Gut throughput rate and satiation of the invasive Lionfish (Pterois volitans) and its potential impact on an endemic, endangered Labrid fish Halichoeres socialis

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GUT THROUGHPUT RATE AND SATIATION OF THE INVASIVE LIONFISH (*PTEROIS VOLITANS*) AND ITS POTENTIAL IMPACT ON AN ENDEMIC, ENDANGERED LABRID FISH *HALICHOERES SOCIALIS*

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ABSTRACT

The invasive Indo-Pacific Lionfish *Pterois volitans* has been recognized as a severe threat to indigenous fish species on Caribbean reefs. Previous studies have identified an extensive variety of Caribbean fishes in the stomachs of lionfish, but few have tried to quantify the impact these invaders could have on endemic or threatened species. The threatened Labrid fish *Halichoeres socialis* has been identified as the primary component of lionfish diet in Belizean lagoonal reef systems. This study aims to answer two questions: what is the average maximum number of prey-fish a lionfish can consume in one sitting, and at what rate can these lionfish pass a meal of three prey fish completely? To test lionfish satiation, the subjects were fed as many *Pseudohemiculter dispar* (a commercially available surrogate) as they could eat within a fifteen-minute window. During the digestion rate experiment, lionfish were fed three similarly sized *P. dispar* and allowed to digest in 3, 6, 9, 12, 15, 19, and 24 hour blocks. From observing prey throughput under near optimal laboratory conditions, the maximum potential impact of lionfish on native populations of Caribbean reef dwelling fishes can be estimated. Given the volume and mass of prey items consumed in this study between 593 and 4658 individual *H. socialis* could be consumed by a single lionfish in one year. Coupled with

further investigation into *H. socialis* stock numbers, lionfish (*P. volitans*) could be considered a potentially immanent threat to fishes that exhibit body morphometrics like those of *H. socialis* at any stage of their life-history.

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Introduction

The tropical western Atlantic and Caribbean have been invaded by one of the most prolific and destructive invaders known within marine reef ecosystems. These invasive Lionfishes (*Pterois volitans and miles*) are now well-documented as having an adverse impact on Atlantic reef fishes (Albins and Hixon 2008; Arias-Gonzales et al. 2011; Cerino et al. 2013; Layman et al. 2014; Lesser and Slattery 2011; Rocha et al. 2015). Field observations suggest that prey throughput can be quite high; in the northern Caribbean, divers observed that a single lionfish consumed 20 reef fishes in 30 minutes (Albins and Hixon 2008). Sampling of gut contents indicates that lionfish can exhibit a strong preference for particular prey species. For example, in Belize Rocha et al (2015) discovered that lionfish sampled in the Meso-American Barrier Reef (MABR) system had consumed large numbers of a small labrid fish that is endemic to the MABR. This labrid, *Halichoeres socialis*, is a recently-described species found only inside the lagoonal regions of the MABR, and is notably in the Pelican Cays region of Belize where they were first discovered (Randall and Lobel 2003, Lobel et al 2009). Rocha et al (2015) found that the endangered *Halichoeres socialis* (listed IUCN Redlist, Rocha 2015) was the primary prey item of the invasive lionfish in Belize's lagoonal reefs, both in numbers (46% of all prey by all lionfish) and in frequency (41% of all lionfish sampled had eaten at least one *H. socialis*).

In this study, we investigated two aspects of lionfish consumption and digestion to better estimate the total impact of their predatory influence on a putatively endangered species.

The first experiment determined how many small fish a lionfish could swallow in 15 minutes. The second experiment determined the rate of digestion clearance time for the stomach and intestine, and hind-gut.

The objective is to provide an improved potential estimate for the total mass, volume and number of prey fish that a lionfish is likely to consume over time, allowing a better assessment of potential population impacts of *Pterois volitans* on *H. socialis* and other small reef fishes on Caribbean coral reefs.

