Using Markets to Control Invasive Species: Lionfish in the U.S. Virgin Islands

Running Head: Modeling Consumer Demand for Invasive Lionfish

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ABSTRACT

Invasive lionfish are damaging reef ecosystems along the Gulf coast and Caribbean. By establishing commercial fisheries and harvesting lionfish in mass ~~however, is~~ it may be possible to reduce their ecological footprint in the region. Nonetheless, there has been little research assessing the viability of a consumer market for lionfish meat. Using data collected in the U.S. Virgin Islands, this study examines individuals' willingness to participate in a hypothetical market for lionfish meat and their potential consumption levels. Consumer willingness to pay (WTP) for lionfish meat is also estimated. Findings suggest that individuals' market participation and consumption levels are correlated with concerns for food safety and the environment, and consumer WTP is compatible with dockside prices of other species of reef fish. These findings

suggest that a latent demand structure for lionfish meat may already exist in the USVI and that the prospect of a commercial fishery is worth ~~exploring further~~additional exploration.

Key words: consumer preferences, contingent valuation, double hurdle Poisson, invasive lionfish

JEL Codes: C24, Q21, Q22

INTRODUCTION

There is scientific consensus that the Earth's coral reefs are under environmental threat. According to a 2008 study by the Global Coral Reef Monitoring Network, an estimated 19% of the earth's coral reef systems have been lost, with an additional 15% expected to disappear in the following 10-20 years (Wilkinson 2008). Marine resource scientists attribute these losses to several factors including rising sea temperatures, overfishing, and pollutants. Invasive species are another threat. Lionfish are causing environmental and economic damage throughout reef systems in the Atlantic and Caribbean (Albins and Hixon 2008, 2013). A carnivorous species of fish native to the Indo-Pacific, lionfish (*Pterois volitans*) have no natural predators along the South Atlantic, Caribbean and Gulf of Mexico and, thus nothing to keep their numbers from rapidly expanding and consuming other fish species (Huth, McEvoy, and Morgan 2016). Invasive lionfish are changing native marine habitats by depleting the populations of herbivorous fish that otherwise keep the coral reefs from being overrun by sea-grass and algae. Furthermore, lionfish prey on commercially-valuable reef species such as grouper, snapper, and lobster that are essential to Caribbean fishing economies (Rocha et al. 2015). According to the World Resources Institute (2011), an estimated 42 million people in the Gulf of Mexico and Caribbean coastal areas are directly dependent on coral reef systems for their food and livelihoods, thus if the lionfish invasion continues, it is likely to bring substantial economic losses to the region. 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 to date (Malpica-Cruz, Chaves, & Cote, 2016; Frazer et al., 2012).

One proposed solution to the lionfish problem is for people to consume them ~~on~~ on a mass scale (Morris et al. 2011). If ~~it is~~ economically feasible, commercial lionfish fisheries could dramatically reduce the lionfish population and restore balance to the region's native ecosystems.

For a commercial lionfish fishery to be economically viable, however, there needs to be a sufficient and sustainable demand for lionfish meat. In addition, consumers' willingness to pay (WTP) needs to exceed the fishery's production costs to make it worthwhile to harvest lionfish and for there to be enough quantity harvested to make an ecological difference ~~(ecologically)~~. Few peer-reviewed studies examining WTP for lionfish exist to date. Huth, McEvoy and Morgan (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, McEvoy and Morgan (2016) recorded how bid values changed as auction participants were informed of the environmental damage associated with lionfish and the potential ecological benefits from harvesting them for food. The baseline WTP dollar value estimated for a three-ounce fillet was $6.28, which could be increased by as much as $1.66 (26%) 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. Other presenters cited prices paid to suppliers ranging from $6.00 a pound to $16.00 a fish depending on the source (Bogdanoff, Akins, and Morris Jr. 2013). While these findings provide a glimpse of middle and end consumers' WTP in certain locations, they fail to provide the figures necessary to make a market feasibility assessment for the U.S. Virgin Islands.

Since 2016, Whole Foods Market~~,~~ Inc. has offered lionfish at select southeastern U.S. locations. The company's official blog includes a section describing lionfish and provides background on the lionfish problem, as well as links to instructional videos on how to make culinary dishes with lionfish. Whole Foods markets its lionfish as a "green" item, displaying whole

fish on ice that can be filleted by their seafood department's fishmongers. The company's reason for marketing the entire fish may be twofold: (1) lionfish fillets are small, ~~"fillets are quite small"~~ so marketing the entire fish conceals relatively expensive fillet pound prices; and (2) displaying the entire fish increases consumer awareness of the problem and augments its appeal as a novelty food item. Whole lionfish sell at Whole Food~~[2]~~s locations throughout the state of Florida for around $7.00 per pound (lb), with usable fillets accounting for approximately one-third of total weight.

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The use of economic research methods to address the lionfish issue is not limited to WTP estimates for lionfish meat. Moonsammy, Buddo, and Seepersad (2011) used the contingent valuation method (CVM) to estimate the aggregate economic ~~value~~ cost of invasive lionfish on Jamaica's reef systems by first calculating a mean estimate of individuals' WTP to protect the reef and then extrapolating to the population level. They conclude that lionfish have resulted in a loss of US$11 million in economic value to residents due to reduced marine biodiversity (Moonsammy, Buddo, and Seepersad 2011).

The U.S. Virgin Islands (USVI) were selected as the place of study because various economic, ecological, and cultural characteristics of the territory appear favorable to the establishment of a commercial fishery for lionfish. Lionfish lead mostly solitary lives as ambush predators and cannot be consistently harvested through scalable methods such as angling and netting, but rather are primarily harvested through spearfishing by trained divers (Myers 2016). Recreational and commercial spearfishing are already widespread in the territory, and seafood features prominently in local cuisine (Goedeke et al. 2016; Stoffle et al. 2009; Crosson and Lia 2017). Given the abundance of divers already frequenting the reefs in pursuit of commercially-valuable species in the USVI, there exists a culture and infrastructure in place to support large-scale harvesting, should sufficient demand materialize. Perhaps more importantly, fishermen would benefit from the availability of a new target species as stocks of other valuable reef fish

species have declined in recent years (Albins and Hixon 2013). To help assess the demand-side of the market, this study seeks to determine the WTP of potential consumers in different markets in the USVI.

Essential to assessing a latent demand structure for lionfish in the USVI is identifying ~~An essential question to assessing~~An essential question in assessing a latent demand structure for lionfish in the USVI is to identify the conditions and characteristics that contribute to consumers being willing to purchase lionfish and, ~~if so, to~~the extent to which ~~what extent~~ they will participate in the market. Just as consumers may not participate in certain markets (e.g., non-smokers in the tobacco market or vegetarians in meat markets), there is good reason to suspect that a portion of those who live in and frequent the USVI will never participate in a market for lionfish meat. The factors that determine whether consumers would be willing to participate in a market for lionfish may be related first and foremost to whether they eat fish and, if so, whether they will consider eating lionfish. As lionfish is not yet a popular food item, we can assume that potential consumers have little idea of its palatability. Additionally, lionfish possess negatively perceived characteristics, including being a transmitter of *ciguatera* (a toxin harmful to humans present in many reef species) and possessing venomous spines (Robertson et al. 2014; McDermott 2017).

In this study, we apply non-linear estimation techniques to two groups of potential consumers of lionfish meat: USVI residents and tourists. First, a double hurdle Poisson (DHP) model is estimated for the resident group. This double hurdle approach allows for the identification of individual consumer preferences and characteristics that increase both the likelihood of participation in a market for lionfish meat and potential frequency of purchase. Second, a logit regression is applied to the tourist group. A logit regression allows us to model the individual tourists' likelihood of participating in a market for lionfish meat. We limited analysis of the tourist data group to a binary rather than a count model given sample size and the relative infrequency of

cases where tourists indicated they would consume lionfish more than once during their vacation (~~figure~~ Figure 2). Another part of our analysis of latent market structures focuses on prices. We estimate the Turnbull Lower Bound on consumer mean willingness to pay (WTP) for both restaurant ~~entrees~~ entrées and lionfish meat fillets purchased from the dockside market for home preparation. Consumer WTP is then estimated a second time, as a linear function of individual characteristics and preferences through the application of maximum likelihood estimation to double-bounded contingent valuation data. Results from our analyses are used to assess the viability of a new commercial fishery for lionfish in the USVI.

DATA AND METHODS

The data for this research were collected via a survey of 413 tourists and residents ~~in the~~on the island of St. Croix (USVI) conducted during the summer of 2016. ~~Researchers intercepted potential participants at local markets and other high traffic areas on the island of Saint Croix.~~ Although the sample is not statistically random, participants were approached outside of every major grocery retail outlet on the island of St. Croix. To increase tourist sample size surveyors also canvassed the airport, the Christiansted Pier, and the Frederiksted tourist district. To reduce additional bias, surveyors were instructed to only approach every third individual they saw. These data include demographic characteristics as well as consumption patterns and seafood preferences of the individuals interviewed. One purpose of the survey was to assess (then current) public perceptions and knowledge of lionfish to serve as a baseline for future outreach programs. Therefore, p~~P~~articipants were presented with a picture of a lionfish but no additional information was shared with regards to lionfish biology or their ecological impact on the region. ~~The survey was to assess, then current, public perceptions and knowledge of lionfish to serve as a baseline for future outreach programs.~~ If survey participants had individual questions about lionfish these were not answered by the researcher until after the survey.

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During the course of the survey p~~P~~articipants were presented with a series of questions designed to solicit their beliefs and attitudes toward the environment, food safety, and their propensity to consume and willingness to pay for lionfish meat. Most questions were designed to extrapolate consumer preferences and attitudes, and were asked in the form of Likert scales (Hanneman, Loomis, and Kanninen 1991).

We determined consumption frequency from ~~local~~ resident participants' response to the question, *"How many times in the month of July would you purchase lionfish meat?"* and by tourists' response to the question, *"How many times during your trip would you purchase lionfish meat*?" ~~All participants reported a value corresponding to the number of times they believed they would purchase lionfish given the opportunity from a restaurant as a cooked entrée or fresh from a market to be prepared at home.~~ Residents' responses indicated their preferred consumption (restaurant or market) during a given ~~31~~30-day period, while the tourists' stated consumption level must be considered relative to the duration of their individual trips. Due to this fundamental difference in proposed consumption time-frames, separate regression models were estimated for the tourist and resident groups during the market participation and consumption portions of the analysis. For ~~both~~ each of the ~~tourist and~~ resident and tourist group~~s~~, consumption frequencies were grouped~~-~~ into four categories or counts based on the distribution of frequencies: ~~greater than zero~~1 but less than 1.5 times, less than 2.5 but greater than or equal to 1.5, greater than or equal to ~~less than 3.5~~2.5 or 3, and 4 or greater ~~but greater than 2.5, and greater than 3.5~~ (Figure 1~~ and Figure 2~~). As our analysis of the tourist group uses a discrete binary model (logit), tourist consumption frequency was ultimately ~~),~~reduced to a dichotomous value coded 0 if the tourist indicated they would not consume lionfish and 1 if the tourist indicated they would consume lionfish at least once during their trip.

[Insert Figure 1]

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Commented [SS-E1]: Coauthors, do you think I should replace figure 2 with a new figure just showing the binary choice rather than the histogram of as is?

