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Feeding habits of the sharpnose shark *Rhizoprionodon longurio* on the west coast of the Gulf of California, Mexico

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Research Article

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Abstract

The sharpnose shark (*Rhizoprionodon longurio*) is among the top three shark species captured by artisanal fisheries of the Gulf of California. This study includes information regarding the feeding habits of this species using the stomach contents of 70 individuals ranged from 54 to 109 cm in total length (TL). Out of the 16 prey items identified, fish of the families Scombridae (*Scomber japonicus*; prey-specific relative importance index [%PSIRI] = 6.3) and Batrachoididae (%PSIRI = 5.5), the cephalopod *Lolliguncula* spp. (%PSIRI = 6.3), and the crustacean *Pleuroncodes planipes* (%PSIRI = 4.3) were the most important prey. Only female stomachs were obtained ($N = 19$) in the central area of the gulf, and the PSIRI indicated that the preferred prey were the cephalopod *Lolliguncula* spp. (%PSIRI = 10.5) and fish of the Sparidae family (*Calamus brachysomus*; %PSIRI = 5.8). The number of stomachs was not sufficient to analyse differences by sex. Regarding its trophic position, *R. longurio* was a tertiary consumer ($TL_K = 4.4$). A $TL_K = 4.4$ was calculated for the central area, and a $TL_K = 4.3$ for the southern area. According to Levin's index (B_i), this shark is a specialist predator in the whole study area ($B_i = 0.19$), including the centre ($B_i = 0.29$). Conversely, it was considered a generalist predator in the southern area ($B_i = 0.63$). The high quantity of empty stomachs could relate to the time the sharks were caught in fishing a gear.

Introduction

Trophic studies provide information regarding the biology and ecology of organisms that allow the comprehension of their interactions with the environment (Cailliet, 1996). Currently, there are two methods used to determine the trophic level of marine organisms: stable isotope analysis and studies regarding diet composition through stomach content analysis (SCA) (Cortés, 1997; Hansson *et al.*, 1997). In this regard, SCA is a valuable tool that describes the interactions between prey and predator in a trophic chain (Langler, 1956; Hyslop, 1980; Krebs, 1989). Studies regarding the stomach contents of different fish species have served as a basis for establishing conservation or their management (Serrano and Soraya, 2016).

In the Gulf of California (GC), the sharpnose shark *Rhizoprionodon longurio* (Jordan & Gilbert, 1882) is considered an important fishery resource. However, it is vulnerable under the red list of threatened species and needs management strategies for its sustainable use.

R. longurio is a small species that inhabits the coastal waters of the eastern Pacific Ocean. Its maximum size ranges from 110 cm total length (TL) up to 154 cm, in which females are larger than males (Mejía-Salazar, 2007; Conde-Moreno, 2009).

This species is commonly found in the GC and represents 10% of the catch volume (CONAPESCA, 2015). It exhibits a seasonal reproductive migration in Baja California Sur during the annual cold period associated with changes in temperature of water, ranking third in the state catches (9%; SAGARPA-CONAPESCA, 2007). This species is considered a generalist opportunistic whose diet mainly comprises teleost fishes, cephalopods, and crustaceans (Márquez-Farías *et al.*, 2005).

The sharpnose shark's distribution is limited to the eastern Pacific Ocean. It is catalogued as vulnerable under the IUCN red list, which indicates the need to gather data that completes its life-cycle characteristics. Moreover, it is a fishery resource exploited throughout the year, figuring among the top three shark species fished in the GC (SAGARPA-CONAPESCA, 2007). Furthermore, this shark's reproductive and nursery areas have been documented within the study region (Salomón-Aguilar *et al.*, 2009).

Despite being a highly exploited species in Mexico, studies regarding its feeding habits in the area are scarce. Thus, this study aimed to determine its feeding habits through SCA.

Materials and methods

The stomach samples of *R. longurio* were obtained every 3 months from October 2017 to April 2018 in the central area (San Bruno and Coloradito), while samples in the southern region (El Saladito) were obtained during March and April 2018 (Figure 1). Biological sampling was

