Update on Invasive Lionfish and Other Emerging Invasives

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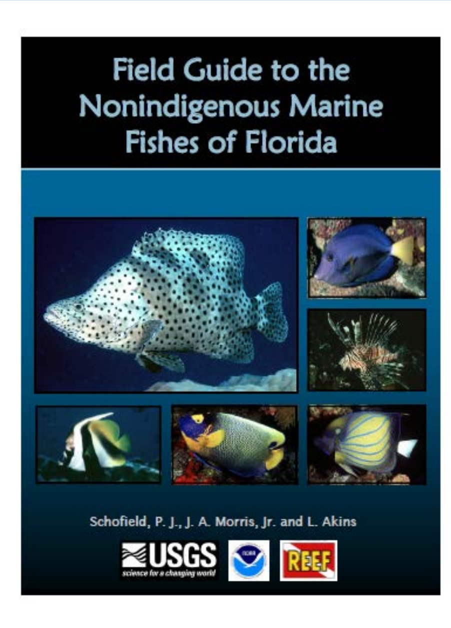
Photo by Rich Carey

How did lionfish get here?

- Hurricane Andrew not the primary source
- First lionfish sighting was in 1985 (Florida)
- Marine ornamental introductions

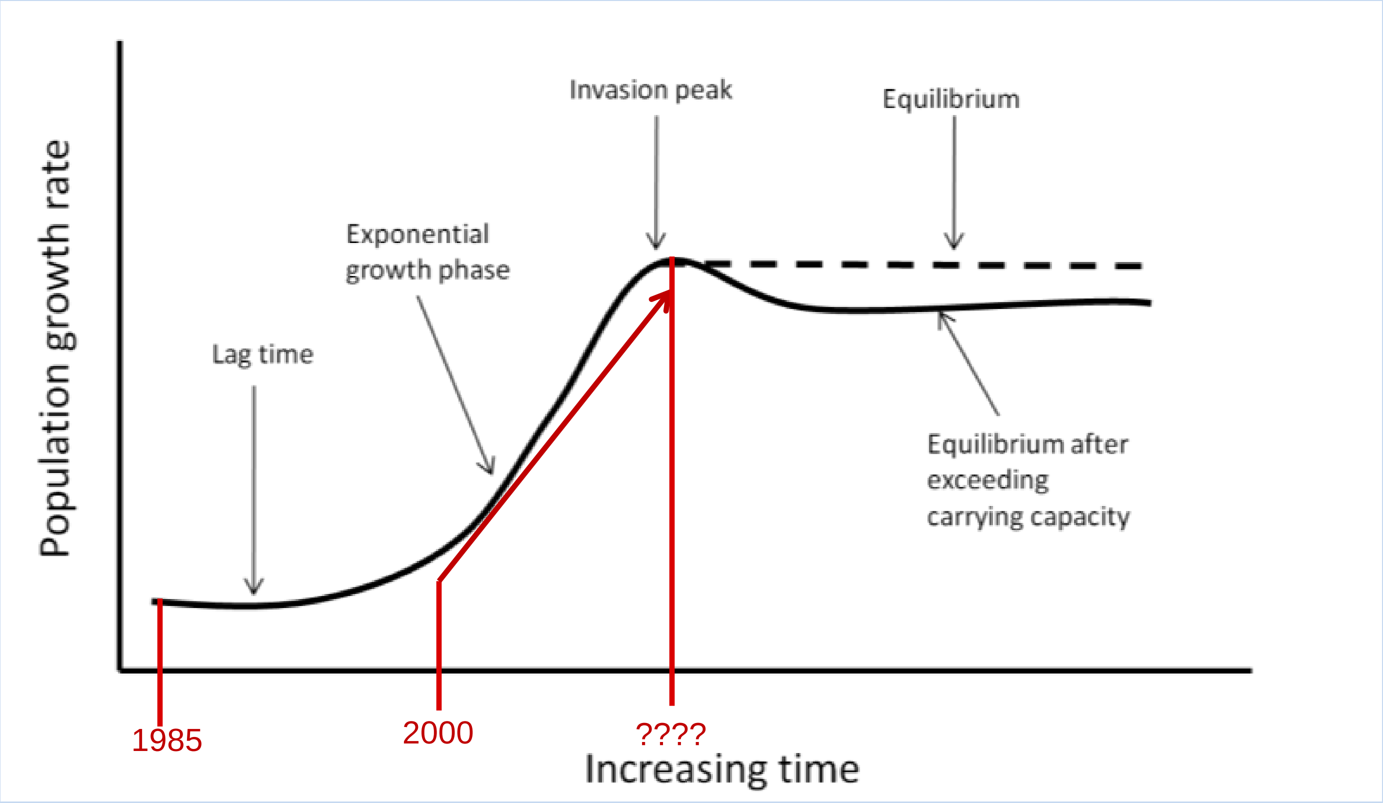


Lionfish invasion status

Documented by CCFHR in 2001 off Beaufort, NC

Schofield et al. 2009; Whitfield et al 2002; 2007, REEF

Where are we in this invasion?



Geographical Spread Projection

Morris and Whitfield 2009

Lionfish biology and ecology

- Numerous studies underway in the Atlantic
- See Lionfish Quickfacts document for a breakdown of findings
- Let's discuss a few highlights….

