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Controlling an Invasive Species through Consumption: Private and Public Values of Eating Lionfish

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Abstract: The rapidly growing population of lionfish – an invasive species in the United States and Caribbean waters – is stressing the already fragile coral reefs in the Gulf of Mexico and is threatening local commercial and recreational fisheries. One potential strategy of controlling population growth is through consumption, which has direct private benefits but also contributes to the broader public good of invasive species management. The viability of this strategy depends in part on the values consumers place on eating lionfish. As an established market for lionfish does not yet exist, we estimate consumers' valuation for eating lionfish using framed-field experiments. Our design allows us to separate consumers' direct private value with their indirect public value of helping to control population growth. Without information about the invasive nature of lionfish and the need for population control, consumers, on average, are willing to pay \$6.28 for a three-ounce prepared fillet. The average bid increases by \$0.71 when consumers learn about the harmful impacts lionfish have on the environment and that consuming them can help curb population growth. Finally, the average bid increases by \$1.66 when consumers also learn about the possibility of localized extinction of valuable commercial species if the lionfish population is left unchecked.

1. Introduction

The traditional approach to analyzing the voluntary provision of public goods is to assume individuals choose between consuming private goods and making contributions to pure public goods (Samuelson 1954; Bergstrom et al. 1986). This characterization of the choice set is becoming increasingly incomplete as consumers are inundated with products that have both private and public attributes (Kotchen 2006). These composite goods, often called “impure public goods” are ubiquitous. Some examples include green electricity, hybrid vehicles, fair trade chocolate, shade grown coffee, environmentally friendly soaps and detergents, eco-labeled food products (such as dolphin-safe tuna), and organic produce. Moreover, in many cases individuals consume products in part because the producer/supplier donates a percentage of profits to charity (e.g., Newman's Own product line). Recent studies show that consumers may respond positively to public good attributes when making private consumption decisions, and in some cases may be willing

to purchase them at a premium (Menges et al. 2005; Kotchen and Moore 2007; Longo et al. 2008). However, a challenge arises when trying to disentangle the premium consumers are willing to pay for the public good attributes from their willingness to pay for the private components. In this study we use experimental methods to examine individuals' private and public values for consuming lionfish. Lionfish – an invasive species along the Southeast Atlantic coast, in the Gulf of Mexico, and throughout the Caribbean Sea - is a particularly unique type of impure public good in the sense that consuming lionfish has direct private benefits but also indirectly contributes to the broader public good of controlling rapid population growth. Our study is the first to solicit willingness to pay estimates to consume lionfish and to further parse these estimates to isolate the premium consumers are willing to pay to help manage an invasive resource through consumption.

Lionfish (*Pterois*) are an invasive species in United States and Caribbean waters. First detected along the Florida coasts in the mid-1980s, their populations have increased dramatically in the past two decades as a result of having no known predators outside of their native habitat (Indo-Pacific). Lionfish were likely introduced into Florida waters after being released from aquariums, either intentionally as owners tired of maintaining them as pets or unintentionally from the destruction caused by hurricanes (Goddard 2008). The rapidly growing population of lionfish is stressing the already fragile coral reefs in the Gulf of Mexico and is threatening commercial and recreational fisheries (such as the grouper and snapper fisheries). Local, state and federal regulatory agencies are actively looking for ways to reduce the population of lionfish, either to a stock size small enough to be commercially sustainable without disrupting native species or driving the stock down toward eradication.

One potentially promising management strategy is through private consumption (Nunez et al. 2012). The National Oceanic and Atmospheric Association (NOAA) recently launched an “Eat Lionfish” campaign aimed at promoting consumption of lionfish as a viable seafood choice. NOAA states that human consumption of lionfish is practical, feasible and should be promoted. Although lionfish possess 18 venomous spines that make catching, handling, and preparing them risky, the fish itself is completely safe to eat, and when prepared lionfish is comparable in taste to other

