Substantial population declines in the northern Gulf of Mexico invasive lionfish following disease emergence

Disminución sustancial de la población en el norte del Golfo de México pez león invasor después de la aparición de la enfermedad

Déclin accéléré de la population de sébastes-lions envahissants du nord du Golfe du Mexique à la suite de l'apparition de la maladie

HOLDEN E. HARRIS[1]*, ALEXANDER Q. FOGG[2], ROBERT N. M. AHRENS[1], MICHEAL S. ALLEN[1], and WILLIAM F. PATTERSON III[1]

[1]*Fisheries and Aquatic Sciences — School of Forest Resources and Conservation*
Institute of Food and Agriculture Sciences — University of Florida
7922 NW 71st Street, Gainesville, Florida 32653 USA.
**holdenharris@ufl.edu*.
[2]*Okaloosa County Board of County Commissioners*
Emerald Coast Convention and Visitors Bureau
1540 Miracle Strip Parkway, Fort Walton Beach, Florida 32548 USA.

EXTENDED ABSTRACT

Introduction

Indo-Pacific lionfish *Pterois volitans/miles* have established high population densities in many western Atlantic marine habitats and regions (Côté and Smith 2018). Lionfish densities in their native Indo-Pacific range are substantially lower than those reported among various systems in the western Atlantic (Darling et al. 2011, Kulbicki et al. 2012), but the principal mechanisms that control native populations remain largely unknown (Côté and Smith 2018). High population densities (Dahl et al. 2019) and low genetic diversity in the western Atlantic (Johnson et al. 2016, Pérez-Portela et al. 2018, Burford Reiskind et al. 2019) suggest lionfish could be vulnerable to pathogenic control (Lee and Klasing 2004, White and Perkins 2012). In August 2017, the first reported disease in invasive lionfish populations was documented in fish collected from northern Gulf of Mexico (nGOM) high-density (> 25 fish per 100 m^2) artificial reefs (ARs) offshore northwest Florida (Harris et al. 2018). Symptoms of the disease include skin ulcers of variable size, location, and number. Deep ulcers through the epidermis expose skeletal muscle with a sloughing of necrotic tissue. Subsequent observations have been reported throughout the GOM, along the US east coast, and in locations throughout the Caribbean (Harris et al. 2018).

Here, we report changes in nGOM lionfish populations observed following the appearance of ulcerated lionfish in the region. Relative condition was examined for ulcerated versus apparently healthy fish using habitat- and sex-specific predicted weight-at-length models. Recruitment patterns were inferred from population size composition data from nGOM lionfish sampled during 2014 - 2018. Lionfish population densities were assessed with remotely operated vehicle (ROV) video surveys and changes in fishery catch per unit effort (CPUE) from commercial spearfishing landings and lionfish tournaments.

Methods and Results

Lionfish population density declines based on ROV sampling

Lionfish population densities were estimated during 2016 - 2018 via ROV surveys (n = 338 sampling events) at 18 Okaloosa County Large Area Artificial Reef Site (LAARS) ARs, 27 Escambia LAARS ARs, and 15 nGOM NRs. Low-density ARs included reefs that had undergone spearfishing during prior lionfish removal experiments; high-density ARs were control sites during those experiments at which no lionfish were removed. During 2016 - 2017, mean lionfish population density on high-density ARs was > 25 fish per 100 m^2 and 2–5X higher than corresponding mean density on low-density ARs (< 15 fish per 100 m^2) (Figure 1A, 1B). Then, population density declines began in late 2017 and continued through 2018. GLMM results (negative binomial with log link) indicate mean lionfish density on high-density ARs declined 77% on Okaloosa ARs and 75% on Escambia ARs. By 2018, high-density ARs were no longer significantly different than corresponding low-density reefs. Like high-density ARs, mean lionfish density on NRs remained relatively stable during 2016–2017, then declined 75% between October 2017 and October 2018 (Fig. 1C) based on generalized linear mixed model (GLMM) results (Poisson with log link).