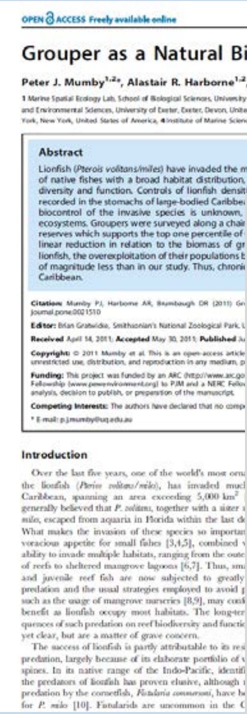
Photo by Sally Thompson

Photo by Doug Kesling

Are lionfish longlived?

What eats lionfish?

- Some observations of "natural predators" but none that appear to be controlling lionfish densities (imposing significant predation mortality)



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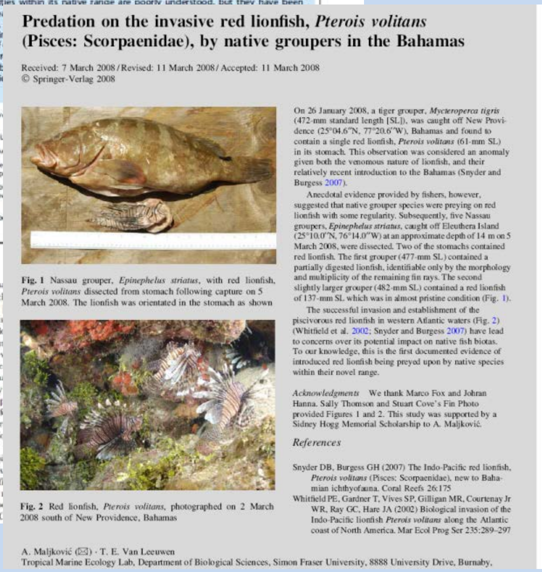
Grouper as a Natural Biocontrol of Invasive Lionfish

Peter J. Mumby[1,2*], Alastair R. Harborne[1,2], Daniel R. Brumbaugh[3,4]



Predation on the invasive red lionfish, *Pterois volitans* (Pisces: Scorpaenidae), by native groupers in the Bahamas

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Fig. 1 Nassau grouper, *Epinephelus striatus*, with red lionfish, *Pterois volitans* dissected from stomach following capture on 5 March 2008. The lionfish was orientated in the stomach as shown

Fig. 2 Red lionfish, *Pterois volitans*, photographed on 2 March 2008 south of New Providence, Bahamas

On 26 January 2008, a tiger grouper, *Mycteroperca tigris* (472-mm standard length [SL]), was caught off New Providence (25°04.6″N, 77°20.6″W), Bahamas and found to contain a single red lionfish, *Pterois volitans* (61-mm SL) in its stomach. This observation was considered an anomaly given both the venomous nature of lionfish, and their relatively recent introduction to the Bahamas (Snyder and Burgess 2007).

Anecdotal evidence provided by fishers, however, suggested that native grouper species were preying on red lionfish with some regularity. Subsequently, five Nassau groupers, *Epinephelus striatus*, caught off Eleuthera Island (25°10.0′N, 76°14.0″W) at an approximate depth of 14 m on 5 March 2008, were dissected. Two of the stomachs contained red lionfish. The first grouper (477-mm SL) contained a partially digested lionfish, identifiable only by the morphology and multiplicity of the remaining fin rays. The second slightly larger grouper (482-mm SL) contained a red lionfish of 137-mm SL which was in almost pristine condition (Fig. 1).

The successful invasion and establishment of the piscivorous red lionfish in western Atlantic waters (Fig. 2) (Whitfield et al. 2002; Snyder and Burgess 2007) have lead to concerns over its potential impact on native fish biotas. To our knowledge, this is the first documented evidence of introduced red lionfish being preyed upon by native species within their novel range.

Acknowledgments We thank Marco Fox and Johran Hanna. Sally Thomson and Stuart Cove's Fin Photo provided Figures 1 and 2. This study was supported by a Sidney Hogg Memorial Scholarship to A. Maljković.

