

Stomach analysis of the Milk shark, *Rhizoprionodon acutus* (Ruppell, 1837) in the Coastal Waters of the Pakistan, Northern Arabian Sea

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SUMMARY

This study examines the feeding habits of the Milk Shark (*Rhizoprionodon acutus*) along the coast of Pakistan to improve our understanding of its ecological role and to aid conservation efforts. Over the course of one year, researchers collected 81 non-empty stomachs from 173 specimens (68 females and 13 males). The stomach contents were categorized into teleosts, crustaceans, and cephalopods, and analyzed using the Frequency of Occurrence method. The results showed that teleosts made up 77.6% of the diet, with a significant presence of fish from the Carangidae and Clupeidae families. Crustaceans constituted 14.14% of the diet, predominantly comprising shrimp (*Parapenaeopsis styliфера*), while cephalopods accounted for 8.26%, mostly consisting of squid. Feeding activity was highest from June to December, with teleosts dominating the diet in autumn, spring, and summer, while crustaceans were more common in winter. Interestingly, females displayed a more diverse diet compared to males. This study confirms that *R. acutus* primarily functions as a piscivore, with dietary variation influenced by local prey availability, seasonal changes, and gender differences. These findings highlight its important role in the marine ecosystem and will inform fisheries management strategies.

Keyword: Stomach analysis, Pakistan coast, Teleosts dominance, Shark

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INTRODUCTION

Sharks are the main leading predators of the marine environment and play a significant role in transferring energy between the top trophic levels of the marine ecosystem (Wetherbee et al., 1990). Limited studies on the feeding habits and role in the ecosystem of sharks have been conducted. Few studies on the food found in shark stomachs have been completed (Baughman and Springer 1950; Clark and von Schmidt 1965; Randall 1967; Dahlberg and Heard 1969). Information on the feeding habits of a number of elasmobranchs is insufficient to adequately analyze the trophic levels of many species (Borrell et al., 2011) or even how sharks prey on species that are commercially significant (Cortés 1999).

A highly diverse and prevalent group of elasmobranchs in tropical and subtropical neritic waters is carcharhiniform sharks, particularly the Carcharhinidae (Compagno et al., 2005; Last and Stevens, 2009). A large portion of the focused commercial harvesting of elasmobranchs is made up of carcharhinids (White, 2004;

Henderson et al., 2007; Harry et al., 2011). Sharks, being apex predators, are essential for regulating prey population dynamics and preserving marine ecosystems. Sharks depend on various easily accessible food sources, influenced by their body size and the macrofauna present in their surroundings (Ahmed et al., 2022; Costa et al., 2023). Identifying the energy needs of sharks and understanding how changes in biological and physical conditions in marine settings—due to natural phenomena and human activities—affect them can be used to regulate shark fisheries (Cortés, 1987; Wetherbee and Cortés, 2004).

Lastly, understanding the interactions between predators and prey enhances our evaluation of the roles and functions of marine ecosystem components (Ellis, 2003; Bethea et al., 2004) and the composition of marine food webs (Braccini, 2008). Research on the diets of various shark species has shown that, while they may consume a wide range of prey that is essentially similar, the quantity of prey items can vary significantly both between and within species. Many species that segregate at different life stages have been observed to exhibit ontogenetic nutritional changes (Wetherbee and Cortés, 2004; White et al., 2004) and sexual differences (McElroy et al., 2006; Saïdi et al., 2009), likely due to opportunism and the availability of prey. Habitat can also play a crucial role in determining the type of prey found in shark stomachs (Cortés, 1987). Most sharks are regarded as opportunistic feeders, and their stomach contents reflect the fauna present in their environment (Budker, 1971).

R. acutus occurs throughout the water column, but mainly near the bottom, over continental and insular shelves from the intertidal to at least 200 m depth (Compagno, 1984; Simpfendorfer, 2003; see in Figure 1). Very few comprehensive detailed studies have been conducted on the diet consumption of *R. acutus*. The digestion process is also poorly studied. Moazzam and Osmany (2022) provide a summary of the diet composition of *R. acutus*, but no comprehensive study on a monthly basis has been conducted on this species yet in Pakistan. Given the foregoing context, the purpose of this study is to present comprehensive data on the nutrition of *R. acutus* in the northern Arabian Sea along the coast of Pakistan.

The purpose of this study is to determine the feeding patterns of the most common shark species that emerge at Karachi Fish Harbor and their function in maintaining balance in marine ecosystems by managing prey populations and affecting the condition of other habitats inside Pakistan's Exclusive Economic Zone. The "feeding habits" of sharks are essential to both their survival and the establishment of their conservation.