Materials and Methods

Acquisition and housing of lionfish

Seven lionfish were acquired in June of 2014 from commercial fish retailer KP Aquatics. Upon arrival the lionfish ranged in size between 17 cm and 22 cm standard length, and 24.1 cm to 28.5 cm total length. Fish were acclimated to a 660-gallon tank. Their aquarium was maintained at 28° C with a salinity of 35 parts per thousand (ppt). The lionfish were fed twice daily a varying diet of the silverside (*Pseudohemiculter dispar*) and other commercial foods. Silversides were selected as the experimental prey as they were the commercially available species exhibiting the most similar body morphometrics and size to *H. socialis* during the time of experimentation (Table 4).

Satiation experiment:

During the satiation trial, within their shared 660-gallon tank, each of the 7 lionfish tested were separated into large cylindrical mesh nets and allowed to acclimate for 48 hours with normal feeding frequency. The lionfish were then starved for 48 hours. The test prey (*P. dispar*) were measured for standard length (mm), mass (g), and volume (mL). Lionfish were then fed as many pre-measured *P. dispar* as they would consume within 30 minutes.

Rate/Digestion experiment:

During the gut throughput trial, as with the satiation experiment, lionfish were separated into large cylindrical nets within their common 660-gallon aquarium and allowed to acclimate for 48 hours. The lionfish were then starved for 48 hours. Three *P. dispar* were chosen randomly and measured for standard length (mm), mass (g), and volume (mL) and then fed to each lionfish (n=7). One lionfish was chosen to be in each of the following seven digestion categories respectively; 3.4*,* 6, 9, 11, 13, 15 or 19 hours. After the assigned time-period had elapsed, lionfish were removed from their aquaria and euthanized with a lethal dose of MS-222 in accordance to IACUC protocol #14-027 and dissected in accordance with published studies (Green et al., 2012; Baker et al., 2013).

Digestion Categories:

P. dispar remains that were removed from the digestive tract of lionfish were assigned one of four digestion categories (Figure 1). The digestion categories ranged from category 1 – "little to no degradation" to category 4 – "paste/feces."

H. socialis calculations:

Estimations for the maximum, average and minimum number of silversides that could be consumed per year were obtained by multiplying the maximum, average and minimum number values of silversides consumed in the satiation trials (Table 2) by 365. Since *P. dispar* is typically on average twice as large as *H. socialis*, these values were multiplied by 2 to estimate the equivalent number of *H. socialis* that could have been consumed. The relative size of *P. dispar* and *H. socialis* was based on the average standard length of 100 silversides determined in this study and on published data on the average standard length of *H. socialis* (Randall and Lobel 2003) (Table 4). Calculations for maximum, average and minimum number of *H. socialis* were made based on data collected and mass/size conversions of *H. socialis* to *P. dispar*, then multiplied by 0.46 as that was the percentage that *H. socialis* made up of the lionfish diet in the Belizean barrier reefs Rocha et al found in 2015.

Silversides:

One hundred silversides were measured for standard length (mm), mass (g), and volume (mL) to determine if both mass and volume could be predicted from standard length in silversides.

Statistics:

A mixed model linear regression was performed to examine the relationship between mass of silversides vs. standard length and volume of silversides vs. standard length (Table 6).

Results

At the time of the satiation experiments the lionfish ranged in size from 17.9 cm to 21.7 cm standard length (Table 1). The number of silversides consumed per trial until satiated ranged from 3 individual fish to 13. The total mass consumed in grams per lionfish per trial ranged from 3.73 (g) to 25.30 (g). The total volume consumed (mL) per lionfish per trial ranged from 3.62 (mL) to 23.913 (mL). The average number of silversides consumed until satiation was 7.7 fish, the average mass consumed in grams was 12.7g and the average volume of fish consumed was 12.1 mL (Table 1).

