PROCEEDINGS

OF THE

12th SYMPOSIUM

ON THE

NATURAL HISTORY OF THE BAHAMAS

Edited by
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Gerace Research Centre
San Salvador, Bahamas
2009

Cover photograph –Barn Owl (*Tyto alba*) at Owl's Hole Pit Cave courtesy of Elyse Vogeli

ISBN 0-935909-89-3

THE LIONFISH INVASION IN THE BAHAMAS: WHAT DO WE KNOW AND WHAT DO WE PLAN TO DO ABOUT IT?

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BIOLOGICAL INVASIONS

Biological invasions include both human and non-human mediated forms of dispersal in which an exotic or non-native species successfully arrives, survives and reproduces in a novel locality and then rapidly spreads throughout a region. On the one hand, species that disperse without the aid of humans into an area where they were not previously found are referred to as range expansions. On the other hand, species that have been released outside of their native range and have spread due to human activity are referred to as species introductions (Carlton, 1989). The recent invasion of the Indo-Pacific lionfish (*Pterois volitans**) throughout the western Atlantic Ocean, including The Bahamas, is generally considered to be the result of several species introductions associated with both the intentional and unintentional release of specimens from private aquariums followed by the natural dispersal process (Hare and Whitfield, 2003; Ruiz-Carus *et. al.,* 2006).

Biological invasions in the form of species introductions, however, are not new. The introduction of non-native species has occurred since the dawn of early human migrations. Historically, flora and fauna were intentionally introduced to a new region usually to satisfy food demands or social needs while other non-native species would have been accidentally brought to an area in the form of hitchhikers. What distinguishes invasions today from those experienced in the past is that the current *rate* and *magnitude* of human-caused invasions is unprecedented (Lowe *et. al*., 2000).

Today's worldwide trend in successful species introductions can be partly explained by the exponential increase in global trade, transport, tourism and travel, which have all served to transfer species to places that would have otherwise been virtually impossible to access due to natural physical barriers (BEST, 2003; Lowe *et. al*., 2000). Furthermore, invasion theory predicts that increased disturbance to an environment should result in increased invader success (Altman and Whitlatch, 2007; Lozon and MacIsaac, 1997). Interpreted from this perspective, Carlton and Ruiz (2005) suggest that current worldwide increases in urban and other disturbed habitats may have created an excess of modified ecosystems that are more susceptible to invasion.

Small Island Developing States (SIDS) like The Bahamas are particularly vulnerable to bioinvasions due to our: 1) import-driven economy; 2) heavy reliance on tourism; and, 3) biological fragility inherent in island ecosystems (BEST, 2003). Explanations for The Bahamas' first two vulnerabilities to invasion are self-evident: a high level in the global traffic of people and goods leads to increased opportunities for non-native species that were once far-removed from The Bahamas to come in contact with our shores as hitchhikers. Evidently a small proportion of hitchhikers prove to be successful invaders.
The third vulnerability of The Bahamas to invasion is a bit more complicated but is probably best explained by the "empty niche hypothesis". Ecological models predict that the likelihood of

establishment of an exotic species is increased when the functional differences between the non-native and the resident/native species are great (Tilman, 2004; Von Holle and Simberloff, 2004). Small islands like those of The Bahamas tend to be missing entire functional groups of organisms – an example being the absence of native mammalian top predators. Introduced species that are able to occupy these missing functional groups may therefore be more likely to become successful invaders due to their ability both to use unexploited resources and to compete for other resources with inexperienced natives (Alpert, 2006).

All invaders impact the environment in which they invade because every organism must utilize resources such as space and food to survive. However, not all invaders have *readily discernible* effects on the invaded community or ecosystem. In cases in which impacts are substantial and thus detectable, biological invasions have resulted in: declines, extirpations and extinctions of native species (Goldschmidt *et. al.*, 1993; Witte *et. al.*, 2000; Lowe *et. al.*, 2000); alterations of natural disturbance regimes (D'Antonio and Vitousek, 1992), habitat structure (Daehler and Strong, 1996) and nutrient cycling (Vitousek *et. al.*, 1987) which have all in turn, changed the ecology of natural systems; changes in food web structure (Vander Zanden *et. al.*, 1999); morphological and behavioural changes in native species (Vermeij, 1982; Trussell and Smith, 2000); and, hybridization of native species with the invader (Rhymer and Simberloff, 1996). Indeed, biological invasions are considered to be one of the leading threats to biodiversity worldwide (Lowe *et. al.*, 2000).

