Consumer Demand and Willingness to Pay for Lionfish Meat in the U.S. Virgin Islands: Zero-Inflated Regression Model

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Abstract

Invasive lionfish are destroying reef ecosystems along the Gulf coast and Caribbean. Millions of people in the region depend on coral reefs for their livelihoods, thus if left unchecked the spread of lionfish will continue to have dire economic as well as environmental consequences for area. Stakeholders have made little progress slowing down this destruction. For a decade researchers and policy makers have encouraged the consumption of lionfish meat as a sustainable means of curtailing the fish's proliferation, yet there is little research assessing the economic viability of a consumer market for lionfish meat. By analyzing a data set of potential end-consumers in the U.S. Virgin Islands, this research examines individuals' willingness to participate in a hypothetical market for lionfish and their potential consumption levels via a zero-inflated negative-binomial regression model. The Turnbull method is also used to estimate potential consumer's mean willingness to pay for lionfish meat in both restaurant and fresh market settings. Significant findings include that individuals' levels of concern about the environment and interest in seafood are positively correlated with being a potential consumer, individuals' level of concern about seafood safety is negatively correlated with potential market participation and individuals' willingness to pay for lionfish meat. Furthermore, potential consumers' mean willingness to pay and potential suppliers' (fisherman) mean willingness to accept for lionfish meat are price compatible. Such findings provide evidence that a lionfish market in the U.S. Virgin Islands may be an achievable goal.

INTRODUCTION

Invasive lionfish are destroying Florida's reefs and despite their best efforts, stakeholders have made little progress slowing down the destruction. For a decade researchers and policy makers have encouraged the consumption of lionfish meat as an economically sustainable means of curtailing the fish's proliferation, yet there is little research assessing the economic viability of a consumer market for lionfish meat. Using survey data collected in the United States Virgin Islands (USVI), we investigate consumer willingness to pay (WTP) for lionfish meat via a Turnbull Lower Bound model. We also estimate consumer WTP as a linear function of individual characteristics and preferences by apply maximum likelihood estimation to double bounded contingent valuation data. Additionally, a zero-inflated negative binomial regression model was used to identify consumer perceptions and characteristics that increase both likelihood of participating in the market and potential quantity consumed by participants. Initial findings suggest that consumer WTP is compatible with potential supplier's willingness to accept (WTA) for lionfish meat. Additionally, individuals' willingness to participate in a market, WTP prices, and consumption quantities are strongly correlated to knowledge variables, including individuals' safety concerns, and level of concern about the environment. These findings provide strong evidence that a latent demand structure for lionfish meat not only exists in the USVI, but may be expandable through targeted marketing and outreach strategies.

Background

There is scientific consensus that the Earth's coral reefs are under threat. According to a 2008 study by the Global Coral Reef Monitoring Network an estimated 19% the earth's coral reef systems had been lost (by that year), with an additional 15% expected to disappear in the following 10-20 years (Clive, 2008). Marine resource scientists attribute these losses to a number of factors

including rising sea temperatures, fertilizer runoff, and other pollutants in the water. Additionally, invasive species are rapidly changing coastal environments. Lionfish, the best known of invasive marine species, is wreaking havoc in the waters of Florida and the Caribbean (Albins & Hixon, 2008; Albins & Hixon, Worst case scenario: potential long-term effects of invasive predatory lionfish (Pterois volitans) on Atlantic and Caribbean coral-reef communities, 2013). A carnivorous species of fish native to the Indo-Pacific, lionfish (*Pterois volitans*) have no natural predators along the Atlantic coast, and thus nothing to keep their numbers from rapidly expanding and consuming other fish species critical for the health of coral ecosystems (Huth, McEvoy, & Morgan, 2016). The lionfish are leading to the destruction of healthy marine habit by depleting the populations of herbivorous fish (e.g. parrot fish (*scaridae)*) which otherwise keep the coral from being overrun by sea grass and algae. This dramatic reduction of herbivorous fish populations, also has dire consequences for humans who depend on the harvest of these commercially valuable species to make a living. According to the World Resources Institute (2011) an estimated 42 million people in the Gulf and Caribbean are directly dependent on coral reef systems for their food and livelihoods, thus if the lionfish's invasion is left to continue, it will bring substantial economic losses to the region.

One proposed solution to the lionfish problem is for people to catch and eat them on a mass scale. If it is economically feasible, the establishment and spread of commercial lionfish fisheries could dramatically reduce the lionfish population and restore balance to the region's native ecosystems. For a commercial fishery for lionfish to be economically viable, however, there needs to exist sufficient demand for lionfish meat. More specifically, consumers' willingness to pay (WTP) needs to exceed fisher's production costs to make it worth their time to harvest lionfish. Few peer-reviewed studies examining WTP for lionfish exist to date. In a working paper by

researchers from the University of Western Florida and Appalachian State University, Huth et al (2016) examined how the price consumers are willing to pay for lionfish meat is a combination of both WTP for public goods and WTP for a private good. Conducting a series of experimental auctions at a seafood festival in Pensacola, Florida, Huth et al recorded how bid values changed as auction participants were informed of the environmental damage associated with lionfish and the potential ecological benefits from culling and eating them. The base-line WTP dollar value estimated for a three-ounce fillet was $6.28 which could be increased by as much as $1.66 through informing participants of the severity of the environmental threat.

In a presentation at the annual Gulf and Caribbean Fisheries Institute Conference (2013), Bethany Young, public relations and marketing assistant of Rainforest Seafood (Jamaica's largest seafood supplier), reported that lionfish cost her supply company about $3.00 a fish, a price deemed high by Jamaican standards. During the same conference other presenters, reporting on their research with independent U.S. retailers, cited prices paid to suppliers ranging from $6.00 a pound to $15.00 or $16.00 a fish depending on the source (Bogdanoff, Akins, & Morris Jr., 2013). While these findings provide a precursory glimpse of middle and end consumers' WTP in certain locations they fail to provide the figures necessary for a market feasibility assessment.

The use of economic research methods to address the lionfish issue is not limited to WTP estimates for lionfish meat. Moonsamy et al. (2011) uses the contingent valuation method (CVM) to indirectly estimate the aggregate economic impact of lionfish on Jamaica's reef systems. They derive a mean estimate of individuals' WTP to protect the reef and then multiply this by the target population. They conclude that lionfish accounts for an economic loss of US$11 million due to reduced marine biodiversity (Moonsammy, Buddo, & Seepersad, 2011).

Research Question

While some work has thus been done estimating consumer and distributor WTP for lionfish, we are unaware of any peer reviewed publications that estimate potential consumer demand for lionfish meat, whether it be in the U.S. Virgin Islands or elsewhere. Our research seeks to answer the question: *How much are USVI consumers willing to pay for Lionfish?* By determining the WTP of potential consumers in a given context (fresh market versus a restaurant), we estimate an essential component of the demand structure. Additionally, we collected data from USVI fishermen to determine the price at which they are willing to catch and sell lionfish. While the primary focus of the present analysis is on the demand side of a potential market, we also estimate willingness to accept (WTA) for lionfish by fishermen, in order to enhance the discussion.

