Future Planning for Marine Invasive Species in the Wider Caribbean and in the Face of Climate Change: A Comparison of Eight Country Plans for the Invasive Indo-Pacific Lionfish

La Planificación Futura de las Especies Invasoras Marinas en el Caribe y en la Cara del Cambio Climático: Una Comparación de Ocho Planes Nacionales para el Indo-Pacífico Invasoras Pez León

La Planification de L'avenir des Espèces Envahissantes dans la Région des Caraïbes et dans le Contexte du Changement Climatique : Une Comparaison de Huit Pays des Plans pour L'Indo-Pacifique Envahissantes Poissons Lion

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EXTENDED ABSTRACT

Introduction

A subject of increasing concern globally, especially for the future is that of invasive species, which causes displacement of native organisms. They further pose a threat to native habitat, the economy and human health (U.S. Fish and Wildlife Service, 2013) and can have social implications as well. Some of the most notorious are invasions by marine species, which have severe impacts on marine and coastal ecosystems where they proliferate (LaJeunesse et al. 2016), and the problem of marine invasions is only becoming more difficult to handle (Kannan 2015). According to Early et al. (2016), reactive national policies aimed at managing invasive alien species (IAS), that are already established and problematic in a given country tend to be more common than having proactive policies to detect or counteract the emergence of potential invasive alien species.

One such invasion and need for improved response management has recently unfolded in the Wider Caribbean and involves two species of Indo-Pacific lionfish *(Pterois volitans and P. miles*). Lionfish threatens the marine and estuarine communities in the Caribbean region. They cause a number of ecological, economic, human health and social problems (Artigues and Morton 2015). In addition to negatively impacting the native ecosystem, climate change also facilitates their establishment and increasing range extensions of the invasive species. This occurs mainly through elevated sea surface temperature, increased frequency, duration and magnitude of storms and hurricanes (Gómez et al. 2013).

Management and control actions of lionfish in the Wider Caribbean territorial waters has been challenging at best. Management is complex at the local and regional level as local activities influences the effectiveness of regional management and vice versa. As their range continues to grow and their abundance increases (Morris et al. 2011) recognition that the lionfish poses a grave threat to the native marine ecosystems prompted the development of lionfish management plans across the Wider Caribbean region. As part of the International Coral Reef Initiative, Gómez et al. in 2013, published the Regional Strategy for the Control of Invasive Lionfish in the Wider Caribbean. However, according to ANST FORCE (2015), efforts have been localized and not well coordinated across agencies or with other stakeholders. Thus, the objectives of this research include:

i) To assess the categories of management in plans for lionfish control in the Wider Caribbean,
ii) To assess each country plan for adaptive capacity for changing conditions (i.e. adjusting in response to climate change), and
iii) To identify the opportunities and obstacles to enhancing the Caribbean's approach to managing the lionfish in this changing climate.

In accomplishing these objectives, this study aims to provide a comprehensive perspective on localized and regional lionfish management practices and challenges in the Caribbean and to determine their adaptive capacity *i.e. their ability to integrate climate change and changing environmental conditions into response and management planning*. Scientists and planners can use the findings and recommendations of this study in revising current plans for lionfish and preparing future well-coordinated plans for marine invasive species (MIS).

Methodology

The Regional Strategy for the Control of Invasive Lionfish in the Wider Caribbean lacks an assessment tool for guiding and evaluating local management plans and outcomes. Thus, the research uses the US Environmental Protection Agency (US-EPA) Aquatic Invasive Species (AIS) Assessment.

Desk research was conducted using eight (8) Caribbean countries' response and management plans (and supplemental workshop planning documents from Joint Nature Conservation Committee) for the lionfish. The countries included

Anguilla, the Bahamas, Cayman Islands, Grenada, St. Eustatius, St. Lucia, St. Vincent, and the US Virgin Islands.

