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Insights into the Food and Feeding Habits of the Indian Mackerel *(Rastrelliger kanagurta)* from the Coast of Goa

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The Indian Mackerel is a commercially important fish species and India contributes to world's 90% of mackerel production. The present study deals with gut content analysis of the Indian Mackerel *Rastrelliger kanagurta* to determine the type of feed and the feeding habitat. The gonado-somatic index and gastro-somatic indices were determined to find out the spawning period and maturity of the fishes. The stomach emptiness was also calculated to estimate the fish appetite from the stomach content. The present study indicated that Diatoms formed the predominant planktonic feed followed by Dinoflagellates. A total of 25 different types of planktons were found to be preferred by *Rastrelliger kanagurta*. The gut content also revealed sand particles, fish scales and cnidarian

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spicules. Highest mean GSI and lowest GaSI were observed in the month of April. The stomach emptiness index revealed gluttonous feeding from November to March and comparatively gluttonous feeding in the month of April. From the present study it can be concluded that *Rastrelliger kanagurta*, though shows preference for diatoms (40.74%) and dinoflagellates (22.22%), the dietary preference is not limited to it, but they also exhibited preference for Crustaceans (except copepods) (14.81%), Cyanobacteria (7.40%), Copepods (7.40%), molluscs (3.70%) and Protists (3.70%). The present study analysed the food constituents and feeding habitat of the Indian mackerel through gut content analysis. The intensity of feeding was also compared to the size of the fishes, reproductive maturity and the spawning time.

Keywords: Rastrelliger kanagurta; feeding intensity; gastro-somatic index; gonado-somatic index.

1. INTRODUCTION

The Indian mackerel, *Rastrelliger kanagurta* is one of the major marine fishery resources of India with fish landing contribution of 2.13 lakh tonnes (7.0% of the national total) in 2021 [1]. The state of Goa, has a 104-kilometer coastline and is a productive zone for the mackerel fishery [2]. The Indian mackerel is a major source of income to the fisherman of Goa [3]. Investigation on food and feeding habits of fishes prove to be of great importance in the fisheries sector in providing information on the distribution patterns, shoaling habits and feeding grounds of the fish under study [4,5].

The Indian mackerel *Rastrelliger kanagurta* is a pelagic, marine water scromboid fish commonly found in the Indo -West Pacific regions. It is reported to be a planktonivore or omnivore with varied diet composition, such as diatoms, dinoflagellates, copepods, crustaceans, molluscan larva, benthic algae and also occasionally on other fish [6-8]. Diet analysis of the fish is important to study their biological aspects to acquire the data sets necessary for future fishery resource management. The data derived can help in better understanding of the species habitat, feeding habits, its migratory period and spawning and predator-prey relationships [9,10]. Knowledge about the fish feed has its applications in Aquaculture, to provide different live food at the different life stages of the fish [11].

A review of the previous studies revealed that there is no recent information on the feeding habits of Indian mackerel from Goa. Since the feeding habit is a reflection on the overall growth of *Rastrelliger kanagurta,* the present study was undertaken to analyse the food constituents and feeding habitat of the fish through gut content analysis and to analyse the intensity of feeding compared to the size of the fishes, reproductive maturity and the spawning time. Since the outcome of such studies will give an insight into the behavioural as well as physiological aspects of the Indian mackerel, the results can play an important role in sustainable management of fisheries resources.

2. MATERIALS AND METHODOLOGY

In order to achieve the objectives of the study, a specific site was chosen and standard procedures were adopted to attain the goals.

2.1 Study Site

The site selected for the study was Benaulim beach, located in south Goa ($15^0$14’45.1"N, $73^0$55’41.1"E). A total of 25 fresh samples of the Indian mackerel, *Rastrelliger kanagurta* were procured each month from the fish landing site at the Benaulim beach, from November 2021 to April 2022. However, covid pandemic interrupted the study and no data could be procured in the months of January and February 2022.

2.2 Sampling

The study included analysis of 100 individuals collected randomly from the fish landing site in Benaulim, Goa. The sample included 40 females and 60 male specimens. The standard procedure given by Mahesh et al. [12] was followed to record the sex of the individual fishes.

The fish length (TL) of each specimen was measured with the accuracy of 0.5 cm and the total body weight and the stomach and gonad weights of the sample fishes were measured with the accuracy of 0.001g through the use of precision balance.

