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SHORT COMMUNICATION

DISTRIBUTION AND LENGTH FREQUENCY OF INVASIVE LIONFISH (*PTEROIS* SP.) IN THE NORTHERN GULF OF MEXICO

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INTRODUCTION

In recent years, the prevalence of invasive marine species in United States (US) waters has greatly increased due to anthropogenic factors such as transportation, trade, and aquaculture (Bax et al. 2003). As populations of invasive species increase in a region, they can displace native species, alter community composition and food webs, and change fundamental ecosystem processes (Molnar et al. 2008). Indo—Pacific lionfishes (*Pterois volitans* and *P. miles*) have spread rapidly within US territorial waters of the western North Atlantic Ocean (Morris and Akins 2009, Green et al. 2011). Lionfishes are now known to occur from Massachusetts to the Florida Keys and in the Caribbean Sea and Gulf of Mexico (GOM) (Morris 2009, Schofield 2010). Genetic analysis revealed that the most likely pathway for the introduction of lionfishes into US waters was the result of multiple aquarium releases off the southeast coast of Florida (Betancur—R et al. 2011). The combination of their high spawning frequency (year round, ~every 4 d, Morris 2009) and protracted pelagic larval phase (~26 d, Ahrenholz and Morris 2010), coupled with release in a region with multiple oceanographic currents (e.g., Gulf Stream, Caribbean Current, Yucatan Current and Loop Current) has resulted in the rapid dispersal of lionfishes into the western Atlantic Ocean, including the Caribbean Sea and GOM (Cowen et al. 2006, Betancur—R et al. 2011). The first lionfish was reported from the northern GOM (defined as all US GOM waters within the boundaries of the US Exclusive Economic Zone) in 2006; however, the origin of this specimen has been questioned as it was found dead (Schofield 2009). The next reported sightings occurred during 2010 off southwest Florida, and since that time individuals have been observed as far west as Ewing Bank in continental shelf waters off Louisiana (Schofield 2010).

The purpose of this communication is to document continued spatial expansion of lionfish farther west into the northern GOM. Furthermore, we provide the first length—mass relationships and length frequency information for lionfishes captured within the northern GOM based on data collected as part of a broader on—going study of lionfish life history in this region.

METHODS

Lionfishes were collected opportunistically throughout the northern GOM by spearfishers (divers using pole spear or speargun), commercial trawl operations, and during fishery—independent bottom trawl surveys (National Marine Fisheries Service, Mississippi Laboratories). Collection date, location, and depth associated with capture were provided with each specimen. After collection, most specimens were frozen and subsequently thawed prior to being processed in the laboratory; however, about 20% of specimens were processed in the field shortly after capture. Total length (TL, mm), standard length (SL, mm), and total weight (TW, 0.1 g) were measured. Sex was determined when possible, however, some individuals showed limited development or were damaged during the capture process and could not be sexed. Because lionfishes possess venomous spines, fishers frequently remove the spines and fin rays before fish are landed. Therefore, to describe the relationship between TW and spineless weight (SW), all lionfish landed with spines and fins intact were weighed and then all spines and fin rays were removed with the exception of the caudle fin rays to obtain SW.

Linear regression was performed to describe the relationships between TL and TW, TL and SW, and TL and depth. As weight did not increase linearly with length, those data were log transformed prior to analysis. Analysis of covariance (ANCOVA) was used to determine if there was a significant difference in the relationship of TW and TL with TL as the covariate between sexes. If any variable failed tests of normality and homogeneity of variance, appropriate data transformations were performed. For those specimens whose sex could be identified, a Chi—square test with Yates' correction for continuity was used to determine if the ratio of males to females was different from the expected 1:1. All statistical tests were performed with Statgraphics 5.1 (Statis-

