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# The Diet of *Cephalopholis Cruentata*: A functional Perspective of a Predator in a Natural Protected Area of the Mexican Caribbean

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## Abstract

Groupers (Family: *Serranidae*) are ecologically and commercially important fishes for the marine ecosystems and coastal communities of the Greater Caribbean. Groupers are considered generalist carnivores, however, detailed trophic information on the diet of most of the species in the group is not available, such is the case of *Cephalopholis cruentata*. This work aims to describe the diet of *C. cruentata* in Puerto Morelos Reef National Park in the Mexican Caribbean. From October 2014 to May 2015, 134 individuals were collected from 18 sites in PMRNP. The roving diver method was used to find and capture the organisms. The size (standard length, cm) and weight (g) of each fish were obtained. Fishes were eviscerated, and the stomach was fixed in 96% alcohol. In the laboratory, the items obtained were identified to the lowest possible taxonomic level. To assess the composition of contents of gastrointestinal tracts, contents the numerical (%N) and gravimetric (%W) percentages were calculated, and the percentage of frequency of occurrence (% FO) was obtained and used to determine the index of relative importance (% IRI). Twenty-four alimentary items were identified as part of the *C. cruentata* diet, representing 16 families, 18 genera, and 15 species. The dietary Index of Relative Importance reaches 64.19% for crustaceans and 35.81% for fish, suggesting that C. cruentata is a generalist carnivore. The most important prey species were the crustaceans *Neogonodactylus curacaoensis* (30.3%), *Periclimenes rathbunae* (6.7 %) and *Pseudosquilla ciliata* (3.8%), and the fish species *Clepticus parrae* (16.6%), *Caranx ruber* (5.8%), *Chromis cyanea* (5.3%) and *Thalassoma bifasciatum* (4.1%).

**Keywords:** Diet; Reef fish; Groupers; Generalist predator

## Introduction

Predatory fishes are an essential component of marine food webs, being ecologically important since species diversity in the ecosystem depends mainly on their feeding habits [1], structural complexity, and food availability [2,3]. Predators control the population of their prey, thus preventing potential impacts that other trophic roles (e.g., herbivory/bioerosion) may have on coral reefs once released due to a decrease in predatory populations. Groupers (Serranidae*: Epinephelinae*) inhabit the littoral and sublittoral zone of tropical and subtropical seas and are considered active predators feeding upon a wide variety of fishes, crustaceans, and cephalopods, benthically or in the water column. The larger groupers (as well as others Pargos: *Lutjanidae* and other carnivores) vary in size and feeding behaviors to be classified as higher trophic levels and are also considered as one of the main predators of rocky and coral reef environments, placed in the higher trophic levels of the food web, therefore playing a key role in the maintenance of the communities they inhabit and in the reef ecosystems in general [3-7].

There are nearly 300 species of groupers, of which approximately 60 species can be found within the Greater Caribbean [8], many other species within the family are mesopredators (medium trophic levels), but the presence of larger groupers within coral reef ecosystems is an indicator of healthy reefs [9,10]. Groupers are also important in artisanal and commercial fisheries, making them vulnerable; a general decrease in abundance and mean catch sizes have been observed [11,12].

The species *Cephalopholis cruentata* is one of the most captured fish within the Caribbean and Gulf of Mexico local fisheries [13], is endemic to the Greater Caribbean and has been classified as "least concern" in the Red List of Threatened Species of the International Union for Conservation of Nature (UICN) [14].

This species reaches 42 cm in standard length and up to 2 kg in weight, inhabiting mainly reefs and the surrounding soft bottoms. It is reportedly at the top of the food web, feeding on gastropods, bivalves, crustaceans, and fishes [15]. Despite its ecological relevance to reef ecosystems and its economic importance in artisanal fisheries, information on the biology of *C. cruentata* is scarce, and little is known about its feeding ecology [15,37], even the entire genus has been poorly studied [1].

Even with the existing information, the study of the feeding habits of *C. cruentata* in natural ecosystems is necessary to understand the ecological role that this species has in marine ecosystems, feeding regimes, diet types and the transfer of matter and energy within the food web. Therefore, they help to determine the trophic level of the species in the food web and their role in the reef ecosystem [16,17]. This information is also important to resource managers and reef conservation policies in protected marine areas such as the Puerto Morelos Reef National Park, Mexican Caribbean (PMRNP).

