

Final Report of the Project:
Quantifying the socioeconomic impacts of an invasive predator on marine ecosystems
Luis Malpica-Cruz

Executive Summary

Coral reefs provide valuable ecosystem services to the environment and to coastal communities. These services depend on the persistence of key ecosystem processes, many of which are currently affected by a myriad of stressors. The Pacific lionfish is an invasive predatory species introduced to the western Atlantic that is having detrimental effects on the ecology of invaded reefs, and potentially on associated socioeconomic activities. My research took place in areas of the Caribbean and Gulf of Mexico, where artisanal fishing and recreational diving activities occur. I combined ecological surveys and socioeconomic interviews to determine the vulnerability of reef-dependent activities to lionfish invasion.

Introduction

Coral reefs provide valuable ecosystem services, including food security and opportunities for ecotourism to coastal communities, particularly in developing countries. These services depend on the persistence of ecosystem processes, currently threatened by a myriad of stressors. Invasive species are ubiquitous stressors of marine ecosystems. The predatory Pacific lionfish (*Pterois volitans*) is a notable recent marine invader now established throughout the western Atlantic Ocean and Caribbean. This species has detrimental effects on the ecology of invaded reefs, and grave concerns exist about its related socioeconomic impacts.

Research Approach

My research took place in two main regions of Mexico: 1) The state of Veracruz, on the Gulf of Mexico, which supports a large artisanal fishing fleet that performs fishing activities in and around a large coral reef system, the Veracruz Reef System National Park; and 2) Cozumel Island in the Mexican Caribbean, home to the Cozumel Reefs National Park and to a large recreational diving industry, renowned as the top destination in Mexico to undertake recreational snorkeling and diving activities.

I combined ecological surveys with socioeconomic interviews to determine the vulnerability of reef-dependent socioeconomic activities to lionfish invasion. Ecological surveys helped me assess the status of lionfish invasion, which will ultimately affect through predation both fisheries yield and the aesthetic value of coral reefs. Socioeconomic interviews targeted the fishing and ecotourism sectors to reveal the dependence of both industries on coral reefs, mainly as a source of revenue and to a lesser extent for food provisioning.

In heavily invaded areas of the Caribbean, efforts aimed at removing lionfish have produced mixed success and appropriate management strategies are needed to mitigate impacts on native fish populations. This study will provide baseline information on the potential negative ecological and socio-economic effects of lionfish in recently invaded areas, and thus help local managers to devise and implement scientifically sound management and mitigation plans.

Activities Undertaken and Current Results Relating to Proposed Research Questions

1. Are lionfish fully established on the coral reefs of the Veracruz Reef System National Park (PNSAV) and Cozumel Reefs National Park (PNAC)?

To perform this part of the project we established collaborations with both the Veracruz Reef System National Park and Cozumel Reefs National Park management authorities. This enabled us to obtain the necessary permits to carry out underwater surveys in Veracruz and to establish working relationships with NGOs involved with lionfish monitoring programs in Cozumel. We also established collaborations with local researchers from the Fisheries and Ecology Institute from the Veracruz University and the Technological Institute of Boca del Río.

- Veracruz Reef System National Park

In early 2012, one lionfish was captured off the coast of Veracruz, in the Veracruz Reef System National Park (Santander-Monsalvo et al. 2012). Furthermore, reports from local authorities throughout 2012 suggest that this species is present along the coast in the Southern Gulf of Mexico. We surveyed 20500 m² in 2014, and 16000 m² in 2015 on 10 different reefs of the Veracruz Reef System (Figure 1). We followed lionfish focal search procedures outlined by Green et al. (2013), and followed monitoring guidelines established by the Canadian Council on Animal Care (Protocol No. 1084B-13). Based on surveys performed during this study we estimated lionfish densities of ~5 lionfish, and ~12 lionfish per Ha. in 2014 and 2015, respectively. Based on the surveys made and the generally low frequency of encounters, we are not certain whether these numbers reflect a self-sustaining population. Despite that the lionfish density we estimated doubled from 2014 to 2015 it was relevant noting the overall low increase, this compared to the rapid population growth it has shown in other invaded areas. However, based on invasion trends in other regions, it is safe to say that the lionfish invasion in this area is well underway and very likely that lionfish numbers will continue to increase in the following months.

