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Short communication

# A brief description of invasive lionfish (*Pterois* sp.) diet composition in the Arrecifes de Cozumel National Park

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ABSTRACT

Invasive lionfish (*Pterois* sp.) have the potential to affect reef communities in the western Atlantic through predation on native species. Lionfish are opportunistic generalist carnivores whose diet varies significantly among locations due to differences in local prey assemblages. As such, site-specific diet studies are needed to better inform local research and monitoring. The objective of this study was to describe lionfish diet in the Arrecifes de Cozumel National Park (ACNP), an ecologically and economically important marine protected area along the eastern Yucatan Peninsula. Through the analysis 343 lionfish stomachs, we determined that 1) species of the genera *Sparisoma*, *Stegastes*, *Bothus*, *Haemulon*, and *Serranus* are the most important prey to lionfish diet in the ACNP, 2) lionfish in the ACNP transition from a shrimp to a fish dominated diet through ontogeny, and 3) the contribution of crabs to lionfish diet in the ACNP is the largest observed in the western Atlantic to date. The data presented here can be used to inform research and monitoring efforts in and around the ACNP.


## 1. Introduction

Indo-Pacific lionfish (*Pterois* sp.) have become an abundant and ubiquitous mesopredator throughout the temperate and tropical western Atlantic (Schofield, 2010). The rapid expansion and proliferation of lionfish is attributed to their broad environmental tolerances, high reproductive output, defenses from predation, and generalist feeding behavior (reviewed by Côté et al., 2013). Several studies suggest lionfish have the potential to negatively affect local reef communities through predation on native species (*e.g.*, Albins and Hixon, 2013), and may affect native fish populations at regional scales (*e.g.*, Ballew et al., 2016). Therefore, understanding lionfish diet is important for identifying their ecological role and potential effects on marine food webs.

More than 15 location-specific diet studies (*e.g.*, Eddy et al., 2016; Dahl and Patterson, 2014; Morris and Akins, 2009) and one regional synthesis (Peake et al., 2018) have been published describing different aspects of lionfish feeding ecology and foraging behavior. The culmination of these reports indicates lionfish are opportunistic generalist carnivores that consume at least 160 vertebrate and invertebrate species across multiple trophic levels. As a result of this feeding behavior, in combination with differences in local prey assemblages, lionfish diet can vary significantly among locations (Peake et al., 2018). As such, there is need for continued location-specific lionfish diet studies to inform local research and monitoring, particularly within protected areas.

The objective of this study was to provide a brief description of lionfish diet composition in the Arrecifes de Cozumel National Park (ACNP), an ecologically and socio-economically important marine protected area along the southern coast of Cozumel, Mexico. By determining the composition and importance of different prey to lionfish diet and by describing their general feeding characteristics, these data can be used to prioritize research and monitoring efforts in and around the ACNP.

## 2. Materials and methods

Lionfish ($n = 343$) were opportunistically collected from various coral reef sites throughout the ACNP (20°17′21.59″N, 87° 0′16.93″W) between August 2013 and March 2015. Samples were pooled across

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sampling dates and locations to represent the general area. The standard length (SL; mm) of each lionfish was recorded and their stomachs removed, frozen, and shipped to the NOAA Beaufort Laboratory for processing following the methods in Green et al., 2012. The lionfish used in this study ranged in size from 42 to 340 mm SL [234.2 ± 37.5 (mean ± SD)]. Ninety-three stomachs (27.1%) were empty and 64 prey items (6.4%) were unidentifiable. This resulted in a total of 935 identifiable prey for analysis with a total weight of 627.6 g.

The relative contributions of each prey group (*e.g.*, fish), family, and genus to lionfish diet was calculated using three relative metrics of prey quantity including percent frequency of occurrence (%F), percent composition by number (%N), and percent composition by weight (%W) (Hyslop, 1980; Bowen, 1996). The relative importance of each prey category was then calculated using three commonly used indices of importance:

(1) Index of Relative Importance (IRI) (Pinkas et al., 1971)

$$IRI_a = F_a * (N_a + W_a)$$

(2) Index of Importance (IOI) (Gray et al., 1997; Hunt et al., 1999)

$$IOI_a = \frac{100 * (F_{a+} W_a)}{\sum_{a=1}^{s} (F_a + W_a)}$$

(3) Index of Preponderance (IOP) (Natajrajan and Jhingran, 1961)

$$IOP_a = \frac{F_a * W_a}{\sum_{a=1}^{s} (F_a + W_a)}$$

where $a$ is the group, family, or genus of interest, $F_a$ is the frequency of occurrence of $a$, $W_a$ is the contribution of $a$ to the total prey weight, $N_a$ is the contribution of $a$ to the total number of prey items, and $s$ is the total number of each prey category for which the index was calculated. Relative dietary importance of each prey was ultimately ranked based on the average rankings of all three indices of importance (see Table 1), which provided a more robust assessment.