Accordingly, we evaluate the diet of *C. cruentata* by review of the stomach contents of gastrointestinal tracts (GIT) of specimens from the Puerto Morelos Reef National Park located in the northern zone of the Mexican Caribbean to ratify the species as a generalist carnivore and to advance the nutritional and ecological knowledge of the species in the region.

## Materials and Methods

### Study area

The PMRNP is located on the northeastern Yucatan Peninsula in Quintana Roo, Mexico. This marine protected area (MPA) was declared in 1998 and is among the first in Mexico to have been created through a community-based approach [41], with local stakeholders assuming the responsibility for elaborating the management program (published in 2000), and has an area of 9,066 ha, extending for 21 km along the NE coast of the Yucatan Peninsula and from the beach to 4.5–5 km seaward. The MPA contains a fringing reef that is close to shore (<3.5 km), which has been described in several papers [18]. Currently, major threats to the PMRNP are reef structure/composition, coral bleaching and white syndrome associated with climate change and tourism-related urban development [18,19].

### Sample collection

To collect *C. cruentata* specimens, 37 dives were conducted at 18 reef areas, with a 3 to 18 meters depth within the PMRNP (Figure 1). Five divers participated in each diving event. Dives were carried out three times a day: morning (between 07 and 11 h), afternoon (between 12 and 17 h), and night (between 19 and 21 h), and each dive lasted 45 min, approximately. A roving diving approach was used to find fish, and they were collected using a multi-pronged pole spear. We recorded the size (standard length; cm) for each individual using a measuring board and its total weight (g) using an electronic weighing balance (ACCULAS Sartorious Group). Once the fish was on board, we dissected specimens and fixed their GIT contents in 96% v/v alcohol for subsequent analysis. Each fish and its GIT contents were labeled with an ID code.

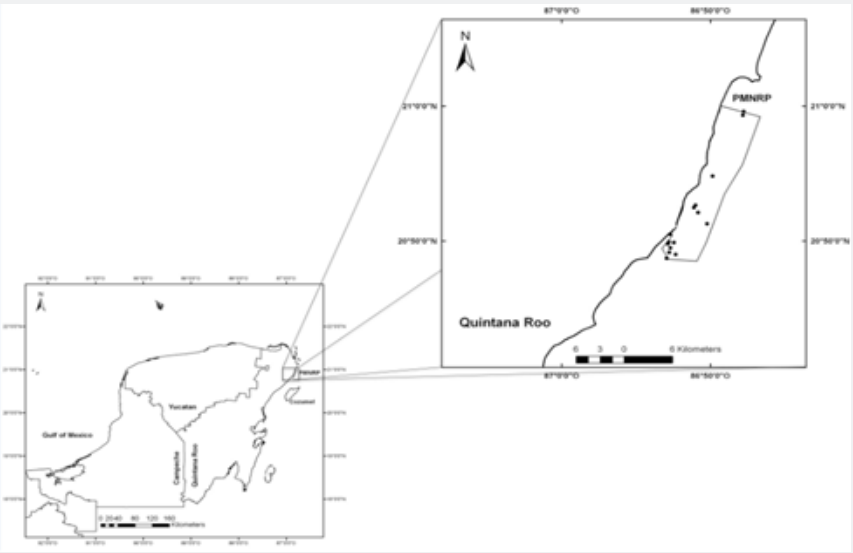


**Figure 1:** Location of the study area. The polygon corresponds to the Puerto Morelos Reef National Park, Mexican Caribbean, Quintana Roo. Collection sites are represented as black dots.



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### Stomach content analysis

In the laboratory, we identified prey items found in the GIT of *C. cruentata* specimens to the lowest possible taxonomic level. We noted the number of empty GIT. Fishes were identified using McEachran and Fechhelm [20], Humman & Deloach [21], Fish Base (2014), and the Shorefishes of the Greater Caribbean online information system v.1.0 [15], age structure and sex determination, was obtained from Heemstra & Randall [5]. We used the keys by Abele & Kim [22] for crustaceans. We used the Food and Agriculture Organization of the United Nations [5] identification keys for both groups. Then, we counted prey items and weighed them to the nearest hundredth of a gram.

