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Captures and Diet of Three Sharks Species in the Veracruz Reef System

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ABSTRACT

During July to November of 2008, the artisanal fisheries captured juvenile sharks belonging to the Carcharhinus and Sphyrnidae family in the Veracruz Reef System (south western Gulf of Mexico). The three most abundant organisms were of the species *Sphyrna lewini*, *Carcharhinus brevipinna* and *Rhizoprionodon terraenovae*. Local fisherman recognized five captured areas of sharks as a direct way or bycatch. Some of these areas are located near to eddies formations and river discharges (high productivity areas). These top predators fed on benthic and demersal prey of coastal and reef habits had been the Teleost group the most important item in its diet. However it is possible to observe differences in its feeding tendency.

Keywords: Captures; Diet; Sharks; Veracruz

1. Introduction

The Veracruz Reef System (VRS) is located in the south western Gulf of Mexico in front of the Port of Veracruz, Boca del Rio village and the fishery town of Anton Lizardo (**Figure 1**), which bases their economy in a multi specific artisanal fishery, which employs different fishing gears [1]. The VRS is a reef complex which is constituted by 23 corallines structures which support a high biodiversity considered a natural protected area since 1992 [2,3].

The elasmobranchs fisheries are not regulated and its records are incomplete or generalized [4]. The artisanal fisheries in the Gulf of Mexico focused on sharks, capture mostly from the Carcharhiniformes species, specifically the Carcharhinidae and Sphyrnidae families. The most important economical species are: *Rhizoprionodon terraenovae*, *Carcharhinus acronotus*, *Squalus cubensis*, *Sphyrna tiburo*, *Carcharhinus limbatus*, *Sphyrna lewini*, *Carcharhinus leucas*, *Carcharhinus falciformis* and *Carcharhinus porosus*, the *Carcharhinus brevipinna* specie is the fifth specie in number of capture, therefore it is considered of low economic value [1].

In May of 2007 it was decreed the NOM-029-PESC-2006 to establish a statistic record of shark fisheries [5], however in the southwestern Gulf of Mexico the artisanal fisheries catch shark without species records [1]. The only knowledge is that the most abundant species in the area is the *Rhizoprionodon terraenovae*, but its records are mostly generalized with another juvenile organism of different species [1].

In the last twenty years the captures of sharks have increased around the world [6,7], this increase is due to the interest in their fins and meat, but also to the increase by bycatch in many fisheries [8]. In general, the existent populations of sharks have been considered threatened or endangered, due to their particular vulnerability under fisheries pressure and to its cycle live (e.g. low fecundity and slow sexual maturity) [9,10], which prevents them from recovering their populations levels [11].

Because they play the role of a top predator in the marine ecosystems, many shark species are considered as key species [12-14]. In 1994 the Convention of the International Trade of Endangered Species (CITES) issued a resolution requesting to the United Nations for Food and Agriculture Organization (FAO) to collect and organize the necessary information regarding the biological and commerce aspects of the shark populations [15,16], because, despite the ecological researches, the consequences of remove top predators in the ocean continue to be uncertain [8,17].