METHODOLOGY

Most of the sharks that reached Karachi or Gwadar were sent to a shark yard in Fish Harbor for processing, where their heads, fins, and internal organs were taken out. From August 2016 to July 2017, 81 milk shark stomachs, measuring between 67 and 101 cm, were collected from the yard and delivered to the Biological Laboratory of the Marine Fisheries Department for stomach examinations, where they were dissected with pointed scissors. All substances were moved into petri dishes. Food items were sorted into three categories: teleosts, crustaceans, and cephalopods, once they were identified at the group level. Selected images of the stomach contents were

captured with the date indicated on them. The food items were identified using the most specific taxon available.

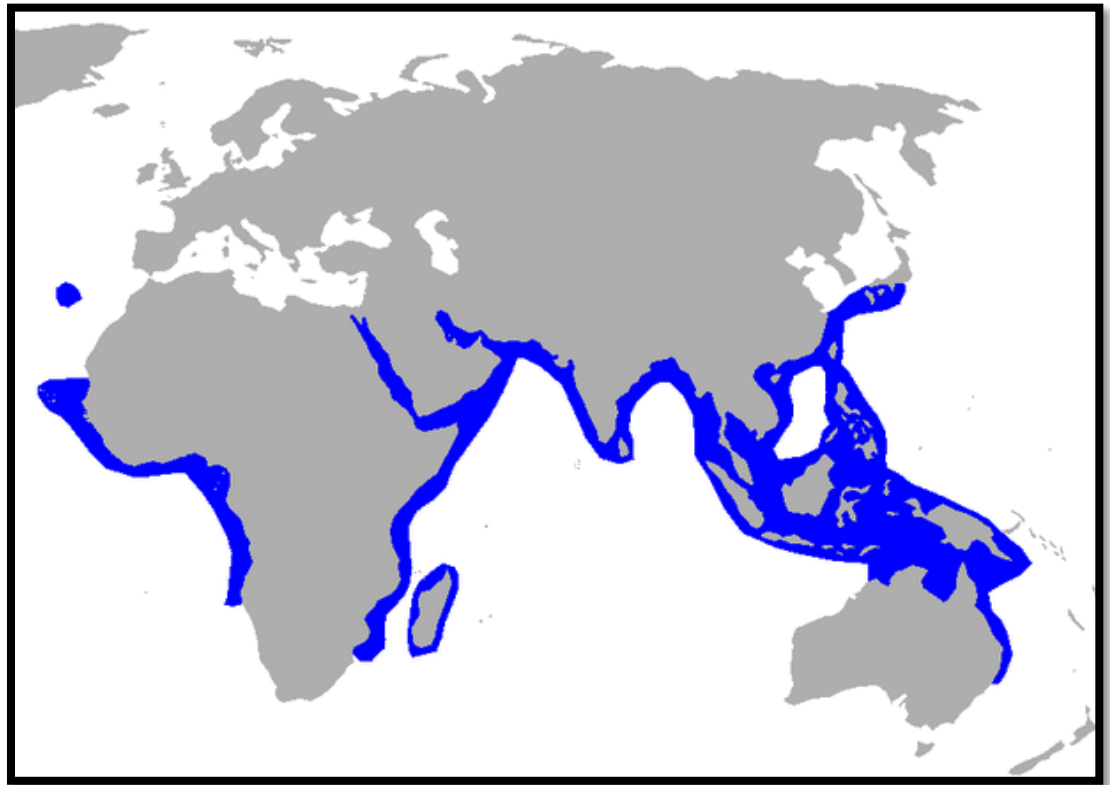


Figure 1: Distribution map of Milk shark (*R. acutus*).



Figure 2: Body and Jaw of Milk shark *R. acutus*.

RESULT

Out of 173 stomachs of Milk shark (Figure 2), 81, including 68 female and 13 male, were found to be on a diet, while the remaining 92 empty stomachs were empty. All food items were summarized in three groups: teleosts, crustaceans, and cephalopods. The combined percentage of food items found in the stomachs of *R. acutus* was dominated by teleosts, which also dominated in both females and males (Figure 3).

The combined dominance of carangids and clupeids in teleosts was observed (Figure 4), which is also seen in females (Figure 5), but only two species were found in males (Figure 6). In the combined percentage, shrimp dominated over squilla (Figure 7). In cephalopods, squid slightly dominated over octopus (Figure 8). Most of the dominant food items were found from June to December, while empty stomachs were observed from February to April (Figure 9). A similar pattern was observed in females (Figure 10), but in males, the diet was found only in June, October, and November (Figure 11). Teleosts dominated in three seasons: autumn, spring, and summer, while winter was dominated by crustaceans (Figure 12).