2.3 Parameters Analysed

The study of the feeding habits of fish based on the direct examination of stomach content is used as a standard practice for many years [13].

The parameters analysed for evaluating the food and feeding habits of *Rastrelliger kanagurta* are as follows:

2.3.1 Feeding intensity

The feeding intensity was studied by degree of fullness of stomach and the stomach emptiness index was calculated.

The stomach emptiness index was used to estimate the fish appetite and the feeding intensity. The feeding intensity was assessed based on distension of the stomach contents classified as full, ¾ full, ½ full, ¼ full and empty [14]. The judging of the distension of the stomach content and classification based on fullness was done by eye estimation [12].

The stomachs were analysed for stomach emptiness index which was calculated as:

SEI % =

$$\frac{Number\ of\ stomachs\ with\ same\ degree\ of\ fullness}{Total\ evaluated\ stomachs}\ X\ 100$$

2.3.2 Gut content analysis

For this analysis, a longitudinal cut was made across the stomach and then sever the stomach (or foregut) from the hindgut to avoid the bias when both easily digested prey & resistant prey are present. For Fishes which did not have a distinct stomach, the first half of the intestine was dissected and the contents were transferred into a petri dish and preserved in 5% formalin for qualitative analysis. The different organisms were identified up to the generic level by identifying the large prey on eye observation and examination of small prey under binocular microscope [12].

2.3.3 Spawning period and feeding patterns

The Gonado-Somatic Index and Gastro-Somatic Index was determined to find out the relation between the spawning period and feeding patterns in the fish.

(a) The Gonado-Somatic Index is a percentage weight of the gonad to the body of the fish which is used to indicate the gonadal state and analyse the maturity index of the fish. The GSI differs among different species of fishes and along with fecundity, it helps in determining the productivity and population dynamics [14].

The Gonado-Somatic Index was calculated as:

Gonado-Somatic Index (GSI)

$$= \frac{Weight\ of\ Gonads}{Weight\ of\ Fish\ body}\ X\ 100$$

(b) The Gastro-Somatic Index is the relationship between weight of fish and the weight of the alimentary canal. It helps in determining the variations in intensity of feeding in different seasons and months.

The Gastro-somatic index was calculated as:

Gastro-somatic index (GaSI)

$$= \frac{Weight\ of\ Gut}{Weight\ of\ Body}\ X100$$

2.3.4 Data analysis

The data obtained was analysed by the Frequency of occurrence method that recorded the presence of a certain plankton species across all the individual to reveal the relative dominance of different plankton and judge the dietary composition of the fish population [12]. The food constituents were estimated from the proportion of total guts containing each food item.

3. RESULTS AND DISCUSSION

The Indian Mackerel, *Rastrelliger kanagurta* is known to be a filter feeder. In the present study, the food and feeding habits of *Rastrelliger kanagurta* were studied to get an insight into its food preference and feeding behaviour. The following parameters were analysed to conclude the same:

3.1 Feeding Intensity

Feeding intensity study enables understanding the fish's maturity and the spawning conditions. This was analysed by studying the Stomach fullness and Stomach Emptiness Index.

The feeding intensity of *Rastrelliger kanagurta* was the lowest in the month of April and the Stomach Emptiness Index was the highest. Presence of empty and one-fourth filled stomach, along with high Stomach Emptiness Index in the

month of April suggested the onset of spawning period of the Indian Mackerel (Fig. 1). Hulkoti et al. [16] and Bhendarkar et al. (2014) also recorded the lowest feeding intensity of *Rastrelliger kanagurta* in April -July, stating onset of spawning season and less availability of food as the possible reasons.

The stomach emptiness index was used to estimate the fish appetite and the feeding intensity. From the results, it can be concluded that the fishes analysed in the month of November, December, March were gluttonous while the fishes analysed in the month of April were comparatively gluttonous (Fig. 1). In agreement with the results of the current study [17] reported, the maximum number of empty stomachs before the onset of the spawning season. The results may be expounded due to the abdominal cavity being entirely occupied by ripe gonads, hence reduced feeding during the spawning season [18]. Studies conducted by Moazzam et al. [19] and Sivadas and Bhaskaran, [7] reported a similar pattern in the spawning and feeding activity of *R. kanagurta*.