To determine if the number of stomachs examined was representative of diet determination, we calculated a species accumulation curve using the software Estimate S 9.1.0. [23,24]. We calculated curves with unconditional 95% confidence intervals using the following equation from Colwell et al. [24,25]: $E(s) = \sum 1 - ((N - Ni)/N) / (N/n)$. We used the percentages of frequency of occurrence (%FO), percentages numerical (%N), and percentages gravimetric (%W) to determine the index of relative importance $(IRI = (\%N + \%W) * \%FO)$ of each of the prey items found in the stomach contents of *C. cruentata* [39,40]. We used the Shannon-Wiener diversity index to analyze variability in the diet [16] as follows: $H' = \Sigma_{i=1}^{s} PjInPj$, where $P_j$ is the proportion of individuals in the j-th prey species.

We calculated the amplitude of the trophic niche to determine if *C. cruentata* shows any specialization for existing food resources using the standardized Levin index [16]: $Bi = 1/n - 1\left\{\left((1/\Sigma pij^2) - 1\right\}\right.$, where $P_j$ is the proportion of individual fish that consumed a certain food resource relative to the number of resources used by the total number of fish, and n is the number of prey categories. This index ranges from 0 (minimum niche width and maximum specialization) to 1 (maximum niche width and minimum specialization).

## Results

We collected 134 specimens of *C. cruentata*. Their total length varied from 7.5 cm to 30 cm (mean = 19.5 ± 0.4 cm). The weight ranged from 5.5 g to 525.3 g (mean = 130.3 ± 6.8 g). Forty-three (32.09 %) of the fish collected had prey items in their GIT; most were adult specimens. The prey species accumulation curve did not reach the asymptote (Figure 2).

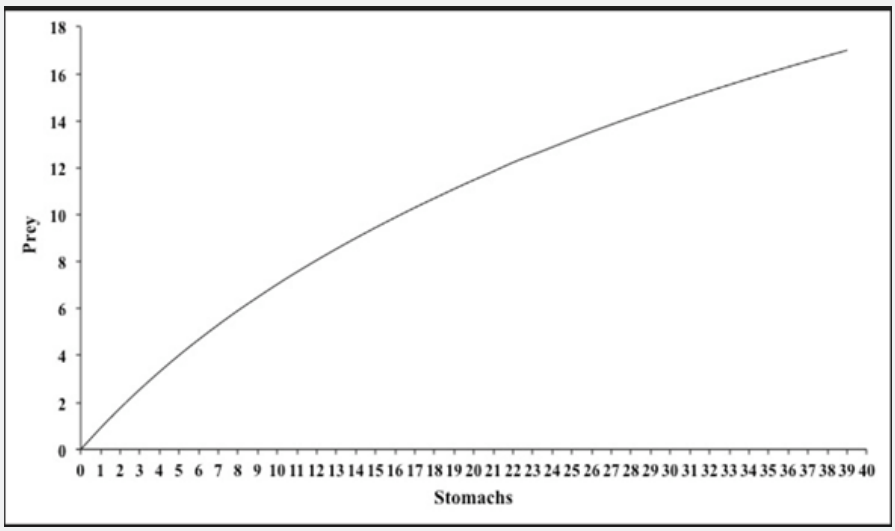


**Figure 2:** The species accumulation curve with the data analyzed.

The 24 items identified as part of the *C. cruentata* diet are represented by 16 families, 18 genera, and 15 species (Table 1). Several food items could only be identified to the family or genus level, and, in some cases, classification was only possible as remains of fish or crustaceans. According to the %W, teleosts were the most important prey item in the diet of *C. cruentata* (78.25%), followed by crustaceans (21.75%). Crustaceans dominated the GIT contents numerically with 62.23 %N, while fish reported 37.77 %N. According to the %FO, the crustaceans were present in 69.7% of the stomachs, while the fish were in 30.3 %. The IRIs obtained were 35.81% for the fish group and 64.19% for crustaceans.

Families with the highest IRI values were *Palaemonidae* (35.37%), Gonodactylidae (27.04%), *Labridae* (9.49%), *Scaridae* (7.05%), *Majidae* (3.08%), *Rhynchocinetidae* (3.08%), *Carangidae* (2.46%) and *Pomacentridae* (2.11%) (Figure 3).