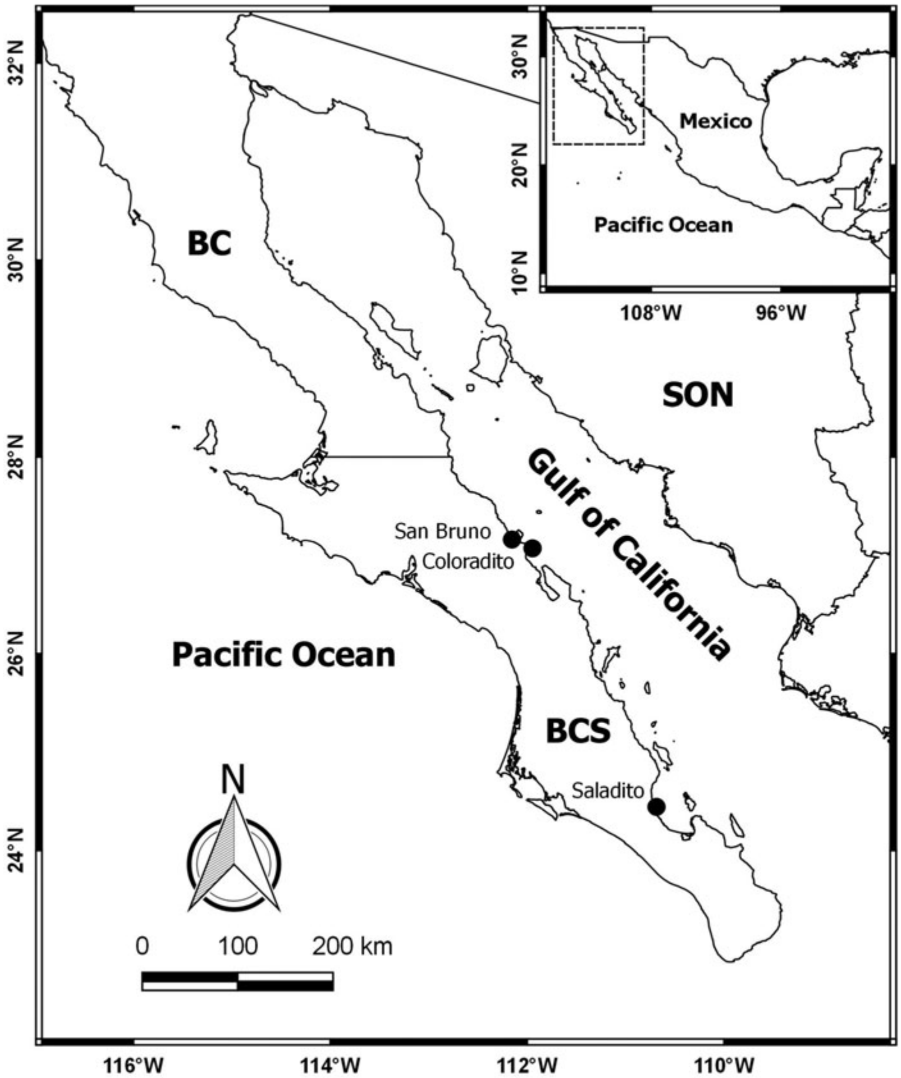

Figure 1. Location of the fishing camps: San Bruno-Coloradito (central area) and El Saladito (southern area) in the west coast of the GC, Mexico.

carried out 1 week of each month using gillnets set by artisanal fishermen the night before capture and left exposed to the sea for 10–12 h. The TL data (cm) of the sharks were registered *in situ*. A cut was made from the pectoral fins to the cloaca of each specimen to extract the stomach from the body. Subsequently, stomachs were stored in labelled plastic bags and transported in ice to the Fish Laboratory at the Centro Interdisciplinario de Ciencias Marinas of the Instituto Politecnico Nacional.

Stomach content analysis

The percentage of stomach fullness for each organism was determined under the five categories established by Galván-Magaña *et al.* (1989), ranging from zero (empty stomach), one (1–25% full), two (26–50% full), three (51–75% full) to four (76–100% full). The digestion state of the prey was determined based on a scale proposed by Galván-Magaña (1999), which considers the following categories: one (fresh: recent), two (intermediate: skinless meat), three (advanced: skeletons and/or exoskeletons), and four (digested: otoliths, squid beaks).

Each prey was identified to the lowest possible taxonomic level using identification guides from Fischer (1995) and studies from Díaz-Murillo (2006) and Lowry (2011) for otoliths. In the case of squid beaks, identification guides were used based on the studies by Clarke (1962, 1986) and Wolff (1982, 1984).

Using the methodology of Hsieh *et al.* (2016), which is a modification to the one proposed by Chao *et al.* (2014) trophic diversity was determined from interpolation and extrapolation curves, which allow us to identify the percentage of the diet calculated from the diversity estimates with 95% confidence intervals.

Food items were quantified with the prey-specific relative importance index (%PSIRI) (Brown *et al.*, 2012) using the below formula:

$$\%\mathrm{PSIRI}_i = \frac{\%\mathrm{FO}_i(\%\mathrm{PN}_i + \%\mathrm{PW}_i)}{2}$$

where $\%\mathrm{FO}_i$ is the number of stomachs containing the prey i divided by the total number of stomachs, $\%\mathrm{PN}_i$ is the specific abundance per prey, and $\%\mathrm{PW}_i$ is the weight of each prey.

The frequency of occurrence ($\%\mathrm{FO}_i$) is calculated as follows:

$$\mathrm{FO}_i = \frac{n_i}{n}$$

where n_i is the number of stomachs containing prey i and n is the total number of analysed stomachs.

Specific abundance per prey ($\%\mathrm{PN}_i$) and weight ($\%\mathrm{PW}_i$) were calculated as follows:

$$\%\mathrm{APP}_i = \frac{\sum_{j=1}^{n} \%A_{ij}}{n_i}$$

where $\%A$ is the abundance of each prey i in the stomach j and n_i is the number of stomachs containing the prey i either in abundance or weight.

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The %PSIRI is a modification of the index of relative importance (%IRI) (Pinkas *et al*., 1971). This measure accounts for %FO redundancies in the %IRI and is additive concerning taxonomic levels; thus, the %PSIRI of a family will be equal to the sum of the %PSIRI of the species in that taxon (Brown *et al*., 2012).