3.2 Gut Content Analysis

The gut contents of *Rastrelliger kanagurta* were analysed to determine the food preference. A total of 25 different planktons were reported during the study period. Due to rise in covid-19 cases, data could not be procured in the month of January and February 2022. Occasionally, the gut content analysis also revealed presence of invertebrate egg, sand particles, fish scales, algae, cnidarian spicules and small fishes. Studies on food habits of the Indian mackerel by Hulkoti et al. [16] indicate that the fish feeds both on zoo- and phytoplankton depending on their availability in the area. The frequency of the different types of food material analysed in the gut is given in Table 1.

The present study showed that *Rastrelliger kanagurta* had high preference for diatoms (40.74% abundance) followed by dinoflagellates. This result was similar with the previous study of Supraba et al. [8], Hulkoti et al. [16]. Diatoms were represented by the species of *Pleurosigma, Skeletonema, Coscinodiscus, Chrysophyte, Proboscia, Lioloma, Pseudo-nitzschia, Cymbella, Bacteriastrum and Licmophora.* Dinoflagellates encountered in the gut were species of *Noctica, Protoperidinum, Noctiluca, Amphidinium and Dinophysis.* The gut analysis also revealed that the food material of *Rastrelliger kanagurta* also included the Crustaceans, Cyanobacteria, copepods, Mollusc and Protists. A total of seven group of organisms were preferred as food material by *Rastrelliger kanagurta* (Fig. 2). The gut content consisted approximately, 40.74%) diatoms, 22.22%), dinoflagellates, 14.81% Crustaceans (except copepods), 7.40% Cyanobacteria, 7.40% Copepods, 3.70% molluscs and 3.70% Protists. Occasionally, sand particles, fish scales, small fish, algae and cnidarian spicules were found in the month of March and April. Previous study by Supraba et al. [8] reported similar findings.

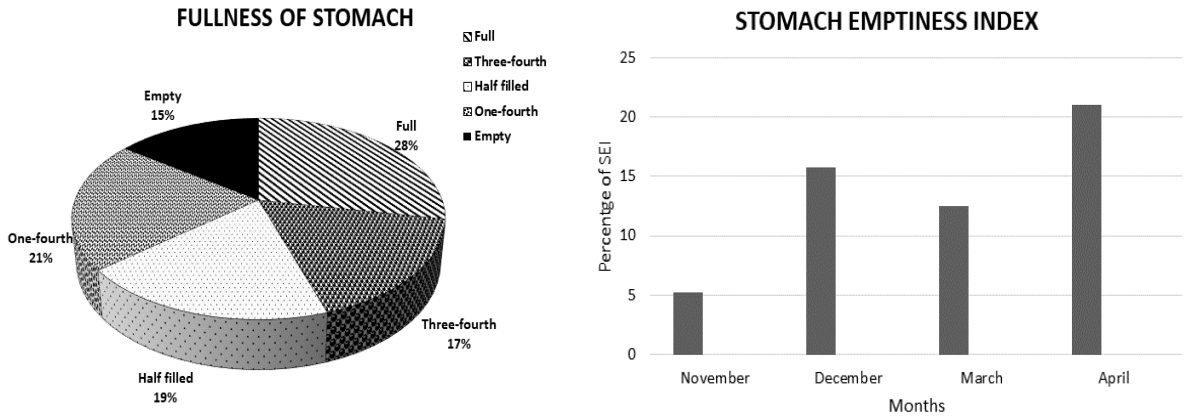


Fig. 1. Showing percentage occurrence of various degrees of stomach fullness and stomach emptiness index in each month in *Rastrelliger kanagurta*