Another essential question to assessing a latent demand structure for lionfish in the USVI is, *what contributes to someone being in the market and what quantity will they consume?* Just as consumers may not participate in certain markets, e.g. non-smokers with regard to the tobacco market, or vegetarians with regard to meat markets, there is good reason to suspect that a significant portion of those who live in and frequent the USVI have no intention of ever participating in the market for lionfish meat. The factors that determine whether someone is willing to participate in a market for lionfish may be related first and foremost to whether they eat fish and seafood. Second, we should consider whether individuals will consider eating lionfish if they are already consumers of finfish. As lionfish is not yet a popular food item, potential consumers have little idea of its palatability. Additionally, lionfish possess negatively perceived characteristics including being seen as a transmitter of *ciguatera* (a toxin harmful to humans present in many reef species), and possessing venomous spines.

DATA & METHODS

The data for this research were collected via a survey of 413 tourists and residents in the US Virgin Islands conducted during the summer of 2016. Researchers intercepted potential participants at local markets and other high traffic areas on the island of Saint Croix. These data include various demographic characteristics as well as consumption patterns and seafood preferences of the individuals interviewed. Participants were presented with a series of questions designed to solicit their beliefs and attitudes towards the environment, food safety, and their propensity to consume and willingness to pay for lionfish meat. Most questions designed to extrapolate consumer preferences and attitudes were asked in the form of four-point Likert scales.

Data was collected on consumer willingness to pay via standard double-bounded contingent valuation methods (CVM). Contingent valuation is an estimation technique commonly used in environmental economics where there is a lack of established markets to observe actual consumption at given price levels (Hausman, 1993). The technique centers on soliciting sampled individuals' opinions on how much they would be willing to pay for a specified item or service. Typically, the data collector proposes a value (bid) to the survey participant, and records their response of yes or no. In the double-bounded method, considered statistically superior to single-bounded, the surveyor follows up on the initial bid with a second value. This second bid value is either higher or lower than the initial bid value depending on the participant's response. Consistent with best recommended practices, our surveyors varied the initial bid prices to avoid what is referred to in the literature as starting point bias (Boyle, Kevin J., & Welsh, 1985; Herriges & Shogren, 1996).

Average willingness to pay can be calculated from CVM data using both parametric and non-parametric methods. In this study, we estimate consumers' mean willingness to pay, with the non-parametric method of Turnbull Lower-bound on WTP. Additionally, we estimate consumer

willingness to pay while controlling for preference and demographic characteristics using standard parametric estimation techniques via maximum likelihood estimation. We hereafter provide brief explanations of how the Turnbull method is used to estimate mean WTP and how the parametric Maximum Likelihood estimation method for WTP as a linear function of preferences and characteristics.

The Turnbull method (1976) requires combining participants' responses to the questions on WTP at given prices. Thereafter the researcher obtains estimates for the relative frequency of accept or reject responses at these different price intervals. The first of these intervals has a lower bound of zero and an upper bound of the next lowest value for which adequate response data exists ($W1AMT_i$). The following interval has a lower bound value of $W1AMT_i$ and an upper bound of $W1AMT_{i+1}$ (the next value immediately above $W1AMT_i$). This process continues for each successive interval until the final interval extends from the highest value for which there is adequate data. Assuming responses were solicited for *M* different monetary values, this results in $M+1$ different intervals with the final interval extending from M through infinity. The CDF (cumulative distribution function) can be constructed by calculating the proportion of no responses (N_j) for each corresponding monetary value (C_j). The CDF consists of $M+1$ segments or intervals which we notate as $F_j, where\ j = 1, 2 \ldots . M+1$.

Each F_j is calculated by dividing the number of No responses by the sum of both No and Yes responses for the given value.

1) $$F_j = \frac{N_i}{N_i + Y_i}$$

Each F_j is a probability measure, namely that, $F_j = P(W \leq c_j)$

The final proportion of No responses F_{M+1}, is assumed to be 1.00 as *M+1* extends into infinity, thus the proportion of no responses is expected to reach 100%. The probability density function

(PDF) can also be calculated by bounding each response set by the upper and lower monetary value denoted as, $p_j = c_{j-1} < W \leq c_j$ or p_j. Each p_j can then be calculated by $F_j - F_{j-1}$. The mean WTP is then calculated by multiplying each PDF segment by the lower-bound of its corresponding price interval and summing these up. This estimation technique can be extended to calculate the variance of mean WTP.

In addition to calculating mean WTP via the Turnbull method, we estimate willingness to pay via maximum likelihood as detailed by Hanneman et al. (1991). This process for estimating mean WTP requires the assumption that an individual's WTP is a linear function of her attributes, so that WTP takes the functional form

2) $$WTP_i = X_i\beta + \varepsilon_i$$

where X_i is a matrix of individual characteristics and ε_i is a stochastic error term. The β coefficients derived through maximum likelihood estimation can be interpreted as explaining how each control variable effects individual WTP. We include a brief explanation of the log-likelihood function of the double bounded CVM (equation 3). For a more in-depth review consult the work of Hanneman et al 1991.

3) $$LogL = \Sigma\left[I_i^{nn}\left(1 - \Phi\left(X_i' \cdot \frac{\beta}{\sigma} - \frac{A_L}{\sigma}\right)\right) + I_i^{ny} ln\left(\Phi\left(Xi' \cdot \frac{\beta}{\sigma} - \frac{A_L}{\sigma}\right) - \Phi\left(X_i' \cdot \frac{\beta}{\sigma} - \frac{A}{\sigma}\right)\right) + I_i^{yn} ln\left(\Phi\left(X_i' \cdot \frac{\beta}{\sigma} - \frac{A}{\sigma}\right) - \Phi\left(X_i' \cdot \frac{\beta}{\sigma} - \frac{A_H}{\sigma}\right)\right) + I_i^{yy} ln\left(\Phi\left(X_i' \cdot \frac{\beta}{\sigma} - \frac{A_H}{\sigma}\right)\right)\right]$$

Recall a yes or no response was recorded for each participant at each of two different bid prices. Thus, each individual's response type falls into one of four possible categories: 1) no, no 2) no, yes 3) yes, no, and 4) yes, yes. These are represented by the symbols I_i^{nn}, I_i^{ny}, I_i^{yn}, and I_i^{yy} respectively as seen in equation (3). I_i^{nn} takes on the value of one for cases where the individual rejected both bid prices, and is zero for all other cases. I_i^{ny} takes on the value of one for cases

where the individual rejected the first bid price, but accepted the second, and is zero elsewhere. The same logic can be extended to I_i^{yn}, I_i^{yy}. The symbol Φ denotes the CDF of the standard normal. A_L and A_H respectively represent the lower and higher of the two bids offered while A (without subscript) represents the individuals true maximum WTP. X_i' denotes a vector of explanatory variables, with β a corresponding vector of parameters. The vector X_i' includes several explanatory variables composed via Likert scales: safety concerns, environmental concerns, interest in seafood, and stated level of knowledge about lionfish. Additionally, we include several demographic variables among these explanatory variables: age, race, gender, income, and resident status.