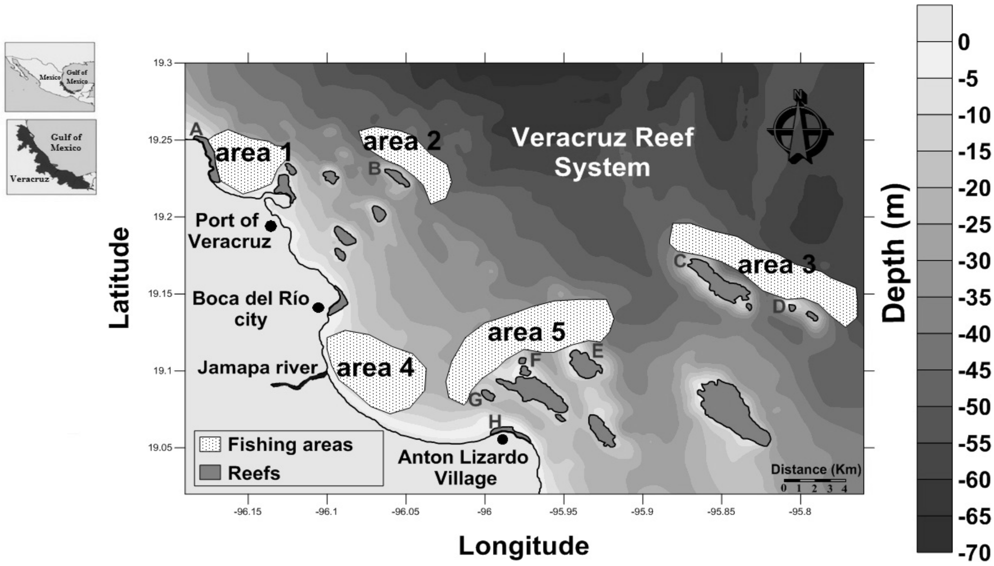

Figure 1. Study area and capture areas of sharks into the Veracruz Reef System, (A) Punta Gorda reef, (B) Anegada de Adentro reef, (C) Anegada de Afuera reef, (D) Satiaguillo reef, (E) Enmedio reef, (F) Polo reef, (G) Blanca reef and (H) Giote reef.

The information obtained from the analysis of stomach contains contributes with necessary information to understand the ecological role of the predators in the ecosystem [16,18,19], showing the feeding behavior and possible relationship between sympatric species [13,20-22]. Therefore, in order to understand the feeding and relationships of top predators a study of the stomach contains and the area of capture were performed in the VRS.

2. Materials and Methods

A sampling of captured sharks by the artisanal fleet of Anton Lizardo, townships of Alvarado and Veracruz City, were analyzed from the 9th of July to November 14, 2008 in order to determine the reproductive stage of sharks, the Total Length (TL cm), the Pre-Caudal Length (PCL cm) were sampled, and the sex of each organism and were compared with previous research of age and growth [23-25].

For the stomach content analysis, gut content of each organism were transported to the laboratory in labeled plastic bags into a refrigerated container. Samples were frozen at −2˚C for further analysis. For the analysis, each stomach was dissected to separate the stomach contents, each food item was described at the lower taxonomic level, and the trophic spectrum was analyzed and quantifying through the rates of numerical abundance percentage (%N), weight of abundance percent (%W) and the percentage of frequency of occurrence (%FO).

The %N was calculated by dividing the numbers of items *i* by the total number of items founded in the diet, the %W was calculated by dividing the weight of the item *i* by the total weight founded in the diet, and the %FO was calculated by dividing the total numbers of stomach were the item *i* was founded by the total of stomach analyzed. The Relative Importance Index (IRI) was calculated [26], in order to obtain the importance of each food group in the diet of the predators in form of percentage [13] as follow:

$$\%\mathrm{IRI} = \left[\left(\%\mathrm{N} + \%\mathrm{W}\right) \times \%\mathrm{FO}\right] \times 100$$

In order to obtain the similarities between the diets of sharks, a cluster analysis of similarity was done using the value of %IRI. The equation of minimum variance or Ward's was used to build the similarity matrix and Bray Curtis distances were used as linkage method. The analysis presents a scale of 0 to 1, were 0 means 0% of similitude and one means 100%. To elucidate the alimentary tendency of each predator a PCA (Principal Component Analysis) plot was developed. Both analyses were performed employing the software CAP 3 (Community Analysis Package, 2004).

3. Results

A total of 191 sharks were sampled from captures of the artisanal fleet. The three species of sharks obtained were: *Sphyrna lewini*, *Carcharhinus brevipinna* and *Rhizoprionodon terraenovae*.

