Assessment of the Economic Impacts of the Lion Fish (*Pterois volitans*) Invasion in Jamaica

Evaluacion del Impacto Economic de la Invasion del Pez León (*Pterois volitans*) en Jamaica

Évaluation des Incidences Économiques de l'Invasion des Rascasses Volantes (*Pterois volitans*) en Jamaïque

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ABSTRACT

The invasion of the Lionfish (*Pterois volitans* and *Pterois miles*) in Jamaica has numerous ecological impacts on the abundant marine ecosystems surrounding the island. The predominant effect of the Lionfish invasion is on the biodiversity in the marine habitats. As a result, there are direct and indirect economic implications especially in the areas of domestic fisheries, marine tourism and the non-market value for maintaining the biodiversity. In assessing the economic impacts of the lionfish invasion in Jamaica, the total economic impact was derived as a function dependent on the direct and indirect costs; where the direct costs were derived by correlating Lionfish gut content secondary data and the domestic market price for varying fish species; the indirect costs were identified as the non-market value and derived by collecting primary data from varying stake holders using the Contingent Valuation Method. The data was collected from fishermen, tourist, locals and dive shop operators using a stratified random sample frame from three parishes in Jamaica, St. Anns, St. James and Trelawny. The data was analyzed in the Gretl program using a combination of econometric techniques; more specifically, Ordinary Least Squares and Logistic Regression. The research establishes a baseline cost of the lionfish invasion which can be used to derive more detailed economic analysis. The results of this research can be used by government officials to quantify in economic terms the presence of Lionfish and develop the necessary policies to effectively manage the situation.

KEY WORDS: Biodiversity, contingent valuation, Jamaica, economic, fisheries

INTRODUCTION

The emergence of Lionfish *(Pterois volitans and Pterois miles*) in the Caribbean has been regarded as the most severe marine finfish invasion in the region's history with the potential to devastate the fragile economic sectors existing in the Caribbean (Morris et al. 2008). Although the channels of entry into the Caribbean Sea are not entirely certain, it is widely accepted by scholars that the mechanism of its entry is predominantly from the aquarium pet trade on the eastern seaboard of North America. The agreed notion is that the lionfish were either released by pet owners who were unable to manage them or the fish were swept into the sea by storm surge runoff as a result of the numerous storms and hurricanes occurring on there in the past ten years (Ruiz-Carus et al. 2006). Some experts have included the possibility of ballast water as being another mechanism of entry.

The invasive Lionfish is of particular concern to the stakeholders of the marine habitats because of its potential threat to the fisheries resource, biodiversity, fish nurseries, numerous microhabitats and human health. The presence of a growing population in lionfish has lead to a project to control the spread in the Caribbean, especially in countries such as Jamaica and the Bahamas. Since 2000, National Oceanic and Atmospheric Administration (NOAA) researchers have partnered with nongovernmental organizations, academics, and other federal and state agencies to develop a programmatic response to the lionfish invasion.

The two species of lionfish strives in the Caribbean Sea because of two reasons:

i) It is an efficient apex predator that feeds on a variety of small fishes and crustacean (Fishelson 1997), eventually outcompeting native species; and
ii) It has limited natural predators in the Caribbean Sea (Allen and Eschmeyer 1973).Aside from the abundance of food and lack of predators, the lionfish has a rapid reproduction rate, with one female producing approximately 2 million eggs annually.

The economies of Small Island Development States (SIDS) like Jamaica are particularly vulnerable to biological invasions because their economies display intensive use of natural resources for domestic livelihoods (WRI 2005). For instance, Jamaica's Fisheries contributes approximately 0.4% to its total Gross Domestic Product (GDP) and affects the livelihood of approximately 13,000 persons. Given that the Lionfish outcompetes and preys on the native commercial species (Fishelson 1997, Allen and Eschmeyer 1973), it directly translates into an economic impact to Jamaica's fishing industry and a cost to its economy. It has been recommended though, that encouraging fishermen to catch small and large

specimens, consume and vend Lionfish can be used as a control mechanism. This translates into some short term benefits while unsustainably reducing the lionfish numbers and protecting the valuable species being impacted.

SIDS like Jamaica are also heavily reliant on tourism especially marine and ecotourism (WRI 2005). Biological invasions pose unique challenges for the tourism sector because of the fragile state of the ecology for which the tourism product is built. It poses a unique challenge because, aside from the costs associated with biological invasions, some benefits can be derived from it, depending upon the species. Lionfish for example, are aesthetically appealing and can be considered an attraction for scuba divers and snorkelers; it also is a species that is suitable as sport for spear fishing and angling.