Table 1. Monthly gut content analysis of *Rastrelliger kanagurta*

Groups	Planktons	November	December	March	April
Diatoms	*Pleurosigma sps*	+	-	+	-
Diatoms	*Skeletonema sps*	+	-	-	-
Diatoms	*Coscinodiscus sps*	+	-	-	-
Diatoms	*Chrysophyte sps*	-	+	-	-
Diatoms	*Proboscia sps*	-	+	-	-
Diatoms	*Lioloma sps*	-	+	-	-
Diatoms	*Pseudo-nitzschia sps*	-	+	-	-
Diatoms	*Cymbella sps*	-	-	-	+
Diatoms	*Ceratium sps*	-	+	-	-
Diatoms	*Bacteriastrum sps*	-	-	+	-
Diatoms	*Licmophora sps*	-	-	+	-
Dinoflagellate	*Noctica sps*	+	-	-	-
Dinoflagellate	*Protoperidinum sps*	-	+	-	+
Dinoflagellate	Dinoflagellate	+	+	+	-
Dinoflagellate	*Noctiluca sps*	-	+	-	-
Dinoflagellate	*Amphidinium sps*	-	-	+	-
Dinoflagellate	*Dinophysis sps*	-	-	+	-
Cyanobacteria	*Oscillatoria sps*	+	-	+	-
Crustacean	Isopod	+	+	-	-
Crustacean	Scud Amphipod	+	+	-	+
Crustacean	Ostracod	-	+	-	-
Decapod crustacean	Zoea shrimp larva	-	+	-	-
Cephalopoda Mollusca	Squid	+	-	+	-
Copepod	Nauplius larva	-	-	+	+
Copepod	Copepod	-	-	-	+
Protists	*Foraminifera sps*	-	-	+	-
	Invertebrate egg	-	-	-	+
	Sand particles	-	-	+	-
	Fish scales	-	-	+	+
	Small fish	-	-	+	-
	Algae	-	-	+	+
	Cnidarian spicules	-	-	+	+

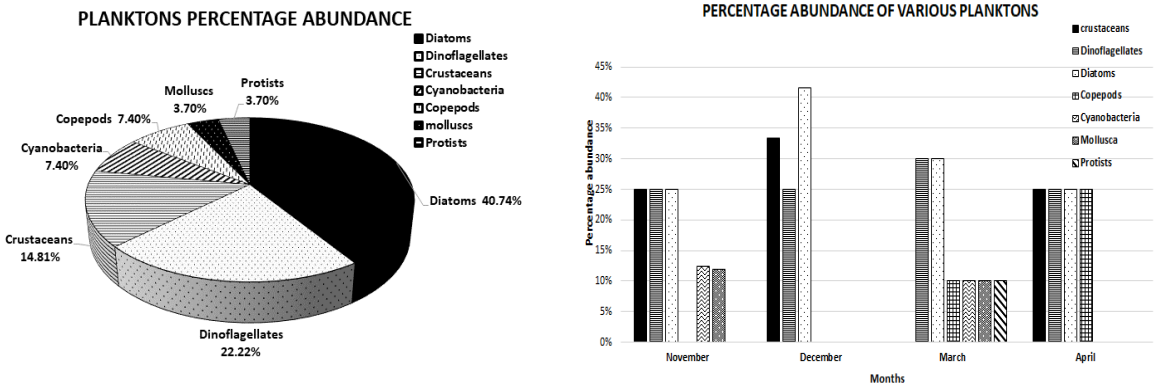


Fig. 2. Showing (a) abundance of planktons in the major groups of food items of the Indian Mackerel and (b) month wise variation of abundance of the planktons

A total of 25 different planktons were reported to be food preference of *Rastrelliger kanagurta.* The types of planktons found in the gut of *Rastrelliger kanagurta* are given in Fig. 3.

3.3 Spawning Period and Feeding Patterns

The correlation of feeding pattern and the maturity of *Rastrelliger kanagurta* was studied by analysing the GSI and GaSI.

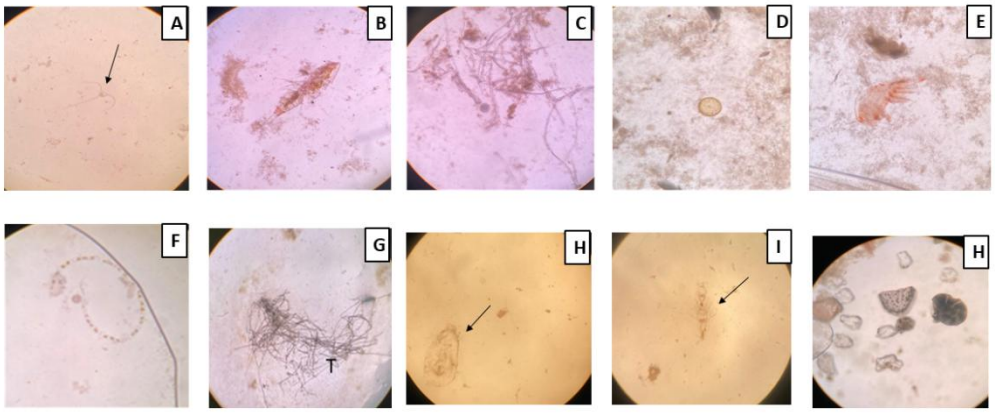
3.3.1 Gonado-somatic index

The Gonado-Somatic Index indicates the gonadal state and maturity index of the fish. GSI is helpful in identifying spawning season, as the gonads increase in size prior to the spawning period. GSI differs among different species of fishes and helps in determining the fecundity, productivity and population dynamics [20].

