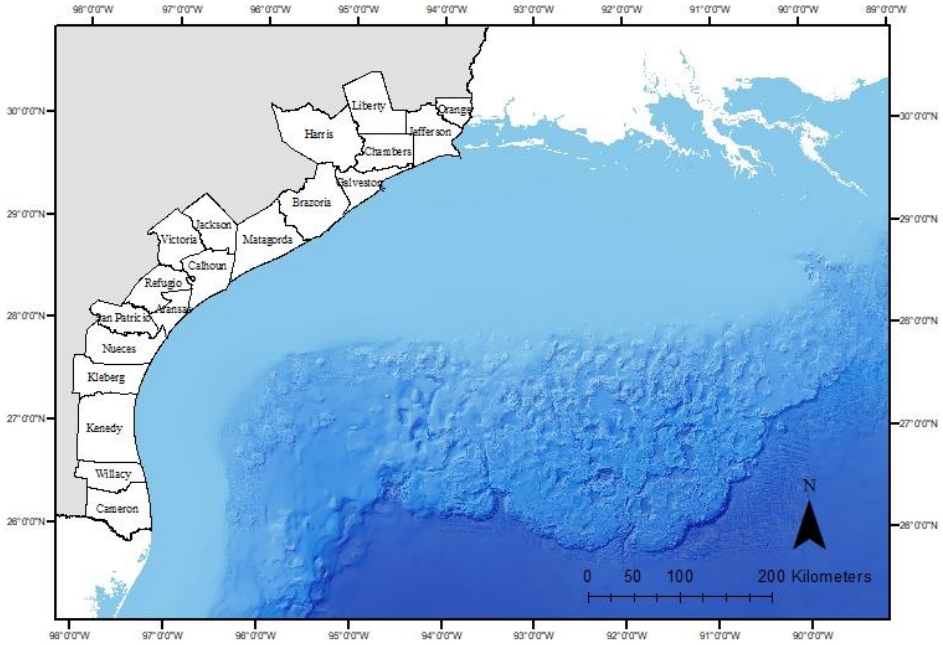

Figure 2. Sampling sites in Texas Gulf Coast counties as designated by the National Oceanic and Atmospheric Administration's [47] coastal zone management program. Continental slope bathymetric data were provided by the U.S. Geological Survey [48]; Texas county data were retrieved from Texas Department of Transportation [49].

Eligible survey participants included adults, age 18 years and older, that reside in one of the 19 counties that comprise the Texas coastal zone. Participants were recruited by the survey company Qualtrics to fill a set of quotas that match population parameters for age, sex, race, and ethnicity obtained from the 2016 US Census Bureau of Statistics. A total of 420 respondents completed the survey. Respondent characteristics are shown in Table 1, alongside population parameters for the survey sample area. Because the sample characteristics closely match population parameters, a survey weight was not needed to adjust the sample to be representative of the population.

Table 1. Demographic characteristics of the survey sample.

Demographic	Individual Characteristic	Sample Proportion (Observations)	Population Proportion
Age	18–24 years	13.1% (55)	13.0%
	25–39 years	39.5% (166)	39.6%
	40–64 years	32.4% (136)	32.3%
	65+ years	15.0% (63)	15.0%
Race	White	36.9% (155)	34.3%
	Hispanic/Latino	40.5% (170)	43.2%
	African-American	15.7% (66)	15.6%
	Asian	5.2% (22)	5.3%
	Other	1.7% (7)	1.7%
Sex	Female	50.7% (213)	50.8%
	Male	49.3% (207)	49.2%

3.2. Measures

We measured the components of the environmental behavior intention model with survey responses to a number of items that assess individual perceptions of environmental problems, knowledge and awareness of lionfish, attitudes toward lionfish control, willingness to purchase and consume lionfish, and lionfish education exposure (Table A1).

Perception of environmental problems was measured using survey items that replicated the connectedness to nature scale (CNS) developed by Mayer and Frantz [50]. CNS captures cognitive beliefs about how individuals relate to nature and has been found to predict environmental behavior [50,51]. Survey responses to the following CNS items were used to calculate a factor score representing environmental connectedness: (1) 'I think of the natural world as a community to which I belong'; (2) 'I feel a sense of oneness with nature'; (3) 'When I think of my life, I imagine myself to be a part of a larger cyclical process of living'; (4) 'I often feel a kinship with plants and animals'; (5) 'I feel as though I belong to the Earth as equally as it belongs to me'; and (6) 'I have a deep understanding of how my actions affect the natural world'. All items loaded to one factor with a Cronbach's alpha coefficient of 0.835, indicating scale reliability that exceeds minimum standards [52].