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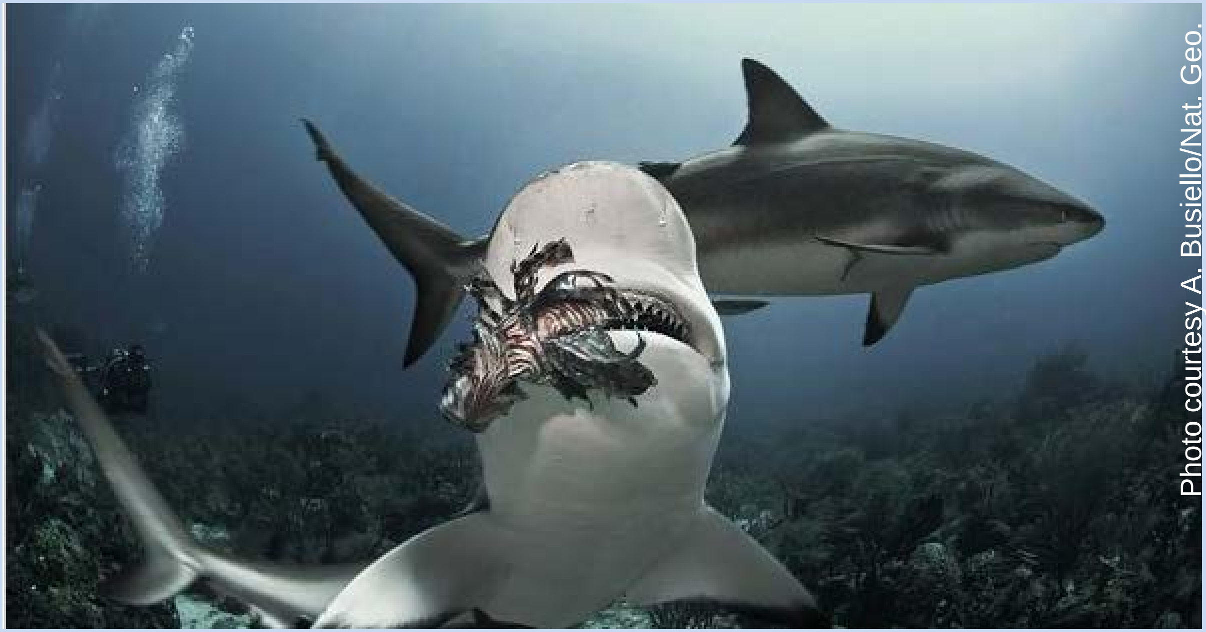
Photo courtesy A. Busiello/Nat. Geo.


Photo courtesy J. Jeffries

What are the ecological impacts

- Changes to the reef community are occurring (site specific)
- Phase shifts – lionfish over-consume herbivorous fish>increased algae>decreased coral biomass
- Forage fish community changes (Green et al. PhD dissertation underway)
- Various diet studies indicate generalist carnivores
- Scale of ecological impacts depends on many factors (lionfish densities, recruitment of forage fishes, etc.)

Numerous studies are reporting impacts!

Biol Invasions
DOI 10.1007/s10530-011-0005-z

ORIGINAL PAPER

Phase shift to algal dominated communities at mesophotic depths associated with lionfish (*Pterois volitans*) invasion on a Bahamian coral reef

Michael P. Lesser · Marc Slattery

Received: 31 December 2010 / Accepted: 19 April 2011

Abstract Mesophotic coral reefs (30–150 m) have been assumed to be physically and biologically connected to their shallow-water counterparts, and thus may serve as refugia for important taxonomic groups such as corals, sponges, and fish. The recent invasion of the Indo-Pacific lionfish (*Pterois volitans*) onto shallow reefs of the Caribbean and Bahamas has had significant, negative, effects on shallow coral reef fish populations. In the Bahamas, lionfish have extended their habitat range into mesophotic depths down to 91 m where they have reduced the diversity of several important fish guilds, including herbivores. A phase shift to an algal dominated (>50% benthic cover) community occurred simultaneously with the loss of herbivores to a depth of 61 m and caused a significant decline in corals and sponges at mesophotic depths. The effects of this invasive lionfish on mesophotic coral reefs and the subsequent changes in benthic community structure could not be explained by coral bleaching, overfishing, hurricanes, or disease independently or in combination. The significant ecological effects of the lionfish invasion into mesophotic depths of coral reefs casts doubt on whether these communities have the resilience to recover themselves or contribute to the recovery of their shallow water counterparts as refugia for key coral reef taxa.

Keywords Lionfish · Coral reefs · Mesophotic · Phase shifts · Herbivory · Mezograzers

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Introduction

The structure and health of many coral reefs worldwide has changed significantly in recent years with losses of coral cover and biodiversity, often accompanied by a transition to algal dominated communities (Gardner et al. 2003; Hughes et al. 2003, 2010; Hoegh-Guldberg et al. 2007; Dudgeon et al. 2010). These "phase shifts" are particularly dramatic on shallow Caribbean coral reefs where there have been unprecedented regional and local disturbances including hurricane damage, coral bleaching, disease, eutrophication, and overfishing (Hughes 1994; Hughes et al. 2003, Precht and Aronson 2006; 2010; Hoegh-Guldberg et al. 2007). Consequently, many of these shallow coral reefs are close to, or have exceeded, their resilience capacity (i.e., their ability to recover from disturbance). When a phase shift from coral to algal dominance occurs, the timeframe

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Predicted impact of the invasive lionfish *Pterois volitans* on the food web of a Caribbean coral reef

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ABSTRACT

The invasion of lionfish in the Caribbean is causing grave concern because of its deleterious impacts on coral reef food-webs. We have used an Ecopath-with-Ecosim model to predict the impacts of lionfish invasion on a coral reef community based on pre-invasion fish community data. Forty-six groups were defined, and an initial Ecopath model was balanced with a near-zero biomass of lionfish. In Ecosim, the near-zero biomass was eradicated by applying a very high fishing pressure in the first year of simulation. We subsequently (re-)introduced lionfish with a very low biomass, and allowed them to increase to very high abundance. With a near-zero lionfish biomass, the great majority of mesocarnivorous/omnivorous coral reef fish were predicted to be dominant while sharks were predicted to be the apex predators. Different management scenarios were established in the ecosystem to explore the eradication and resilience of lionfish. The management scenarios showed that if all adult lionfish were exploitable it will in theory be possible to fish the lionfish to a very low level, but the fishing pressure will have to be maintained, or the lionfish will recover. If the largest individuals are unexploitable it will be much more difficult to control the lionfish population.