The GSI value of male and female individuals were seen to be highest in the month of April indicating growth of gonads and onset of the spawning period of the Indian mackerel.

3.3.2 Gastro-somatic index (GaSI)

GaSI exhibited an inverse relationship with the Gonado-somatic index (GSI), indicating onset of spawning period and reduced feeding.



A- Dinoflagellate, B- Squid cephalopod, C- Oscillatoria, D- *Coscinodiscus sps*, E- Scud Amphipod, F – Lithodesmium diatom, G- *Thalassionema sps*, H- Ostracod, I- Zoea shrimp larva, J- Foraminiferon and Licmophora diatom

Fig. 3. Planktons from the gut of *Rastrelliger kanagurta*

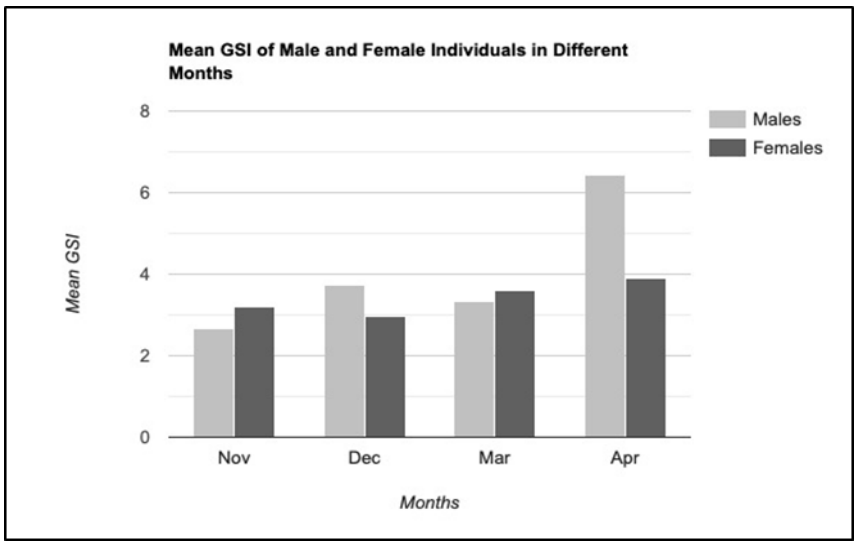


Fig. 4. Showing the mean Gonado-somatic index in different months in females and males of *Rastrelliger kanagurta*

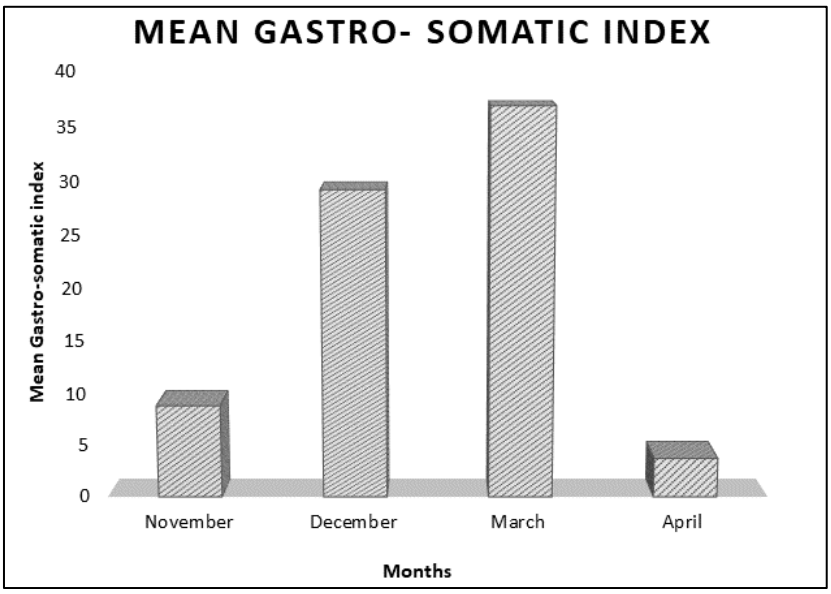


Fig. 5. Showing the mean gastro-somatic index in different month

4. DISCUSSION

Analysis of gut content and feeding intensity from our studies revealed that the Indian mackerel is an exclusive planktonic feeder and occasionally feeds on other component. Occasional food preference included fish larva, eggs and other small vertebrates. These findings of the present study are supported by previous research in other coasts [20], (Krishna et al. 2022).

