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Original Article

Diet composition and feeding habits of the milk shark *Rhizoprionodon acutus* (Rüppell, 1837) in the Gulf of Suez, Red Sea

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Abstract: This study is aimed to provide detailed information on the diet of *Rhizoprionodon acutus* in the Gulf of Suez. The findings suggest the specialized feeding behavior of this species in the Gulf of Suez. A total of 240 Stomachs of *R. acutus* were examined. The number of stomachs that contained prey items was 146 (60.83%), while 94 stomachs were empty (39.16%). Identifiable prey items belonging to 24 species of marine organisms correspond to 13 families of teleost fishes, three families of cephalopods, two families of crustaceans, one of eels, and one of sea urchins. Prey items of little importance included the teleost fishes *Lutjanus bohar* (0.003%) and the sea urchin *Clypeaster humilis*, (0.004%); each was only found in one stomach. Unidentified teleosts comprised the bulk of the observed prey items in terms of frequency of occurrence (63.7%), number (66.67%), weight (53.94%), and relative importance (96.54%). The identified prey items contained pelagic, demersal, reef-associated, and benthic organisms. When grouping food items into their large categories and comparing them in terms of %IRI, teleost fishes were the preferable prey item, with 96.54% unidentified and 1.49% identified, followed by Cephalopods (1.73%), eels (0.16%) and finally, Crustacean (0.09%). The trophic level of *R. acutus* in the Gulf of Suez was estimated to be 4.2, which categorizes it as a tertiary consumer.

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Introduction

Carcharhiniform sharks, in particular the Carcharhinidae, are among the most species-diverse and abundant groups of elasmobranchs within tropical and subtropical neritic waters (Compagno et al., 2005; Last and Stevens, 2009). Carcharhinids form a major component of the targeted commercial catch of elasmobranchs (Henderson et al., 2007; White, 2007; Harry et al., 2011). Sharks, as apex predators, have a crucial role in the composition of marine ecosystems and in managing the dynamics of the prey population. Sharks' dietary forms depend on a variety of accessible food, which is controlled by their body size and the surrounding macrofauna (Ahmed et al., 2022; Costa et al., 2023).

Understanding food habits and feeding behavior allows us to determine the effects of sharks on other organisms through predation and competition. Subsequently, this information can be used in the management of shark fisheries by determining the energy needs of sharks and how changing biological and physical conditions in the marine environment, from both natural processes as well as anthropogenic influences, can affect them (Cortés, 1997; Wetherbee and Cortés, 2004). Furthermore, it provides scientists and resource managers with information on how changes in shark abundance may affect populations of their prey and their competitors (Bethea et al., 2004) or even the role of sharks in predating commercially important species (Cortés, 1999). Finally, understanding the links between predator and prey contributes to a better assessment of the role and function of the components of marine ecosystems and the structure of marine food webs (Ellis, 2003; Bethea et al., 2004; Braccini, 2008). The trophic level of aquatic consumers is a measurable entity that can take any value between 2.0 for herbivorous/detrivorous and 5.0 for piscivorous/carnivorous organisms (Pauly et al., 1998; Pauly and Palomares, 2000).

Studies investigating the diets of various shark

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species have indicated that although they may forage on a relatively similar wide range of prey, the proportions of prey items can vary significantly within conspecifics and inter specifics. Ontogenetic dietary shifts, as well as sexual differences, have been reported from many species that may segregate at different life stages (Wetherbee and Cortés, 2004; White et al., 2004; McElroy et al., 2006; Saïdi et al., 2009). It is assumed that changes in dietary composition accompanying growth reflect sharks' increased ability to consume larger preys such as teleost and cephalopods (Lowe et al., 1996).

Geographical differences in the diet of sharks have also been documented (Joyce et al., 2002; Bethea et al., 2007; Ellis and Musick, 2007; Saïdi et al., 2009), likely due to prey availability and opportunism. Also, elasmobranchs may partition their environment, or the resources within, to reduce the intensity of interspecific or intraspecific competition, facilitating their ability to coexist (Wetherbee and Cortés, 2004; White et al., 2004). For instance, the sandbar shark, *Carcharhinus plumbeus*, varies its diet seasonally, increasing its consumption of crustaceans between fall and winter (McElroy et al., 2006). Based on the background mentioned above, this study aimed to provide detailed information on the diet of *Rhizoprionodon acutus* in the Gulf of Suez.