- Cozumel Reefs National Park

Lionfish were first recorded in the Mexican Caribbean, off Cozumel Island, in early 2009 with subsequent sightings off the coast of mainland Mexico (Schofield 2010). Through a

collaboration and data analysis of surveys performed by the National Commission of Natural Protected Areas of Mexico and a local NGO (Conservation Biology, COBI, A.C.) we can be certain that the lionfish population in Cozumel is fully established, showing variable densities around the island (50 – 250 lionfish per Ha; CONANP 2013, unpublished results).

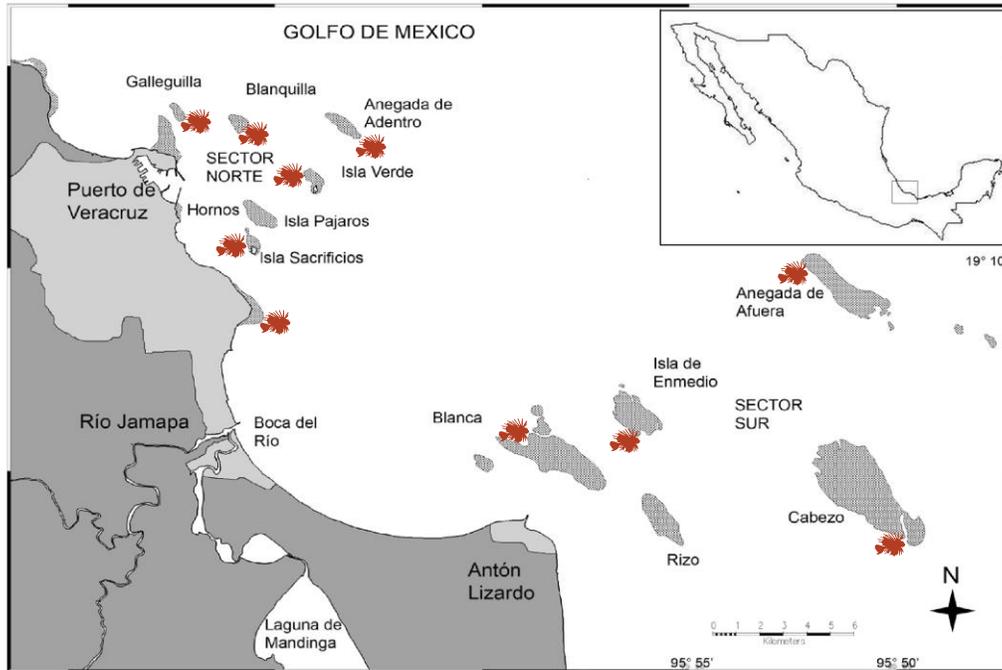


Figure 1. Location in Mexico and geographical area corresponding to the Veracruz Reef System National Park. Red lionfish silhouettes indicate reef locations where lionfish surveys were conducted for the first time during this project.

2. What are the potential impacts on local communities and economic activities of the lionfish invasion?

- Veracruz Artisanal Fisheries

We met with fishermen union leaders and organized a small workshop with interested spear-fishermen to present our general project and listen to their needs and concerns in relation to the lionfish invasion. Meetings occurred both in a formal and informal settings depending on fishermen availability and interest to meet with us.

We performed a total of 70 interviews with spear-fishermen from three towns associated with the Veracruz Reef System National Park: Chachalacas, Veracruz and Antón-Lizardo. We focused on spear-fishermen after approaching fishermen that fish using mainly nets or long-lines and learning that the latter mainly fish in open ocean areas near but not necessarily associated

with coral reefs. Spear-fishermen, on the other hand, were the most likely to interact with lionfish during their fishing activities, and indeed, a large proportion of them (>50%) had already captured lionfish.