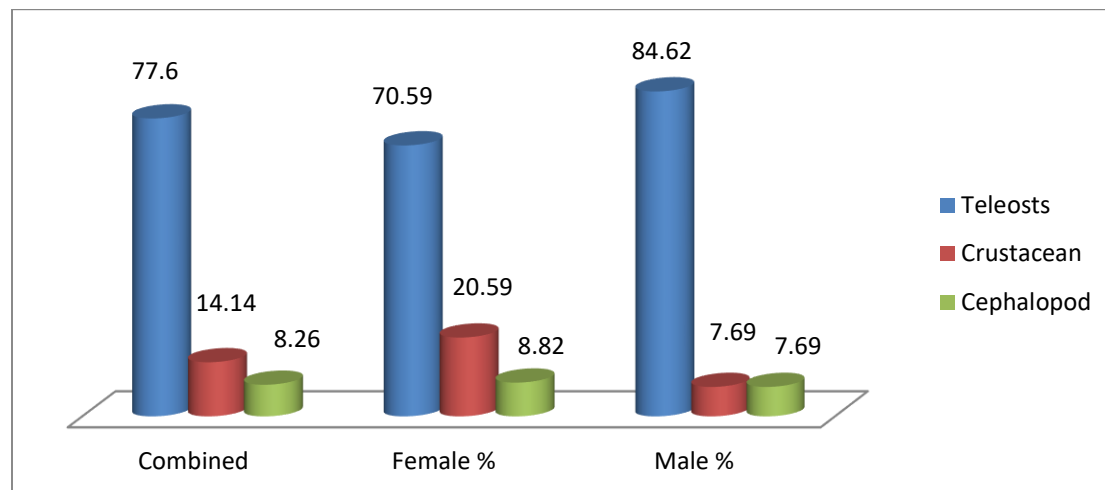


Figure 3: Percentage of food item on group level in *R. acutus*.

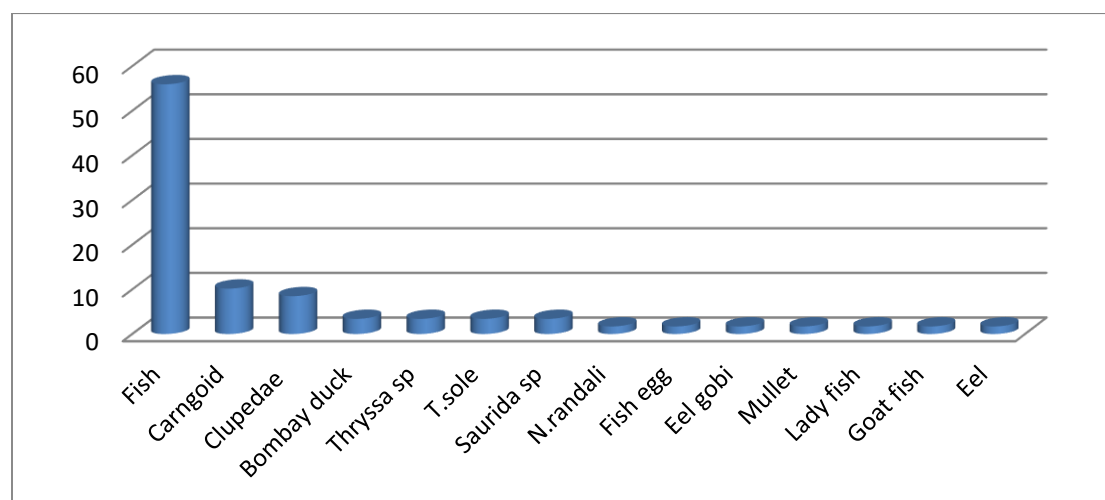


Figure 4: Combined percentage of teleosts in *R. acutus*

TELEOSTS

This food item was dominant throughout the year in the stomach of *R. acutus*. The overall teleost (fish) rate was 77.60%; the female rate was 70.59%, while the male rate was 84.61% (Figure 3). Fishes belonging to 10 families, including Clupeidae (*Sardinella gibbosa* and other sardines), Carangidae (*Decapterus russelli*, *Megalaspis cordyla*, and others), Synodontidae (*Harpadon nehereus* and lizard fish), Engraulidae,

Cynoglossidae, Nemipteridae, Gobiidae, Mugilidae, Silaginidae, and Molidae, were found in the stomach (Figure 4). A similar pattern was found in females, where 9 families—Clupeidae (*Sardinella gibbosa* and other sardines), Carangidae (*Decapterus russelli*, *Megalaspis cordyla*, and others), Synodontidae (*Harpadon nehereus* and lizard fish), Engraulidae, Cynoglossidae, Nemipteridae, Gobiidae, Mugilidae, and Silaginidae—were found in the stomach, with Carangids and Clupeids dominating (Figure 5). In males, only 2 families of fish, Synodontidae and Molidae, were found (Figure 6). Teleosts dominated from June to November (Figure 9). The dominance of teleosts was observed from August to November in females (Figure 10), whereas June was the dominant month for teleosts in males (Figure 11). A variety of fish were found in females throughout the study period (Figure 5), while a limited number of fish items were found in males, consisting only of two identifiable species, including *Saurida* spp. and goatfish (Figure 6).