whitefish like grouper or flounder. Our study specifically considers consumption as a management strategy for controlling the population growth of an invasive species. From an economic perspective, research on invasive species has focused exclusively on *direct* management strategies. That is, management strategies that are conducted by an overseeing agency to prevent, delay, or eradicate the invasive species. This body of research typically estimates the existing economic damages associated with invasive species and/or the cost-effectiveness of different control strategies (Horan et al. 2002; Eiswerth and van Kooten 2002). A more limited contribution to this literature involves measuring individuals' valuations of direct management options toward invasive species (Nunes and van den Bergh 2004; Olden and Tamayo 2014) as well as the social factors that influence these individual valuations (Garcia-Llorente et al. 2011). These studies develop either revealed or stated preference techniques (such as hedonic property price models or contingent valuation methods) to estimate respondents' willingness to pay to manage invasive species. Our application differs as it examines an *indirect* management strategy of human consumption to control the population growth of an invasive species.

As an established market for lionfish does not exist, we solicit individuals' valuation for consuming lionfish via a series of controlled economic experiments. The experiments were conducted at the annual Pensacola, Florida Seafood Festival over two days in September of 2015, during which interested participants voluntarily self-selected into our study. This form of experimentation is typically categorized as a *framed-field experiment* in which the subject pool consists of experienced seafood consumers and takes place in a familiar market context (Harrison and List 2004). Participants were given the opportunity to purchase a single three-ounce fillet of cooked lionfish through an auction mechanism. The auction used the Becker-DeGroot-Marschak (BDM) method as an incentive compatible approach to solicit willingness to pay measures. The experimental treatments differ in the type of information provided to participants. In all treatments, participants were provided with some basic information about lionfish, such as how its taste is similar to other white fish, such as snapper or grouper. In the baseline treatment participants were not provided with any other information. In another treatment, participants were informed about the invasive nature of lionfish in Florida Gulf of Mexico waters and of the "Eat Lionfish" management strategy for controlling the

invasive population through consumption. A comparison of willingness to pay measures between the baseline and this treatment yields the premium consumers are willing to pay to eat lionfish when they are informed that consuming lionfish provides a public benefit. A final treatment is conducted to estimate the change in willingness to pay when the threat imposed by lionfish is intensified. In the social psychology literature, Protection Motivation Theory (PMT) describes adaptive and maladaptive coping behaviors of individuals to threat information (Rogers 1975). Studies within this body of literature have shown that behavior of individuals can be altered by the severity of a threat (Maddux and Rogers 1983). Consumers in this treatment are exposed to an increased severity of threat by being informed of the real possibility of localized extinction of important commercial and recreational fisheries (snapper and grouper) due to rapidly expanding lionfish populations. The impact of the threat severity can be examined by analyzing how the new information alters consumers' willingness to pay for the management strategy.

While our study is the first to solicit willingness to pay estimates to consume lionfish and to further parse these estimates to separate values for public and private attributes of consumption, the approach and methodology of using experimental auctions to value non-market goods have deep roots in the economics literature. Experimental auctions have been used to estimate consumer demand for safer food products (Hayes et al. 1995; Shogren et al. 1999; Fox et al. 2002; Rousu and Shogren 2006; Bruner et al. 2014), hormone-free and organic milk (Bernard and Bernard 2009), insecticide-free apples (Roosen et al. 1998), non-genetically modified foods (Huffman et al. 2003; Lusk et al. 2005), animal-friendly products (Gracia et al. 2011), remanufactured products (Michaud and Llerena 2011) and many other examples. Economic experiments are becoming increasingly popular methods for estimating consumer values for non-market goods. As opposed to hypothetical studies (e.g., surveys), experimental auctions involve the purchase of real products in exchange for real money and therefore there is a strong incentive for people to reveal their true values.

In our baseline treatment we find that consumers, on average, are willing to pay \$6.28 for a three-ounce prepared lionfish fillet. When informed about the invasive nature of the species and consumption as a potential management strategy, willingness to pay

for the same fillet increases by \$0.71 on average. When the severity of the threat is increased – individuals are informed about both the consumption management strategy and the possibility of local extinction of valuable species if lionfish populations continue to flourish - the average willingness to pay jumps \$1.66 above the baseline. The results show that people are willing to pay a premium to consume lionfish when there is a perceived public-good component, and this premium increases significantly when the threat posed by lionfish is escalated.