In general, fishermen showed good awareness of the invasion and of the general ecological impacts it can produce. They were also interested in learning ways to mitigate the invasion, ways to treat injuries produced by the lionfish sting as well as interested in opportunities to commercialize lionfish. I am currently analysing data obtained by collaborators that will allow me to characterize this artisanal fishery better (i.e., numbers of fishermen, species catch rates, landings value, etc.), and data extracted from the interviews performed for this project. Both datasets will be needed to carry out the modeling effort to estimate economic impacts to the artisanal fishing communities depending on the Veracruz Reef System.

- Cozumel Diving and Snorkeling Industry

To perform this part of the project we contacted and created collaborations with local Cozumel National Park management authorities. This enabled us to establish connection and obtain necessary permits to have access to the local airport and ferry terminal facilities to perform interviews. This also enabled us to establish collaborations with local fishermen communities, dive shops and NGOs, all of which are deeply involved with the lionfish invasion.

We performed 450 interviews of tourists, most of them foreign visitors, which were undertaking snorkeling and/or scuba diving activities in Cozumel. Interviews were performed during the peak tourism seasons (summer and winter 2014). Interviews were made at the airport, ferry terminal, and dive shops to assess the largest and most homogeneous tourist diver population possible. Interviews were made using electronic tablets (ipads) and the “Fluid Surveys” online surveying system. Survey complied with guidelines and requirements established by the Research Ethics Committee at Simon Fraser University (Study Number: 2014s0293).

Analysis of these data is on-going, using a latent-class modeling approach based on multinomial conjoint analysis with the Latent Gold software. Modeling results so far indicate that divers and snorkelers have distinct preferences and attitudes towards the presence and type of strategies that could be used to manage the lionfish invasion; however, both tourist groups have very similar preferences regarding other environmental attributes of coral reefs, such as the presence of large predatory fishes, overall coral cover and reef complexity. I am currently refining these early models before incorporating them into a decision support tool. This latter step will allow me to estimate any economic impacts to the Cozumel diving and snorkeling industry of the lionfish invasion, as well as tourists’ support for management strategies in Cozumel.

3. *What are the most effective control and mitigation strategies to reduce the socio-economic impacts of the lionfish invasion in the Veracruz area?*

As this research project was being developed, local authorities began to implement some lionfish management strategies in the Veracruz Reef System. All management strategies were made following recommendations outlined in the recent handbook “*Invasive Lionfish: A Guide to Control and Management*” (Morris, 2013), as well as by following strategies taken in other invaded areas of Mexico. The first strategy was to raise an awareness campaign using media (radio and TV), and place posters in public areas to distribute information to the community. Awareness posters were also placed in local dive shops, thus targeting tourists visiting the park. Managers then organized and held a lionfish tournament, followed by a gastronomic festival offering lionfish dishes. The effort placed into these activities indicates the importance for local authorities to manage the lionfish invasion.

When reviewing the management plan devised by local park authorities in Veracruz, I identified four key weaknesses:

- Lack of comprehensive lionfish monitoring program
- Lack of coordination with local dive shops to control lionfish invasion
- Lack of coordination with the local Aquarium, which could help to facilitate the awareness campaign of the invasion with local and nearby communities
- Lack of coordination with the different groups that comprise the spearfishing community

Most of the weaknesses of this management plan are the result of antagonism between different groups due to an adverse political climate after the approval of a port expansion. It is obviously beyond the scope of my project to try to resolve these broader political tensions. Nevertheless, the lack of a comprehensive monitoring program is worrisome, particularly in light of the local government’s effort to implement lionfish control in the form of a lionfish spearfishing tournament in late 2013.