Materials and Methods

Sampling and data collection: Shark specimens were collected from the commercial trawling, and artisanal fisheries operating in the Gulf of Suez (Fig. 1). The identification of *R. acutus* is done based on Compagno (1984, 2001) and Bonfil and Abdallah (2004). A total of 357 *R. acutus* were collected during this study from the Attaka landing site in Suez City (Long, 32°34'E, Lat, 29°56'N) (Table 1).

Diet analysis: A total of 240 stomachs of *R. acutus* were analyzed. Stomach contents were examined as soon as possible after collection. The excess liquid was drained off, and the remaining mass of the wet prey was determined to the nearest 0.1 g. Contents were washed lightly to remove secretory residues and facilitate identification. Each item was then separated,

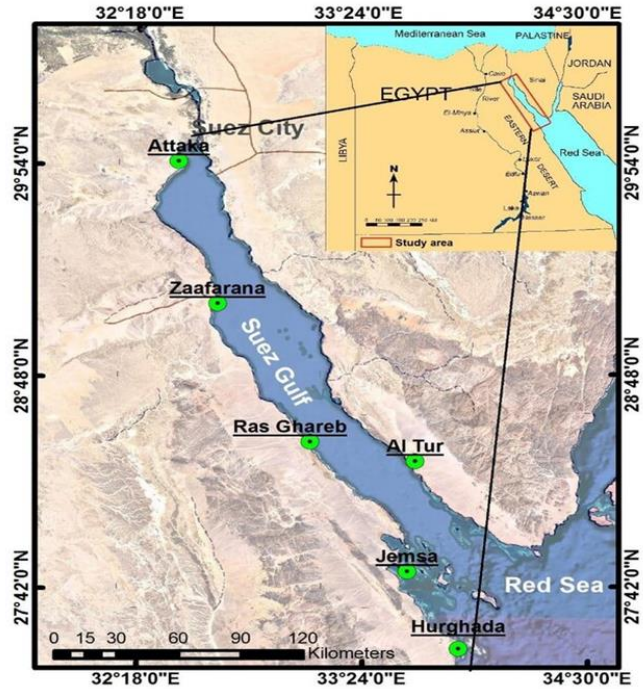

Figure 1. Map showing The Gulf of Suez and sampling site (Attaka fishing harbor).

counted, and identified according to the lowest possible taxon using keys and field guides specific to the region (Randall, 1983; Fischer and Bianchi, 1984). Identification of specimens was only possible when prey items were not fully digested. If identification was not possible, the prey item was included in the category 'unidentified' for that type of prey (e.g., shrimp or teleost). Only stomachs containing prey items were utilized for calculations and analyses. The diet of each species was quantified using three indices (Hyslop, 1980), including:

Percent by frequency of occurrence (%F) = the number of stomachs containing a prey type / the total number of stomachs containing food.

Percent by number (%N) = the number of individuals in each prey type / the total number of prey items in the stomachs.

Percent by weight (%W) = the total weight of each prey type / the total weight of prey items in the stomachs.

Finally, these values were used to calculate the index of relative importance (IRI) to determine the importance of each prey according to Pinkas et al. (1971) using the formula of IRI = %F × (%N + %W).

Table 1. Diet composition of *Rhizoprionodon acutus* in the Gulf of Suez as percentage of prey items by numbers (%N), frequency of occurrence %O), percent weight (%W) and percentage of relative importance (%IRI).