1. Introduction

In three decades, since the first documented Atlantic occurrence in the mid-1980s, the invasive lionfish species (*Pterois volitans*), a voracious fish predator, has spread from the North Western North Atlantic to the Caribbean and Campeche Bank (Morris et al., 2008; Morris and Akins, 2009; Schofield, 2009; Ahrenholz and Morris, 2010; Aguilar-Perera and Tuz-Sulub, 2010; Schofield, 2010; USGSa, 2011a,b). The invasion is assumed to be due to accidental or intentional releases from aquaria (Whitfield et al., 2002; Semmens et al., 2004; Ruiz-Carus et al., 2006; Hamner et al., 2007). Originally uncommon, this species is now one of the most well-known and abundant predators in the center of origin of the invasion (Florida) and is now abundant in the *Bahamian archipelago* off Florida (Albins and Hixon, 2008) and the Caribbean (USGSa, 2011a,b; NCCOS, 2011). Average density estimates on Bahamian coral reefs of 390 lionfish ha^{-1} (Green and Côté, 2009) place Bahamian lionfish at several times higher than on its native ranges, from 2.2 lionfish·h^{-1} in Palau (Grubich et al., 2009) to 80 lionfish ha^{-1} in the Red Sea (Fishelson, 1997). Off the coast of North Carolina, mean densities of 21 lionfish·ha^{-1} were reported in 2004 (Whitfield et al., 2007), which have increased to over 400 lionfish·ha^{-1} in some locations in 2007 (Morris and Whitfield, 2009). No other published density estimations are available, but the lionfish is becoming a common species in the Caribbean (Schofield, 2009, 2010). Thus, 260 lionfish were caught during July 2010–February 2011 on Alacranes Reef, in the southern Gulf of Mexico, (Aguilar-Perera and Tuz-Sulub, 2011). Lionfish are the first marine fish known to invade the western Atlantic Ocean and Caribbean Sea, and have the potential to add additional stress to an environment already compromised by overfishing, pollution and climate change (Schofield, 2010).

The extremely rapid expansion of lionfish represents a potentially major threat to coral reef food webs in the Caribbean region by decreasing the survival of a wide range of native animals via predation (Albins and Hixon, 2008). Individual lionfish can be very efficient hunters (Côté and Maljković, 2010), and have been shown to reduce fish recruitment by 79% on Bahamian coral reefs (Albins and Hixon, 2008). The style of lionfish predation (i.e., ambush predator) is not unique in Caribbean coral reefs, (e.g., red grouper, frog fish and scorpion fish), but the lack of experience of prey species with lionfish specifically may increase its predation efficiency (Hare and Whitfield, 2003). Lionfish in the *Bahamian archipelago* largely prey upon teleosts (78% volume) and crustaceans (14% volume) (Morris and Akins, 2009). Twenty-one families and 41 species of teleosts were

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Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities

Mark A. Albins · Mark A. Hixon

Received: 5 March 2010 / Accepted: 16 March 2011

Abstract The Pacific red lionfish has recently invaded Western Atlantic and Caribbean coral reefs, and may become one of the most ecologically harmful marine fish introductions to date. Lionfish possess a broad suite of traits that makes them particularly successful invaders and strong negative interactors with native fauna, including defensive venomous spines, cryptic form, color and behavior, habitat generality, high competitive ability, low parasite load, efficient predation, rapid growth, and high reproductive rates. With an eye on the future, we describe a possible "worst case scenario" in which the direct and indirect effects of lionfish could combine with the impacts of preexisting stressors—especially overfishing—and cause substantial deleterious changes in coral-reef communities. We also discuss management actions that could be taken to minimize these potential effects by, first, developing targeted lionfish fisheries and local removals, and second, enhancing native biotic resistance, particularly via marine reserves that could conserve and foster potential natural enemies of this invader. Ultimately, the lionfish invasion will be limited either by the lionfish starving—the worst end to the worst case scenario—or by some combination of native pathogens, parasites, predators, and competitors controlling the abundance of lionfish.

Keywords Biological invasions · Biotic resistance · Coral-reef fishes · Ecological release · Invasive species

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Introduction

Biological invasions are a major cause of ecosystem disruption and biodiversity loss, and are a major source of human-caused global change (Elton 1958; Vitousek et al. 1997; Mack et al. 2000). Invasive species are estimated to result in environmental and economic costs exceeding 120 billion dollars annually in the United States alone (Pimentel et al. 2005). While the majority of invasions have occurred in terrestrial and freshwater systems, marine invasions are increasing at an alarming rate and may have substantial impacts on the stability of ocean ecosystems and the multitude of goods and services they provide (Ruiz et al. 1997). However, until recently there have been no documented cases in which an introduced marine fish has become a major invasive threat. This situation has now changed with the invasion of Atlantic and Caribbean coral reefs by the Indo-Pacific red lionfish (*Pterois volitans*), an event that has recently been recognized as one of the world's top conservation issues (Sutherland et al. 2010).