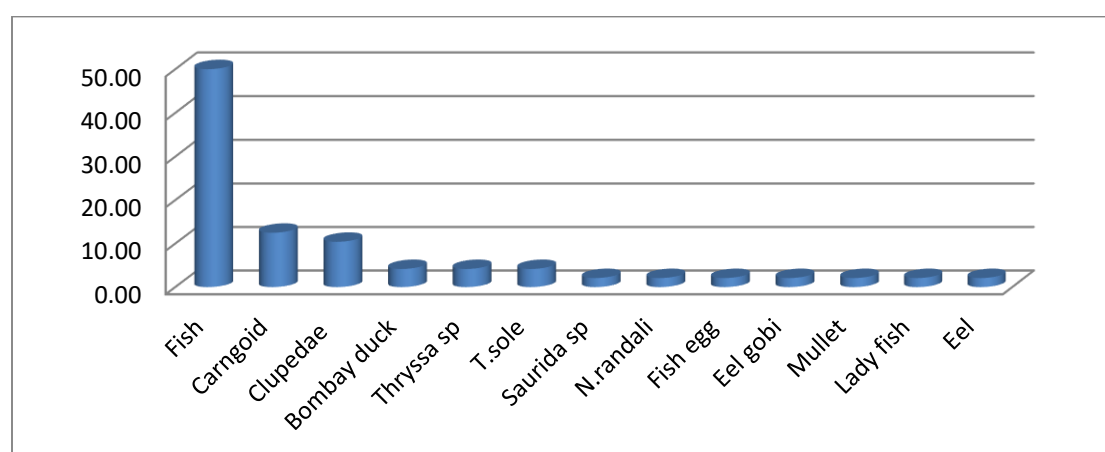


Figure 5: Percentage of teleosts in female of *R. acutus*.

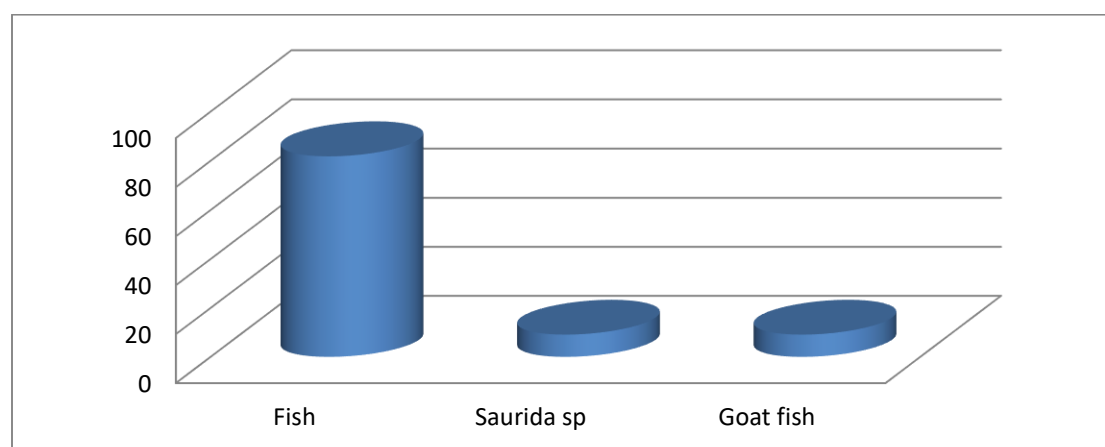


Figure 6: Percentage of teleosts in male of *R. acutus*.

CRUSTACEAN

This second dominating group's combined percentage was 14.14% of the total diet, including female 20.59% and male 7.69% (Figure 3). Separately, shrimp were 86.66% with squilla at 13.53%. *Parapenaeopsis stylifera* (Kiddi) dominated along

with other species of *Metapenaeopsis* shrimp. Shrimp also dominated in females, which accounted for 86.66%, while squilla was 6.66%. Males contributed 6.66%, consisting of squilla. December showed a high rate of crustaceans (Figure 7), a similar pattern observed in females where crustaceans dominated in December (Figure 10). No shrimp were found in males, except for one squilla found in the stomach in June (Figure 11).