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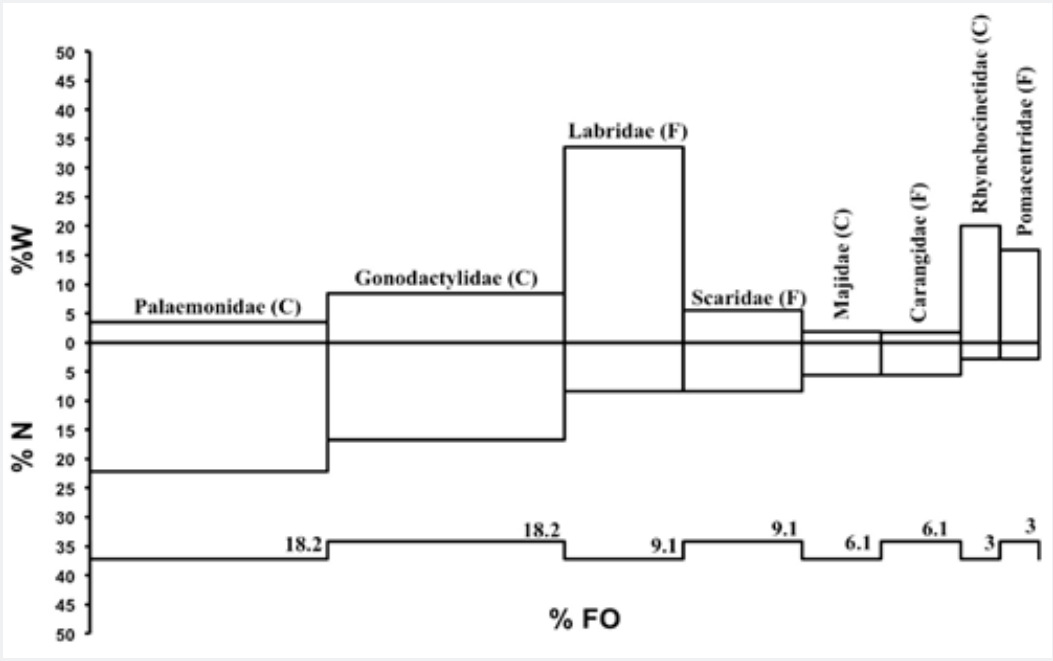


**Figure 3:** Index of the relative importance of the main families recorded in the stomachs of *Cephalopholis cruentata*. (F) = Fishes; (C) = Crustaceans. %W = Gravimetric percentage; %N = Numerical abundance, %FO = Frequency of occurrence.

Genera with the highest IRI values were *Neogonodactylus* (40.89%), *Periclimenes* (12.49%), *Sparisoma* (7.9%), *Palaemon* (7.44%), *Clepticus* (6.05%), *Pleoticus* (4.97%), *Mithraculus* (3.45%) and *Cinetorhynchus* (3.45%) (Figure 4).

Species with the highest IRI values were *Neogonodactylus curacaoensis* (30.3%), *Clepticus parrae* (16.6%), *Periclimenes rathbunae* (6.7%), *Caranx ruber* (5.8%), *Chromis cyanea* (5.3%) and *Thalassoma bifasciatum* (4.1%) (Figure 5).