~~[Insert Figure 2]~~

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Greene (2012a) states that "the Poisson regression model is the fundamental starting point for the analysis of count data". Our review of the empirical literature on count data models suggests that the Poisson and its variant regressions (zero-inflated Poisson, etc.) are the most commonly estimated count models (e.g. Cameron and Trivedi 2013, Greene 1994, Lambert 2012,). Less prevalent, although also represented in this literature, are the negative binomial, ordered discrete, and geometric regression models (e.g. Gardner, Mulvey and Shaw 1995, Kockelman and Kweon 2002). Because the geometric and Poisson are nested within the negative binomial, comparison ~~between~~ of these three models is ~~fairly~~ straightforward (Mullahy 1986). In this research, we employ a test for over-dispersion as suggested by Cameron and Trivedi (1990) to determine between the Poisson and the less-restrictive negative binomial model.

Economists have long theorized that as rational individuals consume goods, each inadvertently makes a series of decisions: 1) whether or not to consume at all, 2) how much to consume, and 3) how often. Whether this sequence of decisions is made simultaneously or in succession is still a matter of debate. Nonetheless, there is broad consensus that econometricians estimating consumption models from consumer survey data must control for these different decision stages or otherwise suffer the fate of biased parameter estimates.

Numerous econometric methods have been proposed to control for the interplay of the decisions of whether to participate in a market and the quantity to consume. Cragg (1971) introduced an extension of ~~"the~~ "multiple probit ~~anlaysis~~ analysis model" wherein the magnitude of the positively-valued dependent variable is also dependent on different variables or parameters from when the dependent variable is zero (p. 829). Mullahy (1986) was the first to apply Cragg's double hurdle approach to models with count data, introducing hurdle specifications for the

Poisson and geometric models. We present the probability mass functions (PMF) for the binary and count portions of the hurdle model used in our application. While we also tested probit and complementary log-log link functions for the binary portion of the hurdle analysis, we ultimately settled on the logit. Estimated results were similar across ~~the three all models three link~~using these different link functions, and the logit was deemed to be most consistent with the literature on market participation and to provide for a more straightforward comparison with our binary analysis of the tourist group.

These PMFs of the binary and count portions of the hurdle model are depicted in equations sets 1 and 2 respectively, where 1 represents the PMF for a logit model, and 2 depicts the PMF of the zero truncated Poisson. In these equations y is the discrete dependent variable, λ_1 is the parameter of a logit distribution governing the probability of observing a positive, and λ_2 is the parameter of a Poisson truncated at zero.

$$\Pr(Y = y) = \begin{cases} \frac{e^{-\lambda_1}}{1+e^{-\lambda_1}}, & y = 0 \\ \frac{1}{1+e^{-\lambda_1}}, & y = 1,2,3, \dots \end{cases} \quad (1)$$

$$\Pr(Y = y|y > 0) = \begin{cases} \frac{\lambda_2^y}{(e^{\lambda_2}-1)y!}, & y = 1,2,3 \dots \\ 0, & otherwise \end{cases} \quad (2)$$

Equation set 3 depicts the unconditional PMF for y, wherein both the binary and count portions of the model are combined.

$$\Pr(Y = y) = \begin{cases} \frac{e^{-\lambda_1}}{1+e^{-\lambda_1}}, & y = 0 \\ \left(\frac{1}{1+e^{-\lambda_1}}\right)\frac{\lambda_2^y}{(e^{\lambda_2}-1)y!}, & y > 0 \end{cases} \quad (3)$$

If we use the log link to model ~~parameters~~ λ_1 and λ_2 ~~in PMF 2~~ this renders these parameters ~~binary and Poisson parameters~~ $e^{X_i\beta_1}$and- $e^{X_i\beta_2}$, respectively. The log likelihood equation for the hurdle model can thus be expressed as

$$lnL = ln\left\{\prod_{i\in\Omega_0}\left(\frac{e^{-e^{X_i\beta_1}}}{1+e^{-e^{X_i\beta_1}}}\right)\prod_{i\in\Omega_1}\left(\frac{1}{1+e^{-e^{X_i\beta_1}}}\right)\prod_{i\in\Omega_1}\frac{e^{y_iX_i\beta_2}}{\left(e^{e^{X_i\beta_2}}-1\right)y_i!}\right\} \quad (4)$$

or

$$lnL = \left\{ \sum_{i \in \Omega_0} -e^{X_i\beta_1} - \sum_{i \in \Omega_0} ln\left(1 + e^{-e^{X_i\beta_1}}\right) - \sum_{i \in \Omega_1} \ln\left(1 + e^{-e^{X_i\beta_1}}\right) \right\} \quad (5)$$

$$+ \left\{ \sum_{i \in \Omega_1} y_i X_i \beta_2 - \sum_{i \in \Omega_1} ln\left(e^{-e^{X_i\beta_2}} - 1\right) - \sum_{i \in \Omega_1} \ln(y_i!) \right\} +$$

~~$\left\{\sum_{i \in \Omega_+} y_i X_i \beta_2 - \sum_{i \in \Omega_+} ln\left(e^{-e^{X_i\beta_2}} - 1\right) - \sum_{i \in \Omega_+} \ln(y_i!)\right\}$~~ ~~(45)~~

~~$= \left\{ \sum_{i \in \Omega_0} -e^{X_i\beta_1} - \sum_{i \in \Omega_0} ln\left(1 + e^{-e^{X_i\beta_1}}\right) - \sum_{i \in \Omega_+} \ln\left(1 + e^{-e^{X_i\beta_1}}\right) \right\} +$$

$\left\{\sum_{i \in \Omega_+} y_i X_i \beta_2 - \sum_{i \in \Omega_+} ln\left(e^{-e^{X_i\beta_2}} - 1\right) - \sum_{i \in \Omega_+} \ln(y_i!)\right\}$ (4)~~

~~The fi~~The first set of brackets corresponds to the binary portion of the model (hurdle 1), while the second set corresponds to the count portion (hurdle 2). As depicted, we assume the decision to participate in the market (binary) is separate from the consumption quantity decision (count), thus ~~the two~~ these two portions are independent. ~~To be comprehensive we include the~~The same set of ~~independent~~ explanatory variables are included at both hurdles as indicated by repetition of the vector X_i~~, . we~~ Although we do not necessarily expect the same effect of these variables across both stages of the model, their repetition permits comparison across the decision process.[1]

The DHP is preferred to the standard Poisson regression model if consumers do indeed go through a two-stage decision process. A good indication that market participants are distinct from

[1] i.e. The concern about seafood safety is likely to be a greater determinant of market participation, than of consumption quantity, while income is likely to be a greater determinant of consumption quantity than market participation.

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non-participants in the sample is the presence of excess zeros. An examination of the reported consumption frequency of residents (F~~f~~igure 1) corroborates the notion that these data contain an abundance of zeros, as the far-left bar (representing the frequency of cases at count zero) extends several times beyond the next highest count frequency.

Best recommended practices suggest one can model the participation decision in the DHP with a probit, logit, or complementary log-log link (clog-log) function (Greene 2012b). The Vuong statistic can be used to test for goodness of fit between two non-nested models, e.g. the DHP with logit link, and the standard Poisson. Vuong z-statistics were computed to provide a comparison between the DHP and the standard Poisson regressions in both the restaurant and home consumption models for the resident group. Statistically significant z-values of 2.90 and 1.92 respectively, provide evidence the double hurdle Poisson fits the data better than the standard Poisson in either the restaurant or home consumption case.

Data were collected on consumer WTP 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~~ Hanneman, Loomis, and Kanninen ~~1993~~1991). The technique centers on soliciting sampled individuals' opinions on how much they would be willing to pay for a specified item or service; or more typically, the surveyor proposes a value (bid) and records a yes or no response. 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 first response.

Only participants who indicated they would be willing to purchase lionfish at least once during the time period specified in the questionnaire were included in the WTP analysis. These participants

were included in the WTP analysis regardless if they had ever purchased lionfish before. Willingness to pay information was gathered from participants through a series of follow up questions to the initial consumption question. For example, after asking a resident how many times she would purchase a lionfish entrée from a restaurant, the surveyor followed up with the question, "Is this what you would do if it cost __ ?" (insert bid value). As part of standard CVM methodology, participants were under no obligation to accept either bid value and in fact a significant number rejected both values (20% in the home model and 12% in the restaurant model). ~~Consistent with best recommended practices, our surveyors varied the initial bid prices to avoid starting point bias (Boyle, Bishop, and Welsh 1985; Herriges and Shogren 1996).~~ All bid values in this study were in 2016 equivalent US dollars. All bid values were framed as ~~proposed as a~~a per pound price in the case of lionfish for home consumption, or as a per entrée price in the case of restaurant consumption. Secondary bids differed from the initial bids (either higher or lower) by a factor of $2. T~~. T~~he starting bid values for restaurant consumption were $16, $19, $22, and $25 dollars. These values were chosen as they span the price range of similar fish restaurant entrées on the island at that time. The starting bid values for raw fillets for consumption were $6, $9, $12, and $15 dollars. These values were chosen based on a review of supermarket and dockside prices ~~for culinarily similar~~of ~~other~~similar ~~types~~ locally sourced fish on the island at that time~~with a similar palate~~. ~~Given~~Due to ~~-~~limitations of the survey design, ~~the analysis~~ we were ~~were unable to~~unable to test for or ~~detect or~~ correct for any anchoring effect, thus some starting value bias may be present in the final WTP estimates.

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Average WTP can be calculated from CVM data using both parametric and non-parametric methods. In this study, we estimate consumers' mean WTP with the non-parametric

Turnbull Lower-bound method to obtain a conservative estimate of the price that suppliers can expect to receive. The Turnbull method (1976) requires combining participants' responses to the questions on WTP at given prices. For a comprehensive description of how to perform Turnbull's estimation process, we recommend the reader consult Turnbull's original paper (1976) or see Haab and McConnell's somewhat condensed version (1997).

In addition to calculating mean WTP via the Turnbull method, we use the CVM data with a parametric approach to determine what factors are correlated with the stated WTP via maximum likelihood as detailed by Hanneman, Loomis, and Kanninen (1991). This approach requires the assumption that an individual's WTP is a linear function of the individual's attributes, such that WTP takes the functional form:

$$WTP_i = X_i\beta + \varepsilon_i, \qquad (6)$$

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 affects individual WTP. The associated log-likelihood function of the double-bounded CVM is as follows:

$$\text{~~Log~~}lnL = \Sigma\left[I_i^{nn} ln\left(1-\Phi\left(X_i'\cdot\frac{\beta}{\sigma}-\frac{A_L}{\sigma}\right)\right)+I_i^{ny} ln\left(\Phi\left(Xi'\cdot\frac{\beta}{\sigma}-\frac{A_L}{\sigma}\right)-\Phi\left(X_i'\cdot\frac{\beta}{\sigma}-\frac{A}{\sigma}\right)\right)+\right.$$
$$\left. I_i^{yn} ln\left(\Phi\left(X_i'\cdot\frac{\beta}{\sigma}-\frac{A}{\sigma}\right)-\Phi\left(X_i'\cdot\frac{\beta}{\sigma}-\frac{A_H}{\sigma}\right)\right)+I_i^{yy} ln\left(\Phi\left(X_i'\cdot\frac{\beta}{\sigma}-\frac{A_H}{\sigma}\right)\right)\right]. \quad (7)$$

Recall that a yes (y) or no (n) response was recorded for each participant at each of the multiple bid prices during the CVM data collection process. This study posed two bids to each individual such that responses fall 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). 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

initial bid value~~individual's true maximum WTP~~. X_i' denotes a vector of explanatory variables, with β a corresponding vector of parameters. Vector X_i' includes many of the same consumer preference and characteristics variables included in the demand portion of the analysis. Willingness to pay for home consumption was calculated for the resident group alone. Tourists were excluded from this model due to concerns about potential bias, as the group consists of only 17 individuals and lacks the variation in bid values present in the resident group. Willingness to pay for restaurant consumption was estimated for the pooled sample of residents and tourists. ~~The vector X_i' corresponds to the vector X_i in equation 2, and includes multiple variables representing consumer characteristics and preferences.~~

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RESULTS

The purpose of this project is to assess latent demand structures for lionfish meat in the USVI. Several econometric models were used to assess both consumer demand and willingness to pay, the results for each of which are presented later in this section. This section begins with summary statistics describing the variables and research sample used in the subsequent analyses. Figures 2-5 describe the Likert type questions that underlie the four composite variables assessing consumer attitudes and preferences (Figures 2-5). Tables 1 and 2 describe demographic and preference variables disaggregated by the group (residents and tourists). Thereafter the results from two double hurdle Poisson models (Table 3), and two logit models (Table 4) are presented. These DHP regression and logit regression models assess individual consumption and market participation levels for the resident and tourist groups, respectively. This section concludes with a presentation of results from the willingness to pay analyses: WTP estimated through the nonparametric Turnbull approach (Table 5), WTP modeled as a linear function of consumer preferences and characteristics and estimated via maximum likelihood (Table 6).