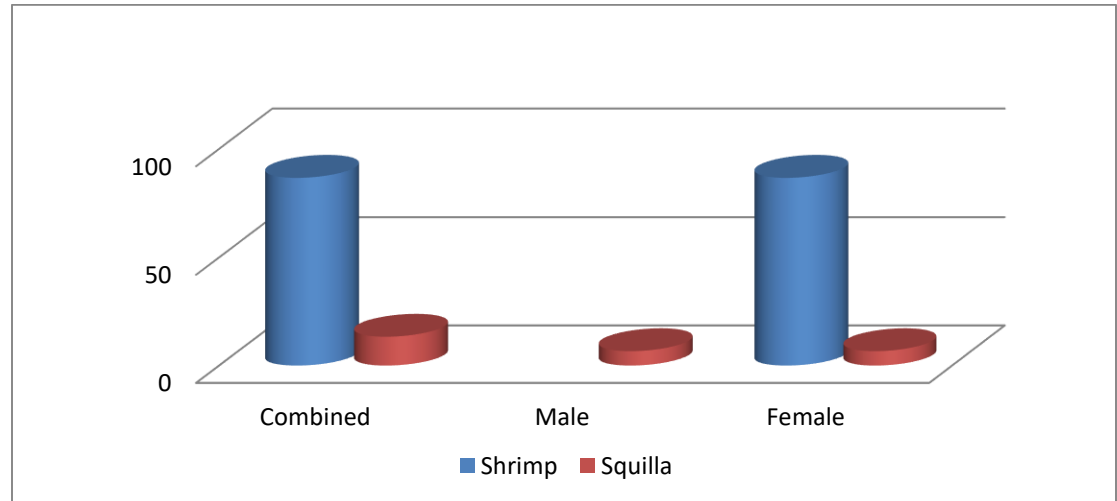


Figure 7: Percentage of crustacean in *R. acutus*.

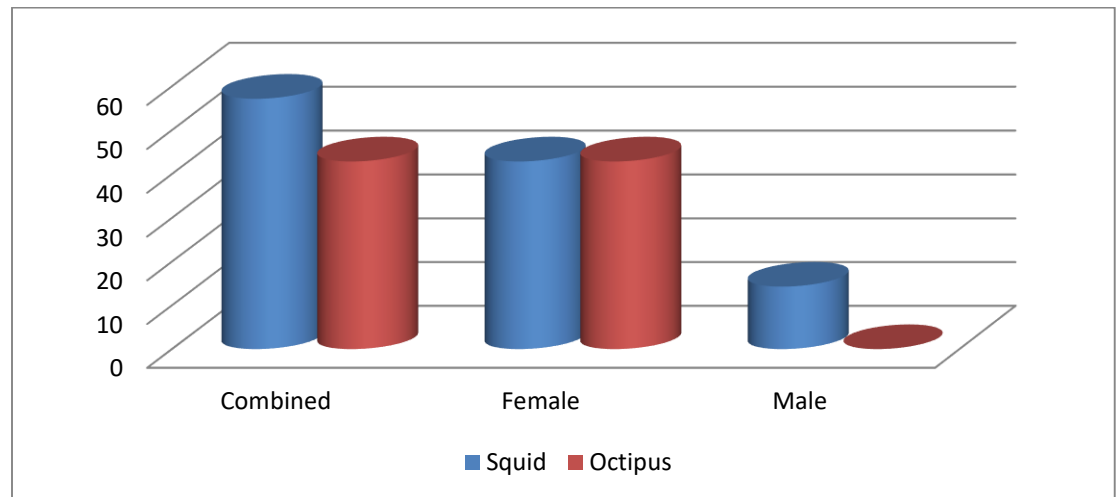


Figure 8: Percentage of cephalopod in *R. acutus*.

CEPHALOPOD

The third dominant group's combined percentage of cephalopods was 8.26% of the total diet in *R. acutus*; including females, it was 8.82%, whereas in males, it was 7.69% (Figure 3). Squid (*Loligo duvauceli*) dominated with 57.14%, followed by octopus at 42.86%. In females, the percentage of squid (42.85%) and octopus (42.85%) was the same (Figure 8), but in males, squid was found only once at 14% (Figure 8). The most dominant month overall was June (Figure 9), while for females,

it was June and November (Figure 10). For males, the most dominant month was June (Figure 11).

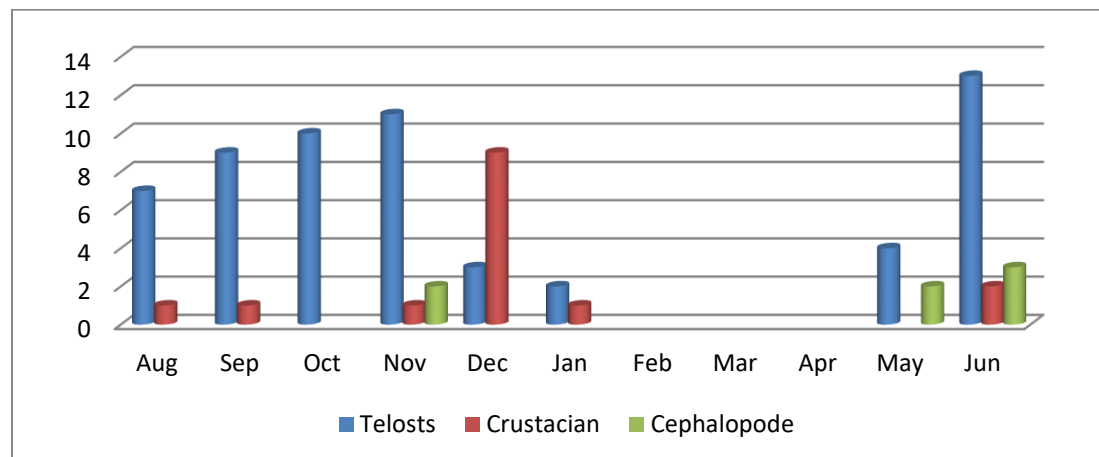


Figure 9: Combined monthly diet composition in *R. acutus*.