Situations like these are problematic as some stakeholders may want to preserve the invasion for immediate short term gains despite it affecting other stakeholders' livelihoods. Even though the lionfish presence in Jamaica can accrue numerous short term benefits, the long term impacts are considered excessively costly to encourage preservation of it for immediate gains. One major long term impact identified is the gradual destruction of the coral reef; if the lionfish overpopulates the marine habitats, it can result in the decline of populations of native species that clean the reef, since the lionfish are ravenous predators.

THE PROBLEM

Jamaica coastal area is dominated by coral reef habitat (NEPA 2007). It is this habitat for which its tourism product is developed and fisheries stock is maintained. The reef habitat plays a significant economic role in Jamaica's economy (WRI 2005). Being already threatened by local activity (Figure 1), the added pressure of the lionfish invasion is proving to be critical especially on the biodiversity in the reef habitats. The lionfish seem to favour the reef habitat, making the dense reef habitats ideal hunting and spawning grounds for lionfish. The most dense reef habitats in Jamaica occur on the West to Northern Coastal area; thus the study undertaken focused on three areas along the Western and Northern coastline in the parishes of St. James, St. Anns and Trelawny; more specifically, Ocho Rios, Montego Bay, and Negril (Figure 1).

According to Sealey et al. (2008), the most prevalent impact identified in the lionfish invasion in Jamaica is the threat to the marine biodiversity. The unexpressed value of marine biodiversity creates the most significant economic impact.

In this regard, the approach of this paper is to identify the immediate and potential costs annually attached to the lionfish invasion on the marine biodiversity in Jamaica especially if the population continues to grow. With this assessment, a baseline cost would be established for future assessment to provide more detailed costing figures.

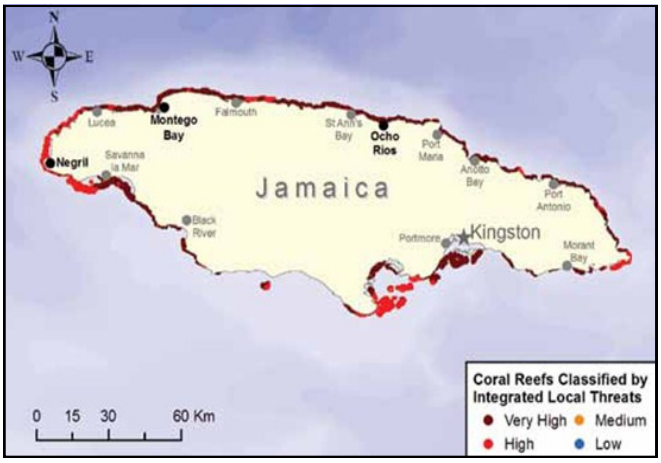

Figure 1. Jamaica's coral reef distribution and locations under threat.
Source: Burke, L., K. Reytar, M. Spalding, and A. Perry. 2011. Reefs at Risk Revisited. WRI.

METHODOLOGY

In order to estimate the economic cost of the impact of the invasive alien species, the study used the Contingent Valuation Method (CVM), where the CVM expresses value as a function of an impacted person's willingness to pay to protect an environmental asset. This necessitated the collection of information based on the importance of biodiversity to the people of Jamaica. The data used for the research included both primary and secondary data.

Data for Estimation of Willingness to Pay

In determining the indirect costs, primary data was used to derive a value for the marine biodiversity of Jamaica. A Contingent Valuation Questionnaire was used as the survey instrument. According to Emerton (2008), the Contingent Valuation Method derives a hypothetical value for the marine biodiversity of Jamaica based on the respondents' willingness to pay to protect the biodiversity. Previous research has shown that the main population distributions of the lionfish in Jamaica occur on the Northern to Western Coastal habitats (NEPA 2010). As a result, the survey was conducted along the northern and western coastline of Jamaica using a stratified random sample framework. Questionnaires were randomly distributed among the targeted population in the parishes of St. Anns, St. James, and Trelawny along the northern and western coasts. Respondents were stratified into five different categories of stakeholders; fishermen; tourists; dive shop operators; environmental officers; and local residents (that do not directly use the marine habitats). With a sample size of 165 respondents, the Contingent questionnaires were compiled and analyzed using Logistic regression to assess the mean willingness to pay for each area surveyed. With further analysis, an estimated total willingness to pay or total value for the Marine biodiversity was then computed.