~~The DHP regression results indicate how participation in the market and consumption frequency of potential consumers of lionfish are correlated with various independent variables: demographic characteristics, and individual stated preferences regarding lionfish, seafood, and the environment.~~

Prior research demonstrates that consumers' perceptions regarding the safety of fish and seafood affects their consumption levels (Roheim, Kline, and Anderson 1996; Grunert 2005; Fonner and Sylvia 2015; Aruga and Makamatsu 2018), thus the survey included several questions designed to measure participants' general levels of concern about seafood safety, and lionfish in particular. All but one of these safety questions were framed in terms of a four-point Likert-scale, with 0 indicating an agreement level of "not at all", 1 indicating they agree "a little", 2 indicating they "somewhat" agree, and 3 indicating if they agree "a lot". These questions and results are summarized in Figure 2. ~~Welch's~~ Mann-Whitney U ~~two sample t tests~~tests were conducted for each variable in order to detect significant differences between the mean responses of tourists and residents.

~~**[Insert Figure 2]**~~

By design, one of these statements used to assess participants' level of safety concern was false: "lionfish meat is poisonous". Although this statement is inaccurate, as lionfish meat is edible, we found that consumer responses are strongly correlated in direction with response to the other safety questions and thus the statement appears to be a consistent indicator of individuals' overall level of concern about seafood safety.

Mean tourist and resident responses were statistically different for all ~~but two~~ of the questions regarding seafood safety. This difference is especially pronounced ~~in~~ for the statements regarding *ciguatera* and fish poisoning. Most tourists from the continental United States are unlikely to be aware of ciguatera and fish poisoning, thus one should expect statistically different

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responses from the tourist and resident groups for these questions. Tourists' mean Likert response to the statement "people can get sick with ~~fish poisoning~~ fish poisoning from eating ~~lionfish~~seafood like amberjack or barracuda from the USVI" (0.~~46~~80), is ~~0.6~~1 point~~s~~ 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" (0.58)~~, is 0.80~~, is ~~a~~ 1.14 ~~full point~~points lower than the average Likert value of residents (1.~~83~~72). Additionally, tourists' mean response to the statement, "People can get sick with *fish poisoning* from eating ~~seafood like amberjack or barracuda from the USVI~~lionfish" (0.41), is ~~0.57 more than a full Likert value lower than that of residents (1.74~~0.65 points lower than the residents' mean response~~)~~.

[Insert Figure 2]

~~The only safety related question framed in binary terms was, "*has anyone in your household gotten sick from eating seafood in the last year?*" of which only 10% of participants responded in the affirmative.~~

Figure ~~3~~ 3 displays participants' mean Likert scales in response to statements indicating their level of accurate knowledge about lionfish. The mean Likert responses were statistically different for the resident and tourist groups in the case of the questions "lionfish harm the marine environment", and "it is safe for people to eat lionfish". In both instances the mean score of residents was higher than that of tourists which is unsurprising given residents live in communities directly affected by lionfish.

[Insert Figure 3]

~~displays participants' mean Likert scales in response to statements about the environment and the sustainability of marine resources. Once again, all responses were expressed in terms of the four-point Likert scale on the degree to which they "agreed" with the statement. Mean Likert~~

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~~scales for all statements are between 1 and 2, suggesting participants are on average a little concerned about environmental issues. Residents' mean response to the statement "lionfish harm the environment" (1.73) is statistically different and higher than that of tourists (1.22), as is their mean response to the statement "people should eat lionfish to help the reef" (1.29, compared to tourists (1.14). Tourists' mean response (1.64) to the statement, "I am worried about overfishing" is also statistically higher than that of residents (1.50).~~

~~**[Insert Figure 3]**~~

A series of questions were included in the survey to capture individuals' interest in seafood; per the factorial analysis two of these variables are grouped under the category "interest in seafood". P~~p~~articipants' mean responses disaggregated by tourists and residents are displayed in Figure 4~~4~~. ~~Results suggest a high level of concordance among participants that the freshness of fish is important with mean response values of 2.8 for residents and 2.9 for tourists, implying overall strong agreement with the statement. To the contrary, there were low levels of agreement with the statement "it is difficult to cook fish", with a tourist mean response of 0.59 and a resident mean response 0.24. It is also worth noting that mean responses are statistically different between respondent categories with residents significantly less likely to agree even a little with the statement "it is difficult to cook fish". It is not surprising that USVI residents on average think it is easier to cook fish since they likely possess greater skill and experience preparing fish given how prominently seafood features in the local diet (Coblenz 1997). On average, both residents and tourists expressed that they agree somewhat with the statement "fish is expensive compared to other meat", although the mean response of residents was significantly higher (1.806) than that of tourists (1.558).~~ Statistically different mean responses ~~The most pronounced difference in mean responses~~occur between tourists and residents ~~occurs with~~for both of the statements: "I am interested in eating lionfish" and "I am interested in trying new kinds of seafood". ~~the statement,~~

~~"I am interested in trying new kinds of seafood".~~ Tourists' mean response ~~is~~ to the statement "I am interested in trying new kinds of seafood" (2.29), ~~indicating~~ indicates relatively strong agreement with the statement, while USVI residents' mean response is 1.~~63~~65, ~~falling~~ falls between the categories "agree a little" and "somewhat agree".

[Insert Figure 4]

Figure 5 displays participants' mean Likert scales in response to statements gaging their levels of concern about the two topically unrelated issues of overfishing and mercury levels in seafood. Once again, all responses were expressed in terms of the four-point Likert scale on the degree to which they "agreed" with the statement. The mean resident and mean tourist responses are not statistically different for these two statements, and all fall between 1 and 2 Likert points suggesting participants are on average "a little" to "somewhat" concerned about overfishing and mercury.

[Insert Figure 5]

~~**[Insert Figure 4]**~~

We expect participants' Likert responses to many of the aforementioned statements to be correlated with the probability of individual participation in a market for lionfish meat and subsequent consumption frequencies. Thus, while the inclusion of these Likert-response variables among the exogenous regressors in a double hurdle regression model makes intuitive sense, there are- data constraints we must consider. First, best recommended practices suggest one needs 10-20 observations per parameter to be estimated in a regression model (Harrell 2001). Our dataset is relatively small, after omitting incomplete responses ~~-~~only ~~308~~ 205 observations for the resident group and 103 observations for the tourist group~~observations~~ remain.~~,~~ ~~thus~~ Thus the inclusion of all 19 Likert response variables among the model regressors would reduce the likelihood of achieving a parsimonious model. Second, one can reasonably expect that correlation among the

Likert response variables will lead to multicollinearity in the regression model and unreliable estimates. Therefore, to eliminate potential multicollinearity and produce a parsimonious model, we have collapsed correlated Likert response variables into composite variables based on their category.

Due to survey design, most Likert questions fall within one of several subject categories. ~~These~~ Some of these subject categories ~~were~~ may include~~determined to be~~, "knowledge about lionfish", "concerns about the environment", "safety concerns" and "interest in seafood". Although somewhat arbitrary, these categories closely resemble the survey design as questions on related topics occur around the same place in the questionnaire. Tests were performed to determine if statistically significant correlation exists among the ~~variables designated~~ variables falling within each topical~~subject~~ category. Cronbach's alpha scores revealed only a significant amount of correlation among the variables grouped in the category "safety concerns." After the variable "level of concern about mercury levels" was removed from the ~~subject~~ topical category~~,~~ safety concerns, the other variables returned a Cronbach's alpha score of 0.7~~ (Appendix Table A-1)~~. ~~The other subject categories, "interest in seafood", "environmental concerns", and "knowledge about lionfish" did not return statistically significant alpha scores, suggesting another approach be followed.~~

A factorial analysis was conducted for all the remaining variables and three additional ~~-~~statistically significant groupings were identified~~ (see Appendix Table A-2)~~.[2] The names selected for each of these groups ~~inspired by the variables included therein~~ are "lionfish specific knowledge", "interest in seafood", and "~~environmental concerns~~worry level". Variables

[2] Test of Hypothesis that 3 factors are sufficient, Chi-square Value 53.27, 42 df, p-value 0.114. Variables with loadings greater than 0.50 were combined.

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were summed within each of the identified categories creating four composite variables: "seafood safety concerns", "knowledge about lionfish", "interest in seafood", and "level of worry".

Although worry level does include one environment specific statement "I am concerned about overfishing", the other significant variable "I am worried about mercury in seafood" is not topically related. Nonetheless, the factorial analysis suggests these two variables are sufficiently correlated to warrant their collapsing into a single composite variable, "level of worry".

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 (Buttel 1979; Dietz, Stern, and Guangnano 1998; Brulle, Carmichael, and Jenkins 2012), including those specific to seafood products (Nauman et al. 1995; Onozaka, Hansen, and Sorvig 2014; Aruga and Makamatsu 2018). Relevant findings from this literature suggest that individuals' concerns about environmental issues are largely contingent on personal and societal factors that can develop and change overtime. Thus, if the variable "level of worry" is correlated with individual willingness to consume lionfish it would bode well for establishing a future market.

~~Variables were summed within each of the identified categories creating four composite variables: "seafood safety concerns", "knowledge about lionfish", "interest in seafood", and "level of worry". Variables values were summed within each category to have arrive at the four preference variables included in the final analysis: "interest in seafood", "safety concerns", "environmental concerns", and "knowledge about lionfish".~~

~~Table 1 displays d~~Descriptive statistics for each of the variables used in the ~~the~~ subsequent analyses are displayed in Tables 1 and 2. Demographic characteristics such as gender, age, race, etc. for the resident and tourist groups are displayed in Table 1 alongside statistics for the Island of St. Croix from the 2010~~collected by the~~ U.S. Census. ~~bureau.~~ These demographic statistics for

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the research sample were formatted to make them consistent with the Census Bureau statistics (e.g. age was divided into four categories). Descriptive statistics of the dependent variables and the variables related to consumer attitudes and preferences are displayed in Table 2.

Comparison of the resident sample with census data for the island of St. Croix suggests residents sampled are on average, older, and more educated than what was found in the 2010 census. Furthermore, males make up a larger percentage of the resident sample than in the true population according to the census data. These differences do not appear to be at a level to compromise findings. Not surprisingly, the tourists in the survey reported more education and a higher household income, than the local residents.

