The Invasion of Indo-Pacific Lionfish in the Bahamas: Challenges for a National Response Plan

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ABSTRACT

The invasion of the Indo-Pacific lionfish to Bahamian waters raises considerable concern due to the uncertainty of its ecological impacts and its potential threats to commercial fisheries and human safety. Lionfish have been reported throughout the archipelago and are the focus of several research and monitoring initiatives. The Bahamas has a National Invasive Species Strategy, but marine invasions require unique partnerships for small islands developing states to develop realistic management goals and actions. The Government of The Bahamas has limited funds to address major resource management issues; hence, collaboration with non-governmental agencies and tertiary education institutions is imperative. The establishment and spread of lionfish has created a novel opportunity for the formation of innovative public-private partnerships to address the ecological, economic and social impacts of biological invasions.

KEY WORDS: Lionfish, invasion, reefs

La Invasión en las Bahamas del Pez León del Indo-Pacifico: Un Caso de Investigación, Planificación, y Manejo

La invasión del pez león del Indopacífico en las aguas de Las Bahamas ha generado una gran preocupación debido a la incertidumbre sobre su efecto ecológico y la posible afectación a la pesca comercial, el turismo y la seguridad de la población. El pez león se ha registrado en todo el archipiélago y ha sido objeto de investigación y monitoreo. Aunque Las Bahamas posee un Plan Estratégico Nacional para las Especies Invasoras, las marinas requieren de esfuerzos institucionales conjuntos para recopilar y analizar la información, lanzar iniciativas educativas, y elaborar medidas realistas de manejo. El gobierno de Las Bahamas posee fondos limitados para enfrentar los problemas prioritarios de manejo; por eso es indispensable la colaboración con agencias no gubernamentales e instituciones terciarias de educación. La invasión del pez león ha creado una oportunidad para la formación de asociaciones innovadoras entre instituciones privadas y públicas con el fin de abordar las consecuencias ecológicas, sociales y económicas de los invasores biológicos.

PALABRAS CLAVES: Pez león, invasión, arrecifes

L'invasion des Rascasses de L'Indo-Pacifique aux Bahamas: Problèmes de Recherche, D'éducation et de Gestion

L'invasion de la rascasse de l'indo-pacifique dans les eaux des Bahamas génère une grande préoccupation liée à l'incertitude de ses impacts écologiques et de ses répercussions possibles sur la pêche commerciale, le tourisme et la santé humaine. La rascasse a été observée sur l'ensemble de l'archipel et fait l'objet de plusieurs programmes d'études et de surveillance. Les Bahamas possèdent un plan stratégique national contre les espèces invasives mais les espèces marines nécessitent des collaborations institutionnelles fortes pour compiler et analyser les informations, promouvoir des programmes éducatifs et développer des moyens réalistes de gestion. Le gouvernement des Bahamas possède des fonds limités pour répondre à ces questions majeures de gestion des ressources, c'est pourquoi il est indispensable d'avoir des collaborations avec des agences non gouvernementales et des institutions éducatives. L'invasion des rascasses a créé une nouvelle opportunité pour la formation d'associations innovantes public-privé dans le but d'analyser les conséquences écologiques, sociales et économiques des envahisseurs biologiques.

MOTS CLÉS: Rascasse, Bahamas

INTRODUCTION

The Commonwealth of The Bahamas faces significant challenges in the management and protection of marine resources over the 1,200 kilometer-long archipelago. Stressors on the marine environment include overfishing, marine and terrestrial sources of pollution, climate change, and invasive species. Biological invasions involve both human and non-human mediated forms of dispersal in which non-native species successfully arrive, survive, and reproduce in a novel locality and then spread throughout a region (Carlton 1987, 1989). The establishment and spread of exotics represent one of the most pressing threats to the diversity and distinctiveness of ecological communities (see Clavero and Garcia-Berthou 2005, Lowe *et al.* 2000, Sax and Gaines 2008, McKinney and Lockwood 1999, 2005, Vitousek *et al.* 1987). Moreover, the rate and magnitude of species introductions are increasing worldwide while the economic costs associated with the impacts and control of invaders are estimated in billions of dollars per year in the US alone (Lowe *et al.* 2000, Pimentel *et al.* 2000, 2005).