Of the specie *S. lewini* 35 were obtained, 20 males and 15 females. The Total Length (TL) ranged was of 66 - 167 cm, with an average length of 85 cm. This species show a sexual maturity at 170 cm (TL) for males and 223 cm (TL) for females [23]. According to this criterion none of the sharks sampled were mature.

A total of 33 sharks of the species *C. brevipinna* were sampled, 19 males and 14 females. The Total Length (TL) ranged from 71 to 176 cm, with an average of 91 cm. This predator reach the maturity at 220 cm (TL) for male and female [24], therefore none of the sharks studied here were sexually mature.

Finally a total of 123 sharks of *R. terraenovae* specie were sampled, 75 males and 48 females. This shark showed a Total Length (TL) between 50 and 104 cm, with an average of 61 cm. This species reaches its sexual maturity at 60 cm of PCL for male and female [25]. Therefore only 5.7% (n = 7) organisms were sexually mature.

3.1. Capture Areas and Fishing Gears

In the VRS five capture areas (**Figure 1**) of sharks were identified, and two fishing gears were used in order to capture sharks: bottom longline and gillnet.

Sphyrna lewini was mostly captured using bottom longline with 33 organisms and one was captured with gillnet, however one shark was captured with beach seine in the area 4, these organism was the nearest captured organism to the coast, at less of 300 meters of the coastal line. The beach seine is used by the fishermen only to capture coastal fishes, but they also may capture sharks and juveniles rays. The *Carcharhinus brevipinna* species was captured using two fishing gears. 29 organisms were captured with bottom longline and four with gillnet. Finally, the *Rhizoprionodon terraenovae* was captured using two fishing gears, 53 organisms were captured with bottom longline and 70 with gillnet.

The capture area 1 locally named "La Pinera" is located in front of Punta Gorda reef, and according with the fishermen it is one of the principal fishing areas to capture juvenile sharks locally known with the name of "cazon" owing to the market price they have. This area is an ideal area for sharks owing to the discharges of residual water in the middle part of the bay and to the swell system, which increase the local productivity, making this area an ideal place for feeding.

The capture area 2 named "Anegada de Adentro" is located at the external area of the Anegada de Adentro reef. This is a deeper area located close to a cyclonic eddy (**Figure 2**) [27].

The capture area 3 named "La Cordillera" is located in the exposed side of Anegada de Afuera and Satiaguillo reefs. It is one of the deepest and less human impacted areas owing to the distance from coast. In this area the fishermen use bottom longline to capture sharks in a directed way, which has relation to the anticyclone eddy formed in the same area (**Figure 2**) generating a feed bottom zone.

The capture area 4 named "La Guada" is located in the coastal area in front of the Jamapa River and close to the cyclonic eddy [27]. Those two characteristics make this place and ideal area for feeding. Further, butcheries located at the entrance of the river (Arrollo Moreno) use to through parts of dead animals (beef, pork and chicken)

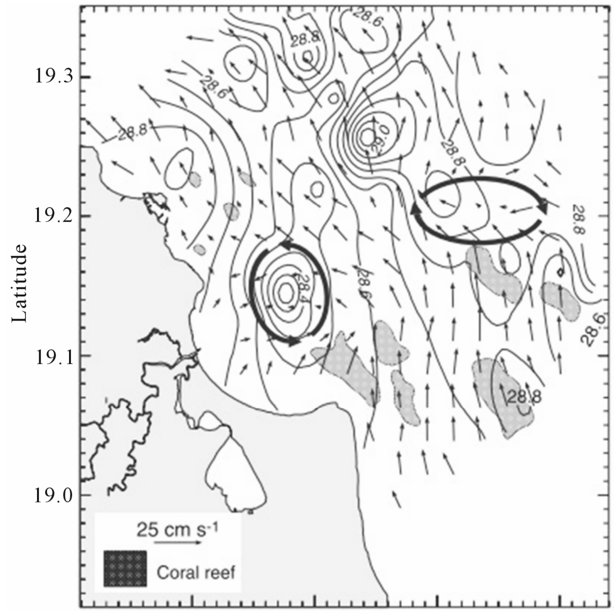

Figure 2. Surface water velocity (1 m depth) and residual sea surface temperature and the coral reefs are shown in light-gray color. The dark circular arrows represent the eddies. Obtained from Salas-Monreal *et al.* (2009), to observer the formation zones of eddies in the VRS.

with no commercial value to the river.