Latent consumer demand for lionfish meat was estimated via a zero-inflated negative-binomial regression model (ZNIB). We consider the ZNIB the best fit for the data given the count nature of the dependent variable and our assumptions about the individuals sampled. Hereafter we briefly describe our model selection process.

The primary dependent variable of interest in this study is the consumption frequency of potential consumers. We determined consumption frequency from local participants' response to the question, *"How many times in the month of July (2016) would you purchase lionfish meat?"* and by tourists' response to the question, *"How many times during your trip would you purchase lionfish meat?"* Each participant reported a value corresponding to the number of times s/he believed s/he would purchase lionfish given the opportunity: first from a restaurant and then fresh from a market (for home preparation). While residents' responses indicate their preferred consumption during a given 30-day period, each tourists' stated consumption level must be considered in context of trip duration. For this reason, all tourists' stated consumption levels were standardized to span a 30-day period allowing for compatibility with locals' stated consumption

quantities.[1] After combining tourist and resident datasets, consumption levels were grouped into 4 categories (greater than zero but less than 1.5 times, less than 2.5 but greater than or equal to 1.5, less than 3.5 but greater than 2.5, and greater than 3.5). Thus, frequency of consumption clearly takes the form of a non-negative count variable.

We assume these data include the consumption habits of three classes of individuals: 1) individuals who are non-market participants; 2) individuals who are market participants but consumed quantity zero at the time of data collection; 3) and market participants who consumed quantities greater than zero (Greene, 2012). Individuals from classes 1 and 2 are represented among those cases where consumption is zero; for this reason, we suspect an excess of cases with zeros i.e. zero-inflation in the data set. By distinguishing between zero consuming market-participants and non-market participants, we not only improve the accuracy and predictability of the consumption quantity estimates, but simultaneously consider which factors contribute to an individual's decision to participate in the market in the first place.

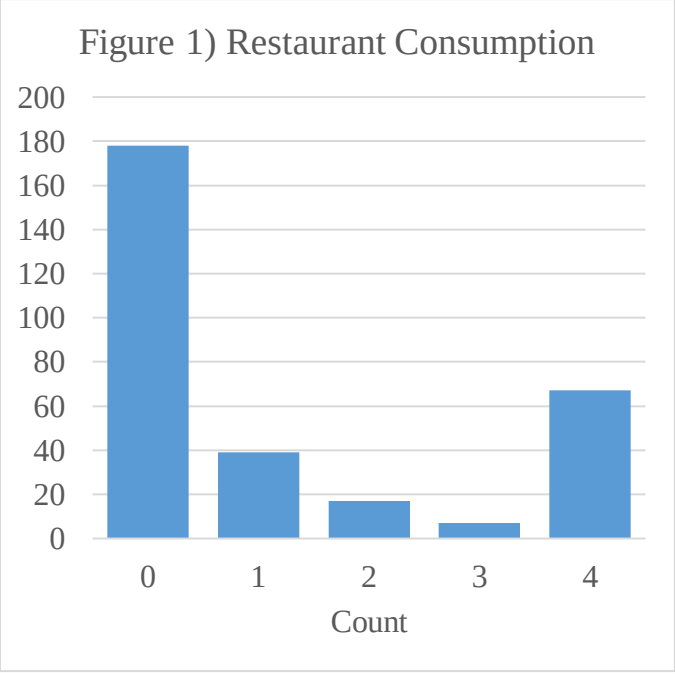
The Zero-inflated Poisson (ZIP) regression model is among the preferred estimation techniques applied by researchers to count data with an excess of zeros (Lambert, 1992) (Sheu, Hu, Keeler, Ong, & Sung, 2004). Two sets of coefficients are estimated in the ZIP regression: the first is the output from a logistic regression wherein the probability of an individual belonging to the certain zero-group given a set of controls is estimated (4), while the second corresponds to the Poisson count estimate for an individual given a set of controls (5). The certain-zero group refers to those individuals who will always consume quantity zero (individuals unwilling to participate in a market for lionfish).

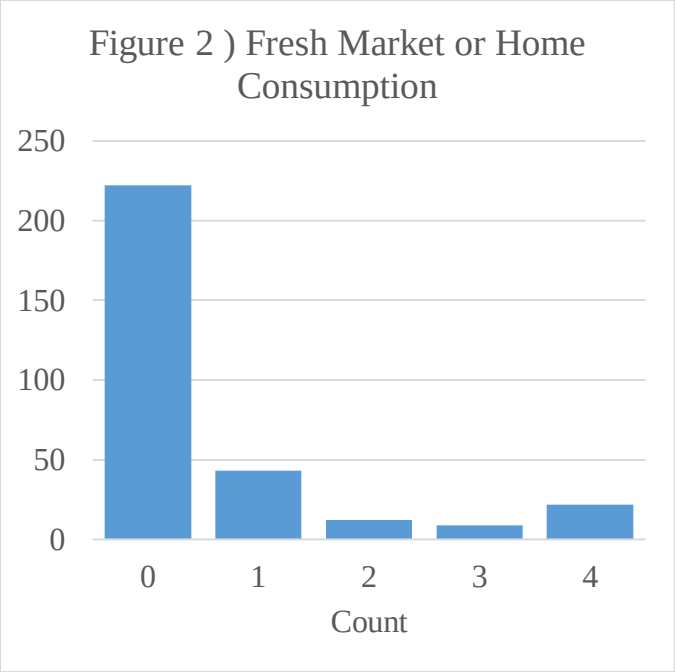
[1] Each tourist consumption quantity (y_i) was divided by the number of days of the trip duration and then multiplied by 30. $30 * \frac{y_i}{days\ of\ stay_i}$

4) $\Pr(y_i = 0|x_i) = \Pr(y_i^* \leq 0) + \Pr(y_i = 0|x_i,) \Pr(y_i^* > 0)$

5) $\Pr(y_i = j|x_i) = \Pr(y_i = j|x_i)$

One can determine the presence of excess zeros by visual checking a histogram of the count variable of interest and or through performing statistical tests such as that recommended by Vuong (1989). A preliminary glance at the histograms of restaurant (figure 1) and home consumption (figure 2) corroborate the notion that these data are zero-inflated, as the far-left bar, representing the frequency of cases at count zero, extends several times beyond the next highest count frequency. The z-statistic computed by Vuong's method indicates rejection of a null hypothesis of sameness for the standard model and zero-inflated model, confirming the presence of excess zeros.