Addressing the current state of invasions is therefore a daunting task for even the most well-equipped management teams. Invasive species management underscores the long-standing tension between decision-makers' need for a rapid, cost-effective and yet, scientifically-informed response to environmental issues and the incremental nature of advances in scientific knowledge. On the one hand, emergent crises demand a timely and viable response to both real and perceived public concerns. On the other hand, the technical and scientific expertise required to guide management options often involves a comparably slow development process. This strain is further exacerbated in small island developing states in which the threat from invasions is high and an immediate concern but national capacity to address the issue in terms of monetary resources and scientific expertise is limited. The recent introduction of the venomous Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) to the Western Atlantic Ocean brings to focus the substantial challenges faced by small developing nations such as The Bahamas to effectively manage high priority invaders and develop realistic prevention and early detection programs for other exotics.

Invasive species management is a long-term proposition that entails partnerships between both local and regional governmental and non-governmental agencies. Accurate and continually updated scientific knowledge in addition to ongoing monitoring is critical to understanding the risks associated with lionfish establishment and spread. The National Invasive Species Strategy for The Bahamas provides a good starting point for work in this area (BEST 2003), but the unique challenges presented by such a widespread and venomous marine invader may require a greater degree of innovation. This paper presents a brief overview of:

i) The unique challenges in creating a NRLP, especially in establishing a central focused goal;
ii) Management options for a NRLP, and
iii) Assessment of stakeholder grounds, and potential partnerships for a NRLP.

Part of the introduction to the management issues is a short review of lionfish ecology and the invasion history. A summary of events related to the Lionfish invasion of The Bahamas is presented in Appendix 1.

LIONFISH ECOLOGY AND INVASION HISTORY

Lionfish (Pteroinae) are a subfamily of the scorpionfishes (Scorpaenidae). There are 17 different species of lionfish that occur within five different genera (Kochzius *et al.* 2003). All *Pterois* species contain venomous dorsal, anal and pelvic spines (Randall *et al*. 1997). *Pterois volitans* (Linnaeus 1758) and a closely related form, *P. miles* (Bennett 1828), share similar morphological resemblance and are generally considered to be allopatric sibling species native to the sub-tropical and tropical waters of the Indo-Pacific, where they are carnivorous mid-level predators on coral, rocky and sandy substrates (Schultz 1986, Fishelson 1997). *P. volitans* has a pelagic egg and larval stage, matures between 180 - 190mm and can grow up to 350 mm or more in total length (Fishelson 1997, Imamura and Yabe 1996). Lionfish have few natural predators most likely due to the venomous nature of the species. In the Indo-Pacific, Bernadsky and Goulet (1991) report an isolated case of a pacific cornetfish *Fistularia commersonii* that consumed a juvenile *P. miles,* while in its invaded range of The Bahamas, groupers may be a potential predator. This is supported by the discovery of juvenile *P. volitans* in the stomachs of adult Nassau grouper, *Epinephelus striatus,* and tiger grouper, *Mycteroperca tigris* (Maljkovic *et al*. 2008).