Nevertheless, it is important to note that there have been some, though few, documented beneficial effects of invasions. For example, Crooks *et. al.* (1998; 1999) found that the invasive Asian mussel, *Musculista senhousia*, created new habitat via producing mats of byssal threads in the predominantly unstructured mudflats of Mission Bay, San Diego. This novel habitat subsequently allowed for the development of a unique community assemblage with a higher diversity and abundance of taxa than the neighboring mudflats. Similarly, King and colleagues (2006) point out that the invasive round goby, *Neogobius melanostomus*, now constitutes more than 92% of prey consumed by the resident Lake Erie Water Snake, *Nerodia sipedon insularum*, which is threatened in the US and endangered in Canada. This shift in diet by the water snake following the invasion of the round goby has resulted in more rapid growth and attainment of a larger body size in the water snake - which the scientists assert may in turn, reduce predation, speed reproductive maturity, increase offspring production and ultimately, promote population growth in this threatened/endangered species.

LIONFISH IN THEIR NATIVE RANGE

Lionfish (*Pterois volitans* and *P. miles*) are tropical reef fish native to the Indian and South Pacific Oceans, including the Red Sea, where they inhabit coral reefs, rocky outcrops and sandy substrates at depths ranging from the surface (<1m) to about 50m (Schultz, 1986). Both *P. volitans* and *P. miles* are variable in color but tend

**Schultz (1986) concluded that Pterois volitans and P. miles are allopatric, sibling species. Kochzius et. al., 2003 showed that there are genetic differences between P. volitans and P. miles but was inconclusive as to whether they are two separate species or two populations of a single species. This paper recognizes P. volitans and P. miles as two separate species as determined by Schultz (1986) – although keeping with convention, both are herein commonly referred to as lionfish - and acknowledges the possibility that a cryptic invasion is occurring in The Bahamas similar to the situation in the US (Hamner and Freshwater, 2007) in which both P. volitans and P. miles are found along the southeast continental shelf.*

to be either red-, maroon-, or black-and-white striped (Figure 1). They are a source of food in their native range and are highly sought after globally as a high priced aquarium fish (FishBase, 2007).

The maximum size record for adult lionfish in their native range varies according to the source with a conservative estimate of about 380 mm TL (FishBase, 2007). *P. volitans* become sexually mature between 140-160g body weight and 180-190mm TL (Fishelson, 1997). Based on spawning information and the collection of larvae from the water column, it is likely that lionfish have a pelagic larval stage (Hare and Whitfield, 2003).

Lionfish are usually solitary as adults and will defend their home range against conspecifics. Nevertheless, they tend to congregate in small groups during mating and as juveniles (Fishelson, 1975). Juveniles have also been observed to gather together in groups of up to 40 individuals (Fishelson, 1997).

Relatively stationary, top-level predators, lionfish feed on a wide variety of smaller fishes and crustaceans (Fishelson, 1997). There are few known, if any, natural predators of lionfish, most likely due to the venomous nature of the species (Allen and Eschmeyer, 1973). However, the literature reports an isolated case of a single pacific cornetfish, *Fistularia commersonii*, (94cm SL) with a *P. miles* in its stomach (10cm SL) (Bernadsky and Goulet, 1991). Furthermore, it has been speculated that some sharks may consume lionfish with no apparent ill-effect (Moyer and Zaiser, 1981).

LIONFISH ENVENOMATION

Members of the family Scorpaenidae, lionfish possess venomous dorsal, anal and pelvic spines and have been known to sting humans when threatened or harassed (Ruiz-Carus *et. al.*, 2006; Vetrano *et. al.*, 2002). Envenomation may also occur due to reckless handling of recently dead specimens (Pulce *et. al.*, 1991). Lionfish venom contains both acetylcholine and a toxin affecting neuromuscular transmission but the major component is an antigenic, heat labile protein (Vetrano *et. al.*, 2002). No fatalities have resulted due to lionfish envenomations; and the majority of stings occurred on the hands of victims who attempted to clean the aquarium of fish kept as pets (Patel and Wells, 1993).

The predominant symptom of lionfish envenomation is severe pain at the wound site, which is usually responsive to hot water immersion therapy. Rare but more serious symptoms include: chills, headache, nausea, vomiting, abdominal pain or cramping, delirium, seizures, limb paralysis, hyper- or hypotension, respiratory distress, congestive heart failure and pulmonary edema (Vetrano *et. al.*, 2002). Victims may develop a hypersensitivity to lionfish venom and experience anaphylactic reactions upon subsequent envenomation (Auerbach, 1991; Patel and Wells, 1993).