[Insert Table 1]

The mean number of times resident participants indicated they would purchase lionfish from a restaurant over a 30-day period was ~~1.175~~0.410.41, whereas the mean number of times they indicated they would purchase from a market for home preparation was ~~only 0.59~~0.61~~.~~. Although these values appear relatively small (less than 1), recall they represent per capita consumption of resident grocery shoppers on the island, and not aggregate consumption. ~~Mean value of the composite variable Safety Concerns is 6.69, with a relatively large standard deviation of 4.542, suggesting substantial variation in aggregate response values. Mean value of the composite variable Environmental concerns is 3.38, also having a relatively large standard deviation of 2.259. Mean aggregate response of the composite variable Interest in Seafood is 6.54, with a smaller standard deviation of 1.49, suggesting less variation within the data.~~ A majority of tourists indicated they would purchase lionfish at least once from a restaurant while o~~i~~n vacation in the ~~U.S. Virgin Islands~~USVI. A smaller percentage of tourists (23%) indicated they would purchase for consumption at their place of lodging while on vacation. ~~A minority of survey participants~~

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~~(36%) identify as white, and respondents' average mean age is 49 years. The mean number of children within respondents' households is 0.67, which is much lower than the U.S. national average of 1.89 for the year 2016 (U.S. Census Bureau). A narrow majority (51%) of survey participants are male, and slightly less than half of respondents (48%) report being college graduates.~~ The majority of survey participants (67%) reside in the USVI.

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[Insert Table ~~1~~2]

The Cameron Trivedi tests for overdispersion returned relatively small values, 1.49 and 1.12, for the restaurant consumption and home consumption models. Under the null hypothesis of equidispersion the Poisson is a better fit for the data. These statistics have limiting Chi-square distributions with one degree of freedom, therefore we failed to reject the null of equidispersion and proceed with estimation of the double hurdle Poisson as opposed to a double hurdle negative-binomial or some other double hurdle variant of the geometric (Greene 2012b).

Results from the DHP regression model for the restaurant resident group (Table 2, top ~~right~~left) suggest that several variables are significant predictors of market participation. ~~Environmental~~ Interest in seafood~~concerns, interest in seafood~~, and high income are positively correlated with being a consumer, while age and ~~,~~ being a male~~, and being a resident of the USVI~~ are negatively correlated with market participation. The only explanatory variable shown to be statistically correlated with consumption frequency in the normal count generating portion of the DHP model for restaurant consumption is ~~resident status~~interest in seafood, which is ~~negatively~~ positively correlated with consumption.

~~**[Insert Table 2]**~~

Results from the DHP regression model predicting home consumption (Table 2, top ~~left~~right) indicate knowledge about lionfish, interest in seafood~~,~~ and age~~, and resident status~~ are positively correlated with market participation. Seafood safety concerns is negatively correlated

with being a consumer~~, which makes intuitive sense and is consistent with a Senhui et al. (2003) study of meat consumers, which found that individuals exhibiting lower levels of confidence in meat safety inspection practices consumed significantly less beef than their counterparts.~~.

With regards to the count portion of the model, interest in seafood is ~~the only~~also statistically significant and positively correlated with consumption frequency. While being white is negatively correlated with both market participation and consumption frequency of lionfish in the home. ~~variable and resident status is negatively correlated with home consumption frequency.~~ These results are ~~discussed further~~further interpreted in the following section.

[Insert Table 3]

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Results for the logit regression of tourist participation in the lionfish market, suggest safety concerns is a negative predictor of participation in the restaurant model (Table 4). Interest in seafood is positively correlated with participation in the restaurant model, as is having children in the home. The only significant regressor in the home consumption model for tourists is age which is positively correlated with participating in a market for lionfish.

[Insert Table 4]

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Results for the mean WTP estimations are presented in Tables ~~3~~ 5 and ~~4~~6. The Turnbull lower bound on resident's willingness to pay for lionfish for home consumption (Table ~~3~~5) is $11.80/lb compared to $10.09/lb for tourists. Tourists' estimated mean WTP for a lionfish entrée at a restaurant is $22.83 compared to $19.51 for residents.

[Insert Table ~~3~~5]

~~**[Insert Table 4]**~~

Consumer willingness to pay for lionfish is also estimated via maximum likelihood estimation as proposed by Hanneman, Loomis and Kanninen. (1991). This method assumes that WTP is a linear function of individual consumers' preference and characteristics, which we include in the independent variable vector X_i' (equation 6). The results for models estimating WTP for restaurant and home consumption are displayed in Table 46. The only significant variable~~s~~ in the home consumption (residents) model is ~~are safety and~~ gender, ~~and~~ whereas income is the only significant explanatory variable on WTP in the restaurant consumption model (Table ~~45~~6).

[Insert Table 6]

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ANALYSIS OF WILLINGNESS TO PURCHASE LIONFISH

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~~SUMMARY AND 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 feasible, it would also be the most cost-effective means (from ~~the~~ a policy perspective) of combatting the spread and population growth of ~~invasive lionfish~~the species. This study ~~focused~~ focused on the demand side of a potential market for lionfish in the USVI. We analyze~~dd~~ survey data from potential end-consumers (residents and tourists) on the island of St. Croix and model~~eded~~ residents' willingness to participate in a potential market for lionfish along with their potential consumption levels via a double hurdle Poisson (DHP) regression model. Tourists' willingness to participate in a potential market for lionfish meat were modeled via a logit regression. Two separate DHP regressions were performed in this analysis, one for restaurant consumption and another for home consumption. Similarly, restaurant consumption and home consumption were modeled for the tourist group with two separate logit regressions. We determined that ~~individuals'~~ individuals' willingness to participate in a market for lionfish (whether they be a resident or a

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tourist) is correlated with a number of individual preference and demographic characteristics. We likewise find that ~~individuals'~~ residents' potential consumption frequencies are correlated with a number of control variables. ~~Additionally, we estimated consumer WTP for lionfish meat using a double-bounded CVM. We find that consumers' WTP are compatible with the typical dockside prices of other species of reef fish in the territory.~~

Residents ~~Home~~ Consumption Models

Several variables were found to be correlated with market participation in the model for residents' home consumption~~ of residents~~. The finding that individuals' level of seafood safety concern is both significant and negatively correlated with their likelihood of eating lionfish is consistent with much of the literature on perceived risk and consumption of meat, poultry, and seafood (Senhui et al. 2003, Shim and You 2015). Yeung and Morris (2001) found that as individuals' 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~~ standard deviation ~~unit~~ increase in safety concerns corresponds to a decrease in the likelihood of a resident consuming lionfish in the home by ~~5~~19% (Table ~~2~~3). The marginal effect of age suggests that for every additional 10 years of age, the likelihood of an individual being a consumer of lionfish increases by ~~10~~ 6 % (Table ~~2~~3). This finding can be interpreted to mean that younger individuals are less likely to participate in a market for lionfish destined for consumption in the home. This inverse relationship with age is ~~finding is~~ consistent with the notion that younger individuals may lack the culinary knowledge to prepare fish in the home and may be ~~more likely to dine out in~~less likely to cook in general.

The parameter estimate for interest in seafood suggests a positive relationship between interest in eating seafood and the probability of ~~being an at-home~~consuming lionfish ~~consumer~~in the home. The marginal~~partial~~ effect~~s~~ estimate value, ~~0.14~~0.24 (Table ~~2~~3), suggests that a ~~a one~~

~~uni~~n~~ t increase of~~ one standard deviation increase in a resident's~~n individual's~~ stated level of interest corresponds to a ~~1~~424% increase in the probability of being a consumer.

~~The probability that an individual~~ resident participates in a market for lionfish meat for ~~home consumption is positively correlated with residential status. This is unsurprising because we assume a resident is more likely to have access to cooking facilities and tourists may be less likely to want to cook during their vacation.~~

The probability that a resident participates in a market for lionfish meat for home consumption increases with her ~~or his~~ knowledge about lionfish. A~~n~~ one standard deviation increase in a resident's ~~the~~ level of knowledge ~~about lionfish by one standard deviation~~ corresponds to an increase in the probability of consuming lionfish in the home by 11%. This finding may imply that through s~~the s~~haring ~~of~~ accurate information to USVI residents about lionfish stake~~-~~holders can potentially increase ~~individuals' likelihood of~~ market participation.

According to these findings white residents have 25% lower probability of purchasing lionfish for home consumption than their non-white counterparts. This relationship between race and lionfish consumption is consistent with studies reporting that non-Hispanic white American~~'~~s tend to consume seafood at lower quantities than their black and Hispanic counterparts (Chen and Capps 1988, Jahns et al. 2014).

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~~The only variables correlated with home consumption frequency of lionfish are interest in seafood and resident status.~~ The marginal effects of ~~these~~ variables predicting consumption frequency are best interpreted in the context of average consumption frequencies by the consuming group alone. We calculate residents' ~~the~~ average consumption ~~levels~~ frequencies of lionfish in the home ~~the residents in the home consuming group~~ by averaging only the positive consumption frequencies reported in the sample and dropping all observations with zero consumption ~~where consumption~~

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~~frequency was reported as 0~~. ~~The~~ Following this calculation method, the average home consumption frequency for residents is ~~2.12~~1.79, ~~which is~~ substantially higher than the value ~~value~~ reported in Table ~~1~~ 2 (0.~~59~~61) ~~that~~ that ~~included~~ include~~ds~~ both consumers and non-consumers in its calculation. As expected, interest in seafood is a positive predictor of ~~-~~consumption frequency among residents, with the estimated ~~partial~~ marginal effect ~~estimate~~ suggesting that a standard deviation ~~unit~~ increase in interest level roughly corresponds to ~~0.13~~0.29 ~~(6%)~~ more purchases per month for home consumption. ~~Resident status is negatively correlated~~Being white is negatively correlated with ~~with~~ home consumption frequency, with a marginal effect suggesting that ~~market participating residents who are~~potential ~~white~~ consumers who are white purchase lionfish 0.~~39~~27 fewer times than non-white market participating ~~tourists~~ residents on average~~, holding all other variables constant and at their means.~~ ceteris paribus.

~~One possible reason for this difference in consumption levels between residents and tourists may be the way that the count data was calculated for tourists. Each tourist was asked the number of times they would consume lionfish for home preparation during their trip. Many reported they would purchase lionfish for home preparation only once during their stay in the USVI. The average trip duration was only 7 days. Upon scaling such responses to a 30 day period, we may have inadvertently inflated market participating tourists' true consumption frequencies. Regardless, the finding that tourists are less likely to participate in a market for lionfish for home consumption yet consume more frequently than residents is explained if tourists would rather eat out but eat a novel seafood product with public benefits to the environment (e.g., ecolabeled) similar to results by Fonner and Sylvia (2015).~~

~~Restaurant Consumption Model~~

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~~Environmental concern~~Interest in seafood is statistically significant and positively correlated with ~~an individual~~a resident ~~being a lionfish consumer~~consuming lionfish at a restaurant. The marginal effect ~~for~~ of ~~environmental concern~~interest in seafood suggests that ~~each additional~~an increase in the interest variable by one standard deviation corresponds to an ~~unit of concern experienced by an individual~~ increases in the ~~likelihood~~ probability of participating in the market by ~~7~~23%.

~~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 (Buttel 1979; Dietz, Stern, and Guangnano 1998; Brulle, Carmichael, and Jenkins 2012), including those specific to seafood products (Nauman et al. 1995; Onozaka, Hansen, and Sorvig 2014; Aruga and Makamatsu 2018). Relevant findings from this literature suggest that individuals' concerns about environmental issues are largely contingent on personal and societal factors that 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~~ unsurprising we observe a positive relationship between income and participation in the market. This conforms to prevailing notions of income and willingness to eat-out at restaurants as well as purchasing seafood items that are relatively expensive compared to other protein sources (Saad 2017). Interpretation of the marginal effect for income suggests that residents from households who earn above $34,600 ~~median income earners~~ have a 2~~1~~% higher probability of participating in a restaurant market for lionfish.