Two species of Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) were apparently introduced to

Impacts on stock rebuilding plans?

- No real new findings on this front; still a major question
- Diet and space overlap is apparent
- Niche takeover scenario possible?
- What can we do to look more closely at this?
- Predation on species of concern an issue (Nassau grouper)
- High predation rate on vermillion snapper observed

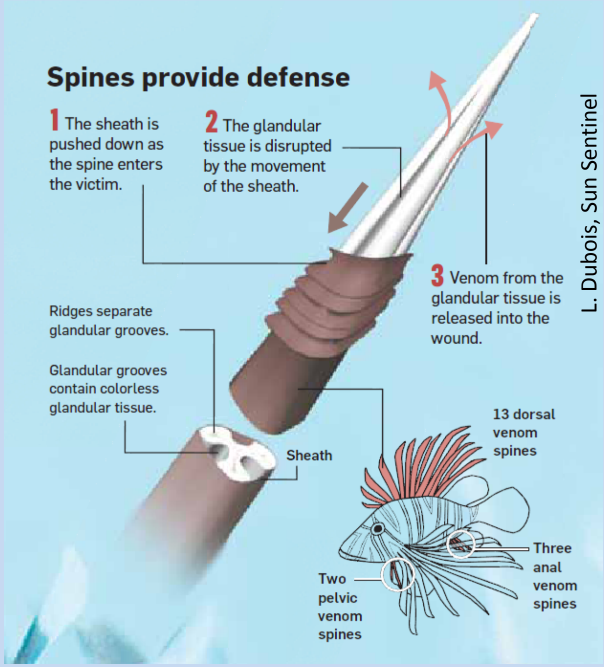
Socio-economic impacts

- Major shifts in staff duties at National Parks, National Marine Sanctuaries, and states.
- Bycatch increasing in trap fisheries
- Potential reduction of native species catch rates
- Economic losses for commercial fishermen include loss of fishing days when envenomation occurs

Credit: REEF

Human health impacts

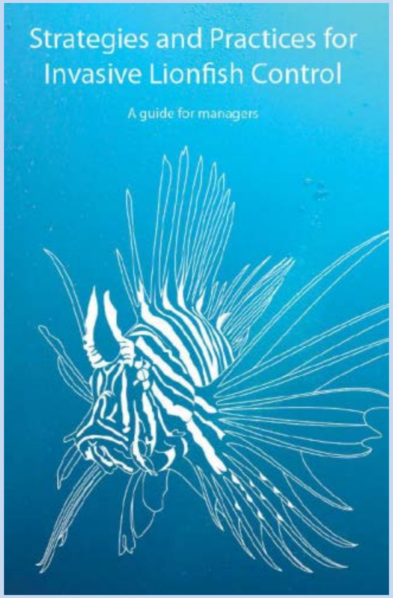
- Lionfish sting symptoms are many from pain to paralysis to death (rare).
- Long term health impacts of envenomations are unknown.
- High densities = high encounter rates.



L. Dubois, Sun Sentinel

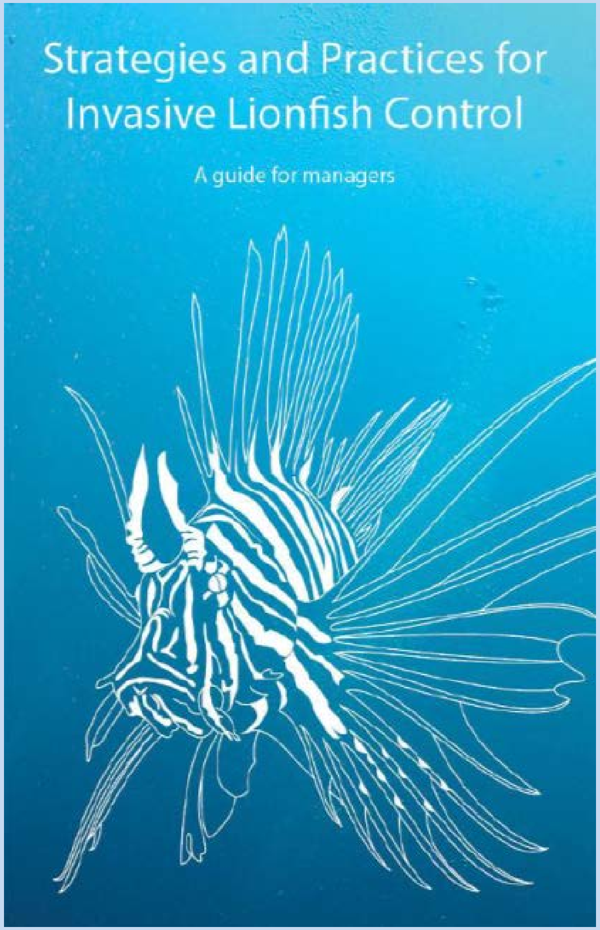
Management Actions

- NPS and NMS have control plans
- SAFMC Invasive Species Policy
- ANSTF Lionfish Control Plan process has begun
- Control tools (models and BMPs are being developed)



Lionfish Manual

- Education and outreach
- Control
- Monitoring
- Research
- Legal considerations



Eat Lionfish Efforts

- Purpose: To inform managers about harvesting lionfish as a control strategy.
- Benefits – control in protected areas, locations with accessible reefs (i.e., some Caribbean islands), economic, and ecological.
- Ciguatera may be an issue in locations that have high incidence. Not a surprise.

