Comparing Age and Growth Patterns of Invasive Lionfish Among Three Ecoregions of the Northern Gulf of Mexico

Comparaison des Paramètres de Croissance et de la Distribution des Classes D'âges chez L'espèce Invasive Poisson Scorpion dans Trois Éco-régions du Nord du Golfe du Mexique

Comparación de los Patrones de Edad y Crecimiento del Pez León Invasor entre Tres Ecoregiones del Norte del Golfo de México

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KEY WORDS: Lionfish, *Pterois*, Scorpaenidae, Gulf of Mexico, growth

EXTENDED ABSTRACT

Although invasive lionfish (*Pterois* sp.) are thought to have been established in the northern Gulf of Mexico (nGOM) since 2010 and are found in some of the highest densities of anywhere in their invaded range (Dahl and Patterson 2014), very little has been published about their regional life history. High growth rates generally lead to the successful invasion and thus are important to estimate. Barbour et al. (2011) estimated lionfish growth using length-at-age data from offshore North Carolina using a von Bertalanffy growth curve. Age when total length (TL) equals zero ($t_{0)}$ was fixed at -0.50 to account for a lack of age-0 lionfish in the samples. This resulted in an increase in the instantaneous growth rate (K) estimate from 0.32 to 0.47, a decrease in asymptotic maximum length (L_{inf}) from 455.1 mm TL to 425.2 mm TL, and a maximum age estimate of eight years. Lionfish age and growth from Little Cayman Island (Edwards et al. 2014), including daily rings, indicated K and L_{inf} as 0.42 and 349 mm TL, respectively, and a maximum age of five years was reported. Finally, Swenarton et al. (2015) using length-based modeling verified by otolith analysis reported an elevated K in the Florida Keys (0.70) compared to northeast Florida (0.47). Other von Bertalanffy growth parameters (L_{inf} and t_o) were not reported. All of the age and growth studies to date have been completed relatively early in the invasion and will likely need to be reevaluated as the invasion levels out.

Since 2012, more than 15,000 lionfish have been collected from the nGOM across three ecoregions: southeast (Florida Keys to north 28.25°), northeast (north 28.25° to west 88°), and west (west 88° to Mexican border). We recorded TL for every lionfish and sagittal otoliths were removed from 4,250 lionfish; a subset of 1,546 sagittal otoliths from lionfish ranging from 81–434 mm TL were embedded and sectioned prior to age determination. Otoliths were read by two separate readers for agreement and if achieved, the width of the marginal increment was measured (0.001 mm) and compared to the proceeding, complete annulus to determine quarter year age resolution. If agreement was not achieved, those samples were not included in analysis (n = 134). Since daily rings were not read, it is likely there was an underestimation of growth. Therefore, a von Bertalanffy growth curve was fit to truncated age data and separate model parameters were determined for each sex and region for comparison (Diaz et al. 2004), followed by a sum of squares reduction test using SAS software to determine if there were differences in growth between regions and sex by comparing non-linear trends between groups (α = 0.05).

The 91.3% agreement in ageing between readers is high compared to Edwards et al. (2014; 42%); this may be as a result of lionfish being collected in tropical water (Little Cayman Island) and otoliths not being sectioned prior to reading (Edwards et al. 2014). Ages of nGOM lionfish ranged from 0 to 4.5 years (mean = 1.35), and the oldest back calculated age confirms lionfish presence in the nGOM in 2008, two years prior to first detection. All three ecoregions of the nGOM showed an age distribution of 93% of fish < 2 years. Similar results were found in Little Cayman Island (Edwards et al. 2014) and North Carolina (Barbour et al. 2011) where the majority of fish were < 3 years old (> 90%). The higher proportion of older fish found in North Carolina and Little Cayman Island may be a result of the fish being present in those locations for a longer period of time.

There were significant differences in age and growth parameters between all three regions and between sexes (Table 1, all $p < 0.01$; see Figure 1). The southeast region had the highest K and L_{inf} and lionfish from this region achieved a greater length at age than in the other two regions (Figure 1A). The west region had the smallest K and L_{inf} compared to the other two regions (Table 1). Males achieved a greater length at given age than females (Figure 1B), and like Edwards et al. (2014), had a significantly greater K and L_{inf} compared to females.

The growth rate of lionfish in the nGOM is greater than other regions as the K parameter from this study was higher than those reported from Little Cayman Island (Edwards et al. 2014), North Carolina (Barbour et al. 2011), and NE Florida (Swenarton et al. 2015), although the K value reported from the Florida Keys was much higher than all studies (Table 1). It

appears that lionfish age and growth from the warm-temperate nGOM is most similar to age and growth reported from NE Florida and temperate North Carolina. Thus, similarities and differences between studies may be more related to climate rather than other biological and ecological factors. However, age and growth will need to be reevaluated in the future as the current study consists of samples from early in the invasion for this region. This information, coupled with other life history information from the nGOM, verifies that lionfish are capable of reproducing within the first year of life. The age and growth information from this study is essential for development of stock assessments and thus management plans that will help mitigate the effects lionfish are having on the native ecosystem.