Relationships between lionfish SL and the contributions of crab, fish, and shrimp to their diet were examined using Spearman's rank-order correlation coefficient. Samples were binned into nine lionfish size classes, each with 16–42 samples, prior to analysis.

Following the methods in Bizzarro et al. (2007) and Peake et al. (2018), cumulative prey curves were used to determine whether the families and genera identified in this study represent all families and genera consumed by lionfish in the ACNP.

**Table 1**
The relative contributions and importance of prey to lionfish diet in the Arrecifes de Cozumel National Park.

| Prey category | Prey metrics | | | Indices of importance | | |
|---|---|---|---|---|---|---|
| | %F | %N | %W | IRI rank | IOI rank | IOP rank |
| Group | | | | | | |
| Fish | 84.0 | 58.8 | 70.4 | 1 | 1 | 1 |
| Shrimp | 38.0 | 22.6 | 10.5 | 2 | 2 | 3 |
| Crab | 28.0 | 11.7 | 14.6 | 3 | 3 | 2 |
| Unidentifiable mass | 11.6 | 2.9 | 3.3 | 4 | 4 | 4 |
| Other invertebrate | 12.8 | 4.0 | 1.3 | 5 | 5 | 5 |
| Family | | | | | | |
| Scaridae | 5.6 | 2.3 | 8.8 | 1 | 1 | 1 |
| Pomacentridae | 5.2 | 1.3 | 6.3 | 2 | 2 | 2 |
| Labridae | 5.2 | 1.7 | 5.0 | 3 | 3 | 3 |
| Monacanthidae | 4.4 | 3.4 | 3.6 | 4 | 4 | 4 |
| Serranidae | 4.0 | 1.5 | 2.6 | 5 | 5 | 5 |
| Bothidae | 1.2 | 1.1 | 1.7 | 6 | 7 | 6 |
| Haemulidae | 0.8 | 0.2 | 2.3 | 9 | 6 | 8 |
| Scorpaenidae | 1.2 | 0.3 | 1.6 | 8 | 8 | 7 |
| Calappidae | 1.2 | 0.6 | 1.5 | 7 | 9 | 9 |
| Gonodactylidae | 0.8 | 0.2 | 1.6 | 11 | 10 | 10 |
| Mullidae | 1.6 | 0.4 | 0.6 | 10 | 11 | 11 |
| Sparidae | 1.2 | 0.3 | 0.4 | 12 | 12 | 12 |
| Gobiidae | 0.8 | 0.2 | 0.1 | 13 | 13 | 15 |
| Portunidae | 0.4 | 0.2 | 0.4 | 14 | 14 | 13 |
| Synodontidae | 0.4 | 0.1 | 0.3 | 16 | 15 | 14 |
| Carangidae | 0.4 | 0.2 | 0.2 | 15 | 16 | 16 |
| Lutjanidae | 0.4 | 0.1 | 0.2 | 17 | 17 | 17 |
| Stenopodidea | 0.4 | 0.1 | 0.1 | 18 | 18 | 18 |
| Pomacanthidae | 0.4 | 0.1 | 0.0 | 19 | 19 | 19 |
| Genus | | | | | | |
| Sparisoma | 2.8 | 0.9 | 7.2 | 1 | 1 | 1 |
| Stegastes | 3.2 | 0.8 | 4.4 | 2 | 2 | 2 |
| Bothus | 1.2 | 1.1 | 1.7 | 3 | 4 | 3 |
| Haemulon | 0.8 | 0.2 | 2.3 | 5 | 3 | 5 |
| Serranus | 1.6 | 0.4 | 1.2 | 4 | 5 | 4 |
| Xyrichtys | 0.8 | 0.3 | 1.6 | 7 | 6 | 6 |
| Clepticus | 1.6 | 0.4 | 0.6 | 6 | 8 | 8 |
| Neogonodactylus | 0.8 | 0.2 | 1.6 | 8 | 7 | 7 |
| Scorpaena | 0.4 | 0.1 | 1.4 | 10 | 9 | 9 |
| Nicholsina | 0.8 | 0.2 | 0.7 | 9 | 10 | 10 |
| Thalassoma | 0.4 | 0.2 | 0.6 | 11 | 11 | 11 |
| Abudefduf | 0.4 | 0.1 | 0.5 | 12 | 12 | 12 |
| Halichoeres | 0.4 | 0.1 | 0.4 | 14 | 13 | 13 |
| Callinectes | 0.4 | 0.2 | 0.4 | 13 | 15 | 14 |
| Chromis | 0.4 | 0.1 | 0.3 | 16 | 16 | 15 |
| Monacanthus | 0.8 | 0.2 | 0.0 | 15 | 13 | 20 |
| Pseudupeneus | 0.4 | 0.1 | 0.3 | 17 | 17 | 16 |
| Synodus | 0.4 | 0.1 | 0.3 | 18 | 18 | 17 |
| Stenopus | 0.4 | 0.1 | 0.1 | 19 | 19 | 18 |
| Diplectrum | 0.4 | 0.1 | 0.1 | 20 | 20 | 19 |
| Pterois | 0.4 | 0.1 | 0.0 | 21 | 21 | 21 |
| Holacanthus | 0.4 | 0.1 | 0.0 | 22 | 22 | 22 |
| Scarus | 0.4 | 0.1 | 0.0 | 23 | 23 | 23 |