These findings also have strong policy implications. The Magnuson-Stevens Act and the 1996 Sustainable Fisheries Act (SFA) have combined to create a fishery management process implemented through eight geographic councils. Three of the councils; Gulf of Mexico, Caribbean, and South Atlantic, are located within the boundaries of the lionfish invasion. The SFA included a provision to protect essential fish habitat and promote conservation through management. Our results can provide important feedback to stakeholders interested in understanding the potential on the demand-side of the market for a viable commercial lionfish fishery to develop.

2. Experimental design and protocol

Private scuba divers off the Pensacola, Florida Gulf Coast, supplied the lionfish used in this study. Harvesting lionfish is labor intensive, as it requires scuba divers to spear them by hand and use PVC tube containers for underwater storage to protect them from the venomous spines. In total, roughly 300 pounds of lionfish were harvested for this study. The majority of lionfish were caught by one of the researchers with assistance from experienced divers, and the remainder was purchased from other local divers. The average cost per pound of whole fish was roughly \$6.50. One pound of whole lionfish yields roughly 1/5 pound of fillet. All the whole fish harvest was cleaned and filleted by the researchers. Lionfish were also available by special order from a Publix supermarket at \$30 per pound for lionfish fillets but the researchers were able to harvest a sufficient quantity of fish for the experiment from local waters.

The experiments were conducted at the Pensacola Seafood Festival during 25-27 of September in 2015. The experiment was run over the first two days of the festival. The

University of West Florida reserved the festival space (a 10 foot by 10 foot area) and a research station was set up near the central area at the festival. The researchers, along with two graduate assistants, were responsible for all aspects of the experiments. The lionfish for auction was individually packaged in three-ounce portions and cooked using the sous-vide method of hot water emersion. The filets were cooked to a uniform 135 degrees Fahrenheit (57C) for 30 minutes.

Participants for the study were recruited at random from the large number of attendees at the seafood festival. Potential subjects were approached, briefly informed that the research team was conducting research on lionfish and asked if they would like to participate. At this point potential subjects were also informed that they would be given money to participate and they could use a portion of that money to try and purchase a fillet of cooked lionfish. The only requirements for participation were that subjects were at least 18 years of age, of good health (self-evaluation) and that they could speak English. Once a person indicated that they were interested in participating they were led into the research station. At that point the researcher read an informed consent form that included the potential risks from participating and asked for verbal consent from the participant.

Before any decisions were made, subjects were provided with ten dollars and told that they will have an opportunity to use all or a portion of the money to try and purchase a three-ounce fillet of lionfish through an auction. The experimenter then began reading through the instructions (attached as a reviewer's appendix). The auction followed a BDM mechanism and was explained to subjects using simple terms. The subjects were shown a random price generator created in Excel that was clearly displayed on a computer screen at the research station. Subjects were informed that the program will randomly choose a single price from \$0.10 to \$10.00 (in ten cent increments) and that each price had the same likelihood of being drawn (uniformly distributed). Before the price was drawn, the subject was required to submit their bid for the lionfish fillet. The random price was then drawn and displayed to the participant. If their bid was higher than the price drawn, then they purchased the fillet at the drawn price and received any change remaining. However, if they bid less than or equal to the randomly drawn price, then they did not purchase the fish and kept their \$10.

Before bidding, each participant received one of three potential treatments, which differed according to the information provided to the subjects. Each subject only participated in one treatment (i.e., between-subjects design), and the researchers conducted each treatment in two-hour blocks spread evenly over both days. The auctions were conducted between lunchtime (11:00 AM) and dinner time/early evening (7:00 PM).

In each treatment, subjects were informed that:

Lionfish are commonly consumed in many parts of the world and are considered to be of excellent quality by most who have tried it. When cooked, lionfish fillets are firm, white and flaky with a very mild non-fishy taste that is comparable to small grouper or hogfish. The lionfish will be served on a paper food tray with a fork. There are lemon wedges available and bottled water.