Lionfish occur outside of their native range in the Mediterranean Sea as well as the Atlantic Ocean. *Pterois miles* entered the Mediterranean Sea via the Suez Canal as a Lessepsian migrant (Golani and Sonin 1992) while both *P. volitans* and *P.miles* were most likely introduced to the Western Atlantic in the early 1990s off the coast of Florida via aquarium releases (Courtney 1995, Hare and Whitfield 2003; Ruiz-Carus *et al.* 2006, Semmens *et al.* 2004, Whitfield *et al*. 2002). *P. volitans* is now established and abundant along the US southeast continental shelf, Bermuda and several Caribbean countries including The Bahamas, The Cayman Islands, Cuba, and The Turks and Caicos (Albins and Hixon 2008, Hare and Whitfield 2003, Meister *et al.* 2005, Ruiz-Carus *et al*. 2006, Snyder and Burgess 2006, USGS NAS Database 2008, Whitfield *et al.* 2002, 2007). Since 2008, lionfish have also been reported in the Dominican Republic, Jamaica and St. Croix (Guerro and Franco 2008, USGS NAS Database 2008). Unlike *P. volitans,* which is now widespread and abundant in the Atlantic, *P.miles* has only been observed in its invaded range in relatively small numbers along the US eastern seaboard (Hamner *et al.* 2007). The overall impact of lionfish in the Atlantic remains largely unknown, but many suggest that the species will negatively affect marine communities by decreasing the abundance of a wide range of reef associated fish via direct predation and competitive interactions in which lionfish monopolize food resources (see Albins and Hixon 2008, Hare and Whitfield 2003, Whitfield *et al.* 2007).

UNIQUE CHALLENGES TO INVASIVE SPECIES MANAGEMENT IN THE BAHAMAS

The Bahamian archipelago is a unique ecological system, with real limitations to how much humans can alter the landscape without irreversible changes to the environment. Invasive alien species has been recognized an important cause for the loss of national biological diversity of both natural communities and species. The primary environmental sensitivities are related to water use, nutrient cycles and island hydrology, and link coastal land use to the adjacent marine resources. Thus, the vulnerability of The Bahamas to near shore marine invasive species is very high. The Government agencies and non-government

organizations have a high level of problem recognition and awareness, yet the general population has a poor understanding of what an "invasive alien species" is. Many invasive alien plant species such as the Australian pine (*Casuarina equestifolia*) are long established in the country, and considered part of the natural landscape. The challenge of just being able to monitor the ecology of an archipelago with 30 different island population centers is substantial. The management of invasive species requires a coordinated response between many different islands with varying capacities. Like many environmental issues, the threat invasive species is the consequence of inadequate infrastructure, regulation and planning both for the fast-growing population on New Providence, and the emerging Family Island communities.

MANAGEMENT OPTIONS

The consensus at the fall 2008 Lionfish Stakeholders' Meeting for The Bahamas was that there is an urgency to develop and implement a National Lionfish Response Plan (NLRP) in lieu of the precautionary principle. The mission of a NRLP should be fourfold:

i) To maintain the distinctiveness and diversity of Bahamian marine communities,
ii) To protect commercially important fisheries,
iii) To safeguard public health, and
iv) To reduce the growth and spread of lionfish populations.

Ideally, the ultimate goal of a NLRP would be the eradication of lionfish and prevention of a possible re-introduction of the species. Realistically, the goal would be to reduce lionfish population growth and spread in targeted areas such as Marine Protected Areas and beaches frequently used by the general public. For any invasive species management plan to be effective it must be informed by sound science, objective data and the financial reality of those charged with its implementation. Table 1 presents a summary of potential lionfish management options suggested at the fall 2008 Lionfish Stakeholders' Meeting. Each option was subjectively ranked by meeting attendees. However, we emphasize that none of these managements options can be implemented or seriously considered without prior rigorous scientific research and economic analyses of their viability.

STAKEHOLDER GROUPS AND POTENTIAL PARTNERSHIPS

One of the most remarkable aspects of the Indo-Pacific lionfish invasion is the wide range of stakeholders and resource user groups that are potentially impacted by its establishment and spread. The lionfish invasion is unprecedented for The Bahamas in terms of the scope of its potential impacts across many different marine and coastal resource user groups. Because of the large number of private businesses and individuals included in the stakeholder groups (Table 2), there are likely to be a number of privately funded initiatives independent of any government action. The geographic extent and rapid rate of spread of the invasion coupled with the large and diverse body of stakeholders demands an equally rapid and coordinated planning and implementation process on the part of the government.

