Hindawi Publishing Corporation
Journal of Marine Biology
Volume 2015, Article ID 870919, 8 pages
http://dx.doi.org/10.1155/2015/870919

Research Article

Food and Feeding Dynamics of *Stolephorus commersonnii* (Lacepede, 1803) (Family: Engraulidae) from South Andaman

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Received 31 July 2015; Revised 28 October 2015; Accepted 29 October 2015

Academic Editor: Jakov Dulčić

The feeding dynamics of *Stolephorus commersonnii* along the coastal waters of South Andaman during October, 2011, to September, 2012, were examined by employing "point's method." The results of the present study has shown that *S. commersonnii* mainly is a planktonivorous carnivore chiefly feeding in the pelagic realm on planktonic crustaceans, bivalves, gastropods, and miscellaneous food items. The copepods formed the main prey item, contributing their maximum during November 2011 (47.55%) and lowest in December (24.21%) which was confirmed by various food preference indices. There was no significant seasonal variation in the feeding preference. Lower length classes fed mainly on planktonic copepods and amphipods whereas the higher length classes fed mainly on postlarval shrimps and planktonic crustaceans like *Lucifer* sp. and *Acetes* sp. Feeding intensity was seasonal, but independent of the length of fish. Gastrosomatic index was highest during monsoon, indicating active feeding. During the period when a maximum percentage of fully mature individuals were present, the feeding intensity was found to be low. The trophic level of this species was found to be 2.96 ± 0.11.

1. Introduction

Analysis of feeding dynamics in fishes is essential prerequisite for the rational and sustainable management of the fish stocks. The spatial and seasonal fluctuations in abundance of the organisms that constitute the food of a species have been found to affect and influence biological activities of fishes such as growth, condition, shoaling behaviour, migration, and the fishery [1]. In ecosystem based fishery management studies, these data are integrated into conceptual models that allow a better understanding of the structure and function of diverse aquatic ecosystems [2].

Anchovies form an important part of marine food chains and the connecting link between the planktonic organisms and the predators including carnivorous fishes, marine mammals, and birds [3]. Anchovies are one of the major pelagic finfish resources exploited along the coastal waters of India, contributing to almost 7–18% in the total landings [4]. Species belonging to the genus *Stolephorus* (whitebaits) alone form 2.5–7.8% of the total pelagic finfish catch. *Stolephorus commersonnii* forms 27% of the total catch of the species belonging to *Stolephorus* and it is the second important *Stolephorus* species in peninsular India [5]. Though several species of anchovies support the pelagic fishery in South Andaman coast, the Commerson's Anchovy (*S. commersonnii*) alone comprises 6–15% of the total pelagic fish catch and 90% of total anchovy catch [6].

Many authors have studied the food habits of commercially important anchovies fishes including *Stolephorus commersonnii* in both the east coast and west coast of India [7–14]. Information on the gut contents of the marine fishes is necessary to understand community ecology, structure and stability of food webs, trophodynamics, resource partitioning, and functional role of different fishes in aquatic ecosystems and ecological energetics [15, 16]. It has been pointed out that there was a correlation between the availability of a preferred food item of a particular fish species and occurrence and abundance of the fishery for the species [17, 18]. Thus the study of the food of a fish around the year is essential for a better understanding of the biology and fishery of the species. The studies on anchovies from Andaman coast are inadequate when compared to east and west coasts of India. From the Andaman and Nicobar Islands, the studies on anchovies are confined only to the works of Marichamy [14]. Here, an attempt is made to fill the lacuna. This paper aims to identify the patterns of food and feeding of *S. commersonnii* and present a comprehensive account of its feeding ecology, especially the ontogenetic variation in diet preferences.

2. Materials and Methods

2.1. Sample Collection and Analysis. *Stolephorus commersonnii* specimens were collected every month during the period from September 2011 to August 2012 from the fish landings at Junglighat, Chatham, Carbyn's Cove, and Burmanallah (Figure 1).