## 3. Results and discussion

Twenty-three genera and 19 families of vertebrate and invertebrate prey were identified in this study (Table 1). Cumulative prey curve analysis indicated the families ($p = 0.01$) and genera ($p = 0.0006$) identified do not represent all families and genera consumed by lionfish in the ACNP (Fig. 1). Based on the slopes of the linear regressions fit to the last four points on each curve, we estimate that up to an additional 57 stomachs would have been needed to identify one new family and genus in the diets of lionfish in the ACNP.

The most important families to lionfish diet in the ACNP were, in order of descending importance, Scaridae (parrotfishes), Pomacentridae (damselfishes), Labridae (wrasses), Monacanthidae (filefishes), and Serranidae (sea basses). The most important genera were *Sparisoma*, *Stegastes*, *Bothus*, *Haemulon*, and *Serranus* (Table 1). Research into the potential direct and indirect effects of lionfish in the ACNP could begin with these prey given their high contribution and importance to lionfish diet. These data can also be coupled with reef survey data to determine whether lionfish are consuming prey that are in relatively low abundance in the ACNP. If so, research and monitoring could focus on these populations as the effects of lionfish predation may be more severe. Lesser and Slattery (2011) and Kindinger and Albins (2017) suggest lionfish may indirectly affect algal communities through predation on herbivores. The large contribution of *Sparisoma* and *Stegastes* species to lionfish diet in the ACNP warrants attention since the loss of grazers could have considerable consequences for overall reef health (*e.g.*, Mumby, 2006).

Fish and shrimp were the largest contributors and most important prey groups to lionfish diet in the ACNP (Table 1). Spearman's *rho* indicated moderate-to-strong (*i.e.*, *rho* > 0.50) relationships between