For the determination of the trophic position (TL_K), the following formula proposed by Christensen and Pauly (1992) was applied:

$$\mathrm{TL}_K = 1 + \left(\sum_{j=1}^{n} \mathrm{DC}_{ij} \right) (\mathrm{PT}_j)$$

where DC_{ij} is the diet composition; prey number proportion (j) in the diet of predators (i); PT_j is the trophic position of the prey (j); and n is the total number of groups.

TL_K was determined from the trophic level of the prey species reported on the website (https://www.fishbase.se/search.php). Trophic levels that could not be identified up to a species level were obtained from Cortés (1999). The trophic overlap was calculated from a non-parametric analysis of similarities (ANOSIM) with software PRIMER-E 7 (Clarke and Gorley, 2006), where values from −1 to 1 were obtained (Osuna-Peralta *et al*., 2014). Positive values mean similarity between sites, values close to zero do not show differences in sites, and negative values demonstrate a higher similarity (Osuna-Peralta *et al*., 2014). To complement ANOSIM, a similarity of percentages of prey species was realised (Clarke, 1993), which determines the level of significance of the results and the possible diet overlap between areas.

In the case of the diet amplitude, Levin's index was used (Krebs, 1989) through the formula:

$$B_i = \frac{1}{n-1} \left(\frac{1}{\sum P_{ij}^2} - 1 \right)$$

where B_i is the Levin's index, P_{ij} is the proportion of each prey that conforms to the diet of the predator, and n is the total number of prey items.

This method allows inferring how broad an organism's diet is, considering the proportion of each prey present and how they are distributed to the total number. The values obtained from Levin's index range 0–1, which indicate if the predator is a specialist (<0.6) or a generalist (>0.6) (Polo-Silva, 2008).

Results

A total of 70 stomachs of *R. longurio* were analysed, of which 43 belonged to the central area and 27 to the southern area. The organisms ranged from 54 to 109 cm in TL. Of the total, 54% (n = 38) of the stomachs were empty and 46% (n = 32) contained food. Fifty-four per cent of the stomachs were found with stomach fullness zero, 33% with stomach fullness one, 7% with stomach fullness two, and finally 3% with stomach fullness three and four each. Most prey (49%) were found in a state of digestion three (skeleton or exoskeleton), 29% were found in a state of digestion four, 13% in a state of digestion two, and 9% in a state of digestion one.

Stomach content analysis

From the interpolation and extrapolation curves, 14 families of prey were identified that made up the trophic diversity of the sharpnose shark, with which it was possible to represent 72% of its diet in the west coast of the GC (67% of its diet in the central and 80% in the southern areas) (Figure 2).

The general trophic prey spectrum was composed of ten teleost fish (nine families; one unidentified teleost fish), three families of cephalopods and three crustaceans (two families; one unidentified crustacean). The diet of *R. longurio* was dominated by fish (%PSIRI = 80.8), followed by crustaceans (%PSIRI = 9.8) and cephalopods (%PSIRI = 9.4). Fish of the Scombridae and Batrachoididae families (%PSIRI = 6.3 and 5.5, respectively), the cephalopod *Lolliguncula* spp. (%PSIRI = 6.3), and the crustacean *Pleuroncodes planipes* (%PSIRI = 4.3) dominated its diet (Table 1).

Only female stomachs were obtained (N = 19) in the central area of the GC. The %PSIRI indicated that the preferred prey were teleost fish (%PSIRI = 88.1), the cephalopod *Lolliguncula* spp. (%PSIRI = 10.5), and crustaceans (%PSIRI = 1.4) (Table 2). In the southern area of the gulf, the diet was dominated by fish (%PSIRI = 70.4), followed by crustaceans (%PSIRI = 22.2) and cephalopods (%PSIRI = 7.4). The %PSIRI indicated that the preferred prey were fish of the family Scombridae (*Scomber japonicus*; %PSIRI = 15. 4) and the crustacean *P. planipes* (%PSIRI = 10.6) (Table 2).

A trophic level of TL_K = 4.4 was obtained for *R. longurio*, while a TL_K = 4.4 was obtained for the central area and a TL_K = 4.3 for the southern area. The general trophic amplitude for this species was B_i = 0.19, considering it a specialist predator (B_i = 0.29) in the central area and a generalist predator in the southern area (B_i = 0.63).

The trophic overlap between areas (Figure 3) had an average dissimilarity ≤72.79, which is consistent with that obtained from the %PSIRI, where the cephalopod *Lolliguncula* spp., as well as fish of the Sparidae (*Calamus brachysomus*) and Merlucciidae families, were the most important prey for the central area of the GC. Fish of the Scombridae (*S. japonicus*) and Batrachoididae families, the crustacean *P. planipes*, and the cephalopod *Argonauta* spp. were the most important prey for the southern area. The *R* values were equal to 0.069, which indicated that there were no statistically significant differences in their diet between both the areas.

Discussion

In this study, the number of stomachs was insufficient to infer the diet differences of *R. longurio* by sex due to the low quantity of analysed samples (female = 51 stomachs and male = 19 stomachs) and a large number of empty ones. The latter can be explained by the fishing gear technique and the time of day when the sharks were caught. Gillnets are placed at night and collected until the following day, remaining for about 10 h at sea.

It could be inferred that prey were consumed at least one day before the sharks were captured since most were in an advanced stage of digestion. Alderete-Macal (2007), Acosta-Alonso (2021), Castillo-Géniz (1990), and Alatorre-Ramírez *et al.* (2013) mention that, according to the time of gillnet placement and collection, sharks are caught with an empty stomach because they feed primarily at night.