Regional declines observed in lionfish fisheries catches and catch per unit effort

Commercial lionfish landings were assessed with catch data from 1,529 commercial spearfishing trips reported to the Florida Fish and Wildlife Conservation Commission (FWC) during 2014 - 2018. From 2017 - 2018, commercial landings declined 52% and the number of trips declined 38%. Generalized linear model (GLM, lognormal with log link) results

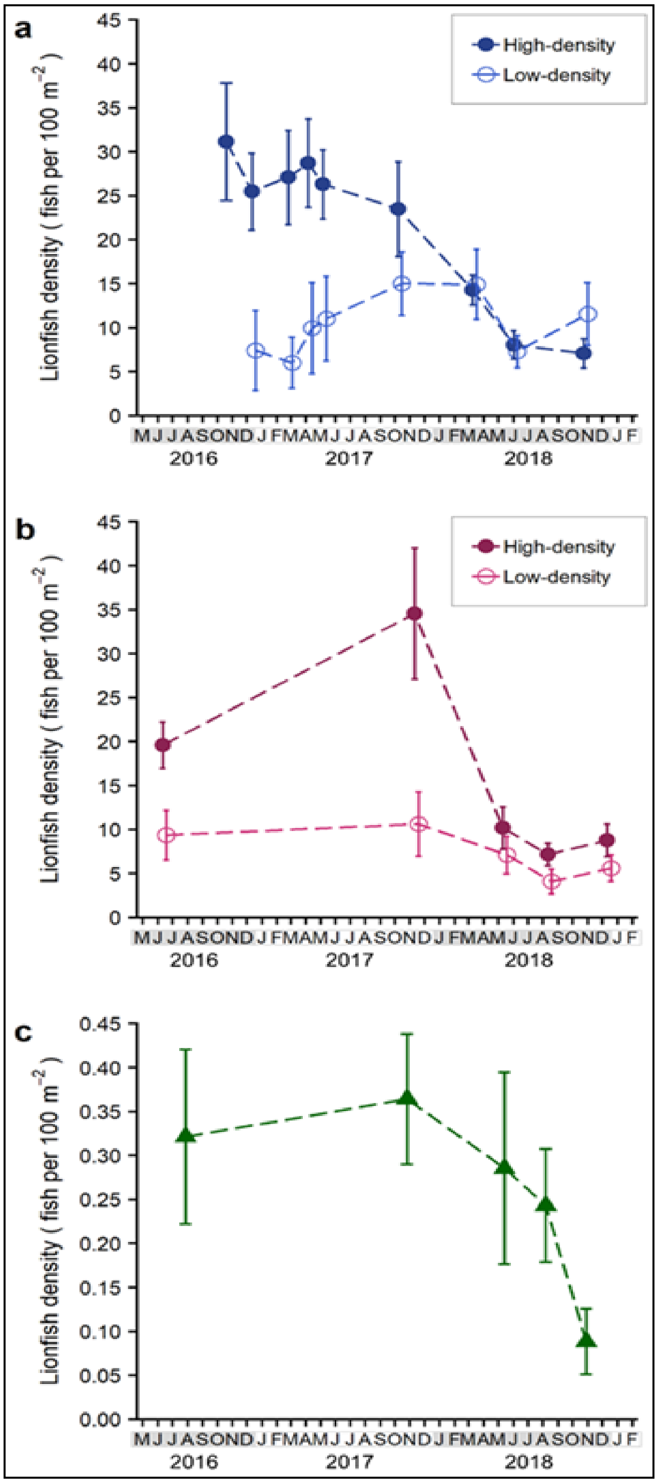

Figure 1. Mean (± SE) lionfish population density estimated via remotely operated vehicle surveys on a) 8 low-density and 10 high-density Okaloosa artificial reefs (ARs), b) 9 low-density and 18 high-density Escambia ARs, and c) 15 northern Gulf of Mexico natural reefs (NRs). Low-density ARs had experimental removals conducted in 2014 (Escambia) and 2017 (Okaloosa) prior to the appearance of ulcerated fish. NR population densities (c) were ~100X lower than those on ARs, thus the difference in y-axis scales.