Lionfish: From Sea to Table

Capturing

Lionfish have venomous spines along the top and undersides of the body (see diagram). Take precautions and use proper equipment when attempting to capture or handle these fish. Clear vinyl collecting nets with mesh bottoms or fish spears with paralyzer tips are ideal for capturing the fish. To collect a lionfish with a net, position one vinyl net behind the fish while using a second net to maneuver the fish into the first. Lionfish can also be caught occasionally by hook and line and sometimes in fish traps.

Handling

Minimize the risk of stings by using puncture-proof gloves. Firmly grasp the dead lionfish by its head to avoid the venomous spines. Gloves will also protect your hands from irritation by non-venomous bones on the head.

First Aid

If stung, seek medical attention promptly. Check for and remove any obvious pieces of spine left in the wound. Apply hot water to the wound (as hot as one can stand without scalding) until the pain subsides. Common symptoms of most stings include pain and swelling. In extreme cases, skin necrosis and paralysis can occur.

Dorsal Spines
Anal Spines
Pelvic Spines

Cleaning

The dorsal, anal, and pelvic spines are venomous. These spines can be removed with kitchen shears or clippers. Once the spines are removed the lionfish can be cleaned like any other fish.

Preparation

Lionfish is a delicious, delicately flavored fish, which can be prepared many different ways. The taste and texture has been compared to highly regarded grouper, snapper or hogfish. Numerous recipes and preparation techniques are available on the web and in upcoming cookbook publications.

Credit Fred Lentz

Where do we go from here?

Current initiatives

- Continuing biology/ecology assessments
- Need to do a better job of documenting ecological/economic impacts
- Developing a Lionfish Manual for Wider Caribbean
- Developing a web portal to facilitate broader training
- Developing a regional strategy for lionfish in Caribbean
- Working with many MPA managers to develop control programs (what does control mean?)

Research Needs

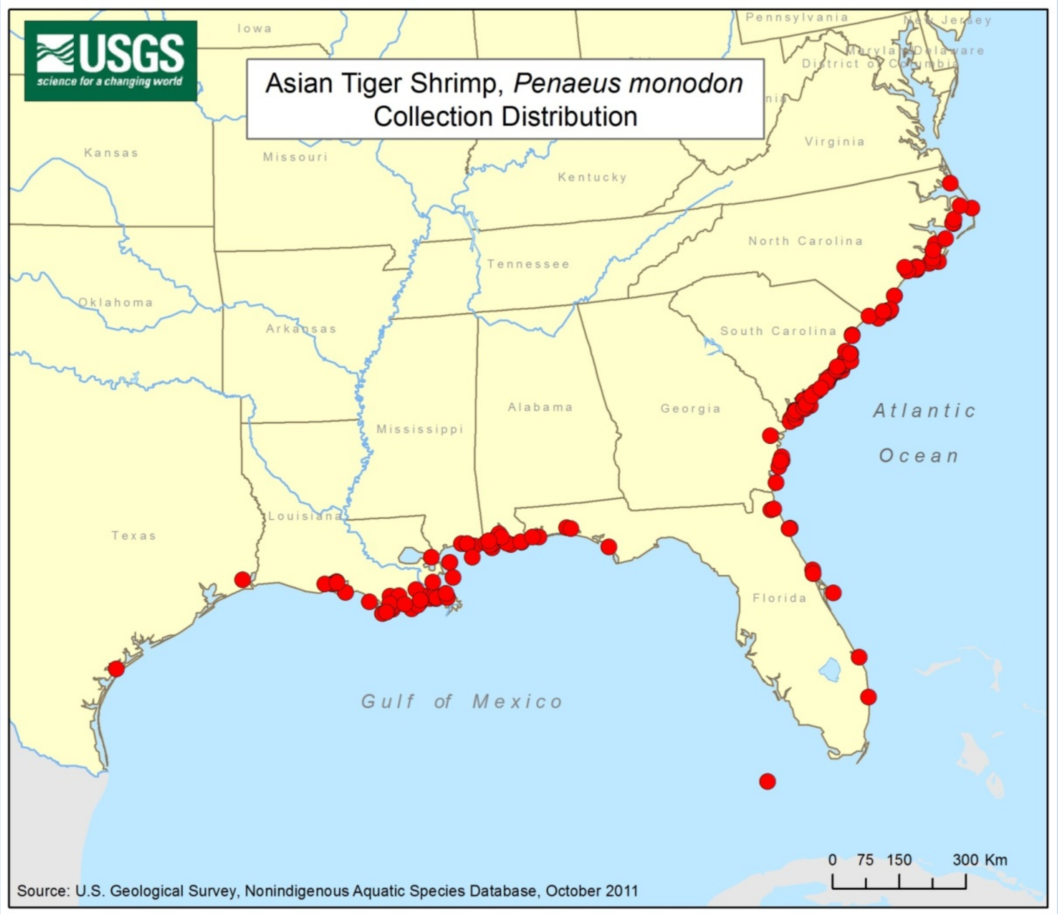
2011 NOS/NMFS workshop to develop priorities

Overall priorities:

1. Economic impacts assessments across all sectors.
2. Effectiveness of developing a lionfish fishery.
3. Impacts on economically important species.
4. Develop temporal/spatial targeted removals for MPAs.