Alatorre-Ramírez *et al.* (2013) also state that the fishing gear/technique used can cause high stress in sharks at the time of capture, resulting in regurgitation of the stomach contents. In this study, regurgitation was observed, which was related to the high number of empty stomachs. Furthermore, the activity of gastric juices can act on the degradation of prey organisms. Other authors Flores-Martínez (2017) and Flores-Martínez *et al.* (2017) agree that the filling percentage of the stomachs and the digestion state of the prey of *R. longurio* and other sharks are related to the time in which the organisms feed.

Regarding the fishing gear, Cabrera-Chávez (2003) mentions that the best capture technique for trophic ecology studies is gillnets, since sharks are not attracted by bait as it happens with longlines that draw individuals with empty stomachs. However, the

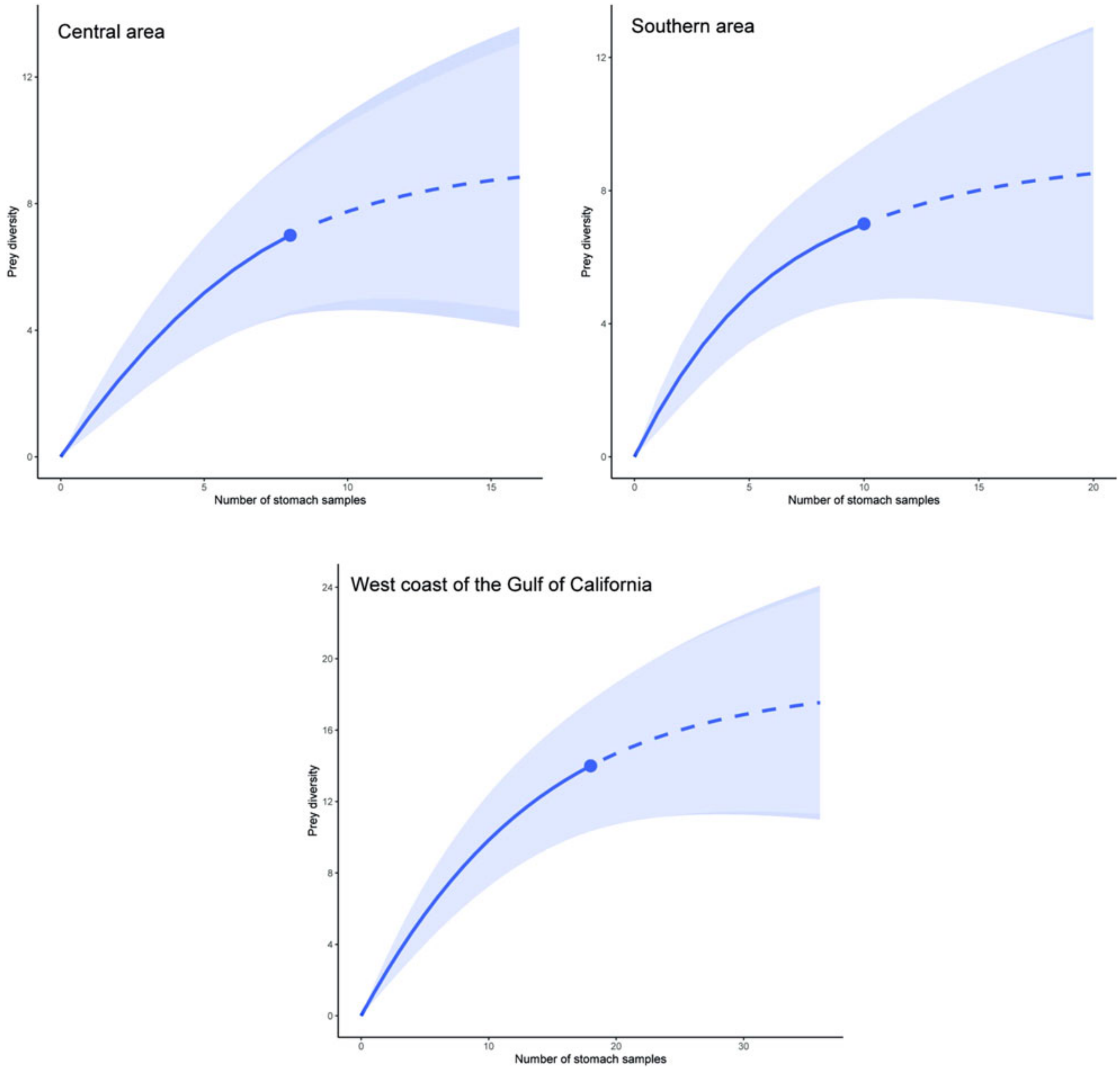

Figure 2. Interpolation and extrapolation curves to determine trophic diversity and represented diet percentage of *R. longurio* on the west coast of the GC.

high number of empty stomachs in this study could be unrelated to the fishing gear, and more related to their feeding time or capture area.

Most prey were found in a state of digestion three (49%); however, prey were found in all four digestion states. Some authors mention that sharks of the genus *Rhizoprionodon* present different digestion stages of their prey due to their slow digestion rate in relation to other species (Flores-Martínez, 2017; Viana-Morayta *et al*., 2020). Therefore, the shark begins to hunt and feed until the digestion state of its prey has been partially or totally finished.