A fundamental assumption of the Poission distribution and related regressions is that the estimated sample variance is equal to the sample mean (Greene, 2012). When this assumption of sameness between the sample mean and variance is violated the data is over-dispersed and the negative binomial will better fit the data (Greene W. , 1994) (Gido, Ayuya, Owuor, & Bokelmann, 2017). We test for over-dispersion using a statistical technique recommended by Cameron and Trivedi (1991). The corresponding z-statistic from Cameron and Trivedi's test suggests we reject the null of sameness, indicating that the negative binomial is indeed the better fit for the data.

RESULTS

The purpose of this project is to assess latent demand structures for lionfish meat in the USVI. We use a zero-inflated negative binomial (ZINB) model to estimate individuals' propensity to consume lionfish and estimate potential consumers' WTP using a double bounded contingent valuation method (CVM). In this section we provide descriptive statistics of the main variables of interested in this study and report the results from the CVM and ZINB model.

The ZINB regression results indicate how participation in the market and consumption levels of potential consumers of lionfish are correlated with a series of independent variables: demographic characteristics, individual stated preferences regarding seafood, and stated levels of knowledge and concern about lionfish and the environment. Variables used in this model, as well as demographics of the participants, are described in Table 1.

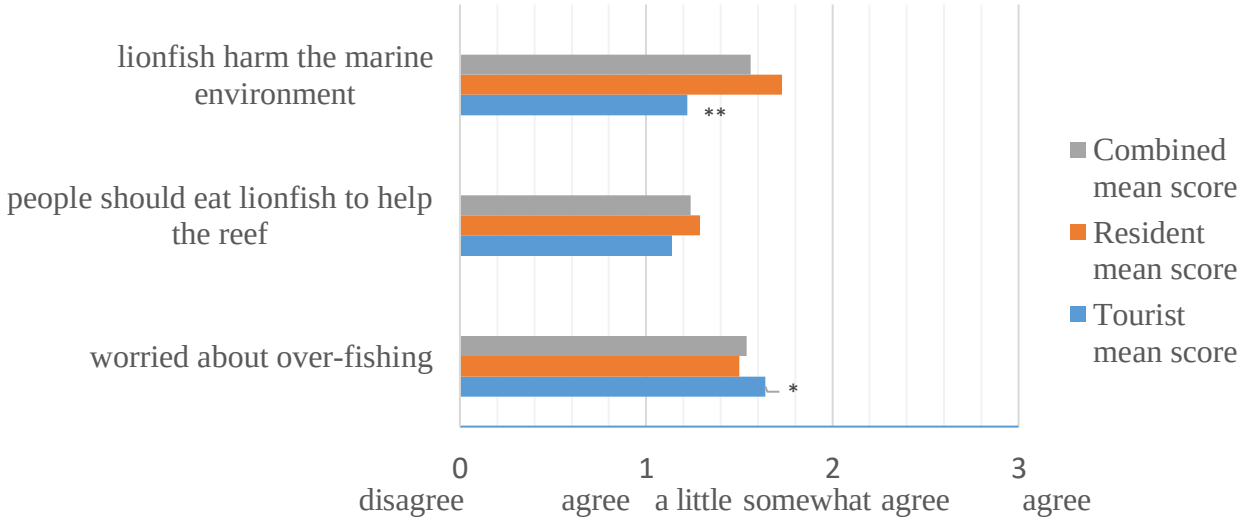
Table 1 | Variables Used in Regression Analysis

Variable	Description	Mean	Std. Dev.	Variance
consu_r	count of times would consume at restaurant (month of June)	1.175	1.631	2.660
consu_h	count of times would consume at home/place of lodging (month of June)	0.591	1.165	1.357
safe	level of concern about seafood safety and lionfish safety	6.688	4.542	20.632
enviro	level of concern about the environment	3.377	2.259	5.102
interest	level of interest in trying new types of seafood including lionfish	6.539	1.495	2.236
white	self-identified race	0.364	0.482	0.232
age	years of age	49.260	16.216	262.962
n.children	number of children under 18 in household	0.672	1.426	2.032
male	sex	0.513	0.501	0.251
income	household income > $34.5 k (locals) household income > 43.5k (tourist)	0.643	0.480	0.230
resident	local or tourist	0.666	0.473	0.223

Figure 3 displays participants' mean Likert scales in response to statements about the environment and the sustainability of marine resources. These include the statements, I am concerned about over-fishing, people should eat lionfish to save the reef, and lionfish harm the reef. Participants respond 0 if they disagree, 1 if they agree a little, 2 if they somewhat agree, and 3 if they agree, with the presented statement. Mean Likert scales for all statements are between 1 and 2, suggesting participants are on average a little concerned about environmental issues.