THE INTRODUCTION OF LIONFISH TO THE WESTERN ATLANTIC OCEAN AND THE BAHAMAS

The first documented release of lionfish in US waters occurred in 1992 in Biscayne Bay, Florida when six lionfish escaped from a private aquarium following its destruction by Hurricane Andrew (Courtenay, 1995). Since then, adult lionfish have been observed along the southeast United States coast from Miami, Florida to as far north as Cape Hatteras, North Carolina - in addition to Bermuda. In comparison, juveniles have been sighted off North Carolina, Long Island, New York and Bermuda (Whitfield *et. al.*, 2002). However, juveniles remaining in US waters farther north than Cape Hatteras in the fall are predicted to perish due to an inability to survive winter bottom temperatures there (Kimball *et. al.*, 2004).

In contrast, the first documented report of lionfish in The Bahamas did not occur until 2004 (Department of Marine Resources, personal communication). Nevertheless by late 2006, lionfish had already been reported on a variety of habitat types throughout much of The Bahamian archipelago by local scientists, environmentalists, fishermen, recreational divers and beach goers alike. Many of the reports were anecdotal and consisted of brief emails or phone calls directed to various Government Ministries or to The Marine and Environmental Studies Institute at The College of The Bahamas.

At the start of 2007, the Reef Environmental Education Foundation (REEF) – a Florida based environmental not-for-profit organization – teamed up with local dive operators and the College of The Bahamas to conduct lionfish surveys throughout the archipelago at popular dive sites. Furthermore, in August 2007, the College of The Bahamas Marine and Environmental Studies Institute (COB-MESI) in collaboration with the Department of Marine Resources established an on-line lionfish sightings questionnaire in order to consolidate information on lionfish occurrences throughout the country and subsequently follow-up by verifying reports.

Preliminary surveys of lionfish around New Providence were conducted in summer of 2007 by The COB-MESI. Their findings revealed, among other things, that a substantial number of lionfish are being found in highly disturbed, near shore, shallow waters of The Bahamas (between 1 – 4m) (Sullivan Sealey and Smith, in prep.) as opposed to the deeper, offshore waters (the majority of lionfish observed between 35 and 45m) of the lionfish introduced range along the southeast coast of the US (Kimball *et. al.*, 2004). This suggests that the pattern of invasion of lionfish in The Bahamas may more closely resemble lionfish occurrences and distributions in their native range of the Indo-Pacific than their introduced range in neighboring US waters. Evidently, further research is needed to fully characterize the nature of the invasion of lionfish in The Bahamas. Nevertheless, this initial difference highlights the need for The Bahamas to invest substantial resources into closely evaluating the lionfish invasion in its own waters, as reliance on the findings and subsequent management policies developed to address the invasion in the US may not necessarily be applicable here.

A PLANNED RESPONSE

The scale and scope of the lionfish invasion in The Bahamas requires innovative approaches and partnerships to: protect public health and interests; assess the potential impacts of lionfish; and, effectively manage the invasion. Biological invasion management is a multi-year endeavour for both marine and terrestrial species; and a draft of a National Invasive Species Policy for The Bahamas has already been developed, which among other things, calls for the country:

- To prepare a strategic management plan for individual species of high priority;
- To facilitate research on the occurrence, distribution and impacts of invasive alien species; and,
- To monitor invasive species populations in The Bahamas (BEST, 2003).

The College of The Bahamas Marine and Environmental Studies Institute (COB-MESI) in collaboration with the Department of Marine Resources is launching a multi-year project to develop a National Lionfish Response Plan (NLRP) that entails a partnership between both local and regional government and non-governmental agencies. The plan focuses on: 1) ecological research, 2) invasion management and policy development, and 3) educational initiatives to understand the implications of the establishment of the Indo-Pacific lionfish on fisheries resources and the ecology of coastal systems in The Bahamas. The project will ultimately build a body of stakeholders that can contribute to the long-term strategic management of lionfish in our waters.

Preliminary research will address questions surrounding which types of near shore habitats are more susceptible to invasion and lionfish diet niches. A few permanent monitoring sites will also be established around New Providence to examine lionfish movement, habitat utilization and recruitment. Longer-term efforts include the creation of a National Lionfish Specimen Library for future investigations into genetics, ageing, growth and reproduction of the species in The Bahamas (Figure 2).