The captured area 5 named "Enmedio" is located in the northernmost part of Enmedio, Polo, Blanca and Giote reefs, and is a high productive area owing to the cyclonic eddy. Also on the capture areas 3, 4 and 5, the local fishermen capture sharks in a directly way using bottom longline and gillnet. They use the leeward area of the reef slope of the areas 4 and 5 to place their fishing gear since they are transit areas to sharks from the open ocean towards the feeding areas between the reefs.

The cyclonic eddy is located between the capture areas 2, 4 and 5, and its vertical water movement resuspended nutrients from the bottom, making this a high productivity area. All captured areas are located near an eddy or near the river discharges.

3.2. Analysis of Stomach Contents

All sharks captured were juvenile organisms. Twelve of the 35 organisms of the *S. lewini* had at least one prey in their stomach. The analysis of the stomach contains obtained for this species resulted on a total of 13 food items of eight different families, eight generous and eight species. The trophic spectrum was composed of two groups. The dominant group was the Teleost with 69% N, followed by the Crustacean with the 31% N. According to the IRI the prey *Litopenaeus setiferus* was the most important item in its diet with 34.6%, followed by *Paralichthys* sp. with 33.7% and *Epinephelus adscensionis* with 14.5% (**Table 1**). These preys are benthic organisms, and the demersal preys have a lower value of relative importance.

Of the total *C. brevipinna* captured, 14 had at less one prey in its stomach. The analysis of the stomach contents was performed with a total of 21 food items belonging to 12 families, 13 generous and 13 species. The trophic spectrum was composed by two groups. The dominant group was the Teleost with 95.2% N, and the other group was the Cephalopods with 4.8% N. The IRI showed that the most important item in its diet was the *Brevoortia gunteri* with 37.9%, *Mugil curema* with 17.2%, and *Scomberomorus maculatus* with 14.3% (**Table 2**). This teleost fishes have demersal behavior, as well as the rest of its items prey, *C. brevipinna* also feed on benthic preys in a smaller proportion, like *Gymnothorax funebris* and *Octopus vulgaris* both with 3.3% of IRI.

Of the total *R. terraenovae* captured, 25 had at least one prey in its stomach. The analysis of stomach contents performed with a total of 28 food items showed eleven families, eleven generous and eleven species. In this case the trophic spectrum was composed by three groups being the dominant group the Teleost with 78.6% N, followed by the Crustaceous and Cephalopods both with the 10.7% N. The index of relative importance showed that *Haemulon aurolineatum* was the most important item in the diet of this predator with 72.9%, followed by *Scombreromorus maculatus* with 15.9% (**Table 3**). Despite the number of items prey in the diet of this predator it is clear a tendency of the feeding behavior on Teleost, counting with an opportunistic behavior on benthic species like *Calappa ocellata* and *Octopus vulgaris* with 1.6% of IRI.

3.3. Analysis of Diet Similarities

Using a cluster analysis of similarity (**Figure 3(a)**) it was possible to determine that between the species *C. brevipinna* and *R. terraenovae*, there is a medium level of similarity of the food spectrum with 43.7%, but they are more similar than for the *S. lewini* specie, since it differ from the other two species by a 81.5% of its food spectrum. The three predators feed on benthic and demersal preys, with coastal and reef habits. In the PCA analysis it is possible to observe that the prey correlation (**Figure 3(b)**). *Gymnothorax funebris* is the prey with more relation between *S. lewini* and the other two predators. *C. brevipinna* and *R. terraenovae* have more similarities and are more correlated to teleosts *Anchoa hepsetus*, *Scomberomorus maculatus* and *Selene vomer*.