The samples were collected randomly and then stored in ice boxes to slow down the spoilage of specimens and digestion process in the gut. The collected samples were then rinsed thoroughly in cold water and stored in freezer for some time (~20 minutes) in order to maintain freshness and the quality of the fish. A total of 1559 specimens (552 males, 947 females, and 60 indeterminates) in the length range of 57 mm to 140 mm and the weight range of 2.08 gm to 19.87 gm were analyzed. The total length (to the nearest 1 mm), weight (to the nearest 0.1 g), and sex and maturity stages were recorded and stomach contents were analyzed. The stage of reproductive maturity was also ascertained for comparison with the feeding intensity.

The full stomach was preserved in 5% formalin for further analysis. Each stomach was emptied into a Petri dish and examined under a binocular microscope. All food items were identified following [20–22], to the lowest taxa level depending on the stage of digestion. Food items were grouped and weighed. To analyze the amount of each food item, the method of Platell and Potter [23] was followed by evenly spreading all contents from each gut in the counting cell chamber and examining under microscope. Analysis was done using frequency of occurrence and numerical methods [24]. The degree of fullness of each stomach was analyzed following the methodology [25]. Some empty stomachs were shrunk and contained mucus, while others were expanded but completely empty; the latter type is believed to occur in fish which have recently regurgitated [26]. In the frequency of occurrence method, the occurrence of total items was expressed as the percentage of total number of stomach containing food. In the numerical method, the amount of each food item was expressed as the percentage of total number of food items found in the stomach [27]. To assess changes in the diet with fish size; it was divided into five size classes from 41–60 mm to 121–140 mm. Stomach contents of juveniles (indeterminate sex groups of length range 57–80 mm) were analyzed separately to determine the ontogenetic variations in feeding habits. Gastrosomatic index (GSI) was recorded using the following equation:

$$\text{GSI} = \frac{\text{weight of stomach}}{\text{weight of fish}} \times 100. \quad (1)$$

2.2. Feeding Indices

2.2.1. Index of Selection or Forage Ratio. A quantitative index of the scale of preference for the organisms in their environment is called the forage ratio [28]:

$$\text{Selection index} = \frac{s}{b}, \quad (2)$$

where s is the percentage representation by weight of a food organism in the stomach and b is the percentage representation of the same organism in the environment. The lower limit for this index is 0; its upper limit is indefinitely large.

2.2.2. Ivlev's Index of Electivity. Ivlev's index of electivity gives the preference for a particular prey item. It is a quantitative measure of selection which is widely used as method of comparing the feeding habits of fishes and other aquatic organisms with the availability of potential food resources in natural habitats [29]. Consider

$$\text{Electivity index} = \frac{s-b}{s+b}, \quad (3)$$

where s is the percentage representation by weight of food organisms in stomach and b is the percentage representation by weight of organism in the environment. Negative values of electivity index indicate either predator avoidance of a given prey or unavailability of the prey in the environment. Zero electivity indicates random selection. Positive index indicates that the prey is commonly available in the environment and/or active selection of the particular prey by the predator.

2.2.3. Diet Breadth. Index of diet breadth (B) was calculated as a measure of degree to which the individuals use available resources in proportion to each other [30]. Consider

$$B = \frac{1}{\sum \left(p_{ij}^2\right)}, \quad (4)$$

where p_{ij} is the proportion of resource state j used by the individual i.

2.2.4. Trophic Level. The trophic level of anchovies was determined, based on the estimations on diet composition data by using the following equation [31]:

$$\text{TL}_i = 1 + \sum_j \left(\text{TL}_j \cdot \text{DC}_{ij}\right), \quad (5)$$

where TL_j is the fractional trophic level of the prey j and DC_{ij} represents the fraction of j in the diet of i. According to the feeding habit, the species were grouped into various categories like herbivores, detritivores, carnivores, and omnivores (Table 1).

The data was processed in Microsoft Excel and PAST packages [32]. Statistical analysis consisted of one-way analysis of variance.