METHODOLOGY LIMITATIONS

According to the National Environmental Protection Agency (NEPA), lionfish research in Jamaica has only been prevalent since 2009. The limited secondary data available on the lionfish in Jamaica hinders more detailed economic analysis. The methodology utilized some of the available secondary data that is currently undertaken in lionfish research in Jamaica that can be analyzed for costs.

The primary data collected in the study also has its limitations; these include the margin of error attached with sampling, the starting point and hypothetical bias' of the contingent valuation survey (Tietenberg 2004). As a result, the costing derived will be an estimated reflection of the economic impacts, thus its values are subject to change with further analysis. Essentially, the results from this study will be utilized as a baseline estimation of cost for further economic analysis.

METHODOLOGY JUSTIFICATION

Assessing the economic impact of the lionfish invasion has presented some unique challenges in establishing an economic costing. Firstly, compared to other biological invasions, such as red palm mite or black sigatoka, whereby the impacts are easily identified, the impacts of the lionfish invasion are not blatantly obvious. For instance, even though the lionfish is impacting the fishing industry, it is difficult to establish the exact proportion of decline in fish stock attributed to the lionfish because other factors such as overfishing and pollution, are also responsible for fish stocks decline in Jamaica. Even with tourism, it is difficult to establish whether or not the lionfish have actually negatively affected tourist numbers; it can be viewed more as a tourist attraction rather than a tourist deterrent. Other factors affect tourist inflows including culture, attractions for the tourist, crime, political disrepute, sex etc. In order to isolate the actual tourist impact, an assessment of the marine tourist is needed. Assessing the marine tourism would identify whether or not the lionfish invasion is actually making a difference. This can only be done over an extended period of research so that marine tourist numbers can be compared over different time intervals.

Since, the main impact of the Lionfish invasion is the loss in marine biodiversity and quantifying other impacts require detailed supporting data, the use of the Contingent Valuation Method to derive a value for biodiversity can be appropriate. However, assessing this as an economic costing is not entirely precise since establishing a value for biodiversity is not direct. Generally, the value of an environmental asset is based on the market price for it. If the environmental asset does not have a market price, then a hypothetical value is the only way to establish or assess any economic costing (Tietenberg 2004). Since biodiversity cannot be ignored as a significant economic impact, the contingent valuation method was used to establish a hypothetical value for biodiversity. In assessing the non-market values for environmental assets affected by the lionfish, it is difficult to establish the economic costing for biological and ecological changes in the marine habitats caused by the lionfish. For instance, the lionfish can affect the food-web, change species niches', and potentially destroy different microhabitats (Tilman2004, Von Holle and Simberloff 2004). Deriving an economic costing for intrinsic ecological changes require research over an extensive period of time. As a result, the economic costing established from this paper would serve as a baseline cost to compare future trends with any extended economic research conducted on Lionfish in Jamaica.

THE ECONOMIC MODEL

In order to estimate the economic impact of the lionfish invasion in Jamaica, the Contingent Valuation Method was employed. The value derived will be based as the expressed value for Jamaica's Marine biodiversity; using this as a one year time frame for a point of reference for future comparison. The value is expressed as Total Willingness to Pay (TWTP) where:

$$TWTP = Mean\ WTP \times Target\ Population \qquad (1)$$

ESTABLISHING THE WILLINGNESS TO PAY

The willingness to pay model looks at the loss in value associated with the potential loss in marine biodiversity. Based on the premise that the lionfish poses the greatest threat to marine biodiversity (Sealey et al. 2008), an inverse relationship between the lionfish population and marine biodiversity is observed. This translates into a cost as the lionfish population increases, the value of the marine biodiversity will be lost.

Since a market price for marine biodiversity does not exist, then deriving a value for it requires establishing a hypothetical value. This hypothetical value is based on the importance of the marine biodiversity to the population and establishes their "willingness to pay" to protect it. The willingness to pay to protect the marine biodiversity in Jamaica is deduced by determining the probability that someone will contribute a stated amount to protect it. In determining the Total Willingness to Pay (TWTP), a Logistic regression model was used, also known as a bid function and expressed as:

$$F_{(Bid)}\ Log\ (Yes/1\text{-}Yes) = {}_0\gamma + {}_1\gamma\ (Bid) \qquad (2)$$

Where:
Log (Yes/1-Yes) = Ratio of willing to pay to not willing
${}_0\gamma$= Coefficient of auto generated constant
${}_1\gamma$= Coefficient of the Bid Variable
Bid = Bid offered to respondents

According to Hanemann(1989), using this bid function, the mean willingness to pay (WTP) of the sample is calculated as:

$$Mean\ WTP = \ln (1 + \exp (\beta_0)) / \beta_1 \qquad (3)$$

The Mean Willingness to Pay is then multiplied by the population for which the sampling framework is designed around to derive the Total Willingness to Pay (TWTP) which is expressed as the value for marine biodiversity.