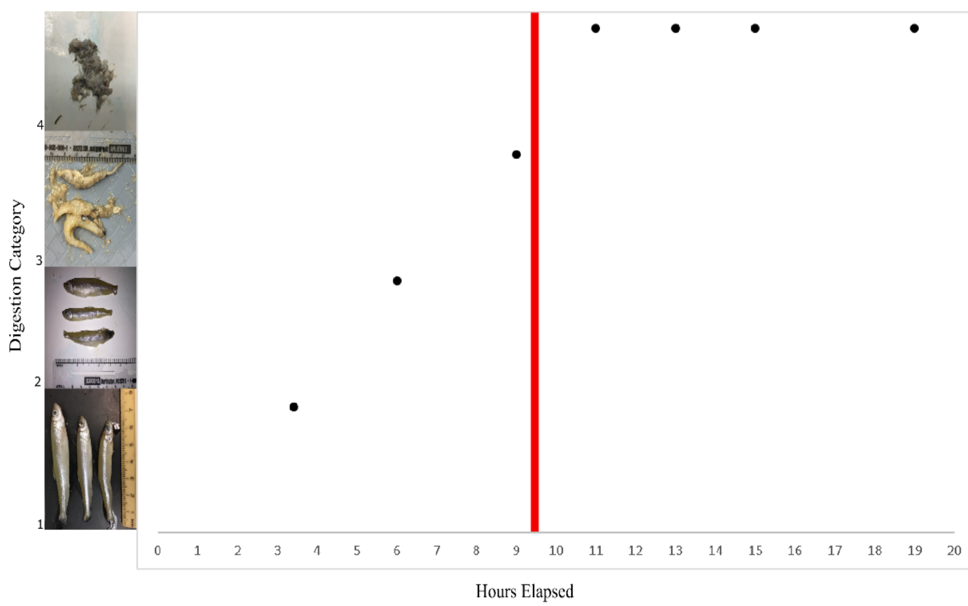
It took 9 hours for the stomachs to empty (Figure 1). After this point, lionfish can readily feed again. It took 20 hours for the lionfish to pass the silversides consumed to completion. During digestion, consumed prey items fell into digestion category 1 until roughly 3.5 hours, category 2 for roughly 3 hours (between hours 3.5 – 6.2), and category 3 for roughly 3 hours (between hours 6.2 – 9). Beyond 3 hours all samples examined fell into category 4 or had been wholly digested.

The average silverside mass (from a sample of 100 silversides) was 2.1 grams. The average silverside volume was 2.0 mL. The average total mass of silversides consumed by one lionfish was 12.8 g. The average total volume of silversides consumed by one lionfish was 12.1 mL. The total mass of silversides that could be eaten by an individual lionfish within a year is 4658.5 g. The total volume of silversides that could be eaten by an individual lionfish within a year is 4430.0 mL. The maximum and minimum numbers of silversides that could be consumed within a year based on mass (max, min/ave ss size) were 4386.2 and 647.3 grams, respectively. The maximum and minimum numbers of silversides that could be consumed within a year based on volume were 4263.9 and 645.5 milliliters, respectively (Table 2).

Based on our data and that of Rocha et al., 2015 we can see that in one year, a single lionfish has a minimum potential consumption of 593 *H. socialis* per year and a maximum potential consumption of 4,035 *H. socialis* (Table 3) (Figures 2, 3).

Lionfish Number	Lionfish Standard Length (cm)	Number of silversides consumed until satiated	Total Mass Consumed (g)	Total Volume Consumed (mL)
1	18.5	13	22.006	20.697
2	20.2	12	25.296	23.913
3	21.7	5	7.285	6.700
4	17.9	11	11.033	11.007
5	19.2	3	3.733	3.620
6	19.7	4	8.443	7.640
7	17.8	6	11.544	11.383
		Average mass (g) and volume (mL) consumed:	12.763	12.137

- Table 1**:** Satiation data for individual lionfish tested. Listed are lionfish standard length (cm), number of silversides each lionfish consumed until satiation, total mass of silversides consumed (g), and total volume of silversides consumed by each lionfish.



- Figure 1**:** The digestion category (DC) of each lionfish tested over a 20-hour period. The digestion categories range from 1 through 4 where 1 is "little to no digestion" and 4 is "feces/paste." The red line denotes the point at which the lionfish stomach is completely empty.