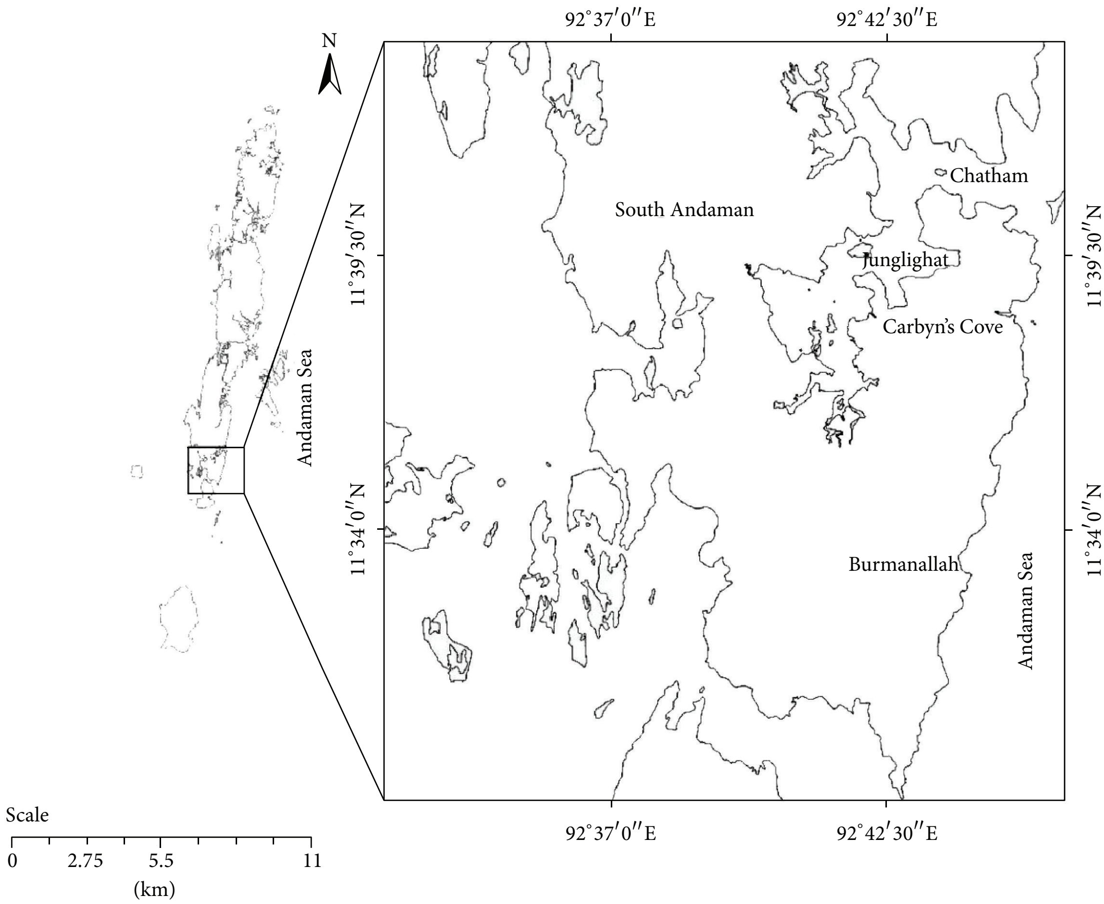

Figure 1: Map showing the study area.

Table 1: Major diet groups of *Stolephorus commersonnii* and their trophic levels.

Sl. number	Food items	Percentage (%)	Trophic level [19]
1	Copepods	32.2	2
2	Decapods	24.7	2.1
3	Molluscan larvae	8.5	2.24
4	Amphipods	2.3	2.29
5	Other prey items	6.5	1.8
6	Semidigested matter	25.8	NA

3. Results

3.1. Qualitative and Quantitative Analysis of the Stomach Contents. The trophic spectrum of *S. commersonnii* is composed of many dietary items, which were classified into six major categories (Table 1): copepods, decapods (*Lucifer* sp., *Acetes* sp., zoea and penaeid protozoea), Molluscan larvae (bivalve larva, gastropod larva) Amphipods, other preys, and miscellaneous items.