First, an assessment was done on the management categories according to the US National Invasive Species Council (NISC) for MIS including leadership and coordination, prevention, early detection and rapid response (EDRR), restoration, research, information management, and education and public awareness. A comparison Matrix (refer to Figure 1), represents the results and also highlights the similarities and differences in plans across countries. Second, management plans were assessed with reference to incorporating climate change and/or changing environmental by examining the: capacity to adapt to changing conditions (using the management categories); potential impacts resulting from climate change/changing conditions; monitoring strategies; periodic revision and update; and funding sources/strategies for plan implementation.

Results and Discussion

The assessment of the categories of marine invasive species management revealed that the highest scoring country was the US Virgin Islands, with seventeen (17) points out of the possible twenty-four (24) points, followed by the Cayman Islands with thirteen (13) and other countries scored lower. The USVI score is highest, possibly in part of them being a U.S territory, and being guided by the US NISC. As it relates to the other countries, a re-evaluation and update on the management framework, using similar US-EPA guidelines, is needed. The major weaknesses derived after assessing the categories of management in the plans for lionfish in the Wider Caribbean were related to EDRR, prevention and restoration. EDRR was non-existent to seldom among the eight (8) country plans. EDRR should be required among plans to train and equip stakeholders with the skills and resources needed to better detect new lionfish invasions within territorial waters and to generally reduce marine invasive species in the Wider Caribbean. In terms of prevention, most plans, with the exception of USVI, does not specify any form of this category. There are two main types of preventions mentioned in the regional strategy and USVI's plan. Since both acknowledged that preventing more lionfish from entering into territorial waters is highly complex and not an option, first there is the option of preventing increased growth of lionfish population. Second, is the prevention of negative effects, such as significant decreases in native species that are economically and ecologically viable, or the endangerment to public safety. As it relates to restoration of affected ecosystems, one hundred percent (100%) of plans did not account for this. This is not necessarily surprising. Caribbean countries do not know the status of their marine ecosystem, nor do they know what fraction or direct negative impacts upon marine biodiversity is due solely to the lionfish (Miloslavich et al. 2010). Coastal restoration projects usually occur due to other issues e.g. mangrove rehabilitations. Perhaps, considering the implications of lionfish control or lack thereof could be worth considering.

According to the US-EPA (2008), it is important to build in considerations of changing conditions into a country's management actions. While most country plans do not specifically mention climate change or changing conditions, the assessment reveals that these countries have the potential or capacity to adapt their program or activities accordingly (Refer to Table 1). By adopting a comprehensive plan such as the NISC's and coordinating our efforts, as well as and considering climate change like as proposed in the US-EPA framework, managers can help minimize the spread of the lionfish and potentially like invasions.

The identification of funding indicates an overall high capacity for states to accomplish tasks in management plans. With the exception of St. Eustatius and St. Vincent, six of the eight countries have identified funding or has a strategy prepared for obtaining the necessary funding and resources.