4.1 Feeding Intensity

The feeding intensity was observed to be highest in the month of December with 66.6% of the stomachs fully filled and lowest in the month of April with only 4.6% of the total guts analysed. A similar trend was seen in the study conducted by Krishna et al. 2022. The values of average length can be used to study the growth and maturity of the fishes. The average length was seen as highest in the month of December (22 cm) and lowest in the month of March (14.1 cm), indicating growth and development in the fishes in the month of December and onset of spawning in the months of March and April. Presence of empty and one-fourth filled stomach, along with high Stomach Emptiness Index in the month of April suggested the onset of spawning period of the Indian Mackerel [16].

4.2 Gut Content Analysis

In the present study, the 25 different types of planktons were broadly classified as Diatoms, Dinoflagellates, Crustaceans, Cyanobacteria, Copepods, mollusc and Protists. Diatoms formed to be the predominant food being eaten throughout the period of study. Previous studies by Das et al. [20] Supraba et al. [8] have also reported Indian mackerel predominantly feeding on phytoplankton with diatoms dominating followed by dinoflagellates. Study by Hulkoti et al. [16] also indicated that the Indian mackerel feeds both on zoo- and phytoplankton depending on their availability in the area. Occasionally in the month of March and April sand particles, fish scales and poriferan spicules were found [21,22] and (Krishna et al. 2022) also reported presence of sand grains and fish scales in mackerel stomach. Pradhan [23] suggested that mackerel impounded using ‘rampan’ net had 80-90% of sand grains in their stomach and according to [21] the Indian mackerel can also supplement their planktonic diet by occasionally feeding on dead and decaying matter or fishes in the bottom of the sea [16].

4.3 Spawning Period and Feeding Patterns

High GSI values are indicative of the spawning season. In studies conducted by Arrafi et al [24] GSI values of *Rastrelliger kanagurta* ovary showed a correlation with the maturation of gonads. The highest mean GSI was observed in the month of April in the case of females and males. This can be interpreted as both, the female fishes and male fishes attaining reproductive mature phase during the same time.

Feeding intensity is reported to vary with maturity and spawning conditions. It is minimal during the spawning period, high in maturing period and maximum during the post-spawning period as studied by Bhimchar and George, [22], Chidambaram et al. [25]. Similar results were seen in our study. The gonado-somatic index was highest in the month of April and the stomach emptiness index was also seen highest in the month of April which showcases the spawning behaviour of the fishes.

Gastro-somatic index (GaSI) exhibited an inverse relationship with the Gonado-somatic index (GSI) as studied by Moohinor Alam Khan [26]. Lowest gastro-somatic index was observed in the month of April. This notes that its feeding habitat is closely related to its reproduction. It suggests that the fishes have less desire for feeding during their reproduction period, because of abdominal cavity being occupied by the ripe gonads [11].

5. CONCLUSION

Upon analysis of the food constituents and feeding habits of *Rastrelliger kanagurta,* it can be concluded that *Rastrelliger kanagurta*,is basically a plankton feeder. The gut content analysis shows that Diatoms and Dinoflagellates are the predominant feed. The feeding habits of the fish mainly depend on environmental factors, the growth phase and the spawning period. The feeding intensity varies with the maturity of the fishes. The feeding intensity is observed to be maximum during the pre-spawning season and minimum during the onset of spawning season as reflected through the outcomes of gastro-somatic index and the stomach emptiness index. It has an inverse relationship with the maturity of the reproductive organs. The Gonado-somatic index was seen highest during the spawning season indicating a high mature reproductive phase of the fish. The interesting observation is the occasional preference for other food material such as fish larva, eggs and other small vertebrates. Besides its primary preference of being a filter feeder it also feeds on mycoplanktons, dead fish remains, fish eggs, particles and algal matter. Thus, *Rastrelliger kanagurta* can be called an opportunistic feeder.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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