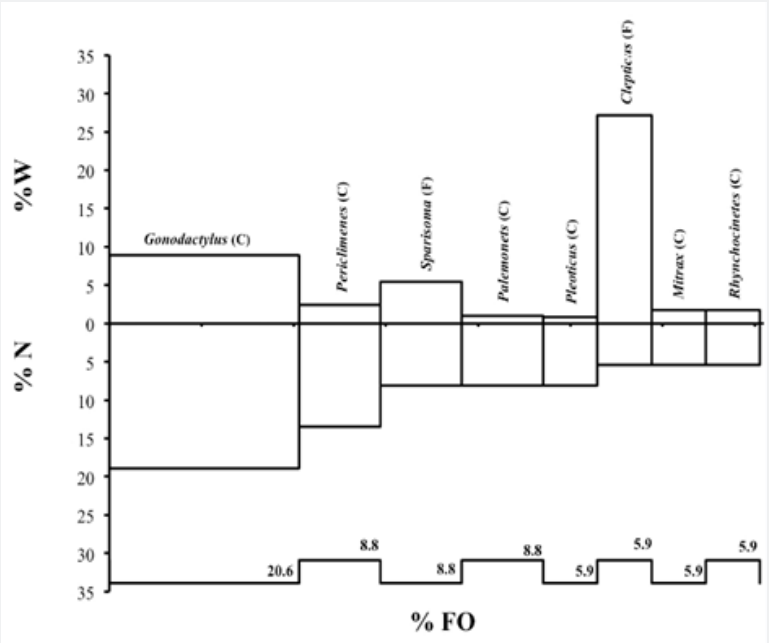


**Figure 4:** Index of the relative importance of the principal genera recorded in the stomachs of *Cephalopholis cruentata*. (F) = Fishes; (C) = Crustaceans. %W = Gravimetric percentage; %N = Numerical abundance, %FO = Frequency of occurrence.



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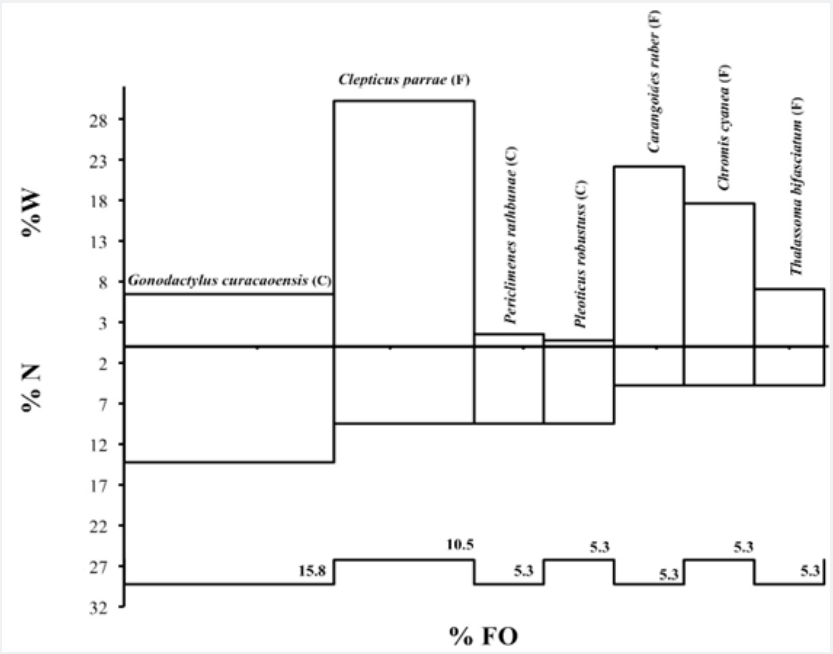


**Figure 5:** Index of the relative importance of the main species recorded (IRI) in the stomachs of *Cephalopholis cruentata*. (F) = Fishes; (C) = Crustaceans. %W = Gravimetric percentage; %N = Numerical abundance, %FO = Frequency of occurrence.

According to the %FO, 96% of the prey records were classified as accidental (Accidental f < 10); the remaining 4% correspond to secondary prey (secondary f >10 o < 50), without a preferential category. According to the Levin index, the value obtained was high (Bi = 0.6), classifying *C. cruentata* as a generalist carnivore. This value is congruent with the %FO, where no preference for any prey was found, and the diversity value of the consumed prey was H´ = 2.65 (bits/ind.).

## Discussion

The coral grouper, *Cephalopholis cruentata*, is a carnivorous predator; its diet consists mainly of a variety of smaller fish, crustaceans, and to a lesser extent, cephalopods. Studies of the feeding habits of *C. cruentata* in the Atlantic regions of the greater Caribbean are scarce. Before this study, the only data was a general description of higher taxonomic groups on which *C. cruentata* feed [11,15]. The information obtained in the present study is the first to report the feeding ecology of *C. cruentata* for the region.