Knowledge of environmental problems was measured by the survey item that asked respondents: 'What would you say is your level of knowledge of lionfish?' Respondents rated their lionfish knowledge on a scale of 0 to 10 where 0 represents 'no knowledge' and 10 represents 'expert knowledge'.

Awareness of environmental problems was measured by the survey item that asked respondents to 'indicate your level of concern for the impacts lionfish can have on each of the listed items: (1) recreational fisheries; (2) commercial fisheries; (3) coral reefs; (4) native fish populations; (5) coastal economy; (6) tourism and recreation; (7) SCUBA diving operations; and (8) offshore energy production'. Response options included: 'not concerned', 'somewhat concerned', 'neutral', 'concerned', and 'very concerned'. Again, a factor score was calculated for the eight items loaded to one factor representing lionfish concern. The Cronbach's alpha coefficient of the factor score was 0.948, indicating high scale reliability.

To measure attitude to environmental problems, with particular attention on environmental protection, a survey item asked respondents to 'indicate how important it is to you to have the following areas managed to control lionfish populations: (1) coral reefs, (2) marine protected areas, (3) artificial reefs, (4) estuaries, (5) boat docks and ports, (6) coasts used for recreational activity, and (7) offshore oil and gas platforms'. Response options included: 'not important', 'somewhat important', 'neutral', 'important', and 'very important'. All items loaded to one factor with a Cronbach's alpha coefficient of 0.945.

To measure environmental behavior intention, two survey items were used that captured willingness to buy and consume lionfish. The first asked respondents to 'indicate how willing you would be to contribute to the following lionfish control efforts: eat lionfish if prepared in a restaurant or sold in a seafood market'. Response options included 'not willing', 'somewhat willing', 'neutral', and 'very willing'. The second item asked respondents: 'How willing would you be to order lionfish at a restaurant or purchase fillets in a seafood market?' Response options included: 'not willing', 'somewhat willing', 'very willing', and 'undecided'. These questions were asked at different times during the survey; therefore, willingness to consume lionfish was considered to be expressed by affirmative responses to either survey item. All other responses were coded as indicating the intention to not buy or consume lionfish.

Finally, we used the following survey item to measure lionfish education: 'Have you ever attended an educational program, activity, or presentation to learn more about lionfish?' Responses of 'yes' were considered to indicate education on this environmental issue. A number of demographic controls were measured, including age (1 = 18–24 years; 2 = 25–39 years; 3 = 40–64 years; 4 = 65+ years), sex (0 = female, 1 = male), and race and ethnicity to include self-identification as Anglo American, African American, Hispanic/Latino, and Asian.

3.3. Descriptive Statistics

Table 2 reports the descriptive statistics of the survey sample across measures of the environmental behavior intention model. Nearly 60% of survey respondents said they were willing to consume lionfish. Environmental connectedness had a negative distribution. With a median value of 0.014, the bottom quartile of the respondent pool

had an environmental connectedness factor score ranging from −3.283 to −0.761 while the top quartile had a score of 0.666 to 1.980. Environmental knowledge, measured on a 0 ('no knowledge') to 10 ('expert knowledge') scale was positively skewed; 28% of survey respondents said they had 'no knowledge' of lionfish. Another 14% of respondents rated their knowledge as '1′, 12% rated their knowledge as '5′, and 4% rated their knowledge as '10′. The environmental concern factor score was normally distributed; with a median value of −0.055, the scores of the bottom quartile ranged from −1.796 to −0.937 while the top quartile ranged from 0.782 to 1.642. Lionfish control was negatively skewed, with the bottom quartile ranging in factor score from −2.171 to −0.642, the median value equaling 0.251, and the top quartile ranging from 0.822 to 1.337. Finally, only 8% of survey respondents reported that they had some form of lionfish education.

Table 2. Descriptive statistics of environmental behavior intention model measures.