Average Mass of Silversides (g)	2.1 g
Average Volume of Silversides (mL)	2.0 mL
Average Mass of Silversides Eaten Until Sated (g)	12.8 g
Average Volume of Silversides eaten until sated (mL)	12.1 mL
Total Mass of silversides that could be eaten in a year-long period (g)	4658.5 g
Total volume of silversides that could be consumed in a year (mL)	4430.0 mL
Maximum number of individual SS that could be eaten in a year based on Mass (g)	4386.2 g
Maximum number of individual SS that could be eaten in a year based on Volume (mL)	4263.9 mL
Minimum number of individual SS that could be eaten in a year based on Mass (g)	647.3 g
Minimum number of individual SS that could be eaten in a year based on Volume (mL)	645.5 mL
Average number of individual SS that could be eaten in a year based on Mass (g)	2213.1 g
Average number of individual SS that could be eaten in a year based on Volume (mL)	2164.1mL

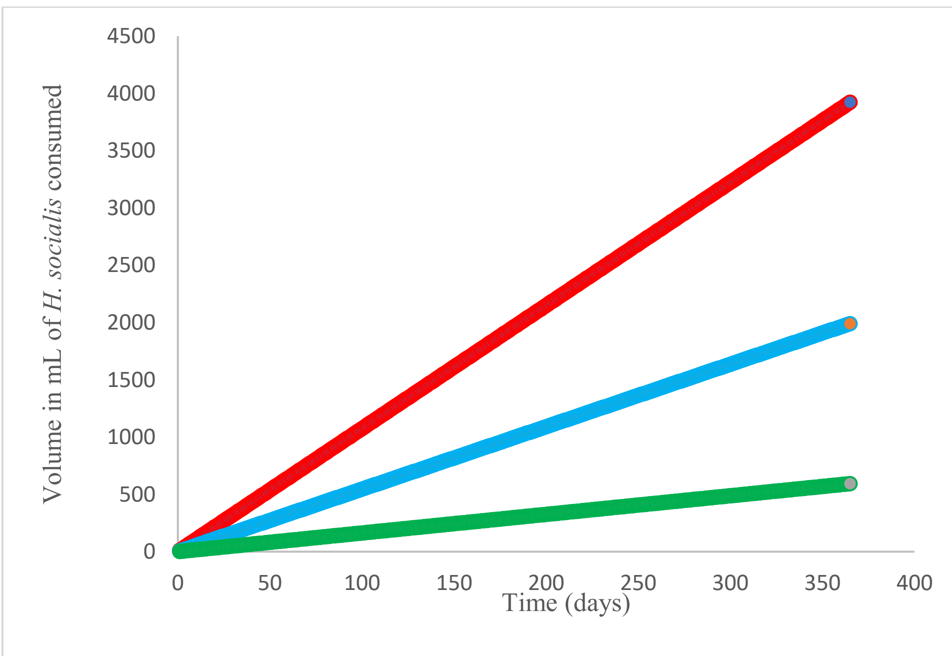
- Table 2**:** Collective data and extrapolations for consumption of silversides (*P. dispar*) (SS) by lionfish.

Maximum number of H. soc that could be consumed in a year based on Mass (g)	4,035
Maximum number of H. soc that could be consumed in a year based on Volume (mL)	3,922
Average number of H. soc that could be consumed in a year based on Mass (g)	2,035
Average number of H. soc that could be consumed in a year based on Volume (mL)	1,990
Minimum number of H. soc that could be consumed in a year based on Mass (g)	595
Minimum number of H. soc that could be consumed in a year based on Volume (mL)	593