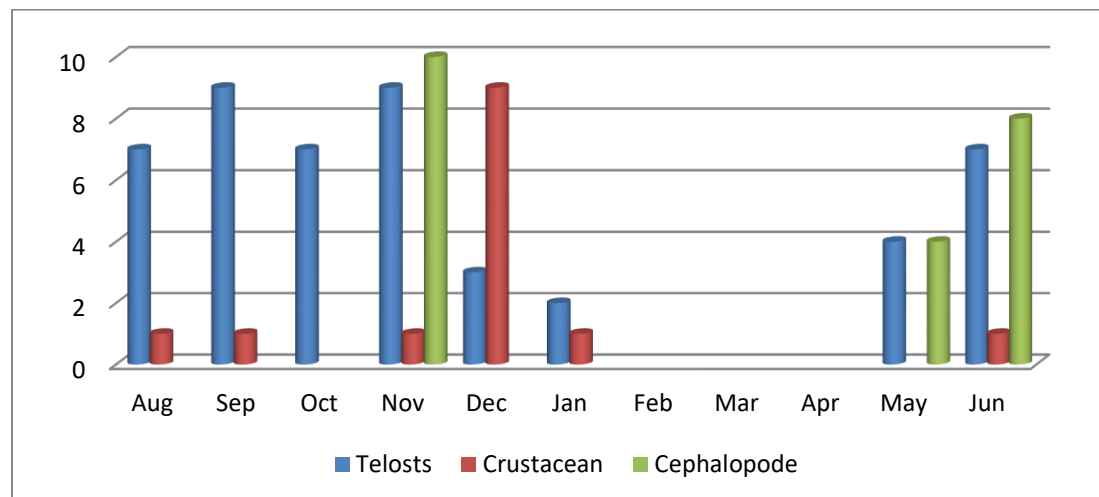


Figure 10: Monthly diet composition in female of *R. acutus*.

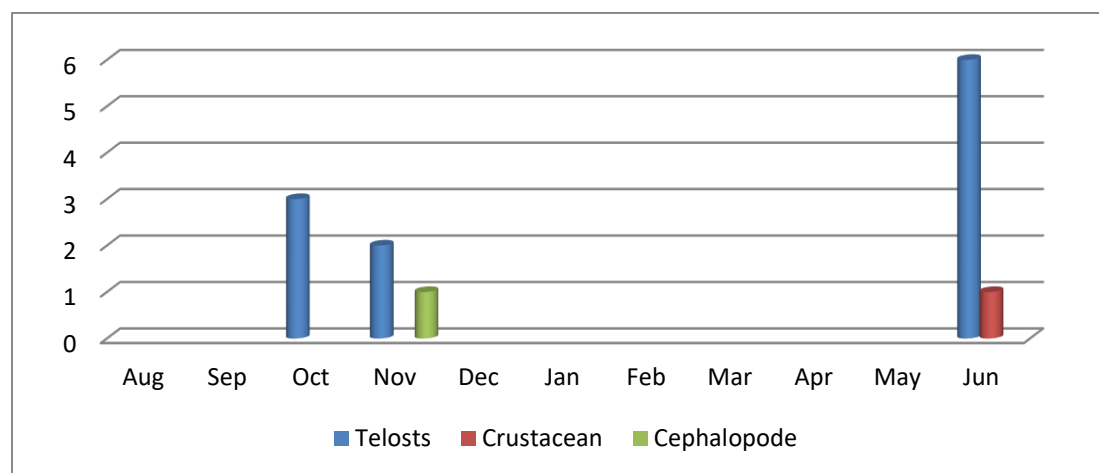


Figure 11: Monthly diet composition in male of *R. acutus*.

DIET COMPOSITION OF FOUR SEASONS

A combined diet composition of both sexes across the four seasons was analyzed (Figure 12). In autumn, teleosts were dominant at 37.5%, with crustaceans and cephalopods at 2.5% each. In winter, crustaceans dominated at 12.5%, with teleosts at 6.25%. In spring, the dominant food item was teleosts at 5.0%, with cephalopods at 2.5%. In summer, teleosts were dominant at 25%, with cephalopods at 3.5% and crustaceans at 2.5%. (Figure 13).



Figure 12: Selected pictures of various food item of one year study of *R. acutus*.