Copepods formed the maximum percentage in the gut content of *S. commersonnii*, followed by decapods, molluscan larvae, amphipods, and others. In other prey items Polychaete larvae, arrow worms (*Sagitta* sp.), invertebrate eggs, and diatoms were included.

The monthly composition of food items of *S. commersonnii* is shown in Table 2. Planktonic crustaceans formed the main food in almost all the months (for *Stolephorus commersonnii* throughout the year). Copepods were found to dominate by occurrence (>80%) in all months. Maximum percentage of the preferred food was recorded in the month of November 2011 (47.61%) and the lowest were observed in September 2012 (24.21%). The larval and postlarval stages of penaeid shrimps (*Acetes* sp., penaeid protozoea, zoea, brachyuran zoea, etc.) formed the second most preferred food item. Bivalve and gastropod larvae are found to be the third important category for *S. commersonnii* in terms of numerical percentage and they were recorded throughout the year. Amphipod formed the fourth position in the preferred food of *S. commersonnii*.

3.2. Diet Composition. Average annual diet composition of *Stolephorus commersonnii* is presented as a percentage in Figure 2. Copepods dominated the diet (32%) followed by semidigested matter (14%) and crustacean appendages (12%).

The presence of a large number of zooplanktonic organisms in the gut contents of almost all the size groups of fishes indicates that the species is a typical zooplankton

Table 2: Numerical (N%) and frequency percentage (F%) of various food items of *S. commersonnii*.

Month	n	Copepods		Decapods		Mollusca larvae		Amphipod		Semidigested matter		Other prey items	
		N%	F%	N%	F%	N%	F%	N%	F%	N%	F%	N%	F%
Oct. 11	118	33.3	89.4	16.1	38.9	17.2	23.6	2.1	33.1	9.2	98.1	24.1	69.1
Nov. 11	155	47.6	98.8	36.1	67.7	2.5	20.5	1.1	16.4	1.6	90.6	12.3	75.3
Dec. 11	132	24.2	96.2	41.1	48.3	0.0	5.6	0.0	9.4	0.0	20.4	25.3	56.3
Jan. 12	129	35.2	100.0	33.0	45.6	9.1	18.1	2.8	10.2	3.4	99.8	19.3	68.2
Feb. 12	139	37.4	100.0	29.7	41.4	8.8	12.8	2.0	13.6	5.5	92.3	18.7	45.3
Mar. 12	169	34.1	99.8	35.2	56.0	9.1	17.1	4.4	9.4	2.3	86.7	19.3	49.0
Apr. 12	122	30.5	95.5	31.7	60.6	9.8	15.4	4.6	11.8	2.4	94.3	25.6	73.1
May 12	105	33.3	100.0	35.2	55.9	4.6	9.9	2.5	14.6	0.0	96.8	17.6	66.6
Jun. 12	149	28.1	96.9	31.5	42.0	6.7	11.4	0.0	12.4	3.4	90.5	19.1	50.0
Jul. 12	134	29.3	98.7	26.8	28.5	11.4	16.2	1.5	6.7	3.2	95.2	18.7	41.9
Aug. 12	107	28.8	100.0	29.7	31.7	11.0	13.9	0.9	9.6	0.8	85.8	21.2	45.8
Sep. 12	100	25.6	98.4	32.5	35.6	12.8	19.1	2.6	13.3	1.7	91.6	21.4	54.5
Total/avg.	1559	32.3	97.8	31.5	46.0	8.6	15.3	2.0	13.4	2.8	86.8	20.2	57.9

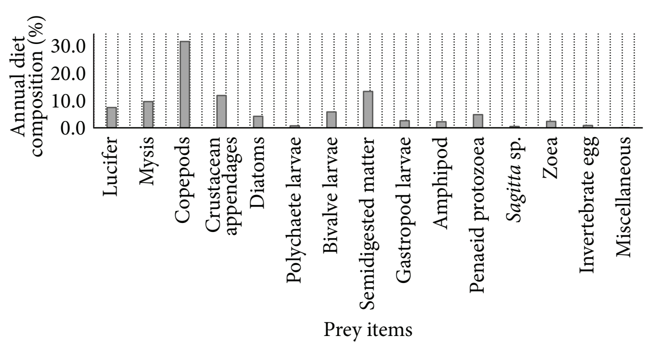

Figure 2: Average annual diet composition of *Stolephorus commersonnii*.