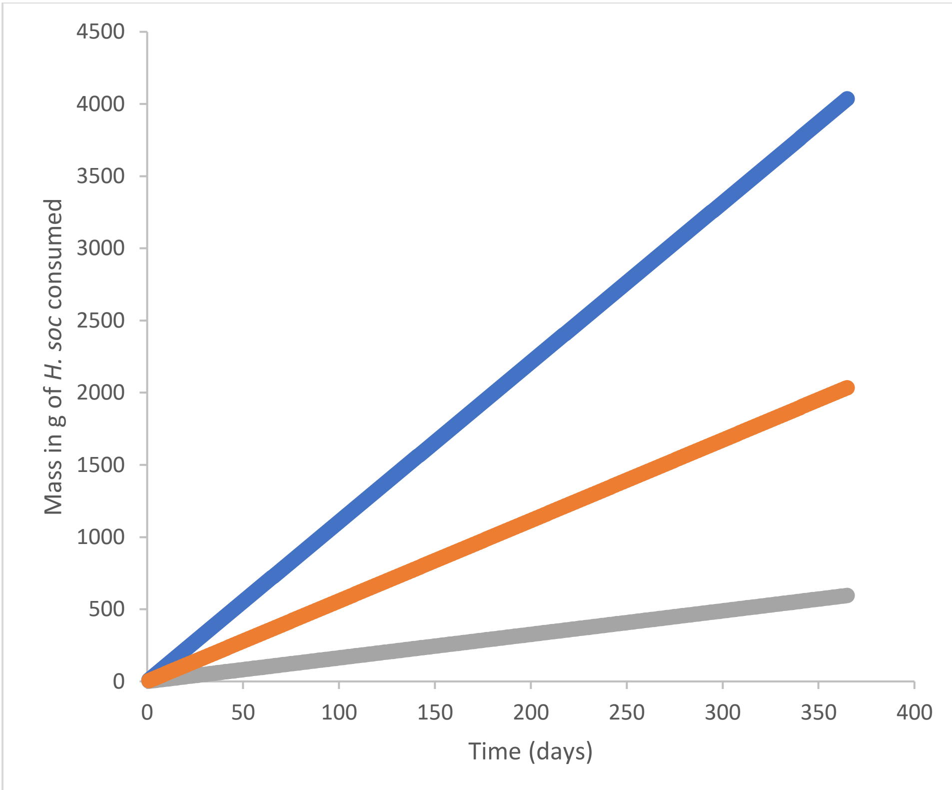
- Table 3: Collective data and extrapolations for consumption of H. socialis converted from silverside data.

Average Standard length for silverside	60.695
Average Standard Length for *Halichoeres socialis*	30.400
Average standard length Ratio of *H.soc* to silverside	1.99:1 (or 2:1)

Table 4: Silverside (*P. dispar*) to *H. socialis* conversion table. *H. socialis* values found by multiplying SS data by 2, then by 0.46 as *H. soc* represented only 46% of the diets of fish surveyed



- Figure 2**:** Projection for the maximum (red), average (blue) and minimum (green) volume (mL) of *H. socialis* consumption by one lionfish in one year.



- Figure 3: Projection for maximum (blue), Average (orange) and minimum (grey) mass of *H. socialis* consumption by one lionfish in one year.

- Citation	Number of species found in study	Percentage of fish with full stomachs	Number of teleost families found in stomachs
Rocha et al 2015.	16	41%	8
McCleery 2015	No data	92.80%	5
Morris Akins 2009	41	79%	21
Green Akins Cote 2011	12	100% (catching LF that actively caught prey)	5
Green Akins Cote 2012	42	No Data	16
Cote Maljkovic 2010	5	100% (catching LF that actively caught prey)	5

- Table 5: Lionfish stomach content data found by related studies (cited here).

Mixed model linear regression results	P-value	adjusted R squared value
Wet Mass vs Standard Length	2.20E-16	0.9148
Wet Volume vs. Standard Length	2.20E-16	0.8435

- Table 6**:** P-value and adjusted R^2 values for the mixed model linear regression done for wet mass vs standard length and wet volume vs standard length.