	Mean	S.D.	Min	Max
Willingness to consume lionfish	0.598	0.491	0	1
Environmental connectedness	1.83×10^{-9}	1	–3.283	1.980
Lionfish knowledge	3.257	3.107	0	10
Lionfish concern	-3.85×10^{-9}	1	–1.796	1.642
Lionfish control	1.01×10^{-9}	1	–2.717	1.337
Lionfish education	0.083	0.277	0	1

3.4. Statistical Analyses

Logistic regression analysis was used to estimate the association of perception (environmental connectedness), knowledge (lionfish knowledge), and awareness (lionfish concern) with environmental behavior intention (willingness to consume lionfish) while controlling for respondent lionfish education, age, sex, and race and ethnicity. Attitude about lionfish control was not included in the model because this variable is highly correlated with the measure of awareness (lionfish concern) (r = 0.759; $p < 0.05$) (Table S2). Because environmental education is conceptualized as an influence on perception, knowledge, and awareness, a second model was estimated including interacting terms between lionfish education and environmental connectedness, lionfish knowledge, and lionfish concern. Stata 14 version 2 was used for analyses [30].

3.5. Ethics Statement

All of the surveys conducted with human subjects in Texas Gulf Coast counties received pre-approval by Texas A&M University's Internal Review Board for Human Subjects Research (IRB2014-0355D) and all of those surveyed provided informed consent to participate. No endangered or protected species were involved in this study.

4. Results

Results of the logistic regression analysis are provided in Figure 3. Only lionfish knowledge and lionfish concern display a statistically significant association with willingness to consume lionfish, as indicated by confidence intervals that do not cross zero. Because logistic coefficients are difficult to interpret directly, marginal effects are used to demonstrate significant relationships. Marginal effects indicate that an individual, on average, who says they have no knowledge of lionfish (minimum value of lionfish knowledge) has a 54% likelihood of expressing willingness to consume lionfish, compared to a 72% likelihood for someone who rates their knowledge of lionfish as 'expert' (maximum value of lionfish knowledge). Similarly, an individual, on average, with the minimum value of concern for the issue lionfish has a 44% likelihood of expressing willingness to consume lionfish while an individual with the maximum value of lionfish concern has a 70% likelihood of the same.

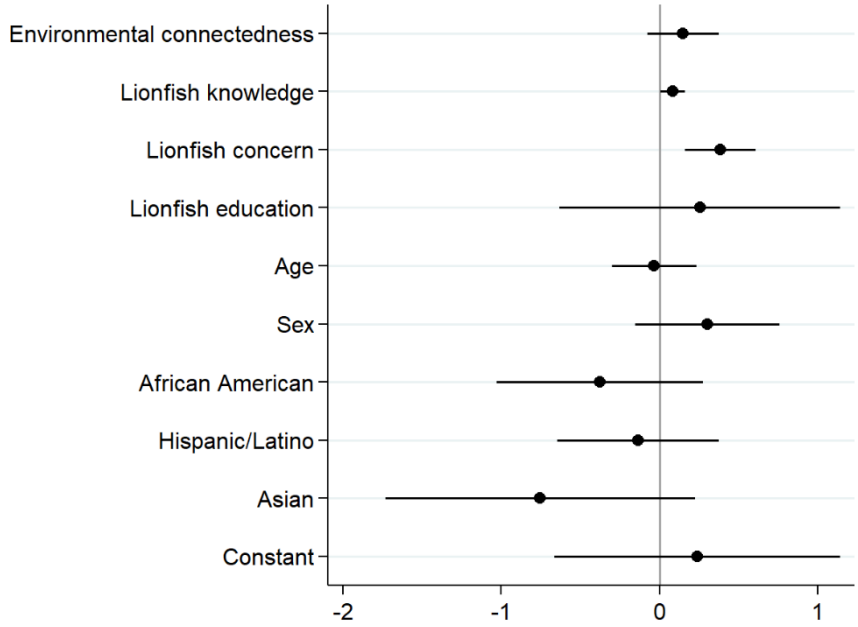

Figure 3. Regression results. Coefficients are marked by dots and confidence intervals are shown as lines.

The second model explored how lionfish education moderates the association between environmental connectedness, lionfish knowledge, and lionfish concern with willingness to consume lionfish. Results indicate that there is a statistically significant interaction effect for lionfish knowledge and lionfish concern with lionfish education (Table 3). Again, marginal effects are used to interpret the results.

Table 3. Regression results including interaction (#) with environmental education.