feeder throughout its life. On a few occasions as in October 2011, March 2012, and August 2012 the entire gut was found to be gorged with copepods. Almost 80–90 copepods belonging to different species have been recorded from the stomach of a single specimen. The main species recorded were (in the order of importance) *Oithona similis, Oithona* sp., *Acrocalanus gracilis, Acrocalanus* sp., *Paracalanus parvus, Paracalanus* sp., *Oncaea venusta, Oncaea* sp., *Pseudodiaptomus* sp., *Acartia erythraea, Acartia* sp., *Euterpina acutifrons, Euterpina* sp., *Centropages* sp., and so forth. Only on very few occasions the stomach was found to be filled with organisms other than copepods, for example, decapods like *Lucifer* sp., *Acetes* sp., Larval and postlarval shrimps, brachyuran zoea, protozoea, molluscan larvae such as bivalve larvae and gastropod larvae, and Amphipod. Invertebrate egg, *Sagitta* sp., Polychaete larvae, and some species of diatoms were observed in less numbers which shows that these are the occasional food items of this fish.

3.3. Ontogenetic Variation in the Diet Composition. Due to change in the size of their mouth the feeding preference was found to be different; that is, the young ones (<80 mm) mainly feed on copepods (45.3%), amphipods, and molluscan larvae. The mature fishes feed on planktonic crustaceans such as *Lucifer* sp., *Acetes* sp., penaeid proto zoea, brachyuran zoea, amphipod, and copepods (Table 3).

Diet of the next group (81–100 mm) also mainly composed of copepods (37.4%), decapods (26.5%), and amphipods. Higher size classes had lesser percentage of copepods and more percentage of decapods, that is, *Lucifer* sp., *Acetes* sp., larval and postlarval shrimps, brachyuran zoea, amphipods, and molluscan larvae. The adults were found to mainly feed on larval and postlarval shrimps and the larvae of Molluscs. The one-way ANOVA analysis on the relationship between the size groups of fish and number of major prey items showed a significant variation ($p < 0.05$).

3.4. Feeding Intensity. Poorly fed fishes were observed in all the months with highest percentage during the period from April (24.59%) to June (26.17) and September (26%), the lowest during the month of October 2011 (14.4%). Actively fed fishes were also observed in all the months but their percentage was found to be highly fluctuating. The peak (85.65%) was observed during October which was probably influenced by the monsoon (Figure 3).

The feeding intensity was the poorest in the month of June 2012 (73.83%). These results correlate with the statistical analysis which indicated the presence of a significant fluctuation in feeding intensity ($p < 0.05$; one-way ANOVA).

Juveniles showed a higher feeding intensity than adults; a higher percentage of actively fed fishes was recorded (79.8%) with smaller length groups (41–60 mm). With increasing size the intensity of feeding decreased. The poorly fed fishes were more (58.4%) in larger length class (121–140 mm) and less in small fishes of size ranging within 41–60 mm (20.2%) (Figure 4). These results show that there is a significant variation in the feeding intensity with varied size classes ($p < 0.05$; one-way ANOVA).

Table 3: Percentage (*N*% and *F*%) of various food items in 20 mm length groups of *S. commersonnii*.

Length group (mm)	*n*	Copepods		Decapods		Mollusca larvae		Amphipod		Semidigested matter		Other prey items	
		N%	*F*%	*N*%	*F*%	*N*%	*F*%	*N*%	*F*%	*N*%	*F*%	*N*%	*F*%
<80	148	45.3	98.3	24.5	87.6	11.2	38.7	4.6	88.8	1.1	93.3	13.3	32.5
81–100	1224	37.4	96.6	26.5	98.9	12.8	39.1	7.2	84.2	3.7	92	12.3	36.4
101–120	166	25.6	90.1	31.5	99.2	14.8	51.6	12.3	90.4	1.5	100	14.3	29.1
>120	21	26.1	80.1	32.8	99.8	11.1	43.6	13.1	93.3	4.8	97.6	12.1	33.3
Total/avg.	1559	40.2	93	26.3	81.7	10.2	40.9	7.4	89.3	3.2	96.6	12.7	33.1