ACKNOWLEDGEMENTS

We thank Coast Watch Alliance, Perdido Key Chamber of Commerce, Mississippi Gulf Fishing Backs Inc., Gulf and Caribbean Fisheries Institute, Mississippi Chapter of American Fisheries Society, National Oceanic and Atmospheric Administration, Florida Fish and Wildlife Conservation Commission, Alabama Department of Marine Resources, Gulf Coast Lionfish Coalition, Dauphin Island Sea Lab, Zookeeper LLC, Lytle Scholarship, Tom McIllwain Scholarship, Reef Pirate Emerald Coast Reef Association, Florida Skin Divers Association, Sarasota Underwater Club, Tampa Bay Spearfishing Club, Louisiana Council of Underwater Dive Clubs, and Canyon Coolers for their generous financial and logistical support. We also thank all of the undergraduate interns for laboratory assistance in processing lionfish.

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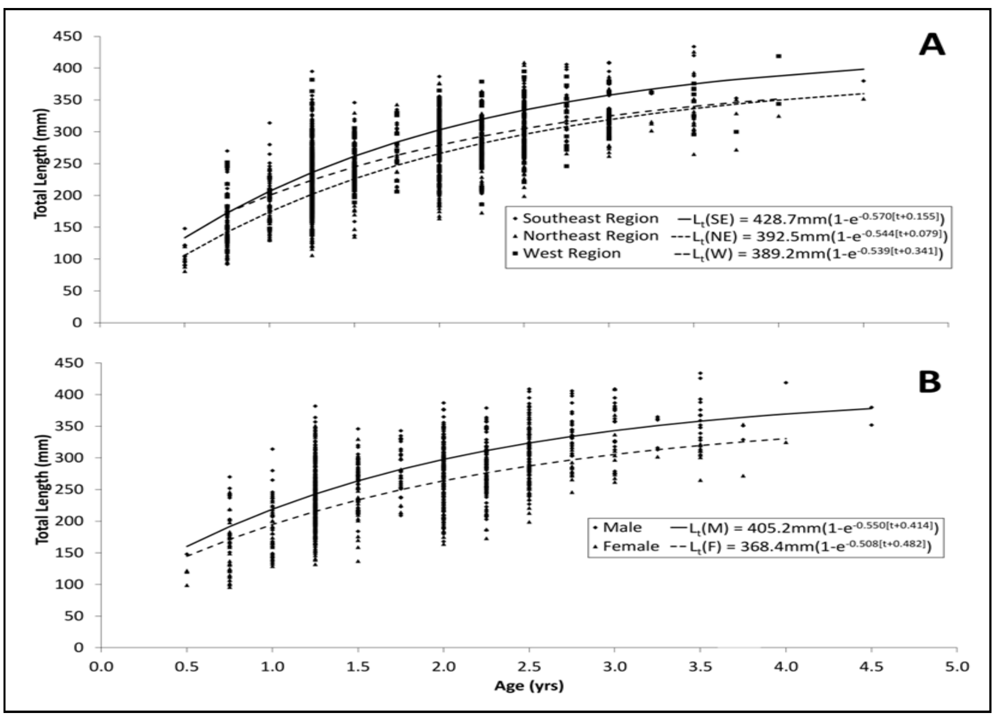

Figure 1. Von Bertalanffy growth curve and associated equations plotted with observed length at age by A) region: southeast (Florida Keys to north 28.25°), northeast (north 28.25° to west 88°), and west (west 88° to Mexican border) and B) Sex: Male and Female pooled across regions.

Table 1. Von Bertalanffy growth curve equation parameter estimates by region (southeast (Florida Keys to north 28.25°), northeast (north 28.25° to west 88°), and west (west 88° to Mexican border)) and sex. Sum of squares reduction test comparisons between all regions and sex were significantly different ($p < 0.01$). Parameters included from North Carolina (Barbour et al. 2011), Little Cayman Island (Edwards et al. 2014) and Florida (Swenarton et al. 2015) for comparison.

	Southeast	Northeast	West	Males	Females	ALL	North Carolina	Little Cayman Island	Florida Keys / NE Florida
L_{inf} (mm TL)	428.7	392.5	389.2	405.2	368.4	400.2	425.2	349.0	N/A
K	0.570	0.544	0.539	0.550	0.508	0.559	0.470	0.420	0.700/0.470
t_0	-0.155	-0.079	-0.341	-0.414	-0.482	-0.212	-0.500	-1.010	N/A