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~~Interest in seafood is positively correlated with participation in the restaurant market for lionfish, with a marginal effect estimate of 0.21, suggesting that an additional unit of interest in~~

~~seafood corresponds to an increase in the probability of an individual being a consumer by 21%. We conclude that individuals who already have a strong preference for seafood are among the most likely to consume lionfish.~~

Age is a negative predictor of participation in a restaurant market for lionfish. The corresponding marginal effect for age suggests that for every additional 10 years of age, the probability of an individual participating in the restaurant market for lionfish falls by 1~~2~~%. 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 the psychology literature suggesting a negative correlation between age and openness to new experiences (Costa Jr. et al. 1986).

~~Resident status is negatively correlated with being a restaurant consumer of lionfish. This is consistent with assumptions that tourists are more likely to eat out than USVI residents and may further be accounted for by income differences between residents and tourists. Seafood items in the USVI are relatively expensive, and the income qualifier (which is based on the last Census) used for residents in the territory ($34,600) is lower than that used for tourists ($43,500). While we control for differences in income with a binary variable (1 ≥ earns greater than qualifying level), residents and tourists are grouped by different income standards. The marginal effect of resident status suggests that holding all other variables at their means, the probability of a resident being a restaurant consumer of lionfish is 43% lower than that of an otherwise equivalent tourist.~~ Male residents were significantly less likely to participate in a market for lionfish meat at restaurants than their female counterparts. It is unclear from the analysis whether this difference reveals more about gender preferences regarding eating out at restaurants, consuming seafood in general, or gender differences in attitudes towards exotic menu items~~ lionfish in particular~~. The

accompanying marginal effects suggests that if a resident is male his probability of purchasing lionfish at a restaurant is 23% lower than his female counterparts, ceteris paribus.

The only explanatory variable found to be significantly correlated with restaurant consumption frequency is resident statusinterest in seafood. In order to better interpret the corresponding marginal effect of resident statusinterest in seafood, we calculate the average consumption levels of the restaurant consuming resident group by averaging only the positive consumption frequencies reported in the sample and dropping all observations where consumption frequency was reported as 0. The average consumption frequency of restaurant consumers is 2.781.56. The marginal effect of residential interest in seafood status on consumption quantity frequency is 0.19 1.306, suggesting that on average holding all other variables at their means, a resident consumes lionfish 1.30.19 fewer additional times for each standard deviation increase in the interest variable. This corresponds to an increase in restaurant consumption of 12%. times

Tourist Consumption models

TheThe variable age is the only significant predictor of an individual tourist's participation in thea market for lionfish for home consumption is age. This finding is consistent with the assumption that preparation of finfish requires prerequisite knowledge that older individuals are more likely to have, and is directionally consistent with the resident sample as discussed previously. The accompanying marginal effect suggests that for each additional ten years of age the probability of a tourist participating in a market for lionfish increases by 6% (Table 4). than an otherwise equivalent tourist, a reduction in average consumption frequency by approximately 47%.

As is to be expected, tourists' level of safety concerns about seafood is a negative predictor of tourist participation in a market for lionfish consumption at restaurants. The marginal effect suggests that an increase of one standard deviation in the variable seafood safety concerns

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corresponds to a decrease in the probability of a tourist consuming lionfish at a restaurant by 13% (Table 4).

Interest in seafood is positively correlated with tourist participation in a restaurant market for lionfish. Interpretation of the marginal effect suggests a single standard deviation increase in interest level corresponds to a 22% increase in the probability of a tourist participating in the market (Table 4).

The number of children in the home is a positive predictor of ~~a tourist participating~~tourist participation in a restaurant market for lionfish meat. For each additional child residing in the home, the ~~porr~~obability of an individual participating in the market increases by 9% ceteris paribus (Table 4). The reason for this positive relationship between family size and restaurant consumption is counterintuitive given ~~dietary budge~~ household budgets~~ts~~ generally experience greater constraints with additional children in the home.

In ~~In~~ summary, our analysis of resident and tourist consumption data reveal that various factors help predict individuals' willingness to participate in a market for lionfish whether for home consumption or restaurant consumption. ~~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.~~ Safety ~~As expected, safety~~ concerns were a significant factor in determining whether ~~or not individuals~~ individuals were willing to participate in ~~the~~ a market for lionfish in both the tourist restaurant (Table 4) ~~model~~ and resident home models (Table 3). Other predictors that were significant across different models and consumer groups were interest in seafood and age.

Results from the double hurdle Poisson models for the resident group, for both ~~the lionfish prepared at-home and lionfish as restaurant entrées~~home and restaurant consumption, conform~~s~~ 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. The most substantial findings from this analysis from a policy perspective, are that accurate knowledge about lionfish, and seafood safe concerns are both significant predictors of market participation. As these variables are related to individuals' level of knowledge, stakeholders may be able to increase market participation through targeted education programs and outreach. Materials oriented towards dispelling misinformation about the inherent risks of seafood consumption and informing about the lionfish problem may be beneficial in increasing the potential consumer base. Previous studies have shown that consumers' food safety concerns can be influenced by media reports and public information (Cao et al. 2015; Zhou et al. 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 and Anderson 1995), eco-labeled (Fonner and Sylvia 2015), or local (Ropicki, Larkin, and Adams 2010). Thus, there exists an incentive for stakeholders to address potential consumers' safety concerns about lionfish through targeted information and outreach campaigns.

ANALYSIS OF CONSUMER WILLINGNESS TO PAY

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At the time ~~this~~the data for this study ~~was conducted~~were collected there was not yet an observable market for lionfish on the island of St. Croix, ~~however~~ given the right conditions however, a fu~~nctioning~~ture market may be possible. Basic economic theory dictates that the market equilibrium price for an item is determined at the intersection of the supply and demand curves~~.~~.

~~thus s~~Therefore at least some ~~ome quantity of~~ lionfish meat will ~~be given~~be exchanged in the market if ~~-~~the price consumers are willingness to pay is at least as high as suppliers' willingness to accept. As lionfish are harvested in a manner similar to other reef fish species one can assume potential supplier (fishers) are willing to accept prices on par with dockside prices of other species of reef fish in the territory. ~~. interplay of the demand for and supply of an item. The equilibrium market prices is Additionally, w~~We estimate~~d~~ consumer WTP for lionfish meat using a double-bounded CVM. ~~Towards the end of this section, we~~First the Turnbull lower bound on mean WTP is estimated for the resident and tourist groups, after which consumer WTP is modeled as a linear function of consumer preferences and characteristics and estimated via maximum likelihood methods. ~~discuss how consumers' WTP are compatible with the typical dockside prices of other species of reef fish in the territory.~~

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~~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.~~

~~concerns were negatively predictors of market participation in the model for home consumption among residents, and the model for restaurant consumption among tourists. in the model for home consumption , both in the tourist at allconsumption in both the two-stage resident model and binary tourist model. The reason~~

~~; 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 both models and was a significant predictor of consumption rates in the home consumption model. Level of environmental concern 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 a restaurant market, but are more likely to be consumers of home-prepared lionfish. 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. Likewise, resident status was a significant predictor of participation in the restaurant market, with residents significantly less likely to be consumers of lionfish at restaurants. Furthermore, in both the restaurant and home consumption models, resident status was a significant determinant of consumption quantity with residents consuming lionfish at lower levels than tourists. Income was a significant factor in determining market participation in the restaurant model, with a higher earner being 20% more likely to consume lionfish at restaurants than an otherwise equivalent individual.~~

Consumer Willingness to Pay

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) (Table ~~3~~5). This is to be expected given tourists are overrepresented among the high earning group and, as basic micro-economic theory dictates, WTP is positively correlated with income (Mankiw 2016). Both estimates of mean WTP are within the price-range of comparable finfish restaurant items in the territory, such as tuna, mahi-mahi, and salmon, which lends support to the idea of market feasibility. It is especially worth

noting that WTP for home consumption is within the range of dockside prices for comparable reef fish species (Kojis B. , 2014).

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Residents' mean WTP for lionfish destined for home preparation ($11.80/lb) exceeds that of tourists' WTP by $1.70/lb, or 16.8% (Table ~~3~~5). Compared to residents, we expect that tourists are generally less interested in cooking and frequently lack access to kitchens during their vacations in the USVI. While no data were collected on the type of lodging tourist participants used during their stay, one can 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. Regardless of this difference, both resident and tourist WTP for lionfish purchased fresh from the dockside market are within the price range of similar reef fish species according to a report by Kojis (2014).

Few variables were found to be significant predictors of willingness to pay for lionfish meat in the double-bounded contingent valuation models estimated through maximum likelihood. This lack of significant predictors may be partially due to the small size of the samples in both CVM models estimated. One curious finding is that ~~The maximum likelihood estimation results for the double bounded CVM suggest that consumer~~ male residents' have a lower WTP for raw lionfish meat than their female counterparts with a corresponding marginal ~~is~~ effect of -$2.65 (Table 6). ~~negatively correlated with safety concerns and being male.~~This observed effect of gender may conform to gender stereotypes that men are less likely to participate in grocery shopping and food preparation in the home which may bias downwards~~e downwards~~ their expectations for what are reasonable prices. ~~This finding regarding safety concerns may be~~

~~valuable to stakeholders 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 et al. 2015; Zhou et al. 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 and Anderson 1995), eco-labeled (Fonner and Sylvia 2015), or local (Ropicki, Larkin, and Adams 2010). Thus, there exists an incentive for stakeholders to address potential consumers' safety concerns about lionfish through targeted information and outreach campaigns.~~ Income is a significant predictor of willingness to pay for lionfish in restaurant settings with a marginal effect of $3.29. This finding means that individuals in the high-income group are willing to pay more for lionfish as a restaurant entrée suggesting it is a normal good.

CONCLUSION

Stakeholders hope ~~to take~~to establish and maintain commercial fisheries for lionfish meat in the USVI. Such an~~d~~ endeavor however, will be contingent on sufficient consumer demand for locally sourced lionfish as a seafood product. ~~advantage of human appetites for novel seafood products and establish 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 and more abundant diversity of reef fish (for consumption or for viewing).

Our study seeks to provide quantitative information on current latent demand structures for lionfish in the USVI. We used a double hurdle Poisson (DHP) regression model to determine which individual preferences and characteristics contributed to lionfish consumption among USVI residents. Separate DHP models were estimated for restaurant consumption and for home consumption of the resident group. Separate logit regressions were estimated for the tourist group,

modeling tourists' willingness to participate in both home and restaurant markets. A number of knowledge and preference characteristics were correlated with whether an individual would participate in a market for lionfish as a consumer. These include seafood safety concerns, (which decrease the probability of market participation) and, and concerns about the environmentknowledge about lionfish, and interest in new kinds of seafood, (which increase the probability of market participation). These findings bode well for a potential market for lionfish in the USVI. Furthermore, eFurthermore, 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, that is, they are higher than dockside prices of other targeted reef species (Kojis 2014). 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 may be an achievable goal. If so, the a market for lionfish would create a positive externality for the USVI, as benefits would extend beyond the suppliers and consumers directly participating in the market. Such a market would suppress the population of lionfish without additional expenditure of public funds. Additionally, it would reduce the predation of human harvesters and lionfish on other native ecologically important species. private market could correct the externality caused by invasive lionfish without addressing the expenditure of public funds, a truly win-win solution. This is critical because invasive lionfish are unlikely to officially become a managed species because tas such an hat action would require public expenditures on stock status determinations. Due to the species' extraordinary rate of reproduction we find it unlikely that future demand for lionfish in the USVI is ever going to exceed supply. Thus, even while reducing their numbers to more manageable levels, commercial fisheries

are unlikely to fully extirpate the species from the region, although complete elimination of the species would be ideal for the ecosystem.