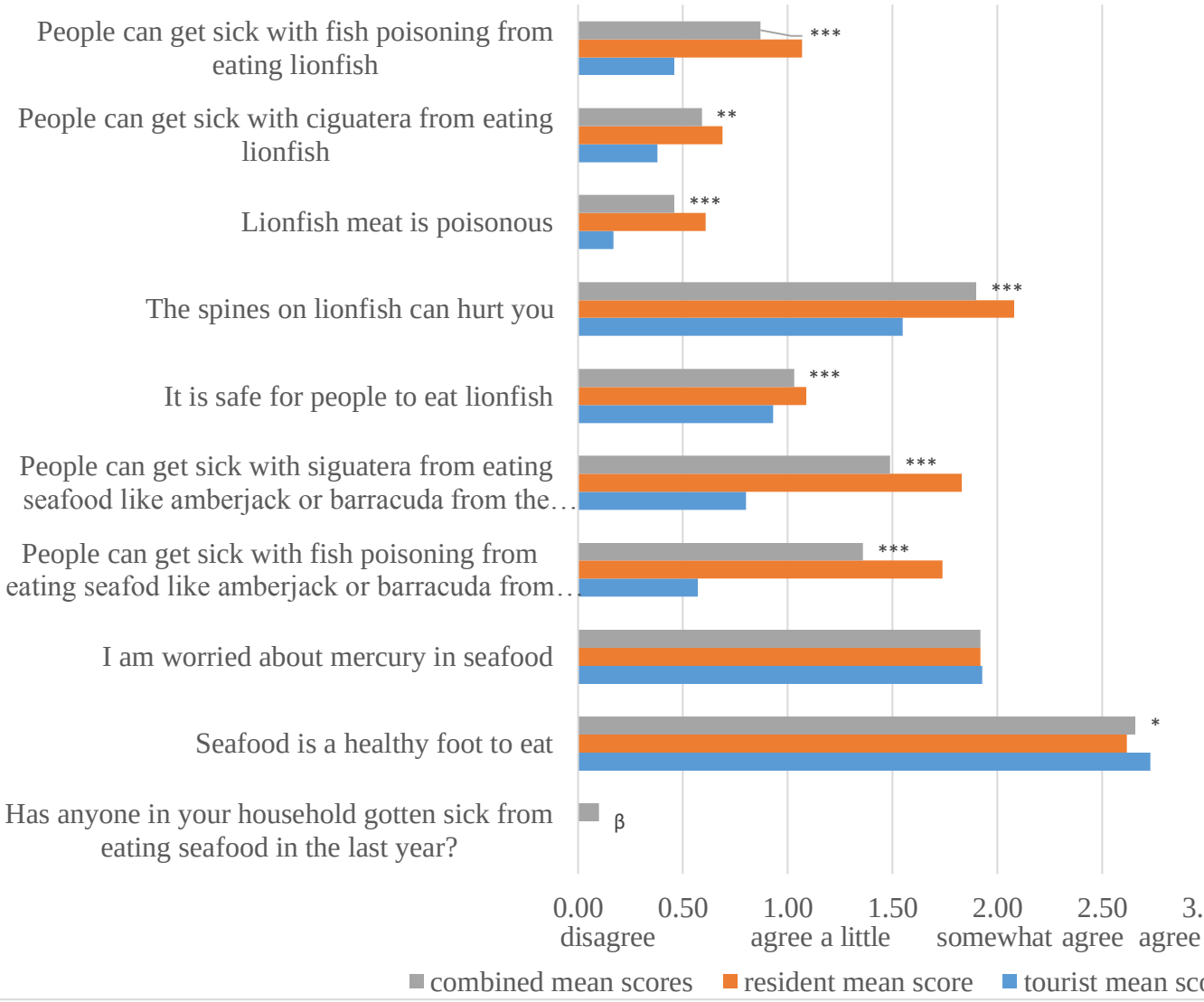
Welch's two-sample t-tests were conducted for each variable in order to detect significant differences between the mean responses of tourists and residents. Residents' mean response to the statement lionfish harm the environment (1.73), is significantly higher than that of tourists (1.22), as their mean response to the statement people should eat lionfish to help the reef (1.29, compared to tourists 1.14). Tourists's mean calculated response (1.64) to the statement, "I am worried about overfishing is significantly higher than that of residents (1.50).

Figure 3) Likert Scale, environmental concern questions



Prior research demonstrates that people's perceptions regarding the safety of fish and seafood affects their consumption levels (Grunert, 2005; Roheim, Kline, & Anderson, 1996), thus the survey included several questions designed to measure participants general concerns about seafood safety, and lionfish in particular. Questions and results are summarized in Figure 4.

Figure 4) Likert Scale, Concerns about seafood safety,



Mean tourist and resident responses differ significantly for all but two of the questions regarding seafood safety. This difference between mean Likert scales between tourists and residents is especially pronounced in statements regarding *ciguatera* and fish poisoning. All but one of the safety questions were framed in terms of a four-point Likert-scale, with 0 indicating disagreement, 1 indicating they agree a little, 2 indicating they somewhat agree, and 3 indicating they agree. Tourists' mean Likert response to the statement "people can get sick with fish

poisoning from eating lionfish" (0.46) is 0.6 points lower than that of residents. Similarly, the mean Likert value for tourists' response to the statement "people can get sick with *ciguatera* from eating seafood like amberjack or barracuda from the USVI", is 0.80, a full point lower than the average Likert value of residents (1.83). Additionally, tourists mean response to the statement, "People can get sick with fish poisoning from eating seafood like amberjack or barracuda from the USVI", is 0.57 more than a full Likert value lower than that of Residents (1.74). The only safety related question framed in binary terms is, "*has anyone in your household gotten sick from eating seafood in the last year?*" of which only 10% of participants responded in the affirmative.

A series of questions were included to capture individuals' interest in seafood; participants' mean responses disaggregated by tourists and residents are displayed in figure 5. Significance levels of the difference between mean tourist and resident responses are indicated with asterisks.

Responses to the Likert questions were grouped into three categories: environmental concerns, safety concerns, and seafood preferences. A series of Cronbach's alpha and chi-square tests were performed to verify significant correlation among variables included in each group. These results are displayed in Tables 2–4.

Table 2 | Chronbach's Alpha Test Results Establishing Correlation Among Groups of Variables Combined for "Seafood Safety Concerns", "Interest in Seafood", and "Concerns About the Environment"

	Variable Description	Cronbach's Alpha
1.	People can get sick with ciguatera from eating seafood like amberjack or barracuda from the USVI	
2.	People can get sick with fish poisoning from eating seafood like amberjack or barracuda from the USVI	
3.	The spines on lionfish can hurt you	0.74[a]
4.	Lionfish meat is poisonous	
5.	People can get sick with ciguatera from eating lionfish	
6.	People can get sick with fish poisoning from eating lionfish	

7.	The freshness of fish is important	
8.	Seafood is a healthy food to eat	
9.	I am interested in trying new kinds of seafood	0.40
10.	Would you say that you are not at all, a little, somewhat, or a lot interested in eating lionfish?	
11.	I am worried about overfishing	
12.	People should eat lionfish to help the reef	0.52
13.	Lionfish harm the marine environment	

Variables 1–6 related to concerns about seafood safety
Variables 5–10 related to interest in seafood
Variables 11–13 related to environmental concerns

a. Cronbach's alpha score > 0.70 (proceeded with summation of variables related to "seafood safety concerns")

Table 3 | Chi-Square Tests of Correlation Between Variables Included in Composite Variable "Interest in Seafood"

	Variable Description	1.	2.	3.	4.
1.	The freshness of fish is important	--			
2.	Seafood is a healthy foot to eat	22.23**	--		
3.	I am interested in trying new kinds of seafood	16.70*	31.35***	--	
4.	Would you say that you are not at all, a little, somewhat, or a lot interested in eating lionfish?	2.66[a]	12.91**	81.99**	--

*** sign. p-value < 0.001
** sign. p-value < 0.05
* sign. p-value < 0.10

Table 4 | Chi-Square Tests of Correlation Between Variables Included in Composite Variable "Concern About the Environment"

	Variable Description	1.	2.	3.
1.	Worried about overfishing	--		
2.	People should eat lionfish to help the reef	37.73***	--	
3.	Lionfish harm the marine environment	36.87***	53.95***	--

*** sign. p-value < 0.001

Results from the ZNIB regression model for restaurant consumers (displayed in Table 5) suggest that several variables are significant predictors of membership in the certain zero group (non-consumers). Safety concerns and age are positively correlated with being non-consumers,

while concern about the environment, seafood interest, and income are negatively correlated with certain zero group membership. Explanatory variables shown to be significantly correlated with consumption levels in the normal count generating portion of the ZNIB model for restaurant consumption include interest in seafood, which is positively correlated, and number of children in the home, and resident status which are negatively correlated with consumption in restaurants.