In each treatment, participants were also informed that they were bidding on lionfish that was recently harvested from the Gulf of Mexico and was prepared using the sous-vide method with a bit of olive oil and salt. At that point the subjects could view the individually packaged fillets in the transparent sous-vide water baths (three sous-vide machines were in operation). They were told that salt and pepper were also available for seasoning if they purchased the fish. Although participants were not given the opportunity to try the product before submitting bids, they were informed that many consider lionfish to be comparative in taste to other whitefish.

In the first treatment, subjects were not provided with any additional information. As such, this is our **baseline treatment** with bids reflecting subjects' prior knowledge and understanding of lionfish.

In the second treatment, which we call the **management treatment**, subjects were provided with all of the information from the baseline treatment with additional information regarding the invasive nature of lionfish and consuming lionfish as a potential management strategy. Specifically, subjects were told:

Lionfish is an invasive species that is not native to the Gulf of Mexico and is threatening the natural ecosystem. Lionfish have very few natural predators in the Gulf of Mexico and because of this their populations are rapidly expanding. One potential way to reduce their populations is by eating lionfish. In fact, the National Oceanic and Atmospheric Association has recently promoted an "Eat Lionfish" campaign that suggests human

consumption can be a viable option to reduce lionfish populations. When you decide to purchase and consume lionfish you are indirectly helping to manage invasive lionfish populations.

When compared to the bids submitted in the baseline treatment, the bids from this treatment will highlight the value of providing information on how consuming lionfish can help reduce the population growth of an invasive species. The difference in bids is therefore interpreted as the premium consumers are willing to pay to help in the management effort.

In the third treatment, which we call the ***management-severe treatment***, participants received all the information from the management treatment plus additional information regarding the possible threat of localized extinction of highly valuable commercial species. Specifically, based on the findings of Shipp (2012), they were provided the following:

If we don't significantly reduce the population of lionfish in the Gulf, their presence could result in localized extinction of species like snapper and grouper.

A comparison of bids between these two treatments will highlight the added premium consumers are willing to pay to assist the management effort when the severity of the threat is intensified. Protection Motivation Theory suggests this premium will be positive and significant.

For each of the three treatments, after the information was read aloud the subjects were asked to complete a decision sheet. The top half of the sheet was their bid card where they wrote how much they would be willing to pay for the three-ounce fillet of lionfish. The bottom half of the decision sheet was a survey that solicited their gender, zip code, age range, income range, whether they have previously consumed lionfish and a likert scale to capture how hungry they are. The decision sheets were also time stamped by the experimenters.

Once a subject submitted their decision sheet, the experimenter then activated the random price generator on the computer at the research station to reveal the market price. A new random price was drawn for each participant and the prices were displayed out of view from other participants. In total 253 subjects participated in the experiments, 73 in

the baseline treatment, 92 in the management treatment and 88 in the management-severe treatment. On average, each participant spent 10-15 minutes from start to finish.

3. Results

We start with reporting summary statistics from the three treatments. Table 1 contains averages bids per treatment along with percentage breakdowns of gender, age, income, participants that had tasted lionfish before and subjects' average hunger level. Across all participants in the sample, there is a 50-50 split in terms of gender. Almost half of participants are in the 50-79 years of age range, with the greatest percentage earning between \$51-\$100 thousand. Overall, subject demographics in terms of gender balance, age, and income from this sample appear to be consistent with the general finfish consuming population in the U.S. (Jahns et al. 2014). Approximately 10% have tasted lionfish before and the average self-reported hunger level (on a scale of 1 to 10) is 5.5.