The results of Index of Relative Importance, cluster and the PCA, could be indicating a lower level of feeding competence due to the high availability of items prey.

4. Discussions

The specie *Sphyrna lewini* have coastal behavior and are observed sporadically on the bays, with segregation by age groups, the juveniles are mostly found near the coast during its development stage. The sharks *Carcharhinus brevipinna* and *Rhizoprionodon terraenovae* are species with coastal habits (shallow waters). They live on the coastal

Table 1. Diet composition of *Sphyrna lewini* (N = 12, size range from 66 to 81 cm of TL), in numerical percentage (%N), percentage of weight abundance (%W), percentage of frequency of occurrence (%FO) and index of relative importance (%IRI).

Groups	Family	Prey	N	%N	%FO	%W	%IRI
Teleosts							
	Paralichthyidae	*Paralichthys* sp.	2	15	17	52	33.7
	Serranidae	*Epinephelus adscensionis*	2	15	17	13.7	14.5
	Muraenidae	*Gymnothorax funebris*	1	8	8	14.3	5.5
	Triglidae	*Prionotus* sp.	1	8	8	11	4.7
	Carangidae	*Caranx hippos*	1	8	8	2.2	2.5
	Haemulidae	*Haemulon aurolineatum*	1	8	8	1.9	2.4
	Mugilidae	*Mugil curema*	1	8	8	0.9	2.1
		Total Teleosts	9	69	75	96	65
Crustaceous							
	Penaeidae						
		Litopenaeus setiferus	4	31	33	4	34.6
		Total Crustaceous	4	31	33	4	34.6

Table 2. Diet composition of *carcharhinus brevipinna* (N = 14, size range from 75 to 176 cm of TL), in numerical percentage (%N), percentage of weight abundance (%W), percentage of frequency of occurrence (%FO) and index of relative importance (%IRI).

Groups	Family	Prey	N	%N	%FO	%W	%IRI
Teleost							
	Clupeidae	*Brevoortia gunteri*	6	28.6	21.4	17.9	37.9
	Mugilidae	*Mugil curema*	2	9.5	14.3	22.1	17.2
	Scombridae	*Scomberomorus maculatus*	2	9.5	14.3	16.8	14.3
	Haemulidae	*Haemulon aurolineatum*	2	9.5	14.3	7.5	9.2
	Muraenidae	*Gymnothorax funebris*	1	4.8	7.1	7.4	3.3
	Carangidae	*Cholorcombrus chrysurus*	1	4.8	7.1	5.4	2.8
	Carangidae	*Selene vomer*	1	4.8	7.1	4.5	2.5
	Synodontidae	*Synodus* sp.	1	4.8	7.1	3.6	2.3
	Paralichthydae	*Paralichthys* sp.	1	4.8	7.1	3.4	2.2
	Sphyraenidae	*Sphyraena* sp.	1	4.8	7.1	2.2	1.9
	Engraulidae	*Anchoa hepsetus*	1	4.8	7.1	0.9	1.5
	Exocoetidae	*Hirundichthys speculiger*	1	4.8	7.1	0.8	1.5
		Total Teleosts	20	95.2	121.4	92.5	96.7
Cephalopods							
	Octopidae	*Octopus vulgaris*	1	4.8	7.1	7.5	3.3
		Total Cephalopods	1	4.8	7.1	7.5	3.3

Table 3. Diet composition of *Rhizoprionodon terraenovae* (N = 25, size range from 53 to 90 cm of TL), in numerical percentage (%N), percentage of weight abundance (%W), percentage of frequency of occurrence (%FO) and index of relative importance (%IRI).