Lionfish removals are efficient strategies used to control lionfish populations locally. They often involve local communities and help to create awareness of the invasion. The NGO Reef Environmental Education Foundation (REEF) has organized several successful lionfish spearfishing tournaments, mainly in the United States and The Bahamas. The recreational diving community actively sponsors and participates in most of these tournaments (REEF website). The events are typically short (24 hrs), occur infrequently (a few times per year) and are held in areas with large lionfish populations so that hundreds of lionfish are captured in a single day. In contrast, the Veracruz tournament occurred in an area only recently colonized by lionfish, targeted the local fishing rather than diving community, was fully sponsored by government

federal funds, and was a protracted event lasting months. The end result was the capture of only ~500 lionfish in over 90 days (CONANP, pers. comm. June 2014). These low lionfish catches are now acting as a disincentive for the participants as well as the managers, who invested much time and effort into fund-raising and organization. Given the low numbers returned by the first tournament, managers now consider the value of further similar tournaments and of lionfish monitoring programs to be limited.

This is not to say that lionfish tournaments could not be useful in Veracruz or other parts of Mexico. However, tournaments should be planned based on solid monitoring programs to assess the potential benefit as well as the impact they could have on the lionfish populations (Barbour et. al. 2011). These observations have led me to collate for the first time the results of lionfish tournaments from the tropical North Western Atlantic, Gulf of Mexico and Caribbean, with the goal of identifying the factors that drive the success (or failure) of lionfish tournaments. I am currently analyzing this extensive dataset.

One strategy I helped to initiate for the region was to design an online lionfish website that includes general information on the goals of the project and on the impacts of the lionfish invasion as a tool to create awareness in the population. Most importantly, it contains an online lionfish sighting system that is now functional and available for managers, divers and fishermen operating in and around the Veracruz Reef System to contribute to and to consult. This online system is hosted on the website of the local environmental NGO ECOCIMATI, has no cost to use and anyone can request the information that will be stored in the system. While similar lionfish reporting systems exist in the United States (USGSS, NOAA and The Nature Conservancy), this is the first in Latin America and in Spanish and will allow the construction of a database to help managers design monitoring and removal efforts. We will offer this platform to other areas of the lionfish invaded range in Central America and the Caribbean to expand its impact and success (lionfish sighting system website: <http://ecocimati.org/lionfish/>).

Current State of Project and Future Steps

As stated in each section, all field activities planned were successfully accomplished and data compilation completed. We currently have preliminary results and full data sets are currently being analyzed. In the following months I expect to complete these analyses, develop them into papers/thesis chapters and present them to my supervisory committee. I will provide a copy of the manuscripts and thesis to the RSGF as these products become available.

A positive by product of this project is that using the data collected from this project, the NGO ECOCIMATI will soon present a proposal to the Veracruz Reef System National Park managers to establish a formal monitoring program and pilot removal project through collaboration with local spear fishermen and researchers. This project envisions periodic

removals of lionfish in specific areas as well as continuing the assessment of the lionfish invasion process. Potentially this project will also shed light on the causes of the apparent slow growth the lionfish population is presenting in the Veracruz Reef System, to aid in the better understanding of this and other marine invasions.

ECOCIMATI will also coordinate workshops with the participation of fishermen from Cozumel, to share experiences and strategies relating to the creation of a lionfish fishery in Veracruz. Lastly, ECOCIMATI will coordinate the participation of a representative of the Cozumel Fishermen Union, to the Gulf and Caribbean Fisheries Institute Conference taking place in Panama on November of 2015. Here relevant results from this project will be presented to regional management stakeholders to further inform lionfish control and management strategies.

Calendar of Activities

Activity	Spring-Summer 2014 (Mexico)	Fall-Winter 2014-2015 (Mexico)	Spring-Summer 2015 (Mexico-Canada)
Ecological surveys			
Workshops and meetings with fishermen			
Socioeconomic surveys			
Data analysis and modeling			
Write final report in English and Spanish			
Present results in workshops and meetings with local entities and stakeholders			
Prepare articles for peer-review			

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