Prey items (Species)	Family	O	N	W	% O	% N	%W	IRI	%IRI
upeneus sulphureus	Mullidae	1	1	28.6	0.68	0.35	0.97	0.91	0.01
parupeneus forskalii	Mullidae	1	1	25.9	0.68	0.35	0.88	0.85	0.01
upeneus vittatus	Mullidae	1	1	10.13	0.68	0.35	0.34	0.48	0.01
Trachurus indicus	Carangidae	5	5	86.2	3.42	1.77	2.93	16.11	0.20
Atule mate	Carangidae	1	1	13.0	0.68	0.35	0.44	0.55	0.01
Carangoides bajad	Carangidae	1	1	114.8	0.68	0.35	3.91	2.92	0.04
Platycephalaus bassensis	Platycephalidae	7	8	116.8	4.79	2.84	3.97	32.65	0.41
Scarus spp.	Scaridae	2	4	22.2	1.37	1.42	0.76	2.98	0.04
Sphyraena chrysotaenia	Sphyraenidae	2	2	159.9	1.37	0.71	5.44	8.42	0.11
Pomadasys stridens	Haemulidae	4	8	59.7	2.74	2.84	2.03	13.34	0.17
Gerres oyena	Gerriedae	3	5	16.0	2.05	1.77	0.54	4.76	0.06
Stephanolepis diaspros	Monacanthidae	3	3	27.6	2.05	1.06	0.94	4.12	0.05
pleuronectes spp.	Pleuronectidae	4	4	43.0	2.74	1.42	1.46	7.89	0.10
saurida undosquamis	Synodontidae	2	2	27.9	1.37	0.71	0.95	2.27	0.03
Engraulis encrasicolus	Engraulidae	7	7	31.4	4.79	2.48	1.07	17.02	0.21
rastrelliger kanagurta	Scombridae	2	2	44.0	1.37	0.71	1.50	3.02	0.04
Lutjanus bohar	Lutjanidae	1	1	0.9	0.68	0.35	0.03	0.26	0.003
Gymnothorax spp.	Muranidae	4	4	91.5	2.74	1.42	3.11	12.41	0.16
Penaeus sp.	Penaeidae	4	4	20.5	2.74	1.42	0.70	5.80	0.07
Portunus spp.	Portunidae	2	2	7.1	1.37	0.71	0.24	1.30	0.02
Octopus spp.	Octopodidae	5	5	72.5	3.42	1.77	2.47	14.52	0.18
Loligo duvauceli	Loliginidae	9	12	201.3	6.16	4.26	6.85	68.45	0.86
Sepia spp.	Sepiidae	10	10	129.8	6.85	3.55	4.42	54.53	0.69
clypeaster subdepressus	Clypeasteridae	1	1	3.3	0.68	0.35	0.11	0.32	0.004
Unide.Teloest		93	188	1586	63.70	66.67	53.94	7682.30	96.54

The IRI values for each prey type were then converted to a percentage (%IRI) to facilitate comparisons between prey items following (Cortés, 1997) using the formula of $\%IRI_i = 100\ IRI_i / \sum IRI_i$. The standardized trophic level of *R. acutus* was calculated using the trophic index (TR) proposed by Cortés (1999):

$$TR = 1 + \sum_{n}^{j=1} Pj \text{ x } TRj$$

Where TR_j is the trophic level of each prey taxa j, and P_j is the proportion of each prey taxa in the diet based on %IRI values. Trophic levels of prey categories from the lowest taxonomic level were taken from Cortés (1999).

Results

Feeding intensity: A total of 240 stomachs of *Rhizoprionodon acutus* ranging from 47.8 to 97.2 cm TL were examined. The number of stomachs that contained prey items was 146 (60.83%), comprising 81 males and 65 females, while 94 stomachs were empty (39.16 %).

Diet analysis: Identifiable prey items in the milk shark stomach belonged to 24 species of marine organisms belonging to 13 families of teleost fishes, three families of cephalopods, two families of crustaceans, one family of eels, and one family of sea urchins (Table 1). The most commonly occurring families were the Engraulidae, Gerreidae, Carangidae, Platycephalidae, Octopodidae, Loliginidae, Sepiidae, Mullidae, Muranidae and Penaeidae. The preferable food items in terms of the %IRI were *Trachurus indicus, Platycephalaus indicus, Sphyraena chrysotaenia, Pomadasys stridens, Pleuronectes* spp., *Engraulis encrasicolus, Gymnothorax* spp., *Octopus* spp., *Loligo duvauceli* and *Sepia* spp. (Fig. 2).