The potential ecological contribution of a robust local market for lionfish in the USVI merits further consideration. In an effort to encourage additional research and discussion on this issue, we conclude by proposing a rough estimate of the potential impact of a lionfish market on the invasive fish's population. Although we suspect the sample of St. Croix residents is fairly representative of grocery shoppers on the island, it is not statistically random, thus ~~a healthy degree of~~some skepticism is warranted. Multiplying the percentage of St. Croix residents willing to buy lionfish per the survey data by population estimates for the island, we estimate that monthly demand for lionfish meat among residents may be as high as 45,000 pounds. We defer from estimating aggregate tourist demand in a similar manner, as we are less confident that the tourists sampled are generally representative of all tourists who visited the island in June 2016.[3]

~~Multiplying the percentage of consumers willing to buy lionfish per the survey data by population estimates for the USVI, we estimate that monthly demand for lionfish meat to be 45,000 pounds.~~ As of 2016, there were 141 registered commercial fishers on the island of St. Croix, with another 119 commercial fishers licensed in St. Thomas and St. John (Kojis, Quinn, and Agar 2017). Based on the participatory observation of this study's data collection team, the true number of active commercial fishers in the territory may be closer to 400. While these numbers of commercial fishers are below those required to meet all estimated consumer demand on the island of St. Croix, fishers can still make a significant ecological contribution by consistently harvesting the species. Data from the geographically similar Cayman Islands suggest lionfish densities of 233 to 650 fish per hectare (Frazer et al. 2012). With a total submerged area in the USVI territory of 485 km

[3] During the month of June 2016 an estimated 12,851 tourists visited the Island of St. Croix (Bureau of Economic Research United States Virgin Islands, 2017)

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squared up to 20 meters in depth, there is reason to believe sufficient lionfish exist to meet demand. Furthermore, research on the impact of culling efforts in the Cayman Islands also indicate that consistent removal of lionfish from targeted areas significantly reduces the presence of the invasive species, albeit temporarily (Frazer et al. 2012). If a dedicated consumer base were to be established in the USVI, then there is promise for a sustainable commercial fishery.

REFERENCES

Albins, M. A., and M. A. Hixon. 2008. "Invasive Indo-Pacific Lionfish Pterois Volitans Reduce Recruitment of Atlantic Coral-Reef Fishes." *Marine Ecology* 367:233-238.

Albins, M. A., and M.A. Hixon. 2013. "Worst Case Scenario: Potential Long-Term Effects of Invasive Predatory Lionfish (Pterois Volitans) on Atlantic and Caribbean Coral-Reef Communities." *Environmental Biology of Fishes* 96(10/11):1151-1157.

Aruga, K., and H. Makamatsu. 2018. "Consumer Perceptions toward Seafood Produced near the Fukushima Nuclear Plant." *Marine Resource Economics,* 33(4), 373-386.

Bogdanoff, A. K., J. L. Akins, and J. A. Morris Jr. 2013. "Invasive Lionfish in the Marketplace: Challenges and Opportunities." *Invasive Lionfish in the Marketplace: Challenges and Opportunities, Proceedings of the Gulf and Caribbean Fisheries Institute* 66:140-147 (Corpus Cristi, TX).

Boyle, K. J., R. C. Bishop, and M. P. Welsh. 1985. "Starting Point Bias in Contingent Valuation Bidding Games." *Land Economics* 61(2):188-194.

Brulle, R. J., J. Carmichael, and J. C. Jenkins. 2012. "Shifting Public Opinion on Climate Change: An Empirical Assessment of Factors Influencing Concern over Climate Change in the U.S., 2002–2010." *Climatic Change* 114(2):169-188.

Buttel, F. H. 1979. "Age and Environmental Concern: A Multivariate Analysis." *Youth & Society* 10(3):237-256.

Cameron, C., and P. K. Trivedi. 1990. "Regression-Based Tests for Overdispersion in the Poisson Models." *Journal of Econometrics* 46(3):347-364.

Cameron, C.; and P. K. Trivedi. 2013. "Regression Analysis of Count Data." New York, BY: Cambridge University Press.

Cao, Y., D. R. Just, C. Turvey, and B. Wansink. 2015. "Existing Food Habits and Recent Choices Lead to Disregard of Food Safety Announcements." *Canadian Journal of Agricultural Economics* 63:491-511.

Coblenz, B. 1997. "Subsistence Consumption of Coral Reef Fish Suggests Non-Sustainable Extraction." *Reef Fish Extraction* 11(2):559-561.

Costa Jr, P. T., R. R. McCrae, A. B. Zonderman, H. E. Barbano, B. Lebowitz, and D. M. Larson. 1986. "Cross-Sectional Studies of Personality in a National Sample: 2. Stability in Neuroticism, Extraversion, and Openness." *Psychology and Aging* 1(2):144-149.

Cragg, J. G. 1971. "Some Statistical Models for LImited Dependant Variables with Application to the Demand for Durable Goods." *Econometrica* 39(5):829-844.

Crosson, S., and H. Lia. 2017. "Integrating Commercial Fisheries Registration, Education, and Social Science in the U.S. Virgin Islands." *North American Journal of Fisheries Management* 37(2):349-352.

Dietz, T., P. C. Stern, and G. A. Guangnano. 1998. "Social Structural and Social Psychological Bases of Environmental Concern." *Environment and Behavior* 30(4):450-471.

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

Frazer, T., C. A. Jacoby, M. A. Edwards, S. C. Barry, and C. M. Manfrino. 2012. "Coping with the Lionfish Invasion: Can Targeted Removals Yield Beneficial Effects?" *Review in Fisheries Science* 20(4):185-191.

Gardner, W., E. P. Mulvey, E.C. Shaw. 1995. "Regression Analyses of Counts and Rates: Poisson, Overdispersion Poisson, and Negative Binomial Models." Psychological Bulletin. 118(3):392-404

Goedeke, T. L., A. Orthmeyer, P. Edwards, M. K. Dillard, M. Gorstein, and C. F. G. Jeffrey. 2016. "Characterizing Participation in Non-Commercial Fishing and other Shore-Based Recreational Activities on St. Croix, U.S. Virgin Islands." NOAA Technical Memorandum NOS NCCOS 209. National Centers for Coastal Ocean Science, Silver Spring, MD.

Greene, W. H. 1994. "Accounting for Excess Zeros and Sample Selection in Poisson and Negative Binomial Regression Models." NYU Working Paper No. EC-94-10. New York University, New York.

Greene, W. H. 2012a. *Econometric Analysis.* Upper Saddle River, NJ: New York University Press.

Greene, W. H. 2012b. *LIMDEP Version 10 Econometric Modeling Guide.* Plainview, NY: Econometrics Software, Inc.

Grunert, K. G. 2005. "Food Quality and Safety: Consumer Perception and Demand." *European Review of Agricultural Economics* 32(3):369-391.

Haab, T. C., and K. E. McConnell. 1997. "Referendum Models and Negative Willingness to Pay: Alternative Solutions." *Journal of Environmental Economics and Management* 32:251-270.

Hanneman, M., J. Loomis, and B. Kanninen. 1991. "Statistical Efficiency of Double Bounded Dichotomous Choice Valuation." *American Journal of Agricultural Economics* 73:1255-1263.

Harrell, F. 2001. *Regression Modeling Strategies.* New York: Spring Science + Business Media.

~~Hausman, J. A., ed. 1993. *Contingent Valuation: A Critical Assessment.* Amsterdam: Elsevier.~~

Herriges, J. A., and J. F. Shogren. 1996. "Starting Point Bias in Dichotomous Choice Valuation with Follow-Up Questioning." *Journal of Environmental Economics and Management,* 30(1):112-131.

Huth, W. L., D. M. McEvoy, and O. A. Morgan. 2016. "Controlling an Invasive Species through Consumption: Private and Public Values of Eating Lionfish". Working Paper No. 16-05. Appalachian State University, Boone, NC.

Lambert, D. 2012. "Zero-Inflated Poisson Regression, With an Application to Defects in Manufacturing." Technometrics 34(1992):1-14

Kockelman, K. M., Y. Kweon. 2002. "Driver Injusry Severity: An Application of Ordered Probit Models." *Accident Analysis & Prevention.* 34(3):313-321

Kojis, B. 2014. "U.S. Virgin Islands Fuel and Seafood Prices Pilot Assessment: This Dataset Contains Fuel and Seafood Price Informaiton for the USVI for 2012-2013 Time Period." Southeast Fisheries Science Center (SEFSC), Miami, FL.

Kojis, B., N. Quinn, and J. J. Agar. 2017. "Census of Licensed Fishers of the U.S. Virgin Islands (2016)." NOAA Technical Memorandum NMFS-SEFCS-715. U.S. Department of Commerce, NOAA-NMFS-SEFCS, Miami, FL.

Malpica-Cruz, L., L. C. Chaves, and I. Cote. 2016. "Managing Marine Invasive Species through Public Participation: Lionfish Derbies as a Case Study." *Marine Policy* 74:158-164.

Mankiw, G. N. 2016. *Essentials of Economics*, 8th Edition. Boston, MA: Cengage Learning.

McDermott, A. 2017. Invasive lionfish are delicious — but is it safe to eat them? (June 21). https://oceana.org/blog/invasive-lionfish-are-delicious-%E2%80%94-it-safe-eat-them-6

Moonsammy, S., D. Buddo, and G. Seepersad. 2011. "Assessment of the Economic Impacts of the Lion Fish (Pterois volitans) Invasion in Jamaica." GCFI_64-13.

Morris, J. A., A. Thomas, A. L. Ryne, N. Breen, L. Akins, and B. Nash. 2011. "Nutritional Properties of the Invasive Lionfish: A Delicious and Nutritious Approach for Controlling the Invasion." AACL BIOFLUX 4(1):21-26.

Mullahy, J. 1986. "Specification and Testing of Some Modified Count Data Models." *Journal of Economics* 33:341-365.

Myers, M. 2016. "Get to Know Lionfish." Whole Foods Market Blog (December 2). https://www.wholefoodsmarket.com/blog/get-know-lionfish-0

Nauman, F. A., C. M. Gempesaw, R. J. Bacon, and A. Manalo. 1995. "Consumer Choice for Fresh Fish: Factors Affecting Purchase Decisions." *Marine Resource Economics* 10(2):117-142.

Onozaka, Y., H. Hansen, and A. Sorvig. 2014. "Consumer Product Perceptions and Salmon Consumption Frequency: The Role of Heterogeneity Based on Food Lifestyle Segments." *Marine Resource Economics* 29(4):351-374.

Burke, L., K. Reytar, M. Spalding, A. Perry. 2011. "Reefs at Risk Revisited." Washington, D.C: World Resources Institute, 2011.

Robertson, A., A. C. Garcia, H. A. Quintana, T. B. Smith, B. F. Castillo II, K. Reale-Munroe, J. A. Gulli, D. A. Olsen, J. I. Hooe-Rollman, E. L. Jester, B. J. Blimek, and S. M. Plakas. 2014. "Invasive Lionfish (Pterois Volitans): A Potential Human Health Threat for Ciguatera Fish Poisoning in Tropical Waters." *Marine Drugs* 12(1):88-97.