Results from the ZNIB regression model predicting home consumption (also displayed in Table 5) indicate that safety concerns and income are positively correlated with membership in the certain zero group. The variables age and resident status, on the other hand, are negatively correlated with certain zero group membership. With regards to the count portion of the model, interest in seafood is the only positively correlated variable that is significant; white and resident status are negatively correlated with home consumption levels.

Table 5 | Coefficient Estimates and Marginal Effects for Logistic, Negative-Binomial, and Zero-Inflated Models (Variable to be Explained: Restaurant Consumption and Home Consumption)

	Restaurant Consumption Count Model				Home Consumption Count Model			
	Coefficient	Std. Error	M.E.	Std. Error	Coefficient	Std. Error	M.E.	Std. Error
Constant	0.59	0.582			-1.17	0.835	--	--
Safety concerns	0.03	0.029	0.00	2.510	-0.03	0.042	-0.07	4.864
Environmental concerns	-0.05	0.046	0.07	0.145	0.09	0.057	0.07	0.528
Interest in seafood	0.14	0.066 **	0.30	0.378	0.33	0.093 ***	0.25	3.014
White	-0.15	0.201	-0.18	0.867	-0.49	0.244 **	-0.30	4.362
Age	0.00	0.006	-0.02	0.418	0.00	0.008	0.01	0.543
# of children in household	-0.22	0.091 **	0.00	1.120	0.02	0.085	0.00	0.23
Male	-0.16	0.190	-0.18	0.872	-0.18	0.244	-0.11	1.597
Income (> U.S. median)	0.18	0.211	0.21	0.983	0.30	0.275	0.18	2.625
Resident	-1.50	0.231 ***	-1.77	8.010	-1.03	0.331 ***	-0.62	9.078
	certain zero group				certain zero group			
	Coefficient	Std. Error	M.E.		coefficient	Std. Error	M.E.	
Constant	4.62	2.025 **			3.73	1.712 **	--	--
Safety concerns	0.26	0.107 **	0.003	2.510	0.19	0.096 *	-0.07	4.864
Environmental concerns	-0.92	0.295 ***	0.07	0.145	-0.06	0.116	0.07	0.528
Interest in seafood	-1.04	0.322 ***	0.30	0.378	-0.19	0.188	0.25	3.014
White	-0.97	0.817	0.13	0.533	-0.32	0.678	0.08	0.219

Age	0.08	0.031	***	-0.02	0.418	-0.05	0.02	**	0.01	0.543
# of children in household	-1.86	1.166		0.00	1.120	0.03	0.255		0.00	0.23
Male	-0.02	0.808		0.00	0.943	-0.34	0.486		0.09	0.067
Income (> U.S. median)	-1.10	0.920	*	0.15	0.109	1.53	0.823	*	-0.39	0.453
Resident	-0.45	1.053		0.06	0.570	-2.79	0.76	***	0.71	1.986

*** signif. p-value < 0.001, ** signif. p-value < 0.05, * signif. p-value < 0.10

Results for the mean willingness to pay (WTP) estimations are presented in Tables 6-8. The Turnbull lower bound on resident's willingness to pay for lionfish for home consumption (Table 6) is $11.80 lb. compared to $10.09 for tourists. Tourists' estimated mean WTP for a lionfish entree at a restaurant is $22.83 compared to $19.51 of residents. The mean estimate of the Turnbull lower bound on restaurant's willingness to pay for lionfish is $5.32 a pound while the mean estimate of the Turnbull upper bound for fisher's willingness to accept is $4.37 a pound.

We also estimate consumer willingness to pay for lionfish via maximum likelihood estimation, optimizing the log-likelihood function for double bounded CVM proposed by Hanneman et al (1991). Hanneman's method assumes that WTP is a linear function of individual consumers' preference and characteristics (equation 2), which we include in the independent variable vector X_i'(equation 6). The results for separate models estimating WTP for restaurant and home consumption are displayed in tables 8 and 9, respectively. The only significant variables in the home consumption model are safety and gender (Table 7). Income is the only significant explanatory variable on WTP for restaurant consumption model (Table 8).

Table 6 | Mean Estimate Turnbull Lower[a] Bound on WTP/WTA

Consumer type	Venue	Mean WTP/WTA[c]	Variance
Resident	Home	$11.80	8.117
Resident	Restaurant[b]	$17.70	6.331
Tourist	Place of lodging	$10.09	1.658
Tourist	Restaurant	$22.83	0.692
Restaurant	--	$4.71	0.880
Fishermen	--	$4.36	0.143

a. Mean lower bound was calculated for consumers, mean upper bound was calcualted for fishermen
b. For a restauran entreé
c. WTA (willingness to accept)

Table 7| MLE Results Double Bounded Contingent Valuation Logit Regression WTP for Home Consumption

Explanatory Variable	Estimate	Std. Error	Marginal Effect	
(Intercept)	5.35	1.425		***
Age	-0.01	0.013		
Male	0.03	0.382		
Income	0.97	0.471	$3.37	*
Resident	0.39	0.468		
White	-0.13	0.427		
# of children in household	-0.09	0.230		
Concern about the environment	0.04	0.079		
Seafood safety concerns	-0.07	0.052		
Interest in seafood	0.15	0.116		
log(bid)	-0.29	0.037		***

*** sign p-value<0.01
** sign p-value<0.05
* sign p-value<0.10

Table 8 | Double Bounded Contingent Valuation Logit Regression WTP for Restaurant Consumption

Explanatory Variable	Estimate	Std. Error	Marginal Effect	
(Intercept)	6.51	1.628		***
Age	0.01	0.015		
Male	-1.05	0.483	-$2.29	*
Income	-0.16	0.548		
Resident	-0.79	0.635		
White	0.54	0.552		
# of children in household	-0.004	0.169		
Concern about the environment	0.16	0.113		
Seafood safety concerns	-0.15	0.069	-$0.33	*

Interest in seafood	-0.02	0.116	
log(bid)	-0.46	0.060	***

*** sign p-value<0.01
** sign p-value<0.05
* sign p-value<0.10

DISCUSSION

The underlying motivation of this research is to find a sustainable way to combat the proliferation of invasive lionfish in the Caribbean region. If a market for lionfish meat in the USVI is a feasible option, it could be the most efficient means yet of combatting the spread of lionfish. This study primarily focuses on the demand side of a potential market structure for lionfish in the USVI. We analyze a data set of potential end-consumers (residents and tourists) in the USVI and model willingness to participate in a potential market for lionfish along with potential consumption levels via a ZINB regression model. Two separate ZINB regressions were performed in this analysis one for restaurant consumption, the other for home consumption. We determine that individuals' willingness to participate in a market for lionfish is significantly correlated with a number of individual preference and demographic characteristics. We likewise find that individuals' potential consumption quantities are significantly correlated with several control variables included in the ZNIB models. Additionally, we estimate consumer WTP for lionfish meat using a doubled bounded CVM. We find that both end consumers' WTP and distributors' (restaurants) WTP are compatible with the Turnbull upper bound estimate of potential suppliers WTA (willingness to accept). We begin this section first with a discussion of the ZINB regression results for the restaurant consumption model and then with a discussion of the results from the ZINB model for home consumption. Thereafter we discuss the main results from the Turnbull model and the double bounded CVM maximum likelihood estimation.