Prey items of little importance included the teleost fishes of *Lutjanus bohar* (0.003%) and the sea urchin *Clypeaster humilis* (0.004%); each was only found in one stomach. Unidentified teleost comprised the bulk of the observed prey items in terms of frequency of occurrence (63.7%), number (66.67%), weight (53.94%), and relative importance (96.54%).

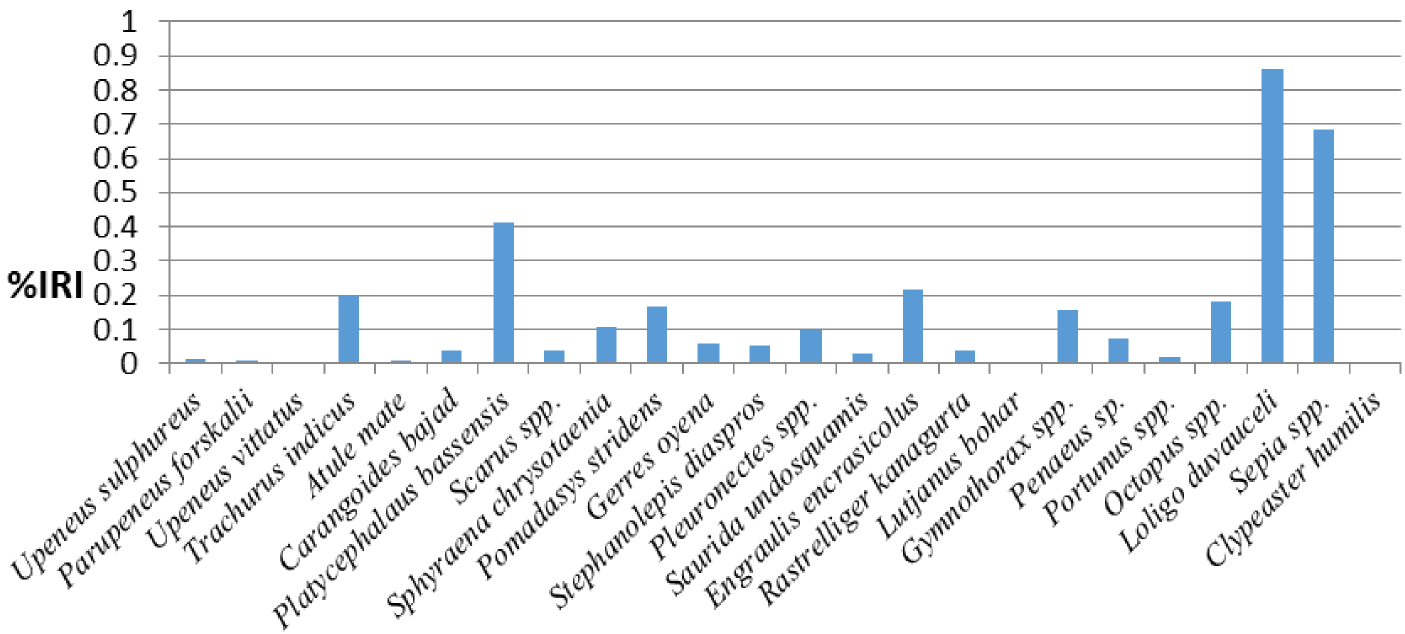

Figure 2. Comparison of the Index of relative importance (%IRI) estimated for Different identified items found in the stomachs of the milk shark *Rhizoprionodon acutus*.

The identified prey items contained pelagic, demersal, reef-associated, and benthic organisms. Pelagic fish included *S. chrysotaenia*, *E. encrasicolus,* and *R. kanagurta*. Demersal fishes included *Stephanolepis diaspros*, *Pleuronectes* spp., *P. indicus, Penaeus* spp., and *Portunus* spp.; Reef-associated species were *Parupeneus forskalii*, *Upeneus vittatus,* and *Atule mate*. Benthic fauna included the sea urchin *C. humilis*.