Groups	Family	Prey	N	%N	%FO	%W	%IRI
Teleosts							
	Haemulidae	*Haemulon aurolineatum*	10	35.7	40	34.3	72.9
	Scombridae	*Scomberomorus maculatus*	3	10.7	12	40.0	15.9
	Engraulidae	*Anchoa hepsetus*	3	10.7	8	2	2.6
	Elopidae	*Elops saurus*	1	3.6	4	11.2	1.5
	Muraenidae	*Gymnothorax funebris*	3	10.7	4	1.6	1.3
	Carangidae	*Selene vomer*	1	3.6	4	7.3	1.1
	Paralichthyidae	*Paralichthys* sp.	1	3.6	4	0.4	0.4
		Total Teleosts	22	78.6	76	96.6	95.8
Crustaceous							
	Calappidae	*Calappa ocellata*	2	7.1	8	0.5	1.6
	Gonodactylidae	*Neogonodactylus* sp.	1	3.6	4	1.2	0.5
		Total Crustaceous	3	10.7	12	1.7	2.1
Cephalopods							
	Octopidae	*Octopus vulgaris*	2	7.1	8	0.5	1.6
	Longinidae	*Sepioteuthis* sp.	1	3.6	4	1.1	0.5
		Total Cephalopods	3	10.7	12	1.6	2.1