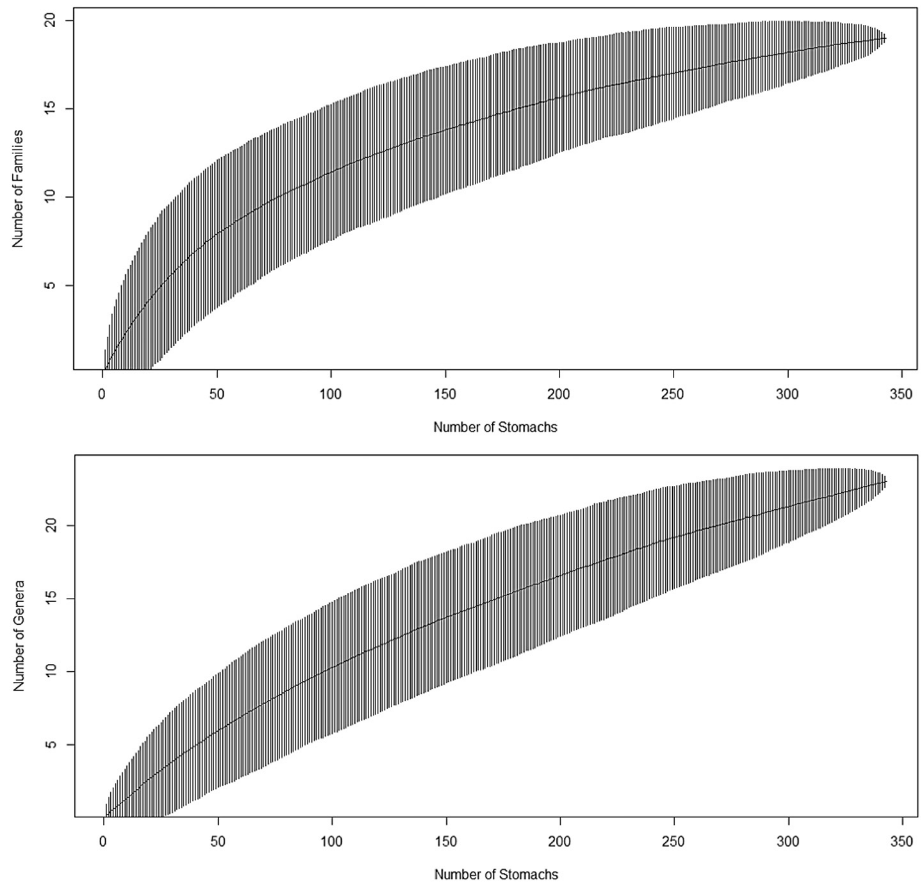


**Fig. 1.** Cumulative prey curves for lionfish in the Arrecifes de Cozumel National Park at the family (top) and genus (bottom) levels.

lionfish SL and the contributions of shrimp (negative relationship) and fish prey (positive relationship) (Table 2). This finding indicates a potential ontogenetic shift in lionfish diet in the ACNP, which is consistent with other location-specific (*e.g.*, Morris and Akins, 2009) and regional reports (*e.g.*, Peake et al., 2018) and appears to be consistent with other scorpaenids (Harmelin-Vivien and Bouchon, 1976).

The contributions of fish and shrimp to lionfish diet in this study were comparable to other locations (see Table 3 in Peake et al., 2018) including other parts of the eastern Yucatan Peninsula (*e.g.*, Valdez-Moreno et al. (2012), Arredondo-Chávez et al., 2016). However, the

**Table 2**
Correlations between lionfish standard length (mm) and the contributions of their prey in the Arrecifes de Cozumel National Park.

| Metrics | Spearman's correlation | |
|---|---|---|
| | Value range | *rho* |
| Fish | | |
| %F | 72.2–97.4 | 0.52* |
| %N | 41.8–65.4 | 0.63* |
| %W | 45.5–93.6 | 0.30 |
| Shrimp | | |
| %F | 58.9–25.0 | −0.60* |
| %N | 36.7–12.3 | −0.80*** |
| %W | 33.2–1.9 | −0.70** |
| Crab | | |
| %F | 6.3–39.5 | 0.02 |
| %N | 2.2–24.5 | 0.13 |
| %W | 0.8–31.4 | 0.20 |

*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

contribution of crabs (*i.e.*, %F = 28, %N = 12, and %W = 15) is the largest observed for lionfish in their invaded range. While lionfish are opportunistic generalist carnivores (Peake et al., 2018), individual and population level dietary specializations can occur, and are more likely to occur at local scales (Layman and Allgeier, 2012). Research is needed to determine whether lionfish in the ACNP preferentially consume crab, or if crab are simply higher in relative abundance.

A total of 54 prey families have been reported across the four known lionfish diet studies conducted along the eastern Yucatan Peninsula (see Table 3). Gobiidae (Gobies), Gonodactylidae (mantis shrimps), Labridae, Pomacentridae, Scaridae, and Serranidae were reported in all four studies, and Labridae, Pomacentridae, Scaridae were ranked within the top six most important prey families to lionfish diet in this study and Arredondo-Chávez et al., 2016 which was the only other study that reported prey importance. Despite the likely effects of differences in methodologies on prey composition among the studies (*i.e.*, differences in prey identification techniques), these findings suggest species in the families Labridae, Pomacentridae, and Scaridae are among the most common and important prey to the diets of lionfish throughout this region. The data presented here can be used to help prioritize research and monitoring efforts in and around the ACNP.

## Declaration of interest

None.