By the methodology proposed by Hsieh *et al.* (2016) it was possible to represent 72% of the diet of *R. longurio*.

Our results from the PSIRI coincide with the results obtained by Castillo-Géniz (1990), Márquez-Farías *et al.* (2005), Alatorre-Ramírez *et al.* (2013), and Acosta-Alonso (2021). All authors used the IRI and reported that the diet of *R. longurio* is dominated mainly by teleost fish, followed by cephalopods and crustaceans. One of the reasons for using the %PSIRI and not the traditional methodology is related to the main weaknesses of the %IRI; its values depend on the taxonomic level or designated prey categories chosen by a researcher, which essentially defeats its purpose as a standardised measure of prey importance to facilitate comparisons. All prey items are not likely to be consistently identified to the same taxonomic level within a study, in addition to the bias resulting from the redundant calculation of the frequency of occurrence (%FO) (Brown *et al*., 2012).

This %PSIRI sums to 200%, and therefore dividing by two results in a version of the standardised %IRI with an important distinction: the %PSIRI is additive concerning taxonomic levels, such that the sum of the %PSIRI for species will be equal to the %PSIRI of the family containing those species, and so forth. This characteristic enhances the %PSIRI for comparisons between predators and studies since its values are not dependent upon the taxonomic level, suitability of or prey categories designated by a researcher (Brown *et al*., 2012). Therefore, our results represent a more robust interpretation.

The presence of other prey such as the pelagic red crab *P. planipes*, fish of the family Batrachoididae, and the cephalopods *Mastigoteuthis dentata* and *Argonauta* spp. coincide with the report by Acosta-Alonso (2021) in La Paz Bay, B.C.S. Mexico.

The sharpnose shark can perform vertical migrations in the water column within the first 100 m of depth, allowing it to

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Table 1. Summary of the diet composition of *R. longurio* in the west coast of the GC, Mexico, expressed as numbers and percentages: the number of stomachs containing the prey (FO), specific abundance per prey (PN), number (*N*), specific weight per prey (PW), and %PSIRI

PREY SPECIES	FO	%FO	%PN	*N*	%*N*	%PW	*W*	%*W*	%PSIRI
Teleost fishes									
Family Atherinopsidae									
Atherinops affinis	1	3.1	100	1	1.6	100	5.7	0.8	3.1
Family Batrachoididae	3	5.5	72.2	7	11.5	45	0.03	0.01	5.5
Family Haemulidae	1	0.9	14.3	1	1.6	45.5	166.7	23.5	0.9
Family Lophiidae	1	3.1	100	1	1.6	100	146.8	20.7	3.1
Family Merlucciidae	2	2.4	73.2	8	13.1	3.2	0.2	0.03	2.4
Family Ophidiidae	1	0.9	25	1	1.6	33.3	0.01	0.01	0.8
Family Scombridae									
S. japonicus	2	6.3	100	2	3.3	100	46.9	6.6	6.3
Family Sparidae									
C. brachysomus	2	6.3	32.1	2	3.3	77.2	276.2	38.9	3.4
Family Triglidae	1	3.1	100	1	1.64	100	17	2.4	3.1
Unidentified teleost fish	20	52.2	79.2	22	36.1	87.7	24.5	3.5	52.2
Cephalopods									
Family Argonautidae									
Argonauta spp.	2	2	39.3	3	4.9	26.6	0.02	0.01	2.1
Family Loliginidae									
Lolliguncula spp.	2	6.3	100	2	3.3	100	17.7	2.5	6.3
Family Mastigoteuthidae									
M. dentata	1	0.9	57.1	4	6.6	6.3	0.02	0.01	1
Crustaceans									
Family Munididae									
P. planipes	3	4.3	3	3	4.9	52.6	0.3	0.1	4.3
Family Penaeidae									
Litopenaeus vannamei	1	3.1	1	1	1.6	100	7.7	1.09	3.1
Unidentified crustacean	2	2.4	2	2	3.3	26.7	0.02	0.01	2.4

Table 2. Summary of the diet composition of *R. longurio* in the west coast of the GC, Mexico: central and southern area, expressed by numbers and percentages: frequency of occurrence (%FO), per cent prey-specific number (%PN), per cent number (%*N*), per cent prey-specific weight (%PW), per cent weight (%*W*), and %PSIRI