Rocha, L. A., C. R. Rocha, C. C. Baldwin, L. A. Weigt, and M. McField. 2015. "Invasive Lionfish Preying on Critically Endangered Reef Fish." *Coral Reefs* 34(3):803-806.

Roheim, C., J. Kline, and J. G. Anderson. 1996. "Seafood Safety Perceptions and Their Effects on Anticipated Consumption under Varying Information Treatments." *Agricultural and Resource Economics Review* 25:12-21.

Ropicki, A., S. Larkin, and C. M. Adams. 2010. "Seafood Substitution and Mislabeling: WTP for a Locally Caught Grouper Labeling Program in Florida." *Marine Resource Economics* 25(1):77-92.

Saad, L. 2017. "Americans' Dining-Out Frequency Little Changed From 2008." *Gallup News*., January 11.

Senhui, H., S. Fletcher, A. Rimal. 2003. "Identifying Factors Influencing Beef, Poultry, and Seafood Consumption." Journal of Food Distribution Research 34(1):50-55.

Shim, M., and M. You. 2015. "Cognitive and Affective Risk Perceptions toward Food Safety Outbreaks: Mediating the Relation between News Use and Food Consumption Intention." *Asian Journal of Communication* 25(1):48-64.

Stoffle, B., J. R. Waters, S. Abbott-Jamieson, S. Kelley, D. Grasso, J. Freibaum, S. Koestner, N. O'Meara, S. Davis, M. Stekedee, and J. Agar. 2009. "Can an Island Be a Fishing Community: An Examination of St. Croix and Its Fisheries." NOAA Technical Memorandum NMFS-SEFSC-593. U.S. Department of Commerce, NOAA-NMFS-SEFSC, Miami, FL.

Turnbull, B. 1976. "The Empirical Distribution Function with Arbitrarily Grouped, Censored and Truncated Data." *Journal of the Royal Statistical Society* 38(3):290-295.

Wessells, C. R., and J. G. Anderson. 1995. "Consumer Willingness to Pay for Seafood Safety Assurances." *The Journal of Consumer Affairs* 29(1):85-107.

Wilkinson, C., ed. 2008. *Status of Coral Reefs of World: 2008.* Townsville, Australia: Global Reef Monitory Network, and Reed and Rainforest Research Centre.

Yeung, R. M., J. Morris. 2001 "Food Safety Risk-Consumer Perception and Purchase Behavior."

British Food Journal 103(3):170-187.

Zhou, L., C. G. Turey, H. Hu, and Y. Ruiyao. 2016. "Fear and Trust: How Risk Perceptions of Avian Influenza affect Chinese Consumers' Demand for Chicken." *China Economic Review* 40:91-104.

Table 1. Descriptive Statistics of USVI Census Data and Comparable Variables in Sample

Variable	St. Croix Residents		Tourists
	Survey Responses (%)	US Census (%)	Survey Responses (%)
Gender			
Male	50.40%	45.60%	48.40%
Female	48.30%	54.40%	51.60%
Education			
High School Graduate or higher	80.40%	74.90%	96.00%
College Graduate or higher	64.20%	36.00%	75.80%
Income			
> than $34,600 (median St. Croix income)	45.40%	50%	n/a
> than $43,500 (median US income)	--	--	82.30%
Age			
18-24	9.20%	8.20%	5.40%
25-54	45.20%	48.10%	66.10%
55-64	20.60%	18.40%	16.90%
> than 65	25.00%	25.30%	7.30%
Don't know/missing/refused	0.10%	--	5.60%

Table ~~1~~2. Descriptive Statistics of Variables Used in Models

Variable	Description	Min.	Max.	Mean	Std. Dev.
REST_FREQ	Number of restaurant entrees purchased per month	0	4	1.18	1.631
HOME_FREQ	Number of times raw fish purchased for meals at home per month	0	4	0.59	1.165
SAFETY	Level of concern about eating seafood and lionfish (0=no concern, ….)	0	18	6.69	4.542
ENVIRON	Level of concern about the effect of lionfish on the environment (0=no concern, ….)	0	7	3.38	2.259
INTEREST	Level of interesting in seafood (0=no interest, ….)	0	9	6.54	1.495
WHITE	Respondent identified their race as being White (0 = no, 1 = yes)	0	1	0.36	0.482
AGE	Age of respondent in years	18	84	49.26	16.216
CHILDREN	Number of children under 18 living in the home	0	16	0.67	1.426
MALE	Respondent was Male (0 = no, 1 = yes)	0	1	0.51	0.501
HIGH_EDU	Respondent was a college graduate (0 = no, 1 = yes)	0	1	0.48	0.500
HIGH_INC	Household income was higher than median (0 = no, 1 = yes)	0	1	0.64	0.480
RESIDENT	Respondent was USVI resident (0 = no, 1 = yes)	0	1	0.67	0.473

Table ~~23~~. Estimated Coefficient and Partial Effects of the Double Hurdle Poisson Regression Models (Resident Sample)

	Restauraunt			Home		
Variable	Coeff.	Std. Error	M.E.	Coeff.	Std. Error	M.E.
Hurdle 1: Participation						
Constant	0.12	1.224	NA	-1.07	0.933	NA
SAFETY	-0.06	0.326	-0.02	-0.73 ***	0.254	-0.19 *
KNOWLEDGE	0.47	0.294	0.12	0.42 *	0.252	0.11
INTEREST	0.95 ***	0.277	0.23 **	0.96 **	0.24	0.24 **
WORRY	-0.08	0.288	-0.02	0.05	0.2	0.01
WHITE	0.54	0.577	0.13	-0.97 *	0.511	-0.25
AGE (10 YRS)	-0.03 *	0.017	-0.01	0.24 *	0.129	0.06 *
CHILDREN	-0.37	0.241	-0.09	0.02	0.15	0.00
MALE	-0.96 **	0.47	-0.23 *	0.42	0.389	0.11
HIGH_EDU	0.24	0.931	0.06	-0.67	0.561	-0.17
HIGH_INC	0.97 **	0.447	0.24 *	-0.17	0.422	-0.04
Hurdle 2: Consumption Frequency						
Constant	1.27	2.036	NA	-0.15	1.172	NA
SAFETY	0.66	0.451	0.15	-0.36	0.36	-0.12
KNOWLEDGE	0.00	0.382	0.00	0.27	0.196	0.09
INTEREST	0.82 *	0.419	0.19 *	0.83 ***	0.272	0.29 ***
WORRY	-0.34	0.274	-0.08	0.23	0.178	0.08
WHITE	-1.06	0.671	-0.25	-0.77 *	0.446	-0.27 *
AGE (10 YRS)	0.01	0.03	0.01	0.01	0.014	0.00
CHILDREN	-0.34	0.707	-0.08	-0.05	0.167	-0.02
MALE	-0.16	0.77	-0.04	-0.31	0.371	-0.11
HIGH_EDU	-1.62	1.187	-0.38	-0.5	0.854	-0.17
HIGH_INC	-0.47	0.844	-0.11	-0.2	0.419	-0.07

Notes: M.E. is marginal effect. NA is not applicable. Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.

Table ~~34~~. Estimated Coefficient and Partial Effects of the Logit Models (Tourist Group)

	Restaurant			Home		
Variable	Coeff.	Std. Error	M.E.	Coeff.	Std. Error	M.E.
Participation						
Constant	1.46	1.268	NA	-2.84 **	1.367	NA
SAFETY	-1.17 ***	0.413	-0.13 ***	-0.07	0.406	-0.01
KNOWLEDGE	0.57	0.361	0.06	-0.17	0.321	-0.02
INTEREST	1.99 ***	0.486	0.22 ***	0.37	0.399	0.04
WORRY	-0.42	0.338	-0.05	0.11	0.343	0.013
WHITE	0.90	0.733	0.11	-0.33	0.755	-0.04
AGE (10 YRS)	-0.28	0.025	-0.03	0.05 **	0.024	0.06 **
CHILDREN	0.84 **	0.398	0.09 **	-1.42	0.942	-0.16
MALE	-0.98	0.695	-0.11	-0.43	0.654	-0.05
HIGH_INC	-0.49	1.193	-0.05	-0.88	1.091	-0.12

Notes: M.E. is marginal effect. NA is not applicable. Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.

Table 54. Turnbull Lower Bound WTP Estimates by Venue and Resident Status

Status	Venue	Mean WTP	Var.
Resident	Home (Purchase raw lionfish to cook at home)	$11.80/lb	$8.12
Resident	Restaurant Entrée	$17.70	$6.33
Tourist	Home/Place of Lodging	$10.09/lb	$1.66
Tourist	Restaurant Entrée	$22.83	$0.69

Table ~~5~~6. Double-Bounded Contingent Valuation WTP Estimation Results

	Home (Residents only)			Restaurant (Pooled)		
Variable	Coeff.	Std. Error	M.E.	Coeff.	Std. Error	M.E.
Constant	4.40 ***	1.058		6.35 ***	1.043	
SAFETY	-0.46	0.337		-0.21	0.279	
KNOW	0.28	0.368		0.11	0.222	
INTEREST	0.19	0.334		0.15	0.247	
WORRY	0.02	0.288		-0.28	0.202	
WHITE	0.65	0.670		-0.32	0.420	
AGE	0.01	0.015		0.00	0.014	
CHILDREN	-0.04	0.170		-0.16	0.221	
MALE	-1.18 *	0.528	-$2.65	0.07	0.382	
HIGH_EDU	-1.02	0.690		--	--	
HIGH_INC	0.56	0.601		0.99 *	0.470	$3.29
RESIDENT	--	--		-0.10	0.448	
BID	-0.45 ***	0.6234		-0.30 ***	0.037	

Notes: M.E. is marginal effect. NA is not applicable. Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.

	Home			Restaurant		
Variable	Coeff.	Std. Error	M.E.	Coeff.	Std. Error	M.E.
Constant	5.82 ***	1.371		6.21 ***	1.160	
SAFETY	-0.06	0.066		-0.03	0.057	
KNOW	-0.24	0.225		0.07	0.217	
INTEREST	0.14	0.141		0.13	0.127	
WORRY	-0.05	0.129		-0.10	0.107	
WHITE	0.35	0.538		-0.02	0.420	
AGE	0.00	0.014		-0.01	0.013	
CHILDREN	-0.08	0.168		-0.15	0.222	
MALE	-0.71	0.479		0.00	0.386	
HIGH_INC	0.45	0.529		1.08 *	0.468	$3.83
RESIDENT	-0.97	0.666		0.31	0.465	
BID	-0.42 ***	0.054		-0.28 ***	0.036	

~~Notes: M.E. is marginal effect. NA is not applicable. Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.~~

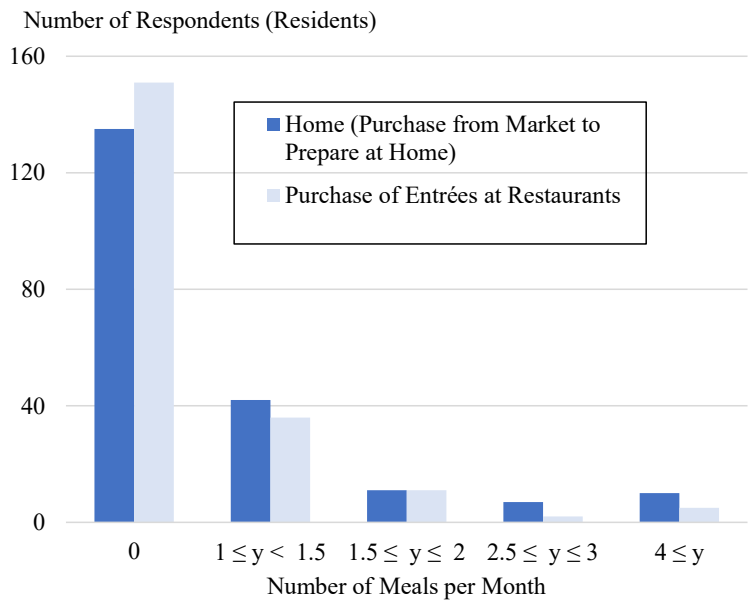

Figure 1. Monthly Consumption Frequency by Venue (Resident Group)