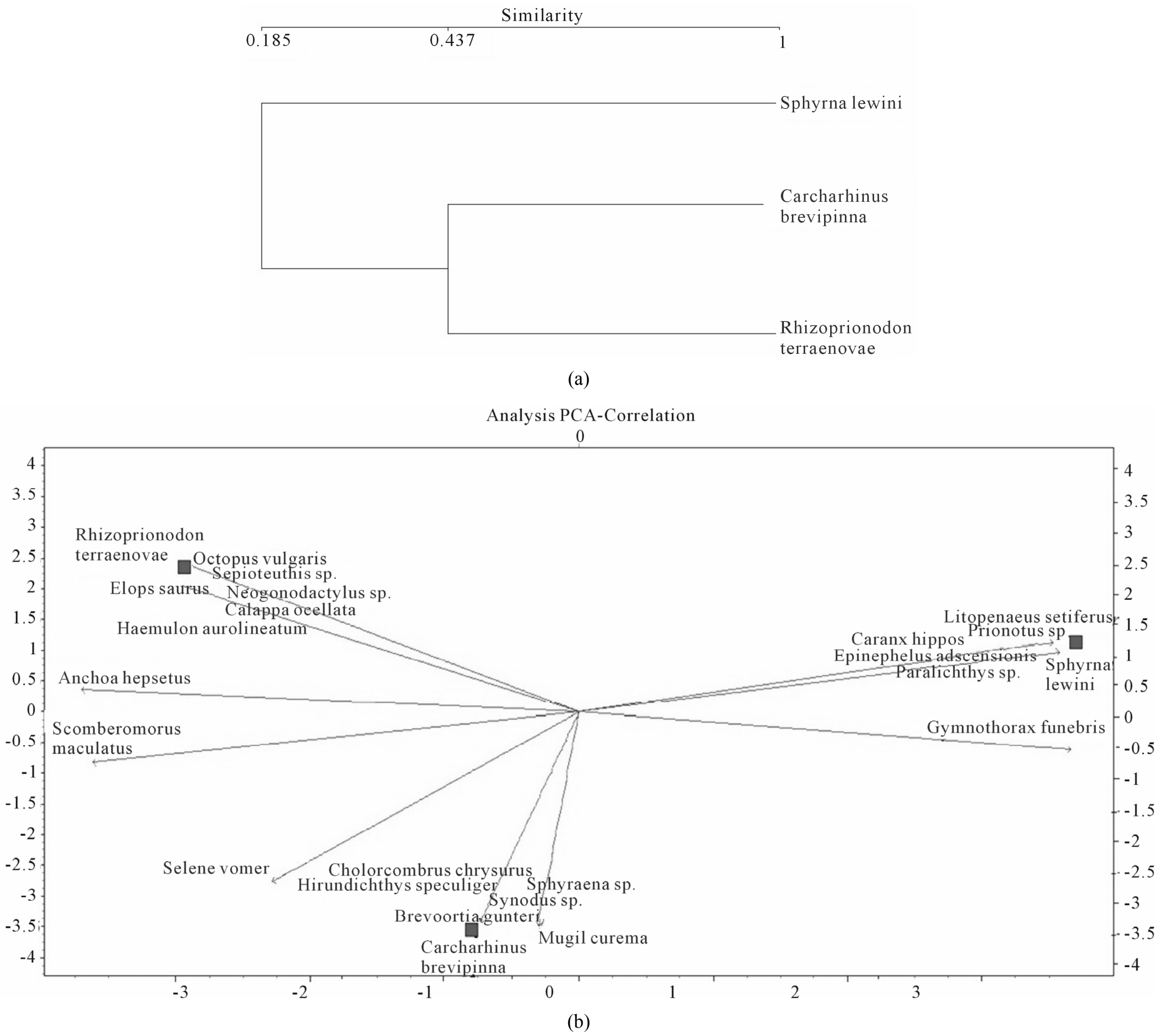

Figure 3. (a) Cluster of similarity and (b) PCA correlation for the trophic spectrum of the sharks species captured in the VRS.

shelf and the littoral areas, including bays, coastal lagoons and estuaries [1,14].

The artisanal fishery during the time of sampling, captured mostly immature shark, this was attributed to the fact that most species of sharks use these kinds of areas (reefs, bays and estuaries) for protection, feeding and development during their juvenile stages [20,28,29]. The areas of captured sharks suggest that sharks feed near to the cyclonic and anticyclonic eddies, the river discharges and to the swell system discharges near to the Port of Veracruz, owing to the abundance of small fishes and benthonic organisms. The VRS has been described as a high productivity area [27,30], making this area a seasonally or temporarily potential development site for some species of top predators such as sharks. It is necessary to pay special attention to the potential breeding areas and regions of local and seasonal abundance for the protection of sharks communities [31,32], since sharks have a continuous reduction in its population number around the world [6].

Due to the opportunistic feeding behavior of the shark species, two or more species of predators that share the same marine habitat may have a similar diet which will be determined by the availability of preys [22]. The sharks species sampled on this study feed on benthic and demersal preys with coastal and reef behaviors, which implies that these predators use the reef system to feed and for protection at least in one stage of its life cycle.

It is possible to observe that *S. lewini* feed more on benthic species. Its predator has been cataloged like an opportunistic predator around the world [14,29,33,34]. In the bay of Kane-Ohe, O'ahu, Hawaii, the juveniles of this species mostly feeds on benthic organisms specially from crustaceous [29]. This feeding behavior is probably due to the evolutionary adaptation of the species to hunt; however its diet changes on the adult stage, when they mainly feed of cephalopods [14,28,33,35].

It has been described that *C. brevipinna* is an opportunistic depredator that feeds essentially of teleosts but it can also feed of cephalopods [36]. This was confirmed in this study due to the notable presence of *Octopus vulgaris* in its diet (3.3% IRI). In the bay of Apalachicola, Florida, the juveniles of this predator mainly feed of teleosts, where the Teleost represent the 96.7% IRI of its diet [37]. This characteristic has mainly been described for the *Carcharhinus* generous around the world [38-44].

Finally, *R. terraenovae* feed on a variety of benthic preys like crustaceous and cephalopods, but, with a clear tendency to feed on Teleost specially *Haemulon aurolineatum* (72.9% IRI). The neonates of this predator in the bay of Apalachicola, Florida, usually to feed of shrimps, and the juveniles and adults usually feed of teleosts [37], the diet of this predator has been described like a generalist depredator with a tendency to feed on small Teleost fishes [45], similar to the once founded in this study.

This information helps to understand the adaptations of the top predators to their marine habitats and their interspecific and intraspecific interactions [22].

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