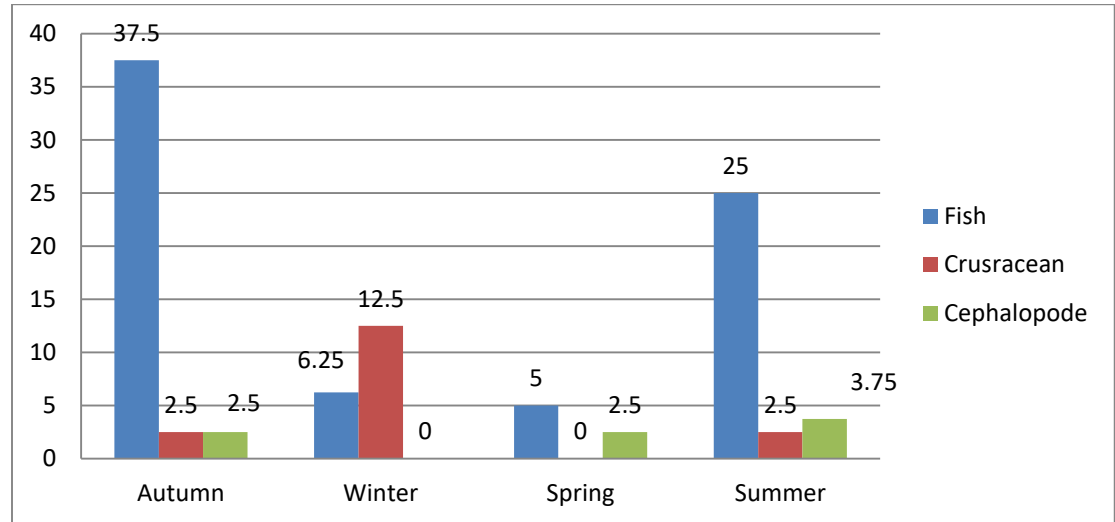


Figure 13: Percentage of diet composition in four seasons of *R. acutus*.

DISCUSSION

All living things require energy to function, and this energy comes from the food that is available in their environment. A shark's gut is well-suited for a high-protein diet in the presence of digestive enzymes like pepsin, trypsin, and lipase. Sharks are carnivores that need at least 45% protein in their diet to survive. Species at the attained nutrient stage require more energy for gonad formation and the egg gestation period, which leads to a shift in food composition (Fishelson, 1987). Understanding shark feeding behaviors is essential for managing fisheries, guiding conservation initiatives, and comprehending the role sharks play in marine ecosystems. By knowing what sharks consume, how frequently they eat, and where they feed, scientists can better model predator-prey relationships, evaluate how feeding affects commercially valuable prey, and ultimately safeguard these crucial apex predators. Studying feeding habits provides vital basic information on the local shark population, which helps to understand the trophodynamics of the species in light of overfishing and climate change (Sen et al., 2018). Sharks are considered to eat everything that comes in their path (Devadoss, 1989). Understanding a species' ecological roles and the relationship between top predators and lower levels requires knowing where it is in the food chain (Heithaus et al., 2010). According to Cortés (1999), sharks are tertiary consumers of organisms with trophic levels greater than four.

According to researchers (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) *Rhizoprionodon* spp. primarily prey on fish, followed by crustaceans and cephalopods. Electroreception, facilitated by the Lorenzini ampullae, enables all sharks, including *R. acutus*, to detect their prey. This organ can even sense the faint electric fields generated by buried rays (Shiftman, 2022). *Rhizoprionodon* spp. are found in coastal tropical waters, ranging from the Indian Ocean to the Indo-Pacific regions, including the Philippines, Japan, and Australia, as well as the Eastern Atlantic near West Africa. Similar to other shark species, the variety of food found in

their stomachs (Simpfendorfer et al., 2001; Preti et al., 2004) indicates their vertical movement from top to bottom in the water column (White et al., 2004; Sims et al., 2008; Nakamura et al., 2011).

Work on *R. acutus* feeding habits is being done in a few locations across the world, which revealed that the species' food consists of small, bony fish, crustaceans, and cephalopods (Bass et al., 1975). The species consumes invertebrates, cephalopods, and bony fish (Compagno, 1984). In research on the Indian coast, species of the Gerreidae (silver bellies) family predominated, along with crustaceans and cephalopods (Appukuttan and Nair, 1988). Small milk sharks in the Gulf of Carpentaria, Australia, eat crustaceans and cephalopods; as they get bigger, they switch to penaeid shrimp, herring mullets, and half-beaks (Salini et al., 1990). In Timor and Northern Australia, fish accounted for 93.3% of *R. acutus*'s diet (Stevens and McLoughlin, 1991). The bulk of teleosts, including Atherinidae, Carangidae, Clupeidae, Labridae, Silagonidae, Mugilidae, Mullidae, Pomadasyidae, Sciaenidae, Sparidae, and Serranidae, are part of the diet of *R. acutus*. In Australia, the abundance of various species in a given area indicates the type of dominant species present in that region (Simpfendorfer, 1992; Lowe et al., 1996). Consequently, *R. acutus* demonstrates a population specialization toward a single prey species (teleosts), which is consistent with the third case study reported by Amundsen et al. (1996). White et al. (2004) described a considerable amount of clupeids found in the stomachs of sharks in Shark Bay, Australia, and their feeding on *Psammoperca waigensis*.