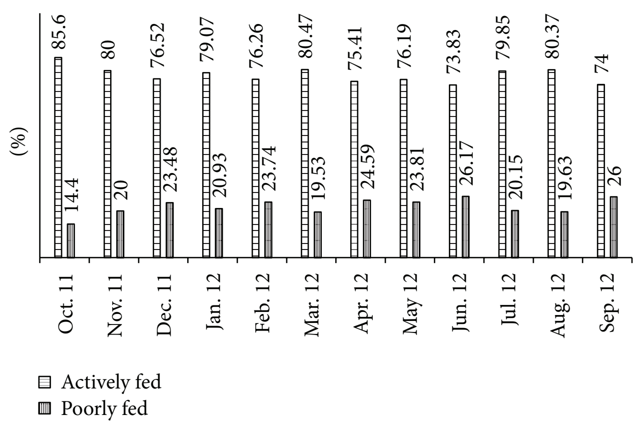

Figure 3: Monthly feeding intensity of *S. commersonnii*.

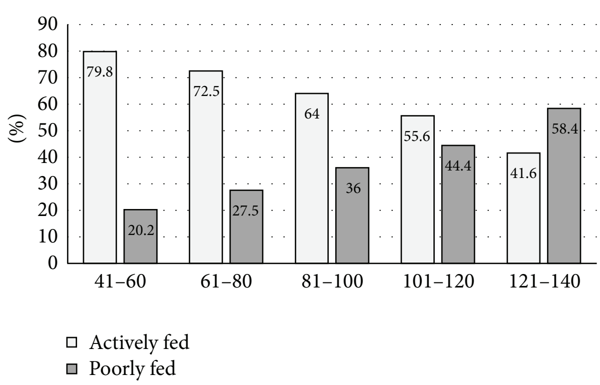

Figure 4: The percentage of feeding intensity in relation to the various length groups of *S. commersonnii*.

3.5. Gastrosomatic Index. The Gastrosomatic index (GaSI) of the specimens is presented in Figure 5.

It is to be noted that the GaSI of females were higher than males in general. The GaSI showed a trend similar to the feeding intensity with peaks during October in females and during the period from July to August in males. The lowest values of GaSI for both males and females were found during the period April–June.

3.6. Feeding Indices

3.6.1. Forage Ratio. The forage ratio of this species with regard to copepods was calculated as 1.8. This indicates that *S. commersonnii* actively forages for and selects copepods.

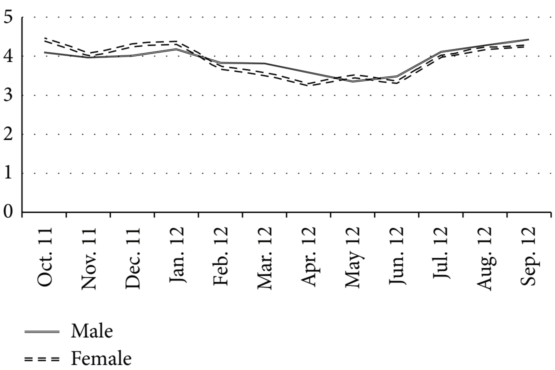

Figure 5: Gastrosomatic index of *S. commersonnii*.

3.6.2. Index of Selectivity. The calculated index of selectivity of *S. commersonnii* for copepods was 0.28, indicating both abundance of copepods in the environment and active search and selection of this prey item. This reveals that copepods are the most preferred food for *S. commersonnii.*

3.6.3. Diet Breadth. The calculated diet breadth/niche breadth for *S. commersonnii* was found to be 3.95. This value indicates that the diet spectrum of this species is extremely broad, revealing this species to be a generalist, feeding on a variety of species, albeit belonging to the same trophic level.