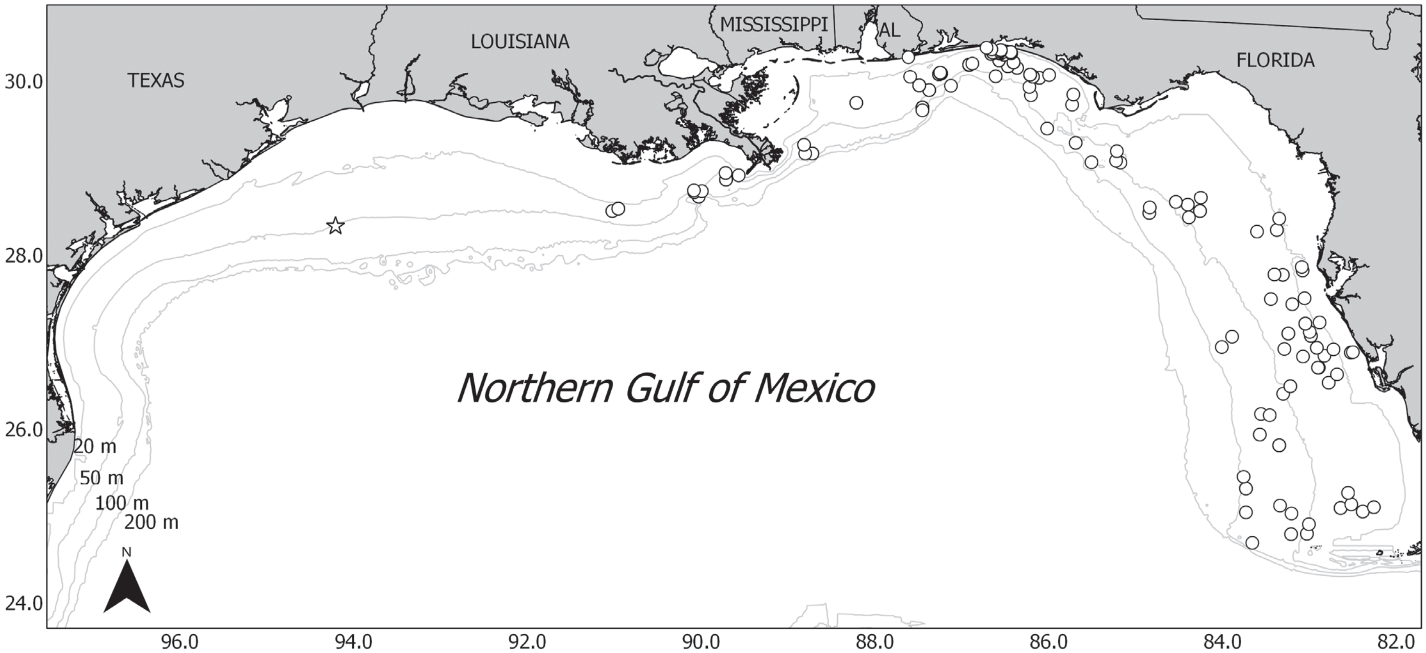

Figure 1. *Locations where lionfish (*Pterois spp.*) were collected in the northern Gulf of Mexico from March to December 2012. Star indicates the western most collection of* Pterois spp. *in the northern Gulf of Mexico.*

tical Graphics Corp.) and significance was indicated when $p \leq 0.05$.

Results

From March to December 2012, about 1,500 lionfish were collected from northern GOM waters (Figure 1). A total of 49 lionfish were collected during National Marine Fisheries Service (NMFS) bottom trawl surveys, whereas the rest were collected by spearfishers and commercial trawl operations. Length and weight data were obtained from 582 specimens (Figure 2A). Sex was determined for 294 individuals and the ratio of males to females was 1.03:1 (119 males; 115 females; 60 unknown) and was not significantly different from 1:1 (X^2 = 0.068, p = 0.794). Sex was difficult to assign in fish < 165 mm TL and resulted in 60 specimens with undetermined sex, which ranged in size from 80—163 mm TL. Males and females ranged in length from 126—385 and 157—337 mm TL, respectively (Figure 2B). In July 2012, 8 lionfish were collected by spearfishers about100 km due south of High Island, Texas (28.329°N, —94.1521°W) in 22.9 m of water, which represents the first confirmed lionfish captured in the western GOM. The fish ranged in size from 143—274 mm TL and 31—290 g. The samples consisted of 5 males, one female, and 2 of unknown sex.

Relationships among length and weight are reported in Table 1. There was no significant difference between length—weight relationships by sex (ANCOVA: slope: F = 3.21, p = 0.07; overall: F = 0.40, p = 0.530). There was a significant positive relationship between TW and SW (n = 510, $F_{1,508}$ = 363,315, r^2 = 0.999, p < 0.001), with SW representing about 95% of TW. Specimens were collected at depths ranging from 2.0—84.1 m (mean = 31.8, se = 0.5); however, there was no relationship between TL and collection depth (sexes combined: n = 460, $F_{1,458}$= 0.004, p = 0.951; females: n = 112, $F_{1,110}$= 0.663, p = 0.417; males: n = 116, $F_{1,114}$= 0.030, p = 0.862).