In the baseline treatment people were willing to pay, on average, \$6.28 for a three-ounce fillet of fully prepared lionfish (roughly \$33 per pound). Considering that the local Publix supermarket will periodically fill special orders of lionfish (raw fillet) for \$5.62 for a three-ounce portion, the average bid for cooked lionfish seems reasonable. When consumers are informed that lionfish are an invasive species threatening the ecosystem and the potential for consumption as a management strategy to control the population, the average willingness to pay increases by \$0.71 (about \$3.80 per pound). A pairwise t-test of the unconditional means indicates that this increase is significant ($p = 0.035$). The result suggests that consumers are willing to pay a significant premium to consume lionfish once they are made aware of the increasing population problem and that consumption contributes to the public benefit of invasive species management. When consumers are additionally informed about the possibility of localized extinction of commercially important species like snapper and grouper, the premium increases even more (\$1.66 more than the baseline and \$0.94 more than the management treatment). Both of these differences are highly significant ($p = 0.000$).

Table 1: Average bids by treatment and characteristics of the subject pool

	<i>Baseline</i>	<i>Management</i>	<i>Management-severe</i>	<i>Pooled</i>
<i>Average Bid</i>	6.28 (1.86)	6.99 (2.33)	7.94 (2.00)	7.12 (2.19)
<i>Gender</i>	Male = 56.2% Female = 43.8%	Male = 43.5% Female = 56.5%	Male = 52.3% Female = 47.7%	Male = 50.2% Female = 49.8%
<i>Age</i>	18 – 34 = 37% 35 – 49 = 23.3% 50 – 79 = 39.7% 80 or more = 0	18 – 34 = 17.4% 35 – 49 = 22.8% 50 – 79 = 47.8% 80 or more = 1.1%	18 – 34 = 27.3% 35 – 49 = 22.7% 50 – 79 = 50% 80 or more = 0	18 – 34 = 30.4% 35 – 49 = 22.9% 50 – 79 = 46.2% 80 or more = 0.4%
<i>Income</i>	\$0 - 50k = 35.6% \$51 – 100k = 41.1% \$101 – 150k = 12.3% > \$150k = 11% Refused = 0	\$0 - 50k = 37% \$51 – 100k = 27.2% \$101 – 150k = 14.1% > \$150k = 16.3% Refused = 5.4%	\$0 - 50k = 25% \$51 – 100k = 43.2% \$101 – 150k = 21.6% > \$150k = 8% Refused = 2.3%	\$0 - 50k = 32.4% \$51 – 100k = 36.8% \$101 – 150k = 16.2% > \$150k = 11.9% Refused = 2.8%
<i>Tasted before?</i>	11.0%	9.8%	10.2%	10.3%
<i>Hunger level</i> (1 = "full"; 2 = "very hungry")	5.78 (2.15)	5.43 (2.28)	5.60 (2.09)	5.52 (2.16)
<i>n</i>	73	92	88	253

While the average bids from Table 1 provide useful comparisons across treatments, it is likely that bid amounts are conditional on the characteristics of the subject pool. To explore this we turn to a linear regression model in which the dependent variable is the individual bid amount and the explanatory variables are dummies for the two management information treatments, gender (male = 1), whether the consumer has tasted lionfish before (yes = 1), age range (1 to 6), income (1 to 7) and hunger level (1 to 10). The model was estimated using robust standard errors and the results are in Table 2.

Table 2: Linear regression results

	<i>Y = Bid</i>
<i>Constant</i>	4.827*** (0.488)
<i>Management</i>	0.654** (0.327)
<i>Management-severe</i>	1.570*** (0.309)
<i>Male</i>	-0.107 (0.265)
<i>Age</i>	0.143 (0.112)
<i>Income</i>	0.188** (0.075)
<i>Tasted before?</i>	-0.643* (0.350)
<i>Hunger level</i>	0.091 (0.061)
<i>n</i>	253
<i>r-squared</i>	0.148
<i>F</i>	8.28***

Notes: robust standard errors are in parentheses and *, **, *** indicate significance at the 10%, 5% and 1% levels respectively.