3.6.4. Trophic Level. The trophic level of *S. commersonnii* was found to be 2.96 ± 0.11, which indicates that it is a carnivorous species.

4. Discussion

The present study shows that planktonic copepods and planktonic crustaceans constituted the core diet of *S. commersonnii*. Bivalve and gastropod larvae, amphipod, Polychaetes, and ostracods were the next preferred foods. It shows that *S. commersonnii* is a planktonivorous fish and it is highly carnivorous in the style of feeding. The result of the present study shows close similarities with earlier observations on the diet of *S. commersonnii* from Indian waters [8, 10]. The present results are similar to the observation by [17], who indicated that anchovy derive the bulk of their carbon from larger (>1.5 mm) zooplankton, typically calanoid copepods and euphausiids captured through size-selective particulate feeding. Van der Lingen has pointed out that the minimum particle size that can be entrapped by anchovy during filtering is 0.20–0.25 mm; hence a large portion of phytoplankton is unavailable to anchovy. They are highly size-selective, selecting for the largest prey available [18]. The variations in the diet composition showed a correlation with the environmental biota, as noticed in other anchovy species by [9, 10, 12]. In Andaman waters Marichamy has done a clear report on food and feeding of short jaw anchovy *T. baelama* [14]. In the present study, there is no significant seasonal variation in the prey items except during December 2011, due to the influence of "Thane" cyclone.

Significant ontogenetic variation exists in the trophic spectrum of *Stolephorus commersonnii*. Diatom was absent in the stomach of fish in larger sizes. As the mouth size severely limits the size of prey which can be ingested [33, 34], the diet of fish is related to their digestive morphology and mouth structure. As the fish grows, the size of mouth increases proportionally, the swimming capacity is modified, and energy requirements vary [35]. Thus larger fish have different diet requirements from smaller ones and attempt to satisfy by consuming a larger variety of prey types. The increasing variety of food consumed by predators as they grow is a common feature among marine organisms [36]. As the fish increased in length, the percentage of copepods decreased and that of bigger organisms like planktonic crustaceans, amphipods, and polychaete larvae increased. Such differences in the feeding habits of juveniles and adults were noticed [8] in *T. hamiltonii* and *A. commersonnii* by [9] in *T. mystax*. Biochemical measurements such as lipid composition [37] suggest that microzooplankton might be an important component of the diet of early anchovy larvae. The gill rakers in anchovies are simple, spine-like projections in structure that are randomly arranged along the gill raker axis [38]. In anchovies, gill arch length and gill raker length increase with increasing fish length, juveniles show an increase in number of gill rakers increasing fish length, and the number of gill rakers remains constant for adults of >80 mm standard length. Gill raker gap also increases with increasing fish length [39].

The species has a small and subterminal mouth (in which the prominent snout projects beyond the lower jaw) and is consequently prevented from consuming larger food particles. The gill rakers are slender and well developed. The gill filaments are numerous (23–28) and closely packed to augment efficient straining of water. The absence of tuft-like structures on the gills for filtering may be one of the reasons for the absence of microplanktonic organisms in the diet. The teeth are minute and undifferentiated as in all other plankton feeders.

The results of the feeding indices highlighted that *S. commersonnii* extremely feeds on their ideal prey. According to previous works [31] the trophic level of *S. commersonnii* indicates that this species is a plankton-feeding carnivore.

Whereas the scarcity of data precludes the extraction of an exact pattern for this species, a number of observations that are worth mentioning are also presented here. The percentage of individuals in various stages of maturity in each set of samples is presented in Figure 2. The stomach contents of these fishes showed a good correlation with the ambient plankton leading to the conclusion that the occurrence and the abundance of the food items in the gut can be strongly correlated with their respective availability and population density in the natural environment [40].