PREY SPECIES	FO	%FO	%PN	*N*	%*N*	%PW	*W*	%*W*	%PSIRI
Central area of the GC									
Teleost fishes									
Family Atherinopsidae									
A. affinis	1	5.3	100	1	3.1	100	5.7	0.9	5.3
Family Haemulidae	1	5.3	14.3	1	3.1	45.5	166.7	25.5	1.6
Family Lophiidae	1	5.3	100	1	3.1	100	146.8	22.5	5.3
Family Merlucciidae	2	10.5	73.2	8	25	3.2	0.2	0.03	4
Family Sparidae									
C. brachysomus	2	10.5	32.1	2	6.3	77.2	276.2	42.3	5.8
Family Triglidae	1	5.3	100	1	3.1	100	17	2.6	5.3
Unidentified teleost fish	13	68.4	86.5	15	46.9	91.6	22.2	3.4	60.8
Cephalopods									
Family Loliginidae									
Lolliguncula spp.	2	10.5	100	2	6.2	100	17.7	2.7	10.5
Crustaceans									
Unidentified crustacean	1	5.3	50	1	3.1	3.3	0.01	0.01	1.4
Southern area of the GC									
Teleost fishes									
Family Batrachoididae	3	23.1	72.2	7	24.1	45	0.03	0.05	13.5
Family Ophidiidae	1	7.7	25	1	3.5	33.3	0.01	0.02	2.2
Family Scombridae									
S. japonicus	2	15.4	100	2	6.9	100	46.9	81.8	15.4
Unidentified teleost fishes	7	53.9	65.5	7	24.1	80.6	2.3	4	39.3
Cephalopods									
Family Argonautidae									
Argonauta spp.	2	15.4	39.3	3	10.3	26.6	0.02	0.03	5
Family Mastigoteuthidae									
M. dentata	1	7.7	54.2	4	13.8	6.3	0.02	0.03	2.4
Crustaceans									
Family Munididae									
P. planipes	3	23.1	38.1	3	10.3	52.6	0.3	0.6	10.6
Family Penaeidae									
L. vannamei	1	7.7	100	1	3.5	100	7.7	13.5	7.7
Unidentified crustacean	1	7.7	50	1	3.5	50	0.01	0.02	3.9

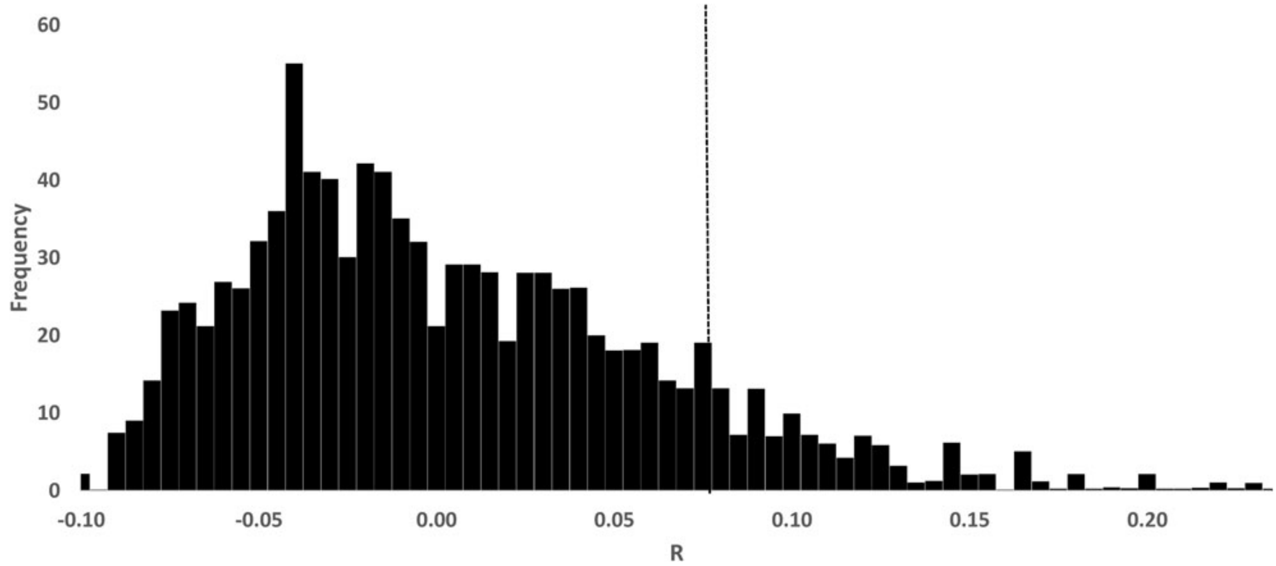

Figure 3. Trophic overlap from ANOSIM in the west coast of the GC.

capture both pelagic species and those with demersal habitats (Conde-Moreno, 2009; Alatorre-Ramírez *et al*., 2013). These migrations would explain the presence of pelagic and benthic prey, such as the pelagic red crab *P. planipes*, which is distributed in muddy and sandy coastal bottoms, as well as the presence of pelagic prey such as fish from the Batrachoididae and Scombridae (*S. japonicus*) families (Acosta-Alonso, 2021). Thus, the preference for different prey between areas can also be related to its abundance and availability in the environment.

Some authors consider *R. longurio* an opportunist predator (Castillo-Géniz, 1990; Alatorre-Ramírez *et al*., 2013) while others consider it a specialist (Alderete-Macal, 2007) or generalist (Trejo-Ramírez, 2017). It is worth mentioning that the selection of a type of predator depends on the zone and the distribution and abundance of their prey inside that zone. Likewise, changes in its diet may be related to environmental changes and each study area's oceanographic and biological characteristics. It is challenging to classify *R. longurio* as a predator under the terms established by Krebs (1989) since the reported values of its prey based on the %PSIRI could indicate that it is an opportunistic predator that feeds on prey that coexist in time and space with them and are abundant in the area. The specialised behaviour of *R. longurio* could be related to its feeding on prey that form large schools, as has been reported by Alatorre-Ramírez *et al.* (2013). In addition, the central zone presented a wide abundance of fish in comparison with cephalopods and crustaceans, presenting a specialist behaviour, while the generalist behaviour in the southern zone can be related to the similar abundance between prey groups.