Restaurant Consumption Model

Several variables were found to be significant predictors of membership in the certain-zero group in the restaurant model. The finding that an individual's level of seafood safety concern is both significant and negatively correlated with the likelihood of eating lionfish is consistent with much of the literature on perceived risk and consumption of meat, poultry, and seafood (Shim & You, 2015). Yeung & Morris (2006) found that as individual's level of perceived danger related to consuming a meat item increases, they often cope by reducing or eliminating consumption altogether. A more explicit interpretation of the marginal effects for this variable is that a single unit increase in safety corresponds to a decrease in the likelihood of consuming lionfish by 0.3%. The marginal effect of age suggests that for every additional year of age the likelihood of an individual being a consumer of lionfish decreases by 1.7%. This finding can be interpreted to mean that younger individuals are more likely to participate in a restaurant market for lionfish (by all accounts, an exotic menu item) and is consistent with psychology literature suggesting a negative correlation between age and openness to new experiences (Costa Jr, et al., 1986).

The negative sign of the coefficient interest in seafood suggests a positive relationship between interest in eating seafood and likelihood to consume lionfish . The partial effects estimate value, 0.30, suggests that a one unit increase in an individual's stated interest level corresponds to an increase in the probability of being a consumer by 30%..

Another finding is that as individuals' level of concern about the environment increases their likelihood of being in the non-consuming restaurant group decreases. The partial effects calculated for the zero-inflated portion of the ZINB model suggests a one unit increase in environmental concern corresponds to a 7% increase in the probability of being in the consuming group. There is a robust literature examining how individual characteristics and preferences, as

well as state policies and education campaigns affect environmental concern at both the micro and macro levels (Brulle, Carmichael, & Jenkins, 2012; Buttel, 1979; Buttel, 1979; Buttel, 1979; Buttel, 1979; Dietz, Stern, & Guangnano, 1998). Relevant findings from this literature suggest that individuals' concerns about environmental issues are largely contingent on personal and societal factors which can develop and change overtime. Thus, a finding that individuals' willingness to participate in a restaurant market for lionfish is positively correlated with their level of concern about the environment bodes well for establishing a future market. If we consider a lionfish restaurant entrée as a normal good in economic terms, it is hardly surprising we observe a negative relationship between income and membership in the certain-zero group. This conforms to prevailing notions of income and willingness to eat-out at restaurants as well as purchasing seafood items which are relatively expensive compared to other protein sources (Saad, 2017).

The explanatory variables found to be significantly correlated with restaurant consumption levels are interest in seafood, number of children in the household, and resident status. Interest in seafood is positively correlated with consumption quantities, with a marginal effect estimate of 0.30 suggesting that an additional unit of interest in seafood corresponds to an individual's desire to consume 0.30 more restaurant units, all other things being equal. We conclude that individuals who already have a strong preference for seafood are likely among those to consume lionfish at the highest levels. Number of children in the household is negatively correlated suggesting that individuals with more children are likely to consume less. We assume that individuals with larger families dine-out less frequently than do childless consumers. The marginal effect of being a resident of the USVI suggests that a resident will consume 1.73 units less than a tourist all else being equal. This finding is consistent with assumptions that residents are likely to eat-out with

less frequently than are tourists. Overall these findings suggest that tourists who are enthusiastic about seafood and have few children are likely to consume higher quantities than others.

Home Consumption Model

Consistent with the findings for restaurant market participation, the variable safety concerns is positively correlated with being in the non-consuming group for lionfish at home. The partial effects coefficient implies that for an additional unit of concern, a person's probability of being in the consuming group decreases by 7%.

Differing from the restaurant consumption model neither environmental concerns nor interest in seafood are significant predictors of membership in the certain-zero (non-consuming) group. The variable age, however, is significant, with the corresponding marginal effect suggesting that an increase in age by one year decreases the probability of an individual being a non-consumer by 2%. This finding is consistent with the notion that older individuals are more likely to have the requisite culinary knowledge and facilities to actually prepare fish at home. Thus, one can assume that younger individuals are less likely to participate in a market for raw lionfish intended for home preparation.

Diverging from our findings in the restaurant consumption model, we find that higher earners (those who earn at or above the U.S. national and USVI medians) have a significantly higher probability of not consuming lionfish in the home. Interpretation of the corresponding marginal effect suggests that individuals in the higher income group have a 39% higher probability of being non-consumers. This implies that raw lionfish is an inferior good, as individuals with higher incomes are less likely to participate in a market for it. This is consistent with qualitative research suggesting that fresh caught lionfish is seen as neither a high-value nor a gourmet item,

but as a “trash fish”. Thus, it is entirely feasible that higher earners are less likely to purchase it should they happen to frequent the piers or open-air markets where it is sold.

Unsurprisingly, residents of the USVI are significantly less likely to be in the non-consuming group when it comes to home consumption. The corresponding partial effect suggests that if an individual is a resident, the probability of her being in the non-consuming group decreases by 71%. This finding that residents are less likely to be among non-consumers of lionfish for home preparation is consistent with an expectation that many visitors to the US Virgin Islands stay in places of lodging that lack convenient cooking facilities. Thus tourists are less likely to engage in the purchase of fresh lionfish for home preparation.

As expected interest in seafood is positively correlated with home consumption levels. The corresponding partial effect suggests that for a one unit increase in interest level consumption increases by 0.248 units all else the same. Both race (Non-Hispanic white) and resident status are significant and negatively correlated with consumption levels with the marginal effect of being white corresponding to a 0.30 unit decrease in consumption. While the reasons for this are unclear, it may have to do with racially correlated culinary preferences and expenditures, given previous findings on seafood consumption levels disaggregated by race: Chen and Capps (1988) showed that North American whites expended significantly less on finfish than their non-white counterparts, while Jahns et al. (2014) has shown that Non-Hispanic whites consume significantly lower levels of seafood than do their Hispanic and African-American counterparts.