When grouping food items into large categories and comparing them in terms of %IRI, teleost fishes were the most preferable prey item (96.54 unidentified and 1.49 identified), followed by Cephalopods (1.73), eels (0.16), and finally, Crustacea (0.09). The trophic level of the milk shark *R. acutus* from the Gulf of Suez was estimated to be 4.2, categorizing it as a tertiary consumer.

Discussions

Determining the position of species in the food web is important for understanding their ecological roles and the link between top predators and lower levels (Heithaus et al., 2010). Sharks are tertiary consumers of trophic levels of more than 4 (Cortés, 1999). The trophic level of *R. acutus* estimated in the current study as 4.2, which is similar to that estimated value from the Senegalese waters (Ba et al., 2013) and lower than the estimated value from the Persian Gulf and Oman Sea, which was 2.5 (Rastgoo and Navarro, 2017). The trophic level of *R. acutus* from the Indian waters was estimated to be 4.7 (Borrell et al., 2011). Cortés (1999) also reported a trophic level of 4.1 for *R. acutus*.

The diet of *R. acutus* was dominated by small teleost. However, our results indicated that *R. acutus* fed a variety of fish species but only on limited numbers of crustaceans and cephalopods. A larger number of studies have focused on the dietary preferences of *R. acutus* and have confirmed that this species feeds mainly on teleost (Salini et al., 1990; Ba et al., 2013). This is agreed with the findings of Jabado et al. (2015), who revealed that the most common food items in the stomachs of *R. acutus,* and the slit-eye shark, *Loxodon macrorhinus,* in the Persian Gulf are teleost fish. However, Ahmed et al. (2022) reported that feeding the smoothhound shark, *Mustelus mustelus*, in the Mediterranean Sea depends on crustaceans followed by fish.

The current study showed that *R. acutus* fed mainly on teleost fishes containing demersal and pelagic species. The diet also contains benthic fauna such as the eel *Gymnothorax* spp. and the sea urchin *C. humilis*. *Rhizoprionodon acutus* can have different feeding behaviors depending on the catch location of specimens (Salini et al., 1990, 1992; Stevens and McLoughlin, 1991; Ba et al., 2013). Geographic differences in diets have been documented for many shark species (Simpfendorfer et al., 2001). Comparing results from various studies can be biased since no standardized sampling protocol currently exists, and such undertakings should be regarded with caution (Jabado et al., 2015).

The occurrence of carangids in the stomachs of *R. acutus* in the current and other studies could indicate a preference and selectivity for them (Salini et al., 1990; Stevens and McLoughlin, 1991; White et al., 2004; Ba et al., 2013; Jabado et al., 2015). However, diversity in prey items within shark diets has been reported previously, and these are due to the types of habitats, species composition, and prey availability within the areas frequented by the sharks (Salini et al., 1992; Bethea et al., 2004). There were ontogenetic diet shifts with aging (Shiffman et al., 2014) reported that the young of year Sandbar Shark, *Carcharhinus plumbeus* fed only on small benthic organisms (crustaceans, elasmobranchs, and teleosts) during the first year of life and expanding their diets to include additional pelagic animals) teleosts and invertebrates during the juvenile years.

The proportion of empty stomachs was generally important in shark populations (Wetherbee and Cortés, 2004). The proportion of the studied specimens with empty stomachs in the current study was 39.16%. It was assessed at 59% for *R. taylori* (Simpfendorfer, 1998) and at 82.8, 75.6 and 79.8%, respectively, for *Orectolobus ornatus, O. maculatus* and *O. halei* (Huveneers et al., 2007). It was found to be 34.6% for *M. mustelus* from the Mediterranean Sea (Ahmed et al., 2022). Ozcan and Basusta (2016) found that 97.5% of the stomachs of *M. mustelus* in the northeastern Mediterranean were full. It was 83.97% in the sample for *R. acutus* from Senegalese waters (Ba et al., 2013).