According to Cortés (1999) and Alatorre-Ramírez *et al.* (2013), sharks occupy a tertiary trophic position. In the case of *R. longurio*, Cortés (1999) reports a trophic level of 4.2, which coincides with the one found in the present study. Therefore, it is a tertiary consumer in the study areas, as it mainly feeds on teleost fish with trophic positions between 2 and 3.5 (Alatorre-Ramírez *et al*., 2013).

The trophic overlap demonstrated no significant differences in the diet between both areas. A global *R* value equal to 0.069 was found from the test of ANOSIM. The *R* values range between −1 and 1, indicating a degree of discrimination among samples that depend on the richness and abundance of each organism's prey species (Clarke, 1993; Torres-Rojas, 2011). *R* achieves its maximum value when all the similarities within groups are greater than those between groups. In contrast, no separation or difference in the trophic spectrum between groups occurs when it achieves its minimum value (Clarke and Warwick, 1994). In this study, the value obtained showed no such differences between the prey found in each area.

Our results could indicate the preference of different prey in both areas due to their availability, environmental factors, and the oceanographic conditions of each site, which is also reported in other study areas by Márquez-Farías *et al.* (2005), Conde-Moreno (2009), Osuna-Peralta *et al.* (2014), and Acosta-Alonso (2021).

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Author's contribution. A.H.-A. analysed the data, interpreted the findings, and wrote the article. F.G.-M. designed the study, collected samples from fishing camps, interpreted the findings, and wrote the article. M.R.S.-A. designed the study, collected samples from fishing camps, analysed the data, interpreted the findings, and wrote the article.

Competing interest. None.

References

Acosta-Alonso AL (2021) *Cambios ontogénicos en la dieta del cazón bironche Rhizoprionodon longurio en la Bahía de La Paz, B.C.S,, México*. MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Alatorre-Ramírez VG, Galván-Magaña F and Torres-Rojas YE (2013) Trophic habitat of the Pacific sharpnose shark, *Rhizoprionodon longurio*, in the Mexican Pacific. *Journal of the Marine Biological Association of the United Kingdom* **93**, 2217–2224.

Alderete-Macal M (2007) *Hábitos alimenticios del tiburón horma Rhizoprionodon longurio (Jordan y Gilbert, 1882) en Salina Cruz, Oaxaca*. BSc thesis. Universidad Autónoma de Baja California Sur, La Paz, Mexico.

Brown SC, Bizzarro JJ, Caillie TGM and Ebert DA (2012) Breaking with tradition: redefining measures for diet description with a case study of the Aleutian skate *Bathyraja aleutica* (Gilbert 1896). *Environmental Biology of Fishes* **95**, 3–20.

Cabrera-Chávez AA (2003) *Hábitos alimenticios del tiburón piloto Carcharhinus falciformis* (Bibron, 1839) *en la costa occidental de Baja California Sur*. MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, México.

Cailliet G (1996) Sample size and data analysis: are we characterizing and comparing diet properly? GUTSHOP'96. Feeding Ecology and Nutrition in Fish Symposium Proceedings, 71–80.

Castillo-Géniz JL (1990) *Contribución al conocimiento de la biología y pesquería del cazón bironche, Rhizoprionodon longurio (Jordan y Gilbert, 1882) (Elasmobranchii, Carcharhinidae), del sur de Sinaloa, Mexico*. BSc thesis. Universidad Autónoma de Mexico, Mexico City, Mexico.

Chao A, Gotelli NJ, Hsieh TC, Sander EL, Ma KH, Colwell RK and Ellison MA (2014) Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs **84**, 45–67.

Christensen V and Pauly D (1992) Ecopath II – a software for balancing steady-state ecosystem models and calculating network characteristics. *Ecological Modelling* **61**, 169–185.

Clarke MR (1962) The identification of cephalopod "beaks" and their relationship between beak size and total body weight. *Bulletin of the British Museum (Natural History)* Zoology **8**, 422–480.

Clarke M (1986) *A Handbook for the Identification of Cephalopod Beaks*. New York, NY: Oxford University Press.

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* **18**, 117–143.

Clarke KR and Gorley RN (2006) User manual/tutorial. PRIMER-E, Plymouth, 6: 192.

Clarke KR and Warwick RM (1994) Change in marine communities: an approach to statistical analysis and interpretation, UK: Natural Environment Research Council, 144.

CONAPESCA: Comisión Nacional de Acuacultura y Pesca (2015) Anuario Estadístico De Acuacultura y Pesca. Mazatlán, Sinaloa, México. 299 pp.

Conde-Moreno M (2009) Ecología trófica del tiburón bironche, *Rhizoprionodon longurio* (Jordan & Gilbert, 1882), en dos áreas del Pacífico Mexicano. MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Cortés E (1997) A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. *Canadian Journal of Fisheries and Aquatic Sciences* **54**, 726–738.

Cortés E (1999) Standardized diet composition and trophic level in sharks. *ICES Journal of Marine Sciences* **56**, 707–717.

Díaz-Murillo BP (2006) Catálogo de otolitos de peces marinos de las costas adyacentes a Baja California Sur. BSc thesis. Universidad Autónoma de Baja California Sur, La Paz, Mexico.

Fischer W (1995) Guía FAO para la identificación de especies para los fines de la pesca. Pacífico centro-oriental. *Plantas e Invertebrados* 646; *Vertebrados*, Parte 1 & 2, 647–1813.