The marginal effect of resident status on consumption suggests that a resident will consume 0.62 units less lionfish in the home than an otherwise equivalent tourist. While this may seem counter-intuitive given the previous finding that residence status is positively correlated with participating in the market for home consumption of lionfish, it provides strong evidence that the

decision to participate in the market is fundamentally different than the decision of how much to consume, lending support to the use of a two-stage estimation model. This finding implies that tourists who want to participate in a market for fresh lionfish are likely to consume at higher rates than their resident counterparts.

In summary, our analysis of consumption data for both fresh lionfish to be prepared at home, and lionfish as restaurant entrées, conforms to the underlying assumption that individuals undergo a two-stage decision process when confronted with the opportunity to consume lionfish. First, they decide whether to participate in the market at all; second, if they are a consumer, they decide how much to consume. As expected, safety concerns were a significant factor in determining whether or not individuals were willing to participate in the market at all; however, it did not affect consumption rates in either model for home preparation or restaurant consumption. Interest in seafood was a significant factor in determining market participation in the restaurant model and consumption rates in both models, with an increase in interest corresponding to a greater likelihood of participation in the restaurant model and higher consumption rates in the restaurant and home models. Environment was a significant factor in determining participation in a restaurant market for lionfish but not in the case of fresh lionfish to be prepared and eaten at home. Age was a significant factor in determining participation in both restaurant and home preparation markets, but was not a significant factor in determining consumption rates in either market. The coefficients for age can be generally interpreted to mean older individuals are less likely to participate in either market. Resident status was a significant factor in determining participation in a market for home preparation with residents more likely to be consumers than their tourist counterparts. Age was not a significant factor, however, in determining participation in a restaurant market. In both the restaurant and home consumption models, resident status was a significant determinant of

consumption quantity with residents consuming at lower levels than tourists. Income was a significant factor in determining market participation in both models but had no identifiable effect on the quantity consumed at either restaurants or at home. As expected income is positively correlated with being a restaurant consumer, given higher earners are more likely to eat at restaurants in the first place, but it is negatively correlated with home consumption, suggesting that higher earners are less likely to be interested in purchasing raw lionfish from the local fresh market.

Willingness to Pay and Willingness to Accept

Tourists' mean WTP for a lionfish entrée at a restaurant ($22.83), as calculated via the Turnbull method, exceeds that of resident consumers ($19.51). This is to be expected given tourists are overrepresented among the high earning group, and as basic micro-economic theory dictates that WTP is positively correlated with income (Mankiw, 2016). Both these estimates of mean willingness to pay are within the price-range of comparable finfish restaurant items in the archipelago, such as tuna, mahi-mahi and salmon, which lends support to the idea of market feasibility.

Residents' mean WTP for lionfish destined for home preparation ($11.80) exceeds that of tourists' WTP by $1.70. We expect that tourists are generally less interested in cooking than residents and frequently lack access to kitchens during their vacations in the USVI. While no data was collected on the type of lodging tourist participants used during their stay, one can comfortably assume the many stay-in hotels and other rented rooms lack adequate cooking facilities. Furthermore, we assume that tourists often lack the seafood specific culinary knowledge of their resident counterparts, which means they have a higher opportunity cost of preparing a lionfish

meal from scratch. Thus, it follows that despite tourists being over-represented in the higher-earning group they are willing to spend less on raw lionfish than USVI residents.

To enhance our discussion of market feasibility, we also estimate the mean WTP and WTA of restaurants and fisherman once again using the Turnbull model. The estimated mean WTP pound price of restaurants is $5.32, which exceeds the mean WTA price of fishers ($4.36) suggesting compatibility between the two. While end consumers mean WTP for lionfish restaurant entrées is critical information for restaurateurs as they consider including lionfish on their menu, restaurants mean WTP is of fundamental importance to potential suppliers (fisherman) as they decide if and where to sell their catch. In all, these value estimates corroborate towards market feasibility in the U.S. Virgin Islands.

The maximum likelihood estimation results for the double-bounded CVM suggest that consumer WTP for raw lionfish meat it negatively correlated with safety concerns and being male. This finding regarding safety concerns may be valuable to stake holders interested in increasing both consumption and potential revenue from lionfish sales. Previous studies have shown that consumers' food safety concerns can be influenced by media reports and public information (Cao, Just, Turvey, & Wansink, 2015; Zhou, Turey, Hu, & Ruiyao, 2016). Additionally, it has been demonstrated that potential consumers are willing to pay more for seafood items that are certified safe under regulated programs (Wessells & Anderson, 1995). Thus, there exists an incentive for stakeholders to address potential consumers' safety concerns about lionfish through targeted information and outreach campaigns, or perhaps even a safety certification program, as this can positively augment consumer WTP for fresh market fish.

CONCLUSION

The unabated spread of lionfish throughout the Gulf coast and Caribbean remains a pressing environmental and economic issue. Fishing derbies and organized culling events have succeeded at temporarily reducing lionfish populations in limited areas, but they are expensive and have no documented long term impact. As human beings, we are not unlike lionfish in that we, reproduce quickly and have a history of decimating or eradicating populations of wild animals we like to eat. Fully aware of this, stakeholders hope to capitalize on human appetites for animal protein and lucre by establishing a commercial fishery for lionfish in the USVI. If sufficient demand exists there is reason to believe that such a fishery could reduce the population of lionfish to more manageable levels, allowing for the restoration of native ecosystems. While some work has been done estimating consumer willingness to pay for lionfish meat, to our knowledge there is currently no other peer-reviewed scholarship looking at consumer demand for lionfish.

Our study seeks to shed needed light on current latent demand structures for lionfish in the USVI. We used a ZINB regression model to determine which individual preferences and characteristics contribute to lionfish consumption. Separate ZINB models were estimated for restaurant consumption and for home consumption. A number of knowledge and preference characteristics are correlated with whether an individual participates in a market for lionfish as a consumer. These include seafood safety concerns which decreases the probability of market participation, and concerns about the environment and interest in new kinds of seafood which are positively correlated with market participation. Additionally, individuals' level of interest in seafood is positively correlated with consumption levels in both restaurant and fresh fish market contexts. These findings that safety concerns and environmental concerns (both knowledge-based variables) are significantly correlated with intended consumption of lionfish bodes well for a potential market for lionfish in the USVI. Furthermore, estimates of mean consumer willingness

to pay for lionfish meat both for home consumption and at restaurants are compatible with prices fisherman are willing to accept. It is our hope that increased education and outreach programs targeting residents and tourists in the USVI, and perhaps a safety certification program, can increase market participation and potential consumption levels. The WTP and consumption estimates derived in this research provide evidence that a viable market for lionfish in the USVI is an achievable goal. The next step of this research will be analyzing data for fisherman to better determine which individual characteristics and preferences influence the prices they are willingness to accept and the quantity they are willing and able to catch.

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