	Coefficient	Standard Error
Environmental connectedness # no lionfish education	0.130	(0.124)
Environmental connectedness # lionfish education	0.331	(0.473)
Lionfish knowledge # no lionfish education	0.081 *	(0.042)
Lionfish knowledge # lionfish education	0.180 *	(0.101)
Lionfish concern # no lionfish education	0.303 **	(0.118)
Lionfish concern # lionfish education	1.726 **	(0.674)
Age	−0.050	(0.136)
Sex	0.286	(0.234)
African American	−0.403	(0.335)
Latino	−0.156	(0.264)
Asian	−0.822 *	(0.497)
Constant	0.313	(0.465)
N	420	

Coefficients reported with standard errors in parentheses; ** $p < 0.05$, * $p < 0.10$.

While the interaction between environmental education and environmental knowledge is statistically significant, marginal effects show that the interaction is driven by lionfish knowledge. The increase in willingness to consume lionfish is steady across both the educated and uneducated group (Figure 4). Among those with no lionfish education, an individual with no knowledge of lionfish has, on average, a 54% likelihood of expressing willingness to consume lionfish. This increases to a 72% likelihood for an individual with 'expert' knowledge. Similar trends were found among the educated group: an individual with no knowledge has, on average, a 53% likelihood of being willing to consume lionfish, compared to a 77% likelihood for an individual with 'expert' knowledge. Although the educated group has a higher likelihood of consuming lionfish at higher levels of knowl-

edge, pairwise comparisons indicate these differences are not statistically significant. These results indicate that self-reported lionfish knowledge is sufficient on its own to influence the purchase and consumption of commercially harvested lionfish.

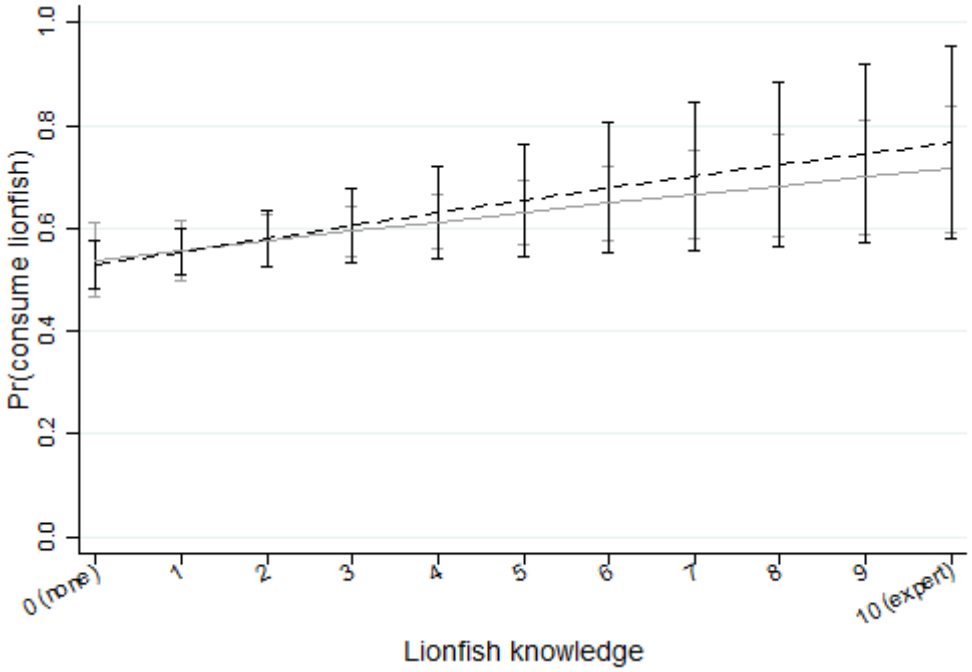

Figure 4. Marginal effects for the interaction of lionfish knowledge # lionfish education. Marginal effects reported with 95% confidence intervals across the values of lionfish knowledge between two groups—those with (black, dashed line) and without (gray, solid line) lionfish education. All other variables are held at their means.

