



## Original Research Article

## A comparison of eight country plans for the Invasive Indo-Pacific Lionfish in the Wider Caribbean

Roxanne E. Graham, Lucia M. Fanning\*

Marine Affairs Program, Life Sciences Centre, Dalhousie University, Room 800, 1355 Oxford Street, PO Box 15000, Halifax Nova Scotia B3H 4R2, Canada



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## ABSTRACT

The effects of climate change and marine invasive species have posed a major threat to significant ecological, aesthetic, economic and amenity value to the countries and territories of the Wider Caribbean Region. Today, the Caribbean Sea is plagued with the invasive lionfish (*Pterois volitans* and *P. miles*). As the range and abundance of the lionfish throughout the Caribbean has grown, recognition of the grave threat it poses to the native marine ecosystems has prompted the development of lionfish management plans across the region. The efforts of eight countries in the region to manage lionfish are evaluated using the US Environmental Protection Agency Aquatic Invasive Species framework and the inclusion of climate change and/or changing conditions. The countries and overseas territories evaluated were Anguilla, Bahamas, Cayman Islands, Grenada, St. Eustatius, St. Lucia, St. Vincent and the US Virgin Islands. Although specific strategies differed amongst the islands depending upon needs, culture, and individual circumstances, most of the plans included aspects of education and outreach, control and monitoring protocols, and research and information management. Areas that were found to be notably weak to nonexistent included leadership, prevention, early detection and rapid response and restoration; This comparative analysis provides opportunities for knowledge sharing and intra- and inter-country cooperation, facilitating the transfer and development of interventions that contribute to the conservation of significant island biodiversity.

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## 1. Introduction

Aquatic Invasive Species (AIS), particularly those in the marine environment, is an issue rapidly increasing in importance and relevance in the Caribbean but thus far, little has been done to address the problem through marine planning and management (Kling and Sanchirico, 2014). As nations become more interdependent and trade continues to flourish, the problem of invasions, defined as species that are not origin to a given region, is becoming more difficult to handle (Kannan, 2015). The current scientific discourse suggests that invasive species, “due to their lack of co-evolutionary history with the native environment” (Simberloff, 2005), may cause significant ecological impacts on native species and their habitat, leading to economic and social impacts for communities that depend on these resources. Some of these negative effects include displacement of native species, loss of native genotypes, changes in community structure, foodweb properties, ecosystem

\* Corresponding author.

E-mail addresses: [roxanne.graham@dal.ca](mailto:roxanne.graham@dal.ca) (R.E. Graham), [lucia.fanning@dal.ca](mailto:lucia.fanning@dal.ca) (L.M. Fanning).

processes and services, impacts on human health, and the potential for substantial economic losses (Carballo-Cárdenas, 2015; Katsanevakis et al., 2014; Layman and Allgeier, 2012). Despite an increased awareness of invasion problems in the scientific community, national governments continue to fall short on implementing preventative measures to detect or counteract their emergence, tending more towards reactive policies aimed at managing invasive species that are already established and problematic (Early et al., 2016; Kannan, 2015). In terms of response management, marine environments present exceptionally challenging conditions for the control of bio-invasions due to the absence of clear borders which severe limits management options in three dimensions (Lopez and Krauss, 2006).

One such invasion and corresponding need for improved response management has recently unfolded in the Wider Caribbean Region (WCR) (Albins, 2016; Andradi-Brown et al., 2017). According to Côté et al. (2013), it is at a rate and magnitude never before documented in any marine system. It involves two species of Indo-Pacific lionfish (*Pterois volitans* and *P. miles*), which represent the first non-native marine finfish to become established in the Atlantic waters of the United States, including the Gulf of Mexico and Caribbean (ANSTF, 2015). The resulting impacts of the invasion in the WCR have been ecological, economic and social.