Discussion

Lionfish are among the most effective marine fish invaders in modern history. However, efforts are being made to reduce their impact. Simulation models predict that lionfish population reductions may be attainable at a regional scale with frequent and consistent removal efforts (Arias-González et al., 2011; Barbour et al., 2011; Morris, Shertzer & Rice, 2010). Culling at a regional scale has been shown to be effective by Green et al. (2014) on coral reefs around Little Cayman – where reductions in lionfish number resulted in a stabilization or reversal of declines in native prey fish (Côté et al, 2014). Conditioning local piscivores has also been suggested as a biotic control for lionfish population reduction. Tethering experiments over seagrass beds, rarely culled reefs, and intensely culled reefs yielded significant increases in predation (1.02x), and for lionfish tethered on intensely culled reefs predation likelihood increased 30x and 14x than fish tethered on rarely culled reefs respectively (Diller et al., 2014). Finally, establishing a seafood market for lionfish will increase demand for the delicious (personal observation) and edible meat of the lionfish, and increase commercial fishing efforts for lionfish (Morris and Whitfield, 2009).

To understand the lionfish impact on the endemic Belizean social wrasse, *H. socialis*, more information must be collected. Surveys of current lionfish stocks on the Belizean Barrier Reef system must be taken. The rate at which the lionfish population is growing in that area must be investigated. Surveys of *H. socialis* numbers must also be collected and their range further delineated. In many places in the MABR lagoonal system, this wrasse superficially appears to remain as the most numerous of all diurnal coral reef fishes (pers comm – Dr. Les Kaufmann 2017). Without these parameters, it is impossible to have anything but a general estimate of the lionfish impact on this endemic and endangered fish.

Invasive predators have been the cause of some of the most deleterious impacts on naïve ecosystems ever recorded, and have accelerated multiple extinctions by means of tenacious, direct and consumptive effects (Blackburn et al. 2004, Jones et al. 2008, Kumschick et al. 2015, Salo et al. 2007). Lionfish are no exception - they have been shown to increase mortality rates and drive local extirpation of the fairy basslet *Gramma loreto* and other native prey (Ingeman 2016). Without intervention, lionfish pose an enormous risk to *H. socialis* populations, and by extension to populations of any small, fusiform reef dwelling endemic species of fish living in the Caribbean. As this study demonstrates, lionfish have the potential to consume massive numbers of endemic prey species in a relatively short amount of time, and this high rate of consumption should be considered when implementing strategies to mitigate or lessen the impact of lionfish on local populations by managers of these ecosystems.

Bibliography

1. Albins M. A., Hixon, M. A. 2008. Invasive Indo-Pacific lionfish Pterois volitans reduce recruitment of Atlantic coral-reef fishes. Mar Ecol Prog Ser. 367:233-238.

2. Albins, M.A., Hixon, M.A., 2013. Worst case scenario: potential long-term effects of invasive predatory lionfish (Pterois volitans) on Atlantic and Caribbean coral-reef communities. Environmental Biology of Fishes 96, 1151–1157.

3. Albins, M.A., Lyons, P.J., 2012. Invasive red lionfish Pterois volitans blow directed jets of water at prey fish. Marine Ecology Progress Series 448, 1–5.

4. Arias-Gonzales J. E., Gonzalez-Gandara, C., Cabrera, J. L., Christensen, V. 2011. Predicted impact of the invasive lionfish Pterois volitans on the food web of a Caribbean coral reef. Environmental Research 111:917-925.

5. Baker R, Buckland A, Sheaves M (2013) Fish gut content analysis: robust measures of diet composition. Fish and Fisheries DOI:10.1111/faf. 12026.

6. Barbour AB, Allen MS, Frazer TK, Sherman KD (2011) Evaluating the Potential Efficacy of Invasive Lionfish (Pterois volitans) Removals. PLoS One 6(5): e19666. doi:10.1371/journal.pone.0019666

7. Blackburn TM, Cassey P, Duncan RP, Evans KL, Gaston KJ (2004) Avian extinction and mammalian introductions on oceanic islands. Science 305: 1955−1958

8. Cerino D, Overton AS, Rice JA, Morris Jr JA (2013). Bioenergetics and Trophic Impacts of the Invasive Indo-Pacific Lionfish. Transactions of the American Fisheries Society, 142(6), 1522-1534.