TABLE 1. *Length—mass relationships for* Pterois sp. *specimens collected in the northern Gulf of Mexico. TL = total length (mm), SL = standard length (mm), TW = total weight (g), and SW = spineless weight (g).*

Conversion	n	Equation	r^2
Pooled			
SL to TL	582	SL = 0.7866(TL) –7.5978	0.99
TW to TL	582	log TW = 3.4349(log TL) –5.8608	0.99
SW to TL	582	log SW = 3.4761(log TL) –5.9783	0.99
SW to TW	582	SW = 0.9581(TW) –0.6100	0.99
Male			
TW to TL	119	log TW = 3.3100(log TL) –5.5693	0.97
SW to TL	119	log SW = 3.3265(log TL) –5.6289	0.97
Female			
TW to TL	115	log TW = 3.1437(log TL) –5.1692	0.94
SW to TL	115	log SW = 3.1546(log TL) –5.2160	0.93

Discussion

With the exception of a single dead specimen collected off Treasure Island, Florida in 2006, additional movements of lionfish into the GOM were not observed until December 2009 when 2 lionfish were collected in the southern

GOM off the northern Yucatan peninsula, Mexico (Aguilar—Perera and Tuz—Sulub 2010). During 2010, lionfish were observed in the northern GOM with 3 lionfish observed north—northwest of Key West, FL in July, and 2 lionfish reported off the coast of Louisiana within the western GOM in September (Schofield 2010). Combined with our data, lionfish distribution in the northern GOM now extends further west into Texas waters. These observations suggest that if lionfish are not already distributed throughout the continental shelf waters of the entire GOM then they likely will be so in the near future.

The largest lionfish collected in this study was 385 mm TL, and based on a lionfish age—at—length equation developed from fishes collected off North Carolina (Barbour et al. 2011), the back transformed age would be 4.5 y. If northern GOM lionfish growth rates are similar to those off the US east coast, then this specimen was introduced into the northern GOM sometime in early 2008, 2 years prior to the first reported sighting of a live lionfish in this region (Schofield 2009). With larval transport thought to be the primary mechanism for dispersal into the northern GOM (Vasquez—Yeomans et al. 2011), an earlier introduction time of lionfish into this region seems likely. As larger specimens are collected and additional age information becomes available, better estimates of their potential time of introduction into the GOM region will be available.

Based on published studies, the largest lionfish have been collected on the US east coast of North Carolina (Whitfield et al. 2006, Barbour et al. 2011, Muñoz et al. 2011), South Carolina (Meister et al. 2005), north Florida (Ruiz—Carus et al. 2006), and the Bahamas (Morris and Akins 2009, Green et al. 2011), followed by the southern GOM (Aguilar—Perera et al. 2012 and the Caribbean Sea (González et al. 2009, Lasso—Alcalá and Posada 2010). The largest specimens collected from the northern GOM were smaller than lionfish collected from the US east coast, similar in size to specimens from the southern GOM (Aguilar—Perera et al. 2013) and larger than specimens collected from the Caribbean Sea.

While there was no significant effect of depth on sex and size distribution of lionfish collected during this study, this could have resulted from a sampling bias as smaller specimens could have been less apparent on reefs, more difficult to spear, and/or perhaps less 'favored' by the spearfishers. The non—significant effect of depth could also be due to the lack of samples from shallow depths. For example, few samples in our study were collected at depths < 20 m; however, 2 studies have shown smaller lionfish occur in shallower areas when compared to deep reef habitats (Barbour et al. 2010, Claydon et al. 2011). Recent reports from divers in Choctawhatchee and Pensacola Bays along Florida's panhandle, and a recent collection of 2 specimens from shallow waters (~3 m) in coastal Alabama (A. Fogg, unpublished data) demonstrate that lionfish also occur in nearshore waters of the northern GOM. This evidence coupled with the findings of Jud et al. (2011) show that it is reasonable that juvenile lionfish can settle in shallow estuarine systems, but a lack of sampling in these areas provides no further evidence besides unconfirmed reports. Furthermore, in the most recent NMFS GOM reef fish video survey, lionfish were observed at Ewing Bank and Pulley Ridge, both of which are located in ~100 m of water (NMFS, unpublished data); however, deepwater habitats are under—represented in diver based studies. Future efforts should focus on collecting lionfishes from all depth ranges equally to address this data gap to determine if there is truly an association among depth, sex and size in the northern GOM.