While environmental education does little to affect the association of lionfish knowledge and consumption, the regression results indicate that the relationship between concern for the issue of lionfish and willingness to consume lionfish is moderated by lionfish education. Willingness to consume lionfish is highest among those who have high concern for the issue and who have participated in an educational activity about the issue (Figure 5). Marginal effects indicate that an individual who has the maximum value of concern for the issue of lionfish and has participated in a lionfish educational activity has, on average, a 93% likelihood of being willing to consume lionfish. An individual with the same level of concern for lionfish but without education on the issue has a 68% likelihood of the same. Pairwise comparisons indicate that this 25% difference is statistically significant ($p = 0.000$). The same trend is seen for moderate-high levels of lionfish concern. Moreover, the 11% difference between the uneducated and educated group is statistically significant ($p = 0.078$). Across lower levels of concern, willingness to consume lionfish is higher among those without lionfish education. Marginal effects show that among individuals with moderate-low levels of concern, the difference in likelihood of being willing to consume lionfish between those with and without lionfish education is 18% ($p = 0.092$). The difference increases to 36% for individuals with the lowest level of concern ($p = 0.002$). These results indicate that educational opportunities are not sufficient to induce pro-environmental behavior. Individuals must also have concern for the issue for their behavior to change.

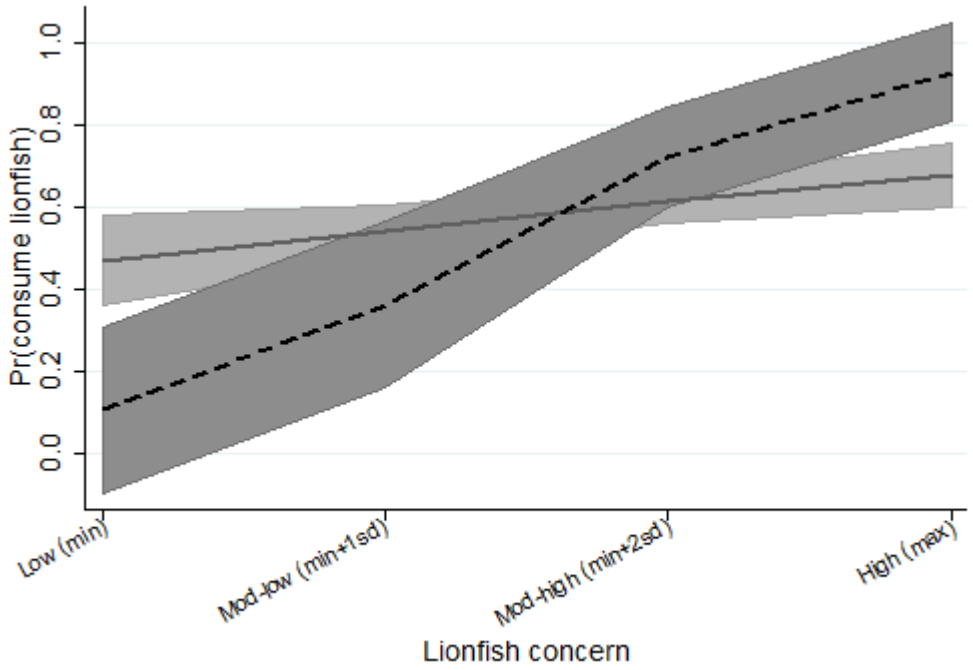

Figure 5. Marginal effects of the interaction of lionfish concern # lionfish education. Marginal effects reported with 95% confidence intervals for varying values of lionfish concern between two groups—those with (black, dashed line) and without (gray, solid line) lionfish education. Given that marginal effects are estimated for specified (not observed) values of lionfish concern, certain probability estimates fall below 0 or exceed 1. All other variables are held at their means.

5. Discussion

Results of the regression analyses indicate willingness to consume lionfish is highest among those who have high concern for the environmental issues posed by this invasive species. In general, there have been recommendations to increase consumers' awareness of their food choices to show they represent significant environmental decisions. Recently, the Food and Agriculture Organization focused on eco-labeled fish products to increase sustainable seafood production and environmental protection [53]. Perez-Ramirez et al. [54] found that coastal residents in northwestern Mexico favored eco-labeled fish as a sustainable seafood option, knowing that it is often costlier than common alternatives. Other research has examined that key stakeholders, such as commercial and recreational fishers and divers, can contribute to informing scientific knowledge and heightening public awareness in support of the control of lionfish [20,55]. Informing consumers about the ecological benefits of eating invasive fish species, such as lionfish, has social, political, and managerial implications that can result in prioritization of ecologically favorable seafood options.