Next steps?

Emerging Invasive Issues



More Marine Ornamentals Continue to Appear

USGS
science for a changing world

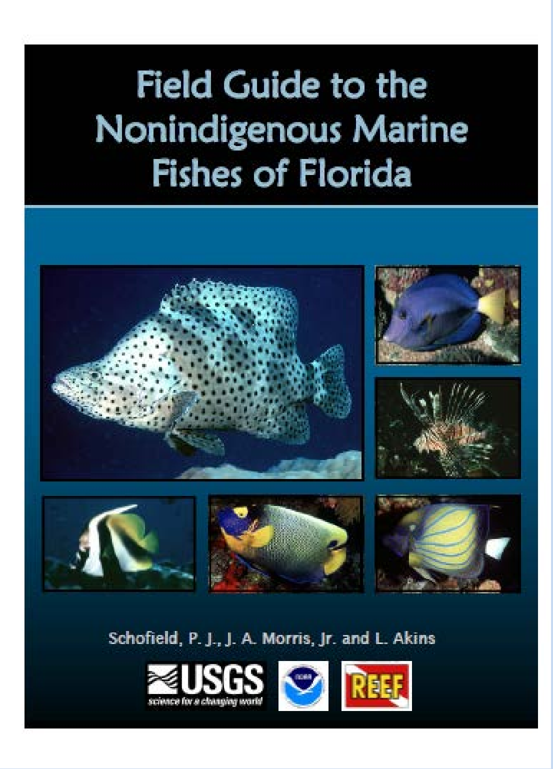
News Release

November 22, 2011	Pamela J. Schofield	352-264-3530	pschofield@usgs.gov
	Rachel J. Pawlitz	352-264-3554	rpawlitz@usgs.gov

Three Non-Native Fishes Found in Florida – Again

GAINESVILLE, Fla. – Three non-native fish species have been spotted in Florida waters again this past year after not being seen for as many as 19 years. The fishes, a panther grouper, spotted scat, and yellow tang, were found off West Palm, Stuart and Pompano Beach.

The sightings, verified by the U.S. Geological Survey (USGS), come after a long gap in reports of these species in Florida's coastal waters. The panther grouper was last seen in 2007, the yellow tang in 2005 and the spotted scat in 1992.



A Workshop to Develop
Research Priorities for Invasive Lionfish in the Southeast Region

NOAA Southeast Fisheries Science Center, Miami, Florida
July 6, 2011

Workshop participants:
Dr. James Morris (NOS/NCCOS)
Dr. Roldan Muñoz (NMFS/SEFSC)
Dr. Ben Ruttenberg (NMFS/SEFSC)
Lad Akins (Reef Environmental Education Foundation)
Tom Jackson (NMFS/SEFSC)
Scott Donahue (NOS/FKNMS)

Workshop Overview:
The objectives of this workshop were to develop consensus of research priorities for lionfish research for the Southeast U.S. These priorities may also be used to focus lionfish research needs in Puerto Rico, the US Virgin Islands, and the Gulf of Mexico pending input from those regions. To develop these priorities, workshop participants provided an update of current and planned research activities in their respective programs, developed a categorized list of research priorities, ranked the priorities in each category, and developed a list of overall priorities across categories. While each priority received a ranking (starting with 1 as high), many of the priorities that received lower rankings are important and should be addressed simultaneously with higher ranking priorities. Future planning meetings will assess inhouse capacity to address top priorities in each category and the scale of additional funding needs.

Consensus on research priorities in SE

Control
1. Effectiveness of developing lionfish as a fishery for local control, both recreational and commercial.
2. Develop temporal/spatial plans for targeted removals in MPAs.
3. Determine target removal levels to mitigate ecological/economic impacts.
4. Evaluate level and effectiveness of removals (e.g. pre and post monitoring of derbies, ongoing removals in SPAs, etc.).
5. Mechanisms for natural control – biotic resistance.
6. Effectiveness of different lionfish removal techniques.
7. Targeted trapping for lionfish using pheromones.
8. Population regulation in native range.
9. Training fish/sharks/predators to eat lionfish. *It was the consensus that this practice should not be encouraged. This priority was included in order to rank the lowest.*

Ecological impacts
1. Impacts on economically important species.
2. Impacts on cryptic/prey/juvenile fish communities including development of baselines by habitat.
3. Impacts on invertebrate communities.
4. Impacts on species of concern.

5. Diet selectivity by lionfish.
6. Ecosystem modeling (Ecopath) to forecast whole trophic impacts.
7. Competition with native species.
8. Trophic cascades/impacts on herbivores/corals in shallow and mesophotic reefs.
9. Feeding ecology and densities of lionfish on deepwater (30-50 m) reefs.
10. Venom effects on native predators.