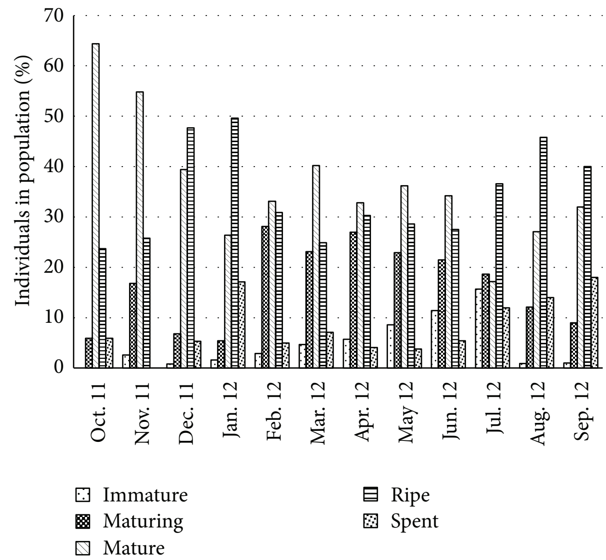

Figure 6: Reproductive maturity-wise distribution of individuals in monthly samples.

Most of the fish collected during postmonsoon and premonsoon months were in advanced stages of sexual maturity with body cavity fully occupied by ripe mature gonads. Although mature fish are seen throughout the year, a large number of mature females with advanced stage of ovary were noticed only during the period July-August and again in December-January (Figure 6). During these seasons, the abdominal cavity was fully occupied by ripe gonad and the stomach was empty and small in size. This not only indicates that spawning takes place during these two time periods but also confirms that they stop feeding during spawning. Also, many environmental factors which influence the feeding intensity in fish are closely related to the duration and onset of reproductive season [39].

The presence of phytoplankton in the diet was significantly less. According to Valenzuela et al. [41], the presence of phytoplankton in gut contents could be explained by fish ingesting zooplankton that had fed on phytoplankton or ingesting copepod faecal pellets. Although zooplankton is generally the dominant dietary component of small pelagic fish, phytoplankton increases in dietary importance (to differing degrees for different species) as fish grow, arising from the ontogenetic development of the branchial basket which allows the retention of small particles [18].

Most microphagous clupeoids possess two feeding modes and switch between the two when conditions dictate, generally filter-feeding on smaller food particles and particulate-feeding on larger food particles [42]. Even though in this study the feeding ecology of *S. commersonnii* could not be analyzed, it was found that both larger and smaller food items were present in the guts of these species, which can be a probable indication of the presence of two feeding modes.

The periodicity of feeding was not directly observed in this study but the presence of a larger number of zooplankton in the diet indicates that this species actively feeds at night. This is in concurrence with the previous results [17] where the feeding periodicity in anchovy appears to be associated with vertical migration, with high feeding activity at night coinciding with shoal dispersal in the surface waters, whereas low feeding activity during the day coincides with shoal aggregation and descent into deeper waters.

Movement of anchovy shoals into the inshore regions coincided with the fishery of larger sized carnivorous and piscivorous fishes for which anchovies are an important food item [43–46]. This spatial relationship between prey and predator leads us to the idea that the movement of apex predators like tuna, seer fishes, barracuda, bill fishes, sciaenids, carangids, ribbonfishes, and sharks can be traced by understanding the migration of anchovy shoals, which in turn will benefit the fishery of these predatory fishes.

5. Conclusion

The trophodynamics of *Stolephorus commersonnii* were studied thoroughly and the study indicated that it is a planktonivorous carnivore with a trophic level 2.96 ± 0.11. Various indices of food preference and forage showed that copepods are the most preferred food and this species actively searches for copepods and feeds on them. Review of previous literature had indicated that though this species is commercially important in small scale fisheries, studies regarding its biology are limited and sparse, especially in these waters. More comprehensive studies including ontogenetic variations and reproductive maturities are to be conducted for a better understanding of the food and feeding of this species.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

The authors are grateful to the authorities of Pondicherry University for providing the requisite facilities for the study. The corresponding author is very much obliged to thank Mr. R. Karthik and Mr. S. Sai Elangovan for the unwavering support for this work. They are very much thankful to all the fisherman and without their help this work would not have been achievable. They are indebted to Mr. A. Saravanan, Department of Disaster Management, Pondicherry University, for preparing the map of the study area.

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