Initial invasion management and policy development includes the creation of a national online lionfish information network that serves both to compile sightings over the entire archipelago and to coordinate efforts with the regional lionfish invasion work being done by REEF and the U.S. National Marine Fisheries Service Laboratory based in Beaufort, North Carolina (NMFS-NOAA). Specifically, the online information network will include: a national lionfish reporting system that is linked to a spatial dataset of marine habitats; a specimen cataloging system for the tracking of lionfish collected in the country and housed either within The Bahamas at the National Lionfish Specimen Library or abroad; and, a contact and project database related to on-going lionfish research permitted in the country that is linked to two the preceding network components.

Future educational efforts of the NLRP involve raising awareness among beach goers as well as the local fishing and recreational diving communities about lionfish invasion management options and fish aid response to envenomation.

WHAT CAN YOU DO?

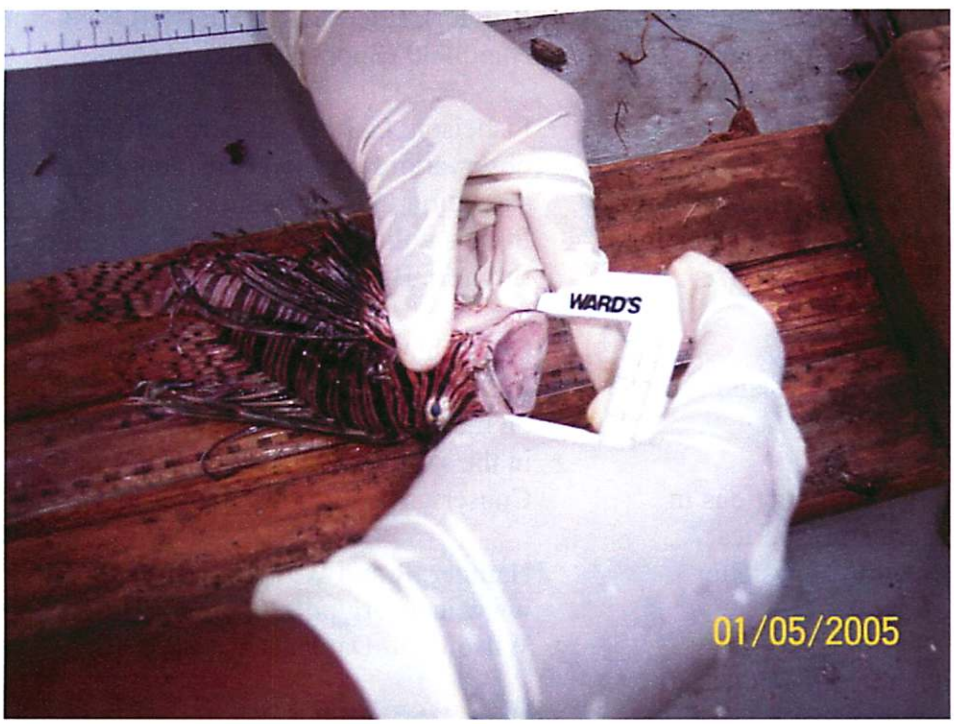
The National Lionfish Response Plan (NLRP) is a costly and ambitious long-term endeavour. The project requires significant financial, technical and logistical support from multiple government and non-governmental agencies at both the national and the regional level. The Indo-Pacific lionfish is now found widely throughout The Bahamas; and the effects of their invasion are expected to become more apparent as their numbers continue to increase. As a concerned individual, you can best contribute to the National Lionfish Response Plan by: reporting lionfish sightings on the national online questionnaire; urging others to report sightings; and, donating money or other much needed resources to the National Lionfish Response TemTeam

ACKNOWLEDGEMENTS

We would like to thank Dr. Donald T. Gerace, Chief Executive Officer, and Dr. Thomas A. Rothfus, Executive Director of the Gerace Research Center, San Salvador, Bahamas as well as the Disney Wildlife Conservation Fund.

Figure 1. An adult lionfish on a near shore patch reef in its introduced range of The Bahamas. Photo credit: COB-MESI, 2007.

Figure 2. COB-MESI researchers record various lionfish morphological characteristics in addition to specific habitat information before housing specimens within the country in the National Lionfish Specimen Library. Photo credit: COB-MESI, 2007.



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