Flores-Martínez IA (2017) Ecología trófica de los cazones *Rhizoprionodon terraenovae* (Richardson, 1836) y *Sphyrna tiburo* (Linnaeus, 1758) capturados en el litoral de Campeche, México. MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Flores-Martínez IA, Torres-Rojas YE, Galván-Magaña F and Ramos-Miranda J (2017) Diet comparison between silky sharks (*Carcharhinus falciformis*) and scalloped hammerhead sharks (*Sphyrna lewini*) off the south-west coast of Mexico. *Journal of the Marine Biological Association of the United Kingdom* **97**, 337–345.

Galván-Magaña F (1999) Relaciones tróficas interespecíficas de la comunidad de depredadores epipelágicos del Océano Pacífico Oriental. PhD thesis. Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, Mexico.

Galván-Magaña F, Nienhuis HJ and Klimley AP (1989) Seasonal abundance and feeding habits of sharks of the lower Gulf of California, Mexico. *California Fish and Game* **75**, 74–84.

Hansson S, Hobbie JE, Elmgren R, Larsson U, Fry B and Johansson S (1997) The stable nitrogen isotope ratio as a marker of food–web interactions and fish migration. *Ecology* **78**, 2249–2257.

Hsieh TC, Ma HK and Chao A (2016) A quick introduction to iNEXT via examples. Available at http://chao.stat.nthu.edu.tw/blog/software-download/ (accessed 2/28/2017).

Hyslop E (1980) Stomach contents analysis a review of methods and their application. *Journal of Fish Biology* **17**, 411–424.

Krebs CJ (1989) *Niche Ovrlaps and Diet Analysis Ecological Methodology*. Harper and Row: New York, NY.

Langler KF (1956) Freshwater fishery biology, Dubuque, Iowa: Wm. C. Brown. 421.

Lowry MS (2011) Photographic catalog of California marine fish otoliths: prey of California sea lions (*Zalophus californianus*). NOAA Technical Memorandum NMFS. U.S. Department of Commerce, La Jolla.

Márquez-Farías JF, Corro-Espinosa D and Castillo-Géniz JL (2005) Observations on the biology of the Pacific sharpnose shark (*Rhizoprionodon longurio*, Jordan and Gilbert 1882), captured in southern Sinaloa, Mexico. *Journal of Northwest Atlantic Fishery Science* **35**, 107-114.

Mejía Salazar LA (2007) Biología reproductiva del cazón bironche, *Rhizoprionodon longurio* (Jordan & Gilbert, 1882) en el Pacífico Mexicano. MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Osuna-Peralta YR, Voltolina D, Morán-Ángulo RE and Márquez-Farías JF (2014) Stomach contents of the Pacific sharpnose shark, *Rhizoprionodon longurio* (Carcharhiniformes, Carcharhinidae) in the southeastern Gulf of California. *Latin American Journal of Aquatic Research* **42**, 438–444.

Pinkas L, Oliphant MS and Iverson ILK (1971) Food habits of albacore, bluefin tuna and bonito in California waters. *California Fish and Game, Fish Bulletin* **152**, 1-139.

Polo-Silva CJ (2008) Ecología trófica de los tiburones zorro *Alopias pelagicus* Nakamura, 1935 y *Alopias superciliosus* Lowe, 1839 en el Pacifico ecuatoriano. PhD thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

SAGARPA-CONAPESCA-Gobierno del Estado BCS-Secretaría de Pesca BCS-CIBNOR-CICIMAR (2007) Propuesta de Carta Estatal Pesquera y Acuícola del Estado de Baja California Sur. Centro de Investigaciones Biológicas del Noroeste S.C. 282 pp.

Salomón-Aguilar CA, Villavicencio-Garayzar CJ and Reyes-Bonilla H (2009) Zonas y temporadas de reproducción y crianza de tiburones en el Golfo de California: Estrategia para su conservación y manejo pesquero. *Ciencias Marinas* **35**, 369–388.

Serrano B and Soraya E (2016) Análisis de la dieta de la curvina golfina *Cynoscion othonopterus* (Jordán y Gilbert, 1882) en el Alto Golfo de California. MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Torres-Rojas YE (2011) Nicho trófico de pelágicos mayores capturados en la boca del Golfo de California. PhD thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Trejo-Ramírez A (2017) Caracterización de la Bahía de la Paz, Baja California Sur, Mexico, como una posible área de crianza del tiburón bironche, *Rhizoprionodon longurio* (Jordan & Gilbert, 1882). MSc thesis. Centro Interdisciplinario de Ciencias Marinas. Instituto Politécnico Nacional, La Paz, Mexico.

Viana-Morayta JE, Torres-Rojas YE and Camalich-Carpizo J (2020) Diet shifts of *Rhizoprionodon terraenovae* from the southern Gulf of Mexico: possible scenario by temperature changes. *Latin American Journal of Aquatic Research* **48**, 406–420.

Wolff (1982) A beak key for eight eastern tropical Pacific cephalopods species, with relationship between their beak dimension and size. *Fishery Bulletin* **80**, 357–370.

Wolff GA (1984) *Identification and estimation of size from beaks of eighteen species of cephalopods from the Pacific Ocean*. NOAA Technical Report NMFS, USA, no. 17, 50 pp.