Ba et al. (2013) studied the Senegal coast and described that the diet of *R. acutus* was composed of teleosts, crustaceans, mollusks, nematodes, annelids, and unknown invertebrates. This indicates a species preference for teleosts, which was 98.75%. By plotting prey-specific abundance versus occurrence frequency, they found that *R. acutus* was a specialized teleost feeder. According to Jabado et al. (2015), *R. acutus* consumed a wide range of teleost species, with the Engraulidae (anchovies) accounting for 28%, Gerreidae (mojarra) for 5.6%, and Carangidae (jacks) for 1.6% in the United Arab Emirates. It also occasionally consumed crustaceans and cephalopods (8%). During a study conducted in Gujarat, India, Sen et al. (2018) noted that favored food items were carangids, engraulids, and clupeids of *R. acutus*. According to Baje et al. (2022), *R. acutus* mostly preys on teleosts in the Gulf of Papua. Mohammadi et al. (2023) analyzed teleosts at 47.44%, crustaceans at 33.33%, and cephalopods at 6.41% in the Persian Gulf. According to a study by Shaaban et al. (2024) on the stomach contents of *R. acutus* in the Red Sea, teleosts were frequently the most common prey (1.49% identified and 96.54% unidentified).

Male and female sharks, including *R. acutus*, have been seen to exhibit distinct eating behaviors in a variety of situations (Klimley, 1987; Stillwell and Kohler, 1993; Simpfendorfer et al., 2001; McCord and Campana, 2003; Ellis and Musick, 2007; Ba et al., 2013). The size of the stomachs of the sexes or different eating regimens could be the cause of this discrepancy (Klimley, 1987; McCord and Campana, 2003; Capape et al., 2006). In order to escape predators, different diets also rely on habitat, sex, juvenile status, and adult status (Stillwell and Kohler, 1982; Cortes and Gruber, 1990; Lowe et al., 1996). Many places have various diets that vary according to the local prey (Stillwell and Kohler, 1982). Many studies have

described the composition of diets in various locations (Simpfendorfer, 1992; Lowe et al., 1996; Ba, 2013). Depending on the region, different teleost prey families were consumed by milk sharks. The Australian coast is home to the Hemiramphidae, Mugilidae, Clupeidae, Atherinidae, Sillaginidae, and Labridae families (Salini et al., 1992). Geographical differences in diet composition have been noted in numerous studies (Salini et al., 1990, 1992; Stevense and McLoughlin, 1991; Simpfendorfer et al., 2001; Ba et al., 2013). The large diversity of foods in various locations suggests that *R. acutus* is an opportunistic feeder. The structure of teeth is essential for generating biting force. In this species, the teeth on the upper and lower jaws are similar in shape; they are oblique triangles and become serrated in adulthood. Males sometimes have cusps that are more erect, which allows them to feed on soft-tissue organisms like fish, cephalopods, and shrimp. Typically, there are 11 to 13 teeth in the upper and lower jaws, with one tooth positioned in the middle. This arrangement provides a strong grip on prey, enabling them to crush larger prey into pieces while swallowing smaller prey whole (Figure 2).

A one-year study of *R. acutus* reveals that the species is a carnivore, with a combined stomach diet of 78.60% teleosts, 14.14% crustaceans, and 8.26% cephalopods. The species' coastal benthic environment is indicated by the predominance of carangids and clupeids in the diet. In contrast to poor swimmers like mullet, bombay duck, ladyfish, and tongue sole, which are sometimes found in the stomach, adult *R. acutus* follow faster swimmers like carangids and sardines. Teleosts were the most common dietary item, with a small number of crustaceans and mollusks observed in the stomach during this study. According to the current study's results, which are consistent with those seen globally, the most dominant item was teleosts, ranging between 67.4% to 77.24%. However, the current investigation will provide crucial fundamental data regarding *R. acutus*'s feeding habits.

Off the western and southern coasts of Africa, mating and parturition occur in the spring or early summer, specifically from April to July (Cadenat and Blache 1981; Capapé 2006; Valadou 2006). In contrast, off the coast of India, these events take place during the winter (Compagno 1984). In Oman, parturition is observed year-round, with a peak in the spring (Henderson 2006). Numerous studies conducted during this period indicate that the stomachs of the subjects were completely empty from February to April. This emptiness may correlate with mating and childbirth activities. Consequently, the pups commonly found during stomach examinations in February and March may be attributed to the empty stomachs observed during this phase.

CONCLUSION

A study of the feeding habits of *R. acutus* conducted in various parts of the world confirms that the preferred food item for this species is teleosts, followed by crustaceans and mollusks in smaller quantities. This finding is also supported by the current study conducted from August 2016 to July 2017 along the Pakistan coast in the Northern Arabian Sea.

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