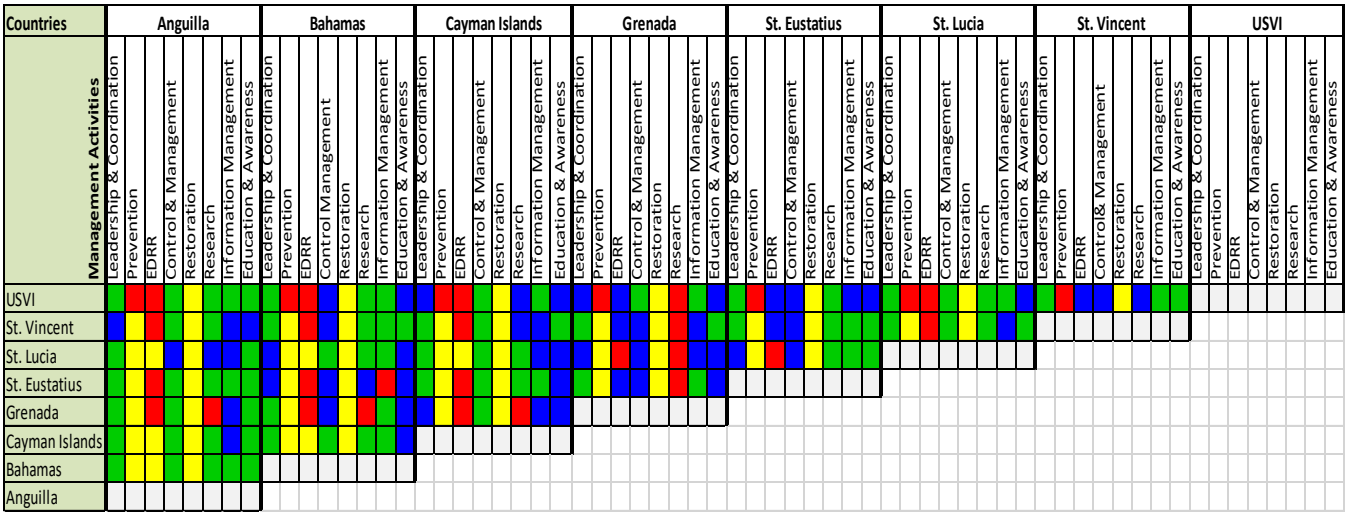

Figure 1. Comparison Matrix: illustrating the level of each country's commonality related to the management activities set for the invasive lionfish. Red boxes- No Match (no activity vs. brief and upward); blue boxes-Complete Match (at similar stage); green boxes- At different stages; yellow boxes- No Action- Similar "0" Stage; gray boxes-Not applicable

Table 1. Total score and ranking for 8 countries' management plan with consideration of climate change.

COUNTRY	Capacity to adapt to changing conditions	Understanding and incorporating potential impacts resulting from climate change	Monitoring Strategies	Strategy for updating an incorporating new information	Dedicated funding source or strategies for implementation	Score	Rank among 8 countries
Anguilla	2	6	0	1	3	12	6th
Bahamas	7	5	4	1	2	19	2nd
Cayman Islands	3	2	4	1	1	11	7th
Grenada	4	5	1	0	3	13	5th
St. Eustatius	8	5	4	1	0	18	3rd
St. Lucia	3	1	2	1	3	10	8th
St. Vincent	6	4	3	1	0	14	4th
USVI	8	4	5	1	2	20	1st

Conclusions and Recommendations

The similarities and differences identified in this study can be used by consultants or managers to enhance regional planning. The regional strategy also needs to have an assessment and evaluation tool similar to that of the US-EPAs for better guidance in local planning, implementing and evaluation of goals and actions items. For instance, prevention of MIS is complicated. Thus scientist, planners, perhaps Departments of Fisheries and other relevant stakeholders need to begin formulating EDRR and restoration activities.

Changes in coastal and marine ecosystem for example, can make conditions either more favorable for lionfish and future introductions while at the same time suppressing native species or causing them to move into temperate oceans. Thus, using this information in future planning especially regionally, will result in more informed and appropriate planning. This research illustrated how the status and trends of climate change in lionfish management or future MIS management underscores the need to consider climate-change effects in every part of marine invasive species management plans and programs in order to address them effectively. Incorporating current and predicted changing conditions or including climate change adaptation strategies through stakeholder consultations is advised when preparing new or updating old lionfish response plans. This will also be useful for potentially new introductions and invasions of marine finfish species.

Given the overall results and discussion, islands should be better prepared in future for controlling the lionfish and for possible new introductions of finfish invasive species. Countries (especially those in proximity e.g. St. Vincent and Grenada) are encouraged to understand how other countries are operating in control and management of marine invasive species like the lionfish. USVI was ranked at the top and could serve as model example for future planning. Case in point, USVI have been cooperating with neighboring countries (British Virgin Islands and Puerto Rico) on marine invasive-species issues. Similarly, Caribbean countries could begin to collaborate by starting to work with their neighbor countries.

KEYWORDS: Caribbean, lionfish, climate change, management, compare

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