According to our results, the diet of *C. cruentata* in the PMRNP is composed of fish and crustaceans, which is similar to the reported for other grouper in the greater Caribbean [1,6,7,26,27] and is similar to that of the lionfish (*Pterois volitans*) [28], indicating a possible competition for prey items with this exotic and invasive species. The %FO determined that most of the prey are considered secondary and accidental; *C. cruentata* did not show a preference to any particular prey. This is supported by the results of the Levin index that classify *C. cruentata* as a generalist carnivore. The species accumulation curve with the data analyzed did not reach the asymptote; a larger number of organisms and a larger sample size are required to achieve it [1,26,29]. This is consistent with what is known for other grouper species, for which prey species accumulation curves also do not reach the asymptote even when included in a high sample size (>200). This suggests a broad trophic niche for the group [26,29] and the need for a more extensive sampling effort.

According to the numerical index (%N) and the frequency of appearance used to estimate the importance of prey, *C. cruentata* had a broad trophic niche and a high percentage of crustacean prey. In contrast, fish are not encountered as frequently but have a higher contribution to dietary biomass (Table 1). According to the IRI, *Palaemonidae* is the most important family in the diet of *C. cruentata*. This family has also been reported in the diet of the congener *Cephalopholis urodeta* [26]. The *Palaemonidae* family is associated with invertebrate organisms such as corals and anemones and is reported as abundant in reef ecosystems of Mexico [30]. The group has an ecological function as a fish parasite cleaner [31]. Within this family, the genus *Periclimenes* is the most abundant prey. Another important family in the diet of *C. cruentata* is *Gonodactylidae*, in the order Stomatopoda, with *Neogonodactylus curacaoensis* being the most recorded species. This stomatopod is a predator that feeds upon different groups (fish, mollusks, annelids, crustaceans, and other invertebrates) and can capture prey of considerable size, while also serving as prey to other carnivorous organisms, such as *C. cruentata* [32-34].

**Table 1:** Composition of the diet of *Cephalopholis cruentata* in the Puerto Morelos Reef National Park (PMRNP), Mexican Caribbean.



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| | %W | %N | %FO | %IRI |
|---|---|---|---|---|
| Crustaceans | | | | |
| Stomatopoda | | | | |
| Gonodactyllidae | | | | |
| *Neogonodactylus* sp. | 1.78 | 5.41 | 5.88 | 5.24 |
| *Neogonodactylus curacaoensis* (Schmitt 1924) | 6.22 | 10.81 | 11.76 | 20.83 |
| *Neogonodactylus oerstedii* (Hansen 1895) | 0.89 | 2.70 | 2.94 | 1.38 |
| Pseudosquillidae | | | | |
| *Pseudosquilla ciliata* (Fabricius 1787) | 4.00 | 2.70 | 2.94 | 1.87 |
| Decapoda | | | | |
| Penaeidae | | | | |
| *Metapenaeopsis smithi* (Schmitt 1924) | 0.56 | 2.7 | 2.94 | 1.33 |
| Solenoceridae | | | | |
| *Pleoticus* sp. | 0.78 | 8.11 | 5.88 | 3.84 |
| Rhynchocinetidae | | | | |
| *Cinetorhynchus* sp. | 0.33 | 2.7 | 2.94 | 1.29 |
| *Cinetorhynchus rigens* (Gordon 1936) | 1.44 | 2.7 | 2.94 | 1.47 |
| Palaemonidae | | | | |
| *Palaemon pugio* (Holthuis 1949) | 1.00 | 8.11 | 8.82 | 11.33 |
| *Periclimenes* sp. | 1.11 | 8.11 | 5.88 | 7.62 |
| *Periclimenes rathbunae* Schmitt, 1924 | 1.33 | 5.41 | 2.94 | 2.69 |
| Porcellanidae | | | | |
| *Petrolisthes galathinus* (Bosc 1801) | 0.44 | 2.70 | 2.94 | 1.31 |
| Majidae | | | | |
| *Mithraculus* sp. | 0.22 | 2.70 | 2.94 | 1.28 |
| *Mithraculus forceps A.* Milne-Edwards 1875 | 1.56 | 2.70 | 2.94 | 1.48 |
| Portunidae | | | | |
| *Cronius ruber* (Lamarck 1818) | 0.22 | 2.70 | 2.94 | 1.28 |
| Diogenidae | | | | |
| *Cancellus* sp. | 0.2 | 2.70 | 2.94 | 1.27 |
| Fishes | | | | |
| Perciformes | | | | |
| Carangidae | | | | |
| *Caranx ruber* (Bloch 1793) | 19.89 | 2.70 | 2.94 | 4.35 |
| Pomacentridae | | | | |
| *Chromis cyanea* (Poey 1860) | 15.78 | 2.70 | 2.94 | 3.70 |
| Labridae | | | | |
| *Clepticus parrae* (Bloch & Schneider 1801) | 27.12 | 5.41 | 5.88 | 9.20 |
| *Thalassoma bifasciatum* (Bloch 1791) | 6.33 | 2.70 | 2.94 | 2.23 |
| Scaridae | | | | |
| *Sparisoma* sp. | 5.45 | 8.11 | 8.82 | 12.02 |
| Gobiidae | | | | |
| *Coryphopterus* sp. | 0.11 | 2.70 | 2.94 | 1.26 |