One challenge in bringing together all the stakeholder groups is building a common body of information or knowledge, the "baseline" information on the lionfish and its impacts. Science-based management requires a close coordination between research and management decision-making. Emerging information from researchers emphasizes the challenges of management, and a NLRP requires engagement of all stakeholder groups for years to come. There are four "functional" components of the plan:

i) Accessing and the management of adequate funding,
ii) Lionfish research, information management and monitoring,
iii) Outreach and education on lionfish control and prevention efforts, and
iv) Revision and further development of invasion policy and regulations.

No component is more important than another, all components work in concert to implement a management plan.

The NLRP will require new and innovative approaches to resource management and regulation. In addition, new international partnerships should to be forged to meet the scientific research and information needs. The level of information exchange and sharing of resources would likely change dramatically when foreign researchers are engaged to help address a national research agenda. Table 3 outlines some basic research areas, with an assessment as to whether sufficient progress could be made with capacity within the country. Research done collaboratively with more student exchanges and formal training will serve to build the long-term resource management capacity. Perhaps the biggest challenge is developing a national data management system for natural resource and biological diversity management. The NLRP can be an initial step towards larger environmental management goals by providing the necessary public focus, funding and international collaborations.

CONCLUSION

The writing and implementation of a National Lionfish Response Plan for The Bahamas is a culmination of many long term efforts to implement broader "ecosystem management" of natural resources and build an integrated coastal zone management plan. The invasion of the Indo-Pacific lionfish is in many ways symptomatic of the overall challenges for Small Island Developing States (SIDS) to

address environmental threats that cut across government agencies and require additional scientific and technical capacity beyond the borders of the country. If The Bahamas can successfully plan and implement actions to control lionfish populations, it will be an important step forward in inter-departmental cooperation and private-public partnerships. The management actions require both regulatory and non-regulatory approaches to the invasion control, with a critical role assigned to public education and outreach programmes.

From the initial stakeholders meetings, it is clear that the overall level of "science literacy" in the country will come into play in building public support for management goals and actions. Fishers, diver operators and Family Island fisheries officers all have opinions on the movement, behaviour and ecology of lionfish based on observations and conversations, yet there is very little information about the science of fish population dynamics and invasion ecology. Often, this lack of "science literacy" leads to unrealistic expectations for management goals, and underestimates of the cost for management actions. Workshops and seminars are critical to bring accurate, factual and up-to-date information to a broad audience of stakeholders, and focus an educational outreach campaign on the broader science of invasive species. Marine alien species invasions are a threat to The Bahamian environment not only from the aquarium trade, but also through ballast water introductions associated with port operations. The focus of any outreach and public education campaign should be on both the specific stewardship actions required for individuals as well as the importance of a broader knowledge of the local environment and its ecology. Clearly, the areas in the above tables where there was a lack of stakeholder consensus were due largely to a lack of information or knowledge by some stakeholder groups. Managing expectations and getting the best lionfish population control results for the resources invested will depend on an aggressive and innovative outreach campaign.

This need for accurate and current information on the biology and ecology of lionfish in Bahamian waters may present some new challenges in partnerships between the Government of The Bahamas and foreign research permit holders. The control of lionfish populations will be a management issue for likely decades to come. The Bahamas would wish to both increase its internal capacity to study, analyze and archive information on invasive species, as well as build stronger and more collaborative relationships with foreign researchers working in the country. Special conditions or arrangements may be necessary on research permit holders to insure that results are presented back to the NLRP management team in a timely manner, and that datasets are available for compiling national archives and databases. A clear focus in management planning can help refine the requests for funding and research priorities. The Bahamas will play an important role as a regional leader in marine invasive species research and management as the NLRP continues to develop.

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