9. Clavero M, Garcı´a-Berthou E (2005) Invasive species are a leading cause of animal extinctions. Trends in Ecology & Evolution 20:110

10. Coˆte´ IM, Akins L, Underwood E, Curtis-Quick J, Green SJ (2014) Setting the record straight on invasive lionfish control: Culling works. PeerJ 2:e398v391

11. Côté IM, Green SJ (2012). Potential effects of climate change on a marine invasion: the importance of current context. Current Zoology, 58(1), 1-8.

12. Côté, I.M., Green, S.J., Hixon, M.A., 2013. Predatory fish invaders: insights from Indo- Pacific lionfish in the western Atlantic and Caribbean. Biological Conservation 164, 50-61.

13. Côté IM, Maljkovic´ A (2010) Predation rates of Indo-Pacific lionfish on Bahamian coral reefs. Marine Ecology Progress Series 404: 219–225

14. Dahl, K.A., Patterson III, W.F. 2013. Diet of the Invasive Pacific Lionfish, *Pterois volitans*, on Natural and Artificial Reefs in the Northern Gulf of Mexico. Proceedings of the 66th Gulf and Caribbean Fisheries Institute. 201-203.

15. Diller, J.l., Frazer, T.K., Jacoby, C.A. 2014. Coping with the lionfish invasion: Evidence that naïve, native predators can learn to help. *J. Exp. Biology* 455: 45 – 49.

16. Doupe R, Knott M (2010) Rapid Digestion of fish prey by the highly invasive 'detritivore' *Oreochromis mossambicus*. Journal of Fish Biology 76: 1019-1024.

17. Essington T, Hodgson J, Kitchell J (2000) Role of satiation in the functional response of a piscivore, largemouth bass (*Micropterus salmoides*) Canadian Journal of Fisheries and Aquatic Sciences 57:548-556.

18. Fishelson L (1997) Experiments and observations on food consumption, growth and starvation in Dendrochirus brachy - pterus and Pterois volitans (Pteroinae, Scorpaenidae). Environmental Biology of Fishes 50:391–403

19. Green SJ, Akins JL, Côté IM (2011). Foraging behaviour and prey consumption in the Indo-Pacific lionfish on Bahamian coral reefs. Marine Ecology Progress Series, 433, 159-167.

20. Green SJ, AkinsJL, Morris JA (2012) Lionfish dissection: Techniques and applications. NOAA Technical Memorandum NOS NCCOS 139, 24pp

21. Green, S. J., Cote, I. M. 2009. Record densities of Indo-Pacific lionfish on Bahamian coral reefs. Coral Reefs.28(1):107-107.

22. Harms CA, Appeldoorn RS (2013) Digestion rate analysis of fish prey items in lionfish (Pterois volitans). Proceedings of the 66th Gulf and Caribbean Fisheries Institute. 548.

23. Ingeman K E (2016) Lionfish cause increased mortality rates and drive local exterpation of native prey. Marine Ecology Progress Series. Vol. 558: 235-245. doi: 10.3354/meps11821

24. Jones HP, Tershy BR, Zavaleta ES, Croll DA, Keitt BS, Finkelstein ME, Howald GR (2008) Severity of the effects of invasive rats on seabirds:a global review. Conservation Biology 22: 16–26.

25. Kitchell JF (1990). The scope for mortality caused by sea lamprey. Transactions of the American Fisheries Society, 119(4), 642-648.

26. Kitchell JF, Eby LA, He X, Schindler DE, Wright RA (1994). Predator-prey dynamics in an ecosystem context. Journal of Fish Biology,45 (SA), 209-226.