indicate mean commercial spearfishing CPUE in 2018 declined 48% compared to highs observed in 2016. Lionfish tournament divers that we investigated during 2017 - 2019 speared 21,789 lionfish from 1,159 nGOM reefs. GLMM (lognormal with log link) results indicated mean tournament CPUE declined by 44% in 2018 compared to 2017, with all six repeating teams having lower CPUE. Mean tournament CPUE declined an additional 18% in 2019 with six of seven repeating teams having lower CPUE.

Relative condition was lower in ulcerated lionfish

Sex-specific lionfish relative condition factor (K_n) was evaluated for 338 lionfish sampled from nGOM natural reefs (NRs) during fall 2017, during which 39 lionfish presented active skin ulcers. Predicted weight-at-length parameters were computed from 282 males and 316 males sampled from similar nGOM NRs prior to disease emergence during 2013–2016. We found mean K_n was significantly lower for ulcerated lionfish ($F_{(1, 334)} = 7.81$; $p = 0.006$). Multiple comparison tests showed the significant decline in ulcerated lionfish K_n was caused by declines in ulcerated females (Tukey HSD, $p = 0.025$), with ulcerated female K_n 8.8% lower than non-ulcerated females.

Size composition changes and recruitment declines

Northern Gulf of Mexico lionfish size composition was assessed for 31,073 lionfish harvested from 201 sampling events during 2014 - 2018. Length frequency density plots of lionfish collected during 2014 - 2016 show bimodal distributions with local minima *c.* 175 - 200 mm (Figure 2A). Mean proportion of age-0 lionfish ($\hat{p}$) among the population sampled during May 2014 - 2018 was 0.17 - 0.22 (Figure 2B). In contrast to 2014 - 2017, density plots for lionfish collected in 2018 show a relatively unimodal distribution during which $\hat{p}$ was 0.05 and 84% lower compared based on GLMM results (binomial with logit link).

Discussion

Lionfish populations declined substantially in 2018 over a broad area of the nGOM continental shelf. Density declines > 75% were observed on artificial and natural reefs in our study areas, which previously had the highest reported lionfish densities within the invasive range. The > 80% drop in the proportion of age-0 fish indicates a recruitment failure likely occurred during the same time period. Reductions in population density and recruitment likely drove regional declines observed in lionfish commercial spearfishing landings, commercial spearfishing CPUE, and tournament CPUE. Collectively, these population changes indicate instantaneous total mortality in the region was > 1.0 per year and that nGOM lionfish populations in the region likely experienced a population crash. Although disease etiology and its mortality rates remain unknown, the appearance and spread of the lionfish ulcerative skin disease about 1 year prior to the lionfish population crashes implicates the disease as a causative mechanism. This may indicate a potential end for their release from parasitic or pathogenic controls in the Western Atlantic. It is unclear at this stage if nGOM lionfish populations will increase to pre -summer 2017 levels, thus repeat a boom-bust population cycle. Invasive species outcomes are notoriously difficult to forecast and continued study will be necessary to understand how disease, fisheries removals, and other forces influence population and community dynamics.

KEYWORDS:Invasion ecology, boom-bust dynamics, *Pterois volitans/miles*, pathogenic control