RESULTS

The respondents that participated represented a wide cross section of stakeholders in the three parishes (Table 1). This included five stakeholder categories with the age ranges of under 18 years to over 50 years.

In deriving the hypothetical value for marine biodiversity, a variety of bids were offered to the different stakeholders in the sample area to determine whether or not they would pay that bid to protect it (Table 2).

Based on the results, 81% of the persons sampled were willing to pay their respective bid to protect the marine biodiversity. Using a Logistic Regression Model, the probability of a persons' willingness to pay is calculated using the Log Odds Ratio between willing to pay and not willing to pay. The Logistic Regression Model showed willingness to pay as a function dependant on the bid (Table 3).

Using the coefficients to calculate the Mean Willingness to Pay; where Mean WTP = ln (1 + exp (β_0)) / β_1 for which β_0 is the coefficient of the constant and β_1 is the coefficient of the bid variable in the Logistic Regression Model, the results were as follows:

$$\text{Mean WTP} = \ln(1+31.6025) / -0.135275 = -25.75$$

Table 1. The stakeholders categories and age of Respondents.

Age Group (years)	Fishers	Tourist	Dive Shop	NGO	Local
<18	0	0	0	0	12
18 – 25	3	0	4	3	2
26 – 30	2	2	8	4	5
31 – 35	17	1	7	1	6
36 – 40	29	7	2	1	7
41 – 45	14	4	2	1	2
46 – 50	7	3	0	1	1
>50	3	1	1	0	2
Total	**75**	**18**	**24**	**11**	**37**

Table 2. Respondents willingness to pay to protect marine biodiversity.

BID (US)	Willing to Pay	Not Willing to Pay	Total
5	31	5	36
10	29	4	33
20	32	5	37
50	22	10	32
100	19	8	27
Total	**133**	**32**	**165**

Table 3. Logistic regression model of willingness to pay to protect marine biodiversity.

	Coefficient	Standard Error	t-ratio	p-value
Constant	31.6052	1.68095	18.80	0.0003
BIDX	-0.135275	0.0329345	-4.107	0.0261

Considering the context of the methodology, then the negative sign is ignored thus the Mean Willingness to Pay for the North and West Coast of Jamaica is US$25.75. The population demographics from the Jamaican census (STATIN 2010) to derive the population of the three sample areas is presented in Table 4.

The total willingness to pay for the population of the three main areas where the research was conducted is:

$$(184{,}854 + 173{,}830 + 75{,}799) \times \text{US\$25.75} = \text{US\$11,187,937}$$

Therefore, the value of the marine biodiversity for the areas of St. James, St. Anns and Trelawny based on the responses as of June 2011 is US$11,187,937. Currently, this represents the potential loss in value from the destruction of the marine biodiversity. Or, the value gained from protecting the marine biodiversity from the Lionfish invasion.

Table 4. Population distribution in sample areas.

Sample Area	Population
St. James	184, 854
St. Anns	173, 830
Trelawny	75, 799

CONCLUSION

The lionfish invasion in Jamaica is an ideal example of the costs that Invasive Alien Species can cause an economy. Even though studies can generate some economic costing of invasions, the true economic impact can never be derived since these invasions impact numerous environmental system for which each is invaluable. Additionally, other economic costing of biological invasions will include the cost of programs and projects developed to manage and mitigate the invasion. Also, the public education campaigns can be seen as a secondary cost since public awareness is a critical management component of controlling biological invasions. The lionfish invasion in Jamaica has significant economic cost which will continue to grow unless some invasive population control plans and policies are not implemented. Future research is required to establish more detailed economic impacts. With further economic analysis, Jamaica can develop the appropriate cost effective policies required to manage biological invasions. This can lead to a change in the legislative approaches in dealing with the prevention and protection of Jamaica's ecosystems from future invasions.

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