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| | | | | |
|---|---|---|---|---|
| Tetraodontiformes | | | | |
| Monacanthidae | | | | |
| *Cantherhines pullus* (Ranzani 1842) | 3.22 | 2.70 | 2.94 | 1.74 |

Gravimetric percentage = %W, Numerical abundance = %N, frequency of occurrence = %FO and Index of Relative Importance = %IRI.

The fish species with the greatest importance in the diet of *Cephalopholis cruentata* is *Clepticus parrae*, from the Labridae family.

Several authors have reported This family in the diet of grouper species [1,26,29]. *Clepticus parrae*, commonly known as the creole wrasse, feeds mainly on zooplankton and is one of the most abundant species in the Caribbean reefs [27,35]. The *Scaridae* family was also recorded in the diet of *C. cruentata*, with the prey of the genus Sparisoma being identified; however, the frequency of this family in the diet of *C. cruentata* was low: only three individuals were recorded. The *Scaridae* are herbivorous and associated with reef areas [15]. Another species recorded was *Chromis cyanea* from the *Pomacentridae* family. This species feeds on zooplankton and pelagic eggs, among other organisms. Some predatory fish species were also recorded in the diet of *C. cruentata*, such as *C. ruber* of the Carangidae family. This species feeds on fish, crustaceans, and mollusks [15].

The main prey identified in the diet of *C. cruentata* has also been recorded in the diet of lionfish [28], generating a possible direct competition for food between the two species. However, the lionfish maintains some advantage over the local predatory species since its prey does not identify it as a threat or potential predator [36]. The diet of *Cephalopholis cruentata* is very varied since it feeds on different species. Since it does not have a preference for any prey, it is considered a generalist carnivore, so more studies are required on the diet of the species to determine the complete trophic spectrum of the species; also, a comparative study between the lionfish and other top predators in Mexican Caribbean National Parks need to be conducted to understand better the invasion of the lionfish and the possible effect in the reef systems food web [37-40].

The predator-prey relationship in *C. cruentata* is important for maintaining the ecological balance in marine ecosystems in the Mexican Caribbean. As a top predator, *C. cruentata* plays a crucial role in regulating the populations of its prey. However, it may impact the composition and relative abundance of organisms and species; predation pressure maintains biodiversity and community structure. Analyzing and understanding these interactions is essential for conserving and managing reef systems and associated habitats inhabited by this predator. With the invasion of the lionfish (*Pterois volitans*) into the wider Caribbean, a predator with similar feeding ranges to *C. cruentata*, the predator-prey relationship may have cascading effects on the trophic structure's lower and upper trophic levels. Increased predation has a direct impact on the availability of food for predators. A decrease in the quantity or quality of prey can affect the fitness and reproduction of predators and their ability to survive and maintain their populations. Conversely, an uncontrolled increase in prey populations can affect the availability of food resources for other species and cause changes in community structure. In contrast, an increase in their predation of prey causes a decrease in their populations, leading to changes in their behavior and interactions with other predators and competitors. These interactions can have important implications for marine ecosystems and fisheries if the population of commercial prey of ecological interest declines due to overfishing or other factors such as water pollution or effects caused by climate change.

In summary, changes in the prey population of interest or a population of key prey species can significantly affect the people of predators, such as *Cephalopholis cruentata*, and vice versa. Studying these interactions is essential for knowledge, sustainability, and long-term conservation of reef ecosystems.

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