Findings also indicate knowledge about lionfish as critical to the viability of controlling this species with commercial harvesting. Survey respondents in this study were, on average, more willing to consume lionfish if they rated their knowledge about the invasive species as high. A previous study investigating consumer willingness to accept consumption of Asian carp (*Hypophthalmichthys* spp.), another invasive fish species in the United States, also found that an individuals' willingness to eat the fish increased with their level of knowledge about the teleost [46]. While self-reported knowledge of lionfish is significantly associated with greater willingness to buy and consume the invasive species, this study found participation in educational programs that address lionfish is not directly associated with willingness to consume it. Instead, the association of lionfish education with environmental behavior intention is indirect and most evident among those individuals with high concern for lionfish impacts. This implies that, to motivate action, environmental education programs must be accompanied by personal concern for the issue of lionfish management [56]. This is consistent with prevailing good practices for scientific communication [57–59]. Filling

the knowledge deficit is not sufficient; however, educational programs should aim to emotionally engage participants.

With regards to education and outreach, Giakoumi et al. [3] found that fisheries managers place the highest priority on efforts that inform the public about the risks associated with an invasive marine species and their respective exploitation. This type of public education is likely to evoke emotions among participants and is crucial for securing long-term social acceptance of management approaches for marine invasive species [56]. Public education and outreach efforts should be a priority within the political and managerial frameworks of developing a commercial fishery for lionfish.

The survey responses presented and analyzed in this study indicate that, similar to the Caribbean [30,33,35], there is considerable potential in Texas for social acceptance of a commercial fishery for lionfish. While only 8% of survey respondents reported ever eating lionfish, nearly 60% expressed willingness to buy and consume this invasive species. Witkin et al. [60] showed that New England consumers were willing to pay more for an underutilized fish if they previously purchased it. It is likely that this is also true for a consumers' willingness to purchase an invasive species that is new to the market. A community's ability to increase consumers' exposure to a new fish (e.g., lionfish) in restaurants, seafood markets, or through organizations that promote its consumption can be successful in establishing social support for the development of a commercial fishery [60]. As such, efforts should be made in promoting the consumption of lionfish in local seafood restaurants in Texas to increase consumer exposure to it being introduced as a new fishery.

Commercial fishing represents a significant component of the total economic value and utilization of the Texas Gulf Coast [61]. The Gulf of Mexico supports an array of commercial and recreational fisheries that include reef fish, sharks, pelagic fish, crustaceans, and oysters. In 2019, the Gulf of Mexico generated over 1.4 billion pounds in commercial finfish and shellfish fishery landings, yielding a value of $800 million [62]. Commercial harvest of finfish occurs primarily through trawling, longlining, hook and line, and spearfishing [63]. Lionfish are not frequently caught by traditional hook and line fisheries; removal by divers with spears is the most effective and accepted method [64], although recent initiatives in trap development may act as a significant contributor to lionfish harvest in certain regions [65]. Lionfish meat is similar in taste and texture to commercially valued grouper species (Epinephelinae) [66] and can act as a favorable addition to seafood markets in Texas. This study did not address consumer acceptance of lionfish as a replacement for any commercially important fish species in Texas, although this may have serious political and managerial implications for implementing a commercial fishery in the future. In addition to this, the effort needed to suppress lionfish populations and monetarily support a fishery will be needed before market initiatives for commercial harvest of lionfish can begin.

While this study offers valuable insights into the attitudinal mechanisms that are associated with social acceptance of consumption of commercially harvested lionfish, there are multiple limitations that should be noted. The initial survey was conducted in 2018, which, in the context of the evolution of consumer behavior, may appear dated. However, in the context of the behaviors underpinning seafood consumption, we argue that the information is still relevant and will not have changed enough to render these results insufficient. Seafood consumptive habits tend to be impacted by olfactory or gustatory dissatisfaction [67–69], availability [68,70], price [71], health benefits [72–75], past behavior [76], and knowledge [67,77]. As supported in other research, the factors such as availability, price, knowledge, and health benefits will result in a greater likelihood to consume lionfish [32,35,66].

The survey sampling frame relied on a non-probability, convenience sample that met a set of demographic quotas. Although quota-based sampling increases the representativeness of the sample by matching sample to population parameters, it does not allow for the calculation of measures of precision. Therefore, unknown sampling biases are introduced into the sampling estimates [78]. Additionally, the survey data is cross-sectional and, therefore, cannot inform causation between the attitudinal mechanisms studied.