27. Kumschick S, Gaertner M, Vilà M, Essl F and others (2015) Ecological impacts of alien species:quantification, scope, caveats, and recommendations. Bioscience 65: 55–63

28. Layman C.A., Jud, Z.R. Nichols, P. 2014. Lionfish alter benthic invertebrate assemblages in patch habitats of a subtropical estuary. Marine Biology. 161:2179-82.

29. Lesser, M. P., Slattery, M. 2011. Phase shift to algal dominated communities at mesophotic depths associated with lionfish (Pterois volitans) invasion on a Bahamian coral reef. Biological Invasions. 13:1855-1868.

30. Lobel, P.S., Rocha, L.A., Randall, J.E. 2009. Color phases and distribution of the Western Atlantic Labrid fish, *Halichoeres socialis*. Copeia. 1:171-174.

31. Lo¨ nnstedt OM, McCormick MI (2013) Ultimate Predators: Lionfish Have Evolved to Circumvent Prey Risk Assessment Abilities. PLoS One 8(10): e75781.doi:10.1371/journal.pone.0075781

32. McCleery, C. 2011. A comparative study of the feeding ecology of invasive lionfish (Pterois volitans) in the Caribbean. Physis 9: 38 – 43

33. Morris, J.A., Akins, J.L. 2009. Feeding Ecology of invasive lionfish (Pterois volitans) in the Bahamian archepelago. Environmental Biology of Fishes. 86: 389 – 398.

34. Morris, J.A., Shertzer, K.W. & Rice, J.A. 2011 A stage-based matrix population model of invasive lionfish with implications for control. Biological Invasions 13: 7. doi:10.1007/s10530-010-9786-8

35. Morris JA, Whitfield PE (2009) Biology, ecology, control and management of the invasive Indo-Pacific lionfish: an updated integrated assessment Tech Mem NOS NCCOS 99. National Oceanic and Atmospheric Administration, Washington, DC

36. Randall, J. E., Lobel, P. S. 2003. *Halichoeres socialis*: A New Labrid Fish from Belize. Copeia. 1:124-130.

37. Rice JA, Cochran PA (1984). Independent evaluation of a bioenergetics model for largemouth bass. Ecology, 732-739.

38. Rocha L.A., Rocha, C.R., Baldwin, C. C., Weigt, L. A. 2015. Invasive lionfish preying on critically endangered reef fish. Coral Reefs. 34:803-806.

39. Rocha LA, Choat JH, Craig MT (2010) Halichoeres socialis IUCN Red List of Threatened Species Version 20122, http://www.iucnredlist.org/details/187435/187430

40. Salo P, Korpimäki E, Banks PB, Nordström M, Dickman CR (2007) Alien predators are more dangerous than native predators to prey populations. Proceedings of the Royal Society. Series B: Biological Sciences. 274:1237−1243

41. Secord, J. J. 2015. Feeding ecology if the invasive lionfish (*Pterois spp.*) and comparison with two native species: schoolmaster *Lutjanus apodus* (Walbaum, 1792) and Graysby *Cephalopholis cruentata* (Lacepede, 1802). Master's thesis. Nova Southeastern University. Retrieved from NSUWorks, . (369).

42. Schofield P.J. 2009. Geographic extent and chronology of the invasion of non-native lionfish (Pterois volitans [Linnaeus 1758] and P. miles [Bennett 1828]) in the Western North Atlantic and Caribbean Sea. Aquatic Invasions. 4: 3. DOI 10.3391/ai.2009.4.3

43. Whitfield PE, Hare JA, David AW, Harter SL, Munoz RC, Addison CM (2007) Abundance estimates of the Indo-Pacific lionfish *Pterois volitans/miles* complex in the Western North Atlantic. Biological Invasions 9:53–64

44. Wilson Freshwater, D., Hines, A., Parham, S. et al. Mar Biol (2009) Mitochondrial control region sequence analyses indicate dispersal from the US East Coast as the source of the invasive Indo-Pacific lionfish *Pterois volitans* in the Bahamas. Marine Biology. 156: 1213. doi:10.1007/s00227-009-1163-8\

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