As an invasive species to the Caribbean, the lionfish, with no known predator, voracious appetites and high rates of reproduction, has the competitive advantage over native species (Albins, 2013; Lesser and Slattery, 2011; Kulbicki et al., 2012; Rocha et al., 2015; Simmons, 2014). Lionfish abundance increased rapidly between 2004 and 2010 in the Atlantic Ocean and Caribbean Sea (Green et al., 2012). By 2010, lionfish comprised nearly 40% of the total predator biomass in the system, coinciding with a 65% decline in the biomass of the lionfish's 42 Atlantic prey fishes in just two years (Green et al., 2012). Additionally, lionfish have been found to have reduced the abundance of small native reef fishes by up to 95% at some invaded sites (Côté et al., 2013) while some studies have found no measurable effect on prey fish community structure (Hackerott et al., 2017).

Economically, in addition to preying on or outcompeting commercially valuable species leading to a decrease in the economies of fishing communities (Ballew et al., 2016), lionfish may also impact the recreational sector and local tourism due to a perceived absence of attractive game and reef cleaning species (Morris and Whitfield, 2009). From a human health perspective, an increasing concern is the capacity for lionfish to inject neurotoxins dangerous to humans (and other animals) from stout spines on several of the main fins, requiring immediate professional medical evaluation and treatment (Haddad et al., 2015).

Given these diversity of issues needing to be addressed, management and control actions of lionfish have been challenging at best (Bratspies, 2013; Hackerott et al., 2017; Morris, 2012; Peiffer et al., 2017). While there is a Regional Strategy for the Control of Invasive Lionfish in the Wider Caribbean (Gómez Lozano et al., 2013), it lacks an assessment and evaluation tool to guide and report on collaboration. Efforts have been localized and not well coordinated across agencies or with other stakeholders (ANSTF, 2015). Additionally, climate change has been shown to benefit some marine invasive species due to range shifts and competition effects (U.S. Environmental Protection Agency (EPA), 2008). For lionfish, research has illustrated the possible correlation between temperature rise and their spread. Small changes of 1 °C in winter bottom water temperatures have already shifted the species balance in some marine ecosystems from tropical towards temperate communities (Burgiel and Muir, 2010; Figueira and Booth, 2010).

The aim of this research is to provide a comprehensive perspective on localized and regional lionfish management practices and challenges in the Caribbean and to determine their adaptive capacity to adjust to climate change and other changing conditions. It does this by conducting a comparative analysis of lionfish management plans in eight islands in the WCR. The countries evaluated were Anguilla, Bahamas, Cayman Islands, Grenada, St. Eustatius, St. Lucia, St. Vincent and the US Virgin Islands. We provide an assessment of the management activities for lionfish control in the Wider Caribbean, and analyze each of the selected country plans for adaptive capacity under possible changing conditions. We also identify opportunities and obstacles to enhancing the Caribbean's current approach to managing the invasive lionfish.

## 2. Method

The countries in this study were selected on the basis of the accessibility and availability of country plans. Due to time and language restrictions, case studies for analysis were limited to English-speaking countries in the Caribbean with lionfish management plans. Documentation on the plans for the eight countries and territories used in the study included both those provided by relevant national informants and those available on the internet. Wherever possible, currency of the plans was confirmed by national informants attached to the relevant institution or government department. National informants also shared detailed information on some of the management practices that were lacking in the plan and provided needed clarification to questions from the researchers.

The analytical framework used to assess the responsiveness of the management plans was the US Environmental Protection Agency (USEPA) Aquatic Invasive Species (AIS) Management Framework (Premo et al., 2014). Despite the geopolitical differences of the countries within the WCR, most effective regional plans associated with coastal and marine management use a strategic management framework (Department of Fisheries and Oceans Canada (DFO), 2004) and offer specific guidance and assessment tools to ensure countries are addressing key aspects of management (Halpern et al., 2012). Since the USEPA AIS Management Framework is the standard and leading example of a framework used for assessing AIS management performance in states and territories within the US, including those in the Caribbean (Premo et al., 2014), we decided to use it as our reference guide. We acknowledge the similarity between this framework and the Wider Caribbean Regional Strategy

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