Despite these limitations, this study offers a first glimpse into the social factors underpinning support of a commercial lionfish fishery with data from the coastal zone of Texas. Future research should explore this further and in other geographical regions to improve resource managers' and scientists' understanding of the social implications of this management strategy. Specifically, future research can build upon this study by:

I. Collecting panel data to assess the relationships between individual exposure to scientific information, education and outreach efforts, perceptions of concern for lionfish impacts, and lionfish consumption. This will enable causal analyses that may identify ways the public (e.g., policy-makers through regulation) and private (e.g., fishing industry through marketing) sectors can boost social support for lionfish fisheries;
II. Conducting focus groups of stakeholders and managers in various geographic locations to evaluate diverse perspectives on the commercial harvesting of lionfish and identify potential conflicts and localized issues in the effort to develop a comprehensive management strategy; and
III. Measuring consumer willingness to pay for lionfish if labeled as an eco-friendly option and whether or not this influences support for the commercial harvesting of lionfish as a management strategy.

6. Conclusions

Invasive species threaten environmental sustainability and, due to their new emergence and pervasiveness, require innovative management strategies. It is important to first gauge the support within the community to manage invasive species such as lionfish, particularly in the context of promoting commercial harvest, about which information can be obtained using surveys [30,33,35]. This study examined willingness to purchase and consume lionfish among a sample of adults residing in the Texas coastal zone. Survey responses indicated that nearly 60% of respondents were willing to buy or eat lionfish sold in a seafood market or prepared in a restaurant. Applying a model of environmental behavior intention proposed by Sudamari et al. [36], regression analyses indicated that willingness to consume lionfish is associated with concern for and knowledge about the impact of the invasive species. Participation in educational programs addressing lionfish was also found to be associated with willingness to eat lionfish among those who have moderate to high concern for the consequences of the invasive species. These findings suggest that social acceptance of a lionfish fishery on the Texas Gulf Coast may already exist and that the prospect of a commercial fishery for lionfish should be further explored. To leverage the attitudinal and behavioral mechanisms that contribute to and largely determine the success of commercial lionfish fisheries as a management strategy, public education and outreach efforts focused on lionfish should be expanded and marketing schemes that promote lionfish as an eco-friendly product should also be explored.

Supplementary Materials: The following are available online via Harvard Dataverse at https://doi.org/10.7910/DVN/WZDAHV, Table S1: Texas Gulf Coast County resident lionfish consumption survey questionnaire; Table S2: Pairwise correlation table of logistic regression variables.

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Appendix A

Table A1. Variable measurement.

Concept	Measure	Survey Instrument	Coding
Subject norm intention	Willingness to consume lionfish	How willing would you be to order lionfish at a restaurant or purchase fillets in a seafood market and/or eat lionfish if prepared in a restaurant or sold in a seafood market?	0 = not willing to eat or neutral; 1 = willing to eat
Perception of environmental problems	Environmental connectedness	Respondent agreement with: I think of the natural world as a community to which I belong; I feel a sense of oneness with nature; When I think of my life, I imagine myself to be a part of a larger cyclical process of living; I often feel a kinship with plants and animals; I feel as though I belong to the Earth as equally as it belongs to me; I have a deep understanding of how my actions affect the natural world.	Factor score
Knowledge of environmental problems	Lionfish knowledge	What would you say is your level of knowledge of lionfish? Rate yourself on the following scale, where 0 "no knowledge" and 10 "expert knowledge".	0 = no knowledge; 10 = expert knowledge
Awareness of environmental problems	Lionfish concern	Indicate your level of concern for the impacts lionfish can have on each of the listed items: recreational fisheries, commercial fisheries, coral reefs, native fish populations, coastal economy, tourism and recreation, SCUBA diving operations, offshore energy production.	Factor score

Table A1. *Cont.*

Concept	Measure	Survey Instrument	Coding
Attitude of environmental problems	Lionfish control	Indicate how important it is to you to have the following areas managed to control lionfish populations: coral reefs, marine protected areas, artificial reefs, estuaries, boat docks and ports, coasts used for recreational activities, offshore oil, and gas platforms.	Factor score
Environmental education	Lionfish education	Have you ever attended an educational program, activity, or presentation to learn more about lionfish?	0 = no; 1 = yes

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