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**Table 3**
Lionfish diet composition and prey importance across studies conducted along the eastern Yucatan Peninsula.

| This study | Arredondo-Chávez et al. (2016) | Valdez-Moreno et al. (2012) | Villaseñor-Derbez and Herrera-Pérez (2014) |
|---|---|---|---|
| Bothidae (6) | Alpheidae | Alpheidae | Apogonidae |
| Calappidae | Apogonidae | Apogonidae | Blenniidae |
| Carangidae | Aulostomidae | Bothidae | **Gobiidae** |
| **Gobiidae** | Axiidae | Euphausiidae | **Gonodactylidae** |
| **Gonodactylidae** | Bothidae | **Gobiidae** | Grammatidae |
| Haemulidae (7) | Calappidae | **Gonodactylidae** | Hippolytidae |
| **Labridae (3)** | Carangidae | Grammatidae | **Labridae** |
| Lutjanidae | Chaenopsidae | Haemulidae | Labrisomidae |
| Monacanthidae (4) | Columbellidae | Holocentridae | Mysidae |
| Mullidae | Cymothoidae | Hippolytidae | **Pomacentridae** |
| Pomacanthidae | Dactyloscopidae | **Labridae** | Portunidae |
| **Pomacentridae (2)** | Disciadidae | Labrisomidae | **Scaridae** |
| Portunidae | Engraulidae | Monacanthidae | Scorpaenidae |
| **Scaridae (1)** | **Gobiidae (7)** | Palaemonidae | **Serranidae** |
| Scorpaenidae (8) | **Gonodactylidae** | **Pomacentridae** | Tetraodontidae |
| **Serranidae (5)** | Grammatidae | Pseudosquillidae | – |
| Sparidae | Haemulidae | **Scaridae** | – |
| Stenopodidea | Hemisquillidae | Scorpaenidae | – |
| Synodontidae | Inachoididae | **Serranidae** | – |
| – | **Labridae (3)** | Tripterygiidae | – |
| – | Labrisomidae | – | – |
| – | Littorinidae | – | – |
| – | Lutjanidae | – | – |
| – | Majidae | – | – |
| – | Monacanthidae | – | – |
| – | Mullidae | – | – |
| – | Muricidae | – | – |
| – | Palaemonidae (8) | – | – |
| – | Palinuridae | – | – |
| – | Penaeidae (4) | – | – |
| – | **Pomacentridae (2)** | – | – |
| – | Porcellanidae | – | – |
| – | Portunidae | – | – |
| – | Pseudosquillidae | – | – |
| – | Rhynchocinetidae (1) | – | – |
| – | **Scaridae (6)** | – | – |
| – | Scyllaridae | – | – |
| – | Sergestidae | – | – |
| – | **Serranidae** | – | – |
| – | Sicyoniidae | – | – |
| – | Solenoceridae (5) | – | – |
| – | Sphaeromatidae | – | – |
| – | Stenopodidae | – | – |
| – | Synodontidae | – | – |
| – | Tripterygiidae | – | – |

Families are listed alphabetically.
Families in bold were identified in all four studies.
Prey importance rank is noted in parentheses where applicable.
Sampling locations, prey identification techniques, and sample sizes for each study were as follows:
• This study (Arrecifes de Cozumel National Park, visual, n = 343).
• Arredondo-Chávez et al. (2016) (numerous locations from Isla Contoy to Xcalak, visual, n = 1482).
• Valdez-Moreno et al. (2012) (numerous locations from Isla Contoy to Xcalak, DNA barcoding, n = 157).
• Villaseñor-Derbez and Herrera-Pérez (2014) (Puerto Aventuras, visual, n = 109).