The type of fishing gear appeared to impact the number of empty stomachs. The empty stomachs would increase in sharks caught by baited fishing gear. The sharks will evacuate their stomachs, turning them inside out to try to rid themselves of the hook (Ba et al., 2013). The relatively high percentage of empty stomachs may also reflect short periods of feeding followed by periods of rapid digestion (Joyce et al., 2002). The proportion of specimens with empty stomachs in the current study (39.16%) was lower than previously reported in other studies for *R. acutus* and other shark species (Stevens and McLoughlin, 1991; Ba et al., 2013) and higher than those reported in other studies (Gutteridge et al., 2011: Jabado et al., 2015). The large number of empty stomachs found in a study might be due to the sampling gear that can be selective towards individuals attracted by the bait (Gelsleichter et al., 1990; Cortés, 1997). The relatively high numbers of stomachs with prey items in this study are presumably because most sharks were captured through trawling.

The milk shark is a pelagic and coastal species that feeds mainly on pelagic prey. Some demersal species in the diet showed that *R. acutus* could conduct vertical movements, like most shark species (White et al., 2004; Sims et al., 2008; Nakamura et al., 2011). These vertical movements allow them to meet a wider range of prey species (Simpfendorfer et al., 2001; Preti et al., 2004). In the current work, examination of *R. acutus* stomach contents showed that teleosts were generally the most abundant prey (1.49% identified and 96.54 % unidentified). Ba et al. (2013) plotted a prey-specific abundance against the frequency of occurrence and reported that *R. acutus* was a specialized feeder of teleosts. Therefore, *R. acutus* corresponds to the third case study presented by Amundsen et al. (1996), showing a population specialization toward one single prey type (teleosts). This is the case when most sharks feed on the dominant prey taxon, but small numbers of other prey types are occasionally included in the diet of some individuals.

Among shark species of the genus *Carcharhinus, Sphyrna,* and *Rhizoprionodon*, over 90% of stomachs contained teleosts (Stevens and Mcloughlin, 1991;

Salini et al., 1992; Simpfendorfer, 1998; Gelsleichter et al., 1999; White et al., 2004; Kara et al., 2019). The results of the current study confirm these previous observations on the diet of many shark species. The largest prey families of teleosts in the diet of the milk shark varied in different localities. On Australian shores, there were Hemiramphidae, Mugilidae, Clupeidae, Atherinidae, Sillaginidae, and Labridae (Salini et al., 1992). In the Senegalese waters, predation pressure was higher on Clupeidae, especially on Sardinella, and then on Carangidae, Mugilidae, Mullidae, Muraenidae, Pomadasyidae, Sciaenidae, Sparidae, and Serranidae (Ba et al., 2013).

In the current study, Carangidae, Mullidae, Muraenidae, and Scaridae were the most abundant prey families. Differences in the diet among different geographic regions may have resulted from the types of habitat and prey groups that dominate these regions and the abundance of the different prey types within these habitats (Simpfendorfer, 1992; Lowe et al., 1996). The diet of *R. longurio* was dominated by small teleost fishes, serranids of the genus *Diplectrum*, and crustaceans (Márquez-Farías et al., 2005). Gómez and Bashirulah (1984) reported that crustaceans and fish were the principal food of *Rhizopionodon porosus* in the waters of eastern Venezuela.

In general, fishes tend to be the most important prey of *Rhizoprionodon* spp., followed by crustaceans and / or cephalopods (Stevens and McLoughlin, 1991; Salini et al., 1992; Simpfendorfer, 1998; Gelsleichter et al., 1999; Silva and Almeida, 2001; Hoffmayer and Parsons, 2003; Bethea et al., 2004; Drymon et al., 2011; Bornatowski et al., 2012; Ba et al., 2013).

Conclusion

This study is the first to provide detailed information on the diet of *R. acutus* in the Gulf of Suez. The findings suggest that this species has specialized feeding behavior in this area.

Ethical Statements

This study does not need formal approval, as no live fish were used in an experimental form. Nevertheless, the minimum number of specimens that meet the requirements of the study were collected. The study area is not restricted to fishing activities and is not subject to species protection. The species is designated as ‘vulnerable by IUCN’s Red List of threatened species. We have not violated the directives of the NIOF Committee for Ethical Care of Marine Organisms and Experimental Animals, Egypt (NIOF-IACUC) in any way.

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