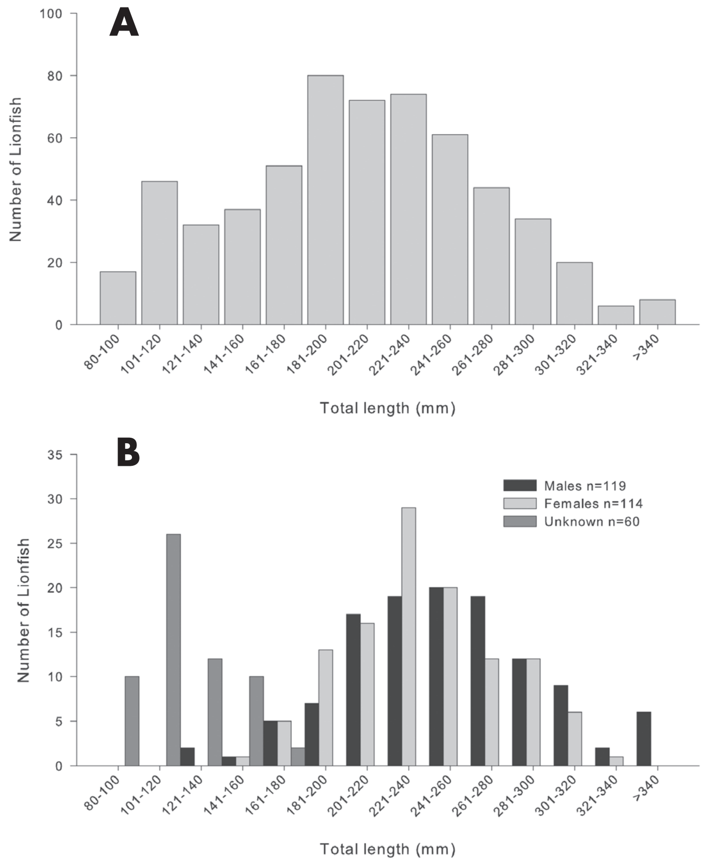

Figure 2. *Length frequency of lionfish (*Pterois *spp.) from the northern Gulf of Mexico.* ***A.*** *All measured specimens (n=582).* ***B.*** *All specimens examined by sex (n=294)*

Since data reported by Schofield (2009, 2010) and in this study were not collected systematically, it has not been possible to establish an accurate rate of expansion for the northern GOM; however, catches of lionfish during fishery—independent surveys suggest the movement of these invasive fishes into the northern GOM has occurred relatively rapidly. During annual groundfish surveys, NMFS conducted about 20,000 bottom trawls in the northern GOM from 1972—2012. During this period no lionfish were collected until 2010 and 2011, when one and 3 lionfish were captured, respectively. Subsequently, a 16–fold increase in the number of lionfish was observed in 2012 when 49 specimens were captured. Similarly, from 1993–2012, over 7,000 camera array deployments were conducted during NMFS reef fish video surveys throughout the northern GOM from the Dry Tortugas to Brownsville, Texas. No lionfish were observed until 2012, when numerous individuals were recorded on video (exact number not available at the date of submission; NMFS, unpublished data). Importantly, these 2 surveys were conducted on vastly different habitats (e.g., mud to hard bottom vs. reef) so the patchy distribution of reef habitat in the northwestern GOM is unlikely to preclude further expansion into this region.

Based on the rapid expansion of lionfish into the GOM, combined with the scarcity of predators in the region (Mumby et al. 2011), it is likely sightings and captures of these invasive fishes will increase. To better understand the ecological impacts of lionfish in the GOM, it will be necessary to gain a basic understanding of their biology and trends in population abundance similar to what has been done in other regions of the western North Atlantic Ocean (Whitfield et al. 2006, Morris 2009, Morris and Akin 2009, Morris et al. 2011). Future research should focus on mechanisms of dispersal for lionfish in the northern GOM, not only to understand their population dynamics, but also to understand mechanisms of dispersal for other potentially invasive organisms.

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