The conditional results from Table 2 confirm what we found comparing average bids from the summary statistics. Principally, both information treatments motivate significant increases in consumers' willingness to pay for lionfish. The first component of this effect is that participants will pay a premium over their private valuation for the public good component of managing an invasive species. This supports other empirical research that indicates that consumers are willing to pay a higher price for the public good attributes of an otherwise private good (Menges et al. 2005; Longo et al. 2008). Further, other research also indicates that individuals are willing to pay for a management policy that *directly* controls an invasive species (Nunes and van den Bergh 2004; Olden and Tamayo 2014). Our results add to this body of literature as we find that a significant premium exists for an *indirect* management strategy of population control through consumption. By further highlighting the potential for unperturbed lionfish population growth to eradicate popular reef fish species like grouper and snapper, we find that increasing the threat severity further raises the premium that participants will pay. This supports the general findings from the PMT literature that, all else equal, raising the severity of the

threat influences behavior, causing in this case a significant increase in willingness to pay (Maddux and Rogers 1983; Abraham et al. 1994).

For the other explanatory variables, the results also show that a movement up in an income bracket significantly increases bid amounts – therefore lionfish is a normal good. Finally, those participants that tasted lionfish in some form before the study were willing to pay less for the lionfish fillet (but only at the 10% level). This coefficient can be interpreted as the estimate of the novelty factor for tasting lionfish for the first time. On average, naïve consumers are willing to pay about \$0.64 more to try lionfish compared to experienced consumers.

4. Conclusion

While recent studies have shown that consumers may be willing to pay a premium for private goods that also exhibit public good characteristics, a challenge arises when trying to disentangle the premium consumers are willing to pay for the public good attributes from their willingness to pay for the private components. Lionfish are an invasive species to Atlantic and Gulf of Mexico waters. With a voracious appetite and lack of predators, their uncontrolled population growth is threatening the population of domestic reef fish, such as grouper and snapper. Policy makers are actively looking for ways to control the rapid population growth and NOAA recently launched an “Eat Lionfish” campaign aimed at promoting consumption of lionfish as a viable seafood choice. Consumption of lionfish therefore has direct private benefits but also indirectly contributes to the broader public benefit of controlling rapid population growth.

Our research uses a framed-field experiment with experienced seafood consumers to examine consumers’ willingness to pay for lionfish and to further parse these estimates to isolate the premium consumers are willing to pay to help manage an invasive resource through consumption. While other research has indicated that individuals will pay for methods of population control that directly remove the invasive species, we consider a unique management strategy of indirectly controlling the population growth of an invasive species through consumption.

Our sample is drawn from experienced seafood consumers at the annual Pensacola, Florida Seafood Festival. Over a two-day period, willingness to pay estimates

for a three-ounce portion of prepared lionfish were solicited from 253 participants using the Becker-DeGroot-Marschak mechanism. By varying the information provided to participants, consumers' willingness to pay for the private and public good elements of consuming lionfish were examined.

We find that consumers, with only their prior understanding of lionfish, were willing to pay, on average, \$6.28 for a three-ounce fillet of fully prepared lionfish (roughly \$33 per pound). When consumers are informed that lionfish are an invasive species threatening the ecosystem and the potential for consumption as a management strategy to control the population of invasive lionfish, the average willingness to pay increases by \$0.71 (about \$3.80 per pound). By increasing the severity of the threat, we further find that if consumers are informed about the possibility of localized extinction of popular reef species like snapper and grouper, the premium increases by \$1.66 over the baseline (\$0.94 over the management treatment).

Beyond the contribution to the literature, there is a strong policy component to the research. The Magnuson-Stevens Act and the 1996 Sustainable Fisheries Act (SFA) have combined to create a fishery management process within the geographic boundaries of the lionfish invasion. The SFA included a provision to protect essential fish habitat and promote conservation through management. In a study of the economic value of artificial reefs in Florida, Huth, Morgan, and Burkart (2014) surveyed over 6,000 Florida saltwater fishing license holders that were both residents of Florida and non-residents. Their findings indicated that the majority of sampled reef users agreed (86%) that lionfish do pose a serious threat to native species along the Florida coastline but did not believe (58%) that there were any effective methods that could be used to control lionfish populations. Our results suggest that the "Eat Lionfish" campaign is one management method that has the potential to mitigate lionfish population growth. That is, the potential exists for a viable lionfish commercial fishery to develop if consumer willingness to pay measures solicited in this study exceed the supply-side costs of bringing the lionfish to market.

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