Monitoring
1. Adult/juvenile/recruit indices of abundance by habitat type.
2. Habitat utilization of lionfish.
3. Movement, drivers of movement, and variability of movement.
4. Deepwater surveys (>30-50m).
5. Detectability of lionfish in various survey types.
6. Larval connectivity to determine sources for control. *It was the consensus that this approach is not feasible and was included in order to rank low.*

Biology/Ecology
1. Age/growth for population dynamics assessments.
2. Spawning habitat assessments.
3. Fitness/condition indices and changes over time.
4. Parasitological assessments.
5. Genetics.
6. Egg predation.

Socioeconomics
1. Economic impacts of invasion on all sectors of the economy (fishing, tourism, etc.)
2. Ciguatera monitoring.
3. Envenomation and human health.

Ranking of overall priorities

Below is a ranking of the top ten priorities across all categories.

1. Economic impacts of invasion on all sectors of the economy (fishing, tourism, etc.)
2. Effectiveness of developing lionfish as a fishery for local control, both recreational and commercial.
3. Impacts on economically important species.
4. Develop temporal/spatial plans for targeted removals in MPAs.
5. Determine target removal levels to mitigate ecological/economic impacts.
6. Adult/juvenile/recruit indices of abundance by habitat type.
7. Habitat utilization of lionfish.
8. Impacts on cryptic/prey/juvenile fish communities including development of baselines by habitat.
9. Evaluate level and effectiveness of removals (e.g. pre and post monitoring of derbies, ongoing removals in SPAs, etc.).
10. Mechanisms for natural control – biotic resistance.

Invasive Lionfish Facts

Ecological impacts

- Impacts to biodiversity and resilience of coral, hardbottom, and artificial reefs.
- Potential reduction of ecologically important species such as cleaners, herbivores, and forage fishes.
- Interactions with other reef stressors could exacerbate lionfish impacts (e.g., ocean acidification, fishing impacts, etc.)
- Cascading impacts across food webs is possible (e.g., predation on herbivores, increased macroalgae, decreased coral biomass).
- Potential impacts to species if concern (Nassau grouper, Warsaw grouper, speckled hind, striped croaker, key silverside).
- Scale of ecological impacts is high in magnitude and geographically broad (North Carolina to the Caribbean and the Gulf of Mexico).

Socio-economic impacts

- Potential impacts to stock rebuilding efforts for commercially important species.
- Economic losses for commercial fishermen include loss of fishing days when envenomation occurs and reduction of native species catch rates.
- Potential economic loss in the trade of native marine ornamental species.

Human health impacts

- Lionfish sting symptoms include tachycardia, hypertension, hypotension, seizures, chest pain, abdominal pain, swelling, pain, and subdermal necrosis at the sting site, and temporary paralysis to all extremities.
- Long term health impacts of repeated envenomations are unknown.
- Divers, fishermen, and swimmers are at increased risk of envenomation at locations where lionfish have reached high densities.
- Envenomation risk to bathers/swimmers increases at locations with structure such as piers, breakwaters, and confined tidal swimming pools.
- Lionfish, similar native reef fish, may cause ciguatera fish poisoning in some locations.

Control

- Control plans that support sustained removals can significantly reduce local lionfish densities.
- Tools for local lionfish control include commercial harvesting as a food fish, harvesting juveniles for the aquarium trade, sport tournaments, and adopt-a-reef and other citizen-based removal efforts.
- Based on current technology, lionfish eradication at the regional scale is likely not feasible given the expansive depths and geography of lionfish habitat.

Information provided by James Morris **james.morris@noaa.gov**
NOAA National Centers for Coastal Ocean Science
Updated Dec 5, 2011

Invasion history

- Lionfish was first documented as established off the coast of North Carolina in 2000.
- Two visually identical species (*Pterois miles* and *P. volitans*) of lionfish were introduced into the Atlantic via the U.S. aquarium trade beginning in the 1980's.
- Lionfish are widespread throughout the Southeast U.S., Caribbean, and are presently invading the Gulf of Mexico.
- Lionfish are expected to invade South America as far south as the northern coast of Argentina.
- Lionfish have established throughout most of the Caribbean in less than five years.

Biology

- Lionfish may live decades and reach sizes up to 47cm (19 inches).
- Lionfish inhabit all marine habitat types and depths (shoreline to over 1000').
- Lionfish possess venomous spines capable of deterring predators and inflicting serious stings and reactions in humans.
- Lionfish temperature tolerance is approximately ~10 – 35C.
- Lionfish become sexually mature in less than one year and spawn in pairs.
- A single female lionfish spawns over ~2 million eggs/year.
- Lionfish eggs are held together in a gelatinous mass and are dispersed by currents.
- Lionfish larval duration is ~25 days.

Ecology

- Lionfish can reach densities higher than 200 adults per acre.
- Lionfish are generalist carnivores that consume >70 species of fish and many invertebrate species, with prey exceeding half the lionfish's body size.
- Many lionfish prey are commercially, recreationally, and ecologically important.
- Native predators have been observed to exhibit avoidance for lionfish.
- Lionfish have very few parasites compared to native species.
- Lionfish exhibit site fidelity.
- Lionfish have high affinity for structure and feed primarily during dawn and dusk time periods.

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