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## References

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. Environ. Biol. Fish 96, 1151–1157.
Arredondo-Chávez, A.T., Sánchez-Jimenez, J.A., Ávila-Morales, O.G., Torres-Chávez, P., Herrerias-Diego, I., Medina-Nava, M., Madrigal-Guridi, X., Campos-Mendoza, A., Domínguez-Domínguez, O., Caballero-Vázquez, J.A., 2016. Spatio-temporal variation in the diet composition of red lionfish, Pterois volitans (Actinopterygii: scorpaeniformes: scorpaenidae), in the Mexican Caribbean: insights into the ecological effect of the alien invasion. Acta Ichthyol. Piscat. 46 (3), 185–200.
Ballew, N.G., Bacheler, N.M., Kellison, G.T., Schueller, A.M., 2016. Invasive lionfish reduce native fish abundance on a regional scale. Sci. Rep. 6, 32169.
Bizzarro, J.J., Robinson, H.J., Rinewalt, C.S., Ebert, D.A., 2007. Comparative feeding ecology of four sympatric skate species off central California, USA. In: Ebert, D.A., Sulikowski, J.A. (Eds.), Biology of Skates. Springer, Dordrecht, pp. 91–114.
Bowen, S.H., 1996. Quantitative description of the diet. In: Murphy, B.R., Willis, D.W. (Eds.), Fisheries Techniques. American Fisheries Society, Bethesda, pp. 513–522.
Côté, I.M., Green, S.J., Hixon, M.A., 2013. Predatory fish invaders: insights from Indo-Pacific lionfish in the western Atlantic and Caribbean. Biol. Conserv. 167, 5061.
Dahl, K.A., Patterson, W.F., 2014. Habitat-specific density and diet of rapidly expanding invasive red lionfish *Pterois volitans* populations in the Northern Gulf of Mexico. PLoS One 9 (8), e105852. https://doi.org/10.1371/journal.pone.0105852.
Eddy, C., Pitt, J., Morris, J.A., Smith, S., Goodbody-Gringley, G., Bernal, D., 2016. Diet of invasive lionfish (*Pterois volitans* and *P. miles*) in Bermuda. Mar. Ecol. Prog. Ser. 558, 193–206.
Gray, A.E., Mulligan, T.J., Hannah, R.W., 1997. Food habits, occurrence, and population structure of the bat ray, *Myliobatis californica*, in Humboldt Bay, California. Environ. Biol. Fish 49 (2), 227–238.
Green, S.J., Akins, J.L., Morris, J.A., 2012. Lionfish dissection: techniques and applications. NOAA Technical Memorandum NOS NCCOS. 139, pp. 1–24.
Harmelin-Vivien, M.L., Bouchon, C., 1976. Feeding behaviour of some carnivorous fishes (Serranidae and Scorpaenidae) from Tule'ar (Madagascar). Mar. Biol. 37, 329–340.
Hunt, S.L., Mulligan, T.J., Komori, K., 1999. Oceanic feeding habits of Chinook salmon, *Oncorhynchus tshawytscha*, off northern California. Fish. Bull. 97, 717–721.
Hyslop, E.J., 1980. Stomach contents analysis -a review of methods and their application. J. Fish Biol. 17 (4), 411–429.
Kindinger, T.L., Albins, M.A., 2017. Consumptive and non-consumptive effects of an invasive marine predator on native coral-reef herbivores. Biol. Invasions 19 (1), 131–146.
Layman, C.A., Allgeier, J.E., 2012. Characterizing trophic ecology of generalist consumers: a case study of the invasive lionfish in The Bahamas. Mar. Ecol. Prog. Ser. 448, 131–141.
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. Biol. Invasions 13, 1855–1868.
Morris, J.A., Akins, J.L., 2009. Feeding ecology of invasive lionfish (*Pterois volitans*) in the Bahamian archipelago. Environ. Biol. Fish 86, 389–398.
Mumby, P.J., 2006. The impact of exploiting grazers (Scaridae) on the dynamics of Caribbean coral reefs. Ecol. Appl. 16, 747–769.
Natajrajan, A., Jhingran, V., 1961. Index of preponderance: a method of grading food elements in the stomach analysis of fishes. Indian J. Fish. 8 (1), 54–59.
Peake, J., Bogdanoff, A.K., Layman, C.A., Castillo, B., Chapman, J., Dahl, K., Eddy, C., Faletti, M., Higgs, N., Johnston, M., Munoz, R.C., Sandel, V., Villasenor-Derbez, J.C., Morris, J.A., 2018. Feeding ecology of invasive lionfish (*Pterois volitans* and *Pterois miles*) in the temperate and tropical western Atlantic. Biol. Invasions 20 (9), 2567–2597.
Pinkas, L.M., Oliphant, S., Iverson, I.L.K., 1971. Food habits of albacore, bluefin tuna and bonito in Californian waters. Calif. Fish Game 152, 1–105.
Schofield, P.J., 2010. Update on geographic spread of invasive lionfishes (*Pterois volitans* [Linnaeus, 1758] and *P. miles* [Bennett, 1828]) in the Western North Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Aquat. Invasions 5, S117–S122.
Valdez-Moreno, M., Quintal-Lizama, C., Gómez-Lozano, R., del Carmen, G., 2012. Monitoring an alien invasion: DNA barcoding and the identification of lionfish and their prey on coral reefs of the Mexican Caribbean. PLoS One 7 (6), e36636. https://doi.org/10.1371/journal.pone.0036636.
Villaseñor-Derbez, J.C., Herrera-Pérez, R., 2014. Brief description of prey selectivity and ontogenetic changes in the diet of the invasive lionfish *Pterois volitans* (Actinopterygii, Scorpaenidae) in the Mexican Caribbean. Pan-Am. J. Aquat. Sci. 9 (2), 131–135.