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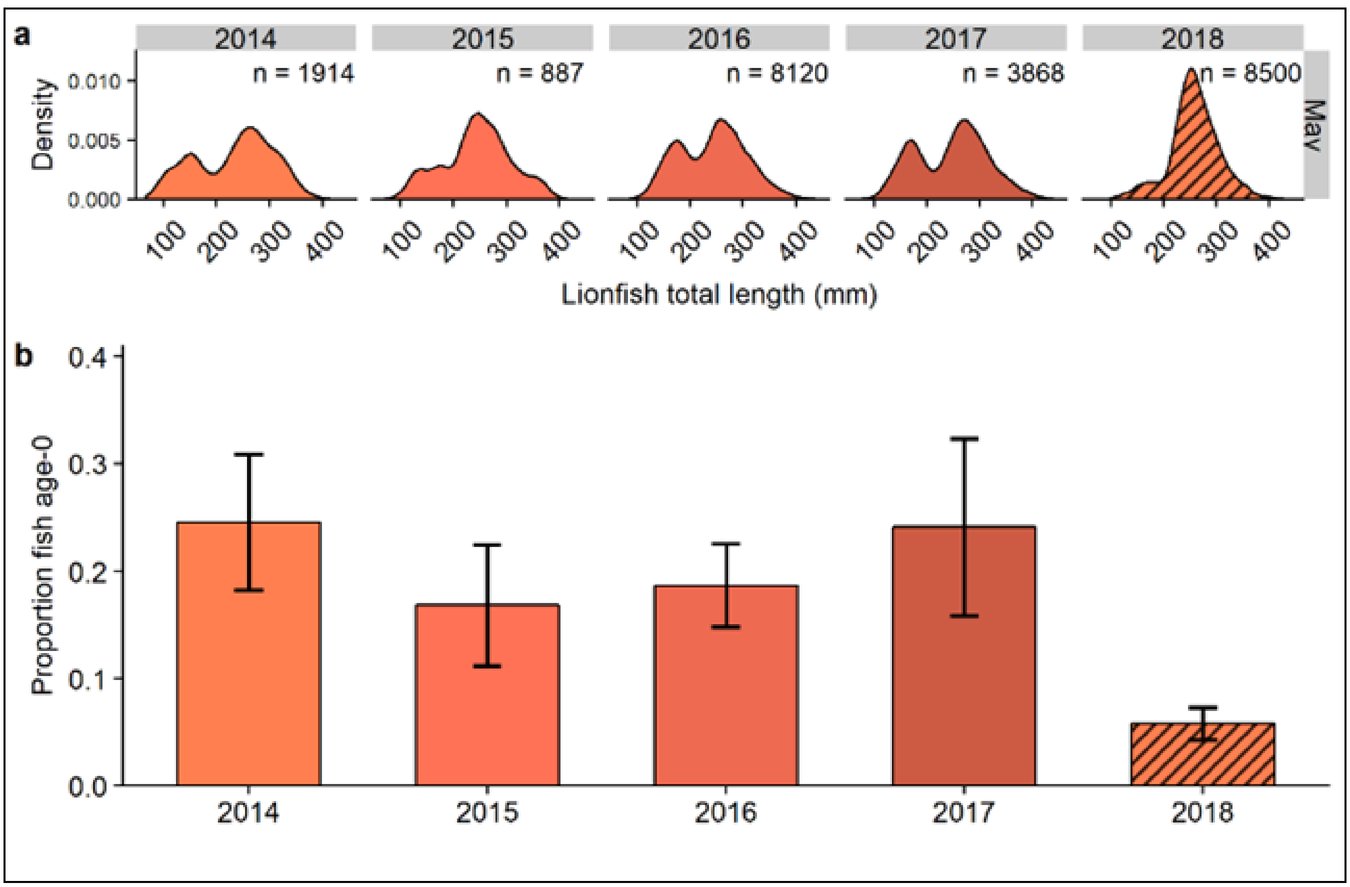

Figure 2. Northern Gulf of Mexico lionfish population size composition and recruitment during 2014 - 2018. a) Density plots of lionfish total length (TL) sampled in May 2014 - 2018 with sample sizes (n) indicated. b) Mean (± 95% CI) proportion of age-0 lionfish among samples per sampling event ($\hat{p}$) during May 2014 - 2018. c) Density plots of lionfish TL sampled during May - October 2014 (solid plot) and May - October 2018 (hatched plot). d) Paired means (± 95% CI) of $\hat{p}$ during May - October 2014 (solid bars) and May - October 2018 (hatched bars).