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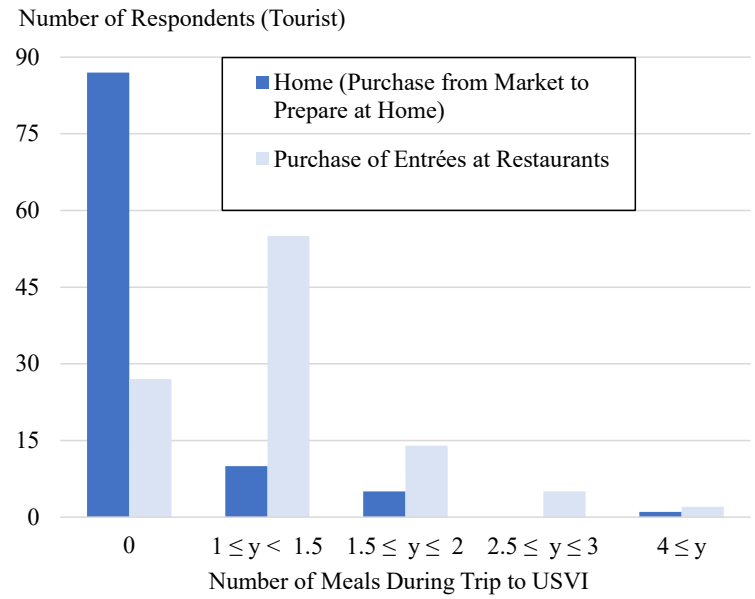
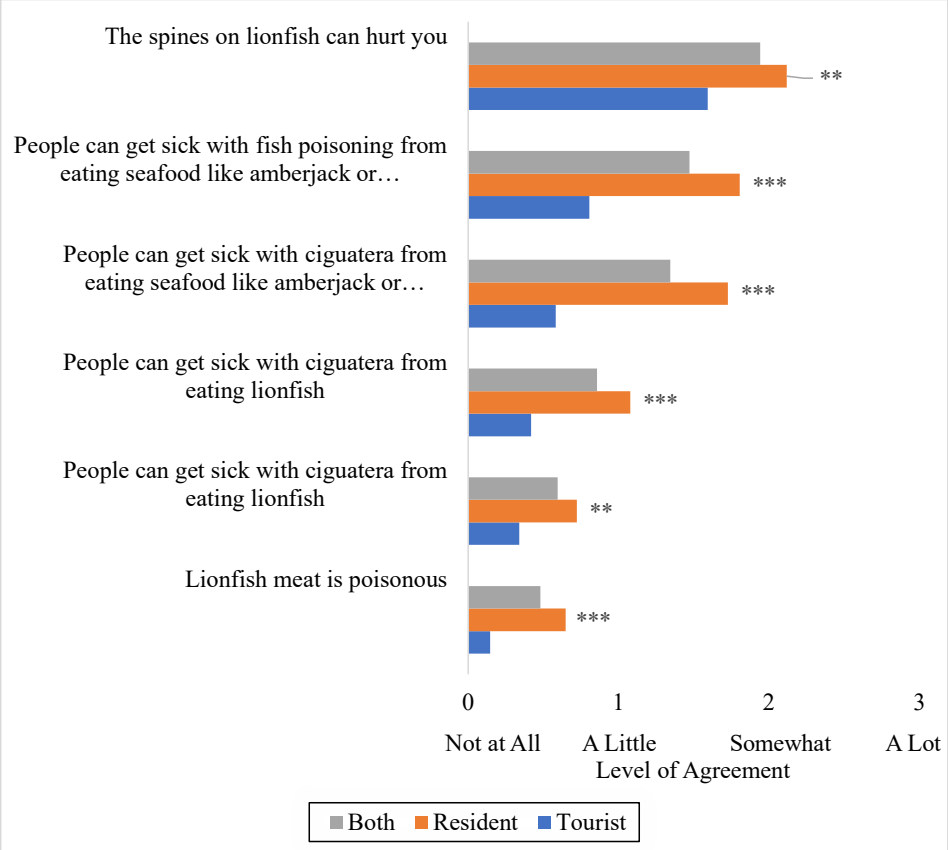
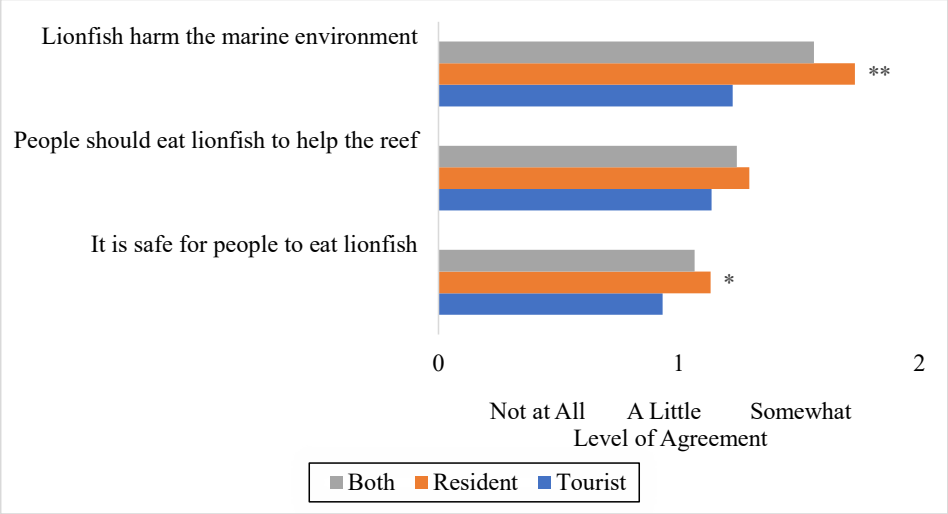


~~Figure 2. Consumption Frequency by Venue (Tourist Group)~~

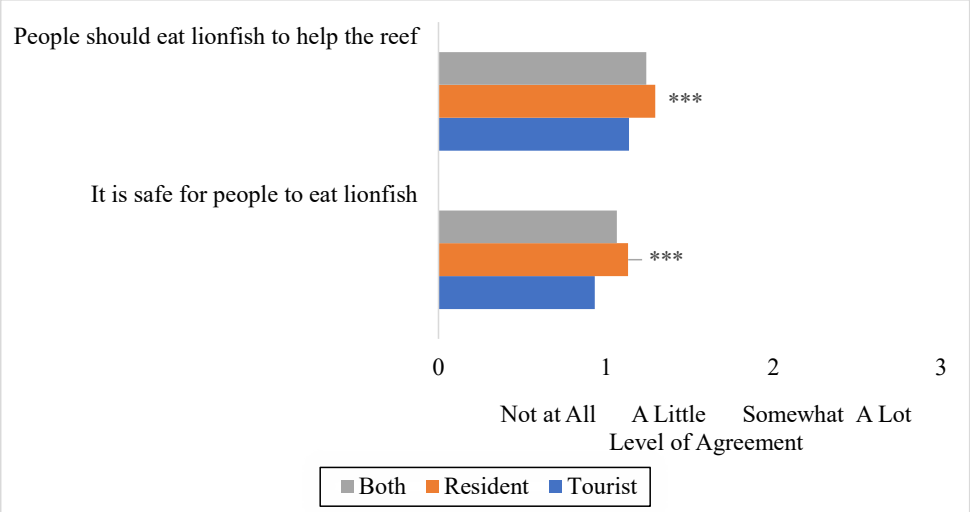


~~Figure 3. Mean Responses to Statements about Seafood Safety Concerns by Respondent Type~~
Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.
Figure 2~~3~~. Mean Responses to Statements about Seafood Safety Concerns by Respondent Type



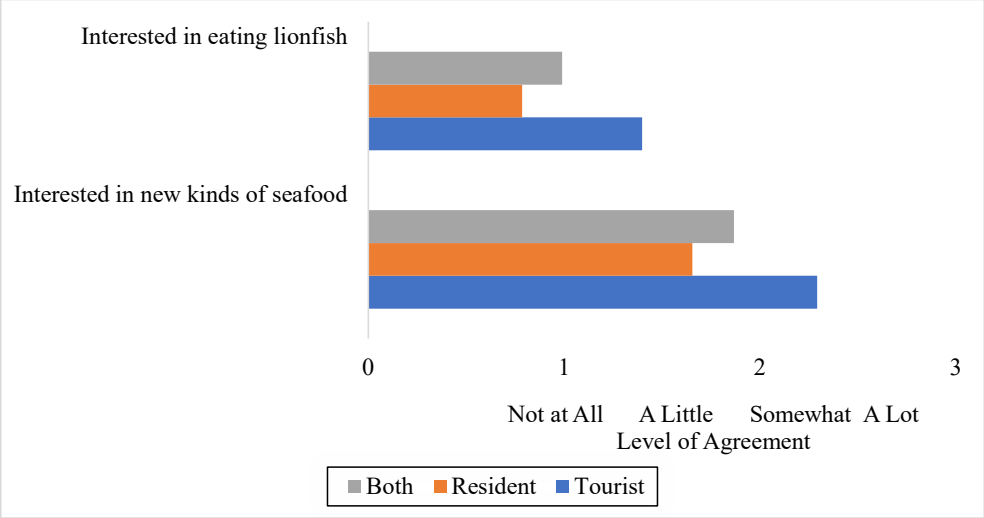
Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.

Figure 34. Mean Responses to Statements Gaging Individual Knowledge of Lionfish by Respondent Type



Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.

Figure 4~~5~~. Mean Responses to Statements about Interest in Trying Seafood by Respondent Type



Asterisks used to indicate significance levels: * = 10%, ** = 5%, and *** = 1%.

Figure 5~~6~~. Mean Response to Statements about Mercury and Overfishing by Respondent Type

APPENDIX

Table A-1. Cronbach's Alpha Test Results Establishing Correlation among Groups of Variables Combined for "Seafood Safety Concerns"

N	Variable description	Cronbach's alpha	-
Seafood Safety Concerns:		-	-
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		-
		0.74	
3	The spines on lionfish can hurt you		-
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		-

Cronbach's Alpha value ≥ 0.70 Indicates High level of Correlation Among Variable Group

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~~Table A-2. Factor Analysis for Determining Additional Composite Variable~~

	Factor Loadings		
Variable	Knowledge about lionfish	Interest in Seafood	Worried about environment
Freshness of seafood important			0.281
Seafood is healthy		0.287	
prefer fish in restaurant	0.108	0.328	0.175
Interest in new types of seafood		**0.654**	
Worried about overfishing	0.362		**0.685**
Worried about mercury in seafood	0.129	-0.108	**0.542**
Wild caught seafood better than farmed		0.1	0.178
Interest in eating lionfish	0.335	**0.668**	
Lionfish meat is safe	**0.731**	0.288	-0.112
Lionfish harme marine environment	**0.524**		0.186
Important that my seafood is caught in USVI		0.103	0.168
People should eat lionfish to help the ree	**0.809**	0.18	
Have eaten lionfish before	0.424	0.196	
Test of Hypothesis that 3 factors are sufficient, Chi-square Value 53.27, 42 df, p-value 0.114			

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