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Feeding habits and reproductive biology of the rabbitfish, *Siganus vermiculatus*, along the central west coast of India

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Original Article

Abstract

Rabbitfishes are commercially important, and the aquaculture sector is interested in them because of their fast growth, herbivorous habits, and good market price. An attempt was made to understand the feeding and reproductive biology of vermiculate rabbitfish, *Siganus vermiculatus*, along the Ratnagiri coast, which lies central to the west coast of India. *S. vermiculatus* feed mainly on algae (filamentous algae, seaweeds) during most of the year, along the Ratnagiri coast. The majority of mature fish were with empty stomachs or with little food during active spawning. The highest monthly GSI was from February to March for females and December to March for males. Throughout the year, a significant difference ($P<0.05$) was noted in the sex ratio with the dominance of females in the population. The length at first maturity of males and females was estimated at 28.13 cm and 32.73 cm, respectively. *S. vermiculatus* is highly fecund with fecundity ranging from 7,80,136 to 12,56,674 eggs. This information on food and feeding habits, sex ratio, maturity size, and reproductive potential will be helpful to develop culture practices of this species along the studied region.

***Keywords**: Feeding, reproductive biology, siganus vermiculatus, mariculture, Ratnagiri coast*

Introduction

The rabbit fishes, also known as siganids, belonging to the family Siganidae are found across the subtropical, tropical, and temperate Indo-West Pacific region and the Indian Ocean. They are primarily herbivorous fishes consisting of 29 known species worldwide (Froese and Pauly, 2019), out of which 15 species have been described along the Indian coasts (Murugan and Namboothri, 2012). The family Siganidae consists of the single genus *Siganus* and two subgenera, such as Siganus and Lo (Woodland, 1979). They get attention from the mariculture sector because of their fast growth, herbivorous feeding behaviours, and high commercial value (Lam, 1974; Alcaca, 1979). Worldwide, numerous studies are reported on the life cycle and biology of siganids due to their mariculture potential (Siganid Mariculture Group, 1972; Lam, 1974). Noticeable studies have been carried out on *Siganus rivulatus,* and *S. luridus* from the Mediterranean (Popper and Gundermann, 1975; Hussein, 1986), *S. argenteus* (Quoy and Gaimard, 1825) from both the Red and Mediterranean Sea (George, 1972), and *S. canaliculatus* from Palau (Hasse and McVey, 1977). The majority of studies on the biological characteristics of siganids have focused on temperate species (Bryan *et al*., 1975; von Westernhagen and Rosenthal, 1976; Hasse *et al*., 1977; Abu-Hakima, 1984; Cyrus and Blaber, 1984). Little attention has been received on the reproductive biological aspects of siganids (George, 1972; May *et al*., 1974; Nzioka, 1979,1981; Gundermann *et al*., 1983). *S. vermiculatus* (Valenciennes, 1835) is commonly known as vermiculated spine foot because of its body marked with irregular light brownish interspersed zigzag stripes.

To gain information on the biology of any species and to attempt their farming possibilities, knowledge about the feeding and reproductive aspects is important (Anand and Reddy, 2017; Gurjar *et al*., 2018). There are very few studies on the biological aspects of *S. canaliculatus* from the east coast of India (Jayasankar, 1990; Anand and Reddy, 2017). There are three species common along the Ratnagiri coast of Maharashtra, India, *viz. S. vermiculatus, S. canaliculatus* and *S. javus* (Metar *et al*., 2019). Among the three, *S. vermiculatus* grows faster and fetch higher prices due to its delicious meat. The present study was carried out to summarize the observations on the feeding and reproductive biology of this species from the central west coast of India to generate baseline data for future conservation strategies and practices. The present study is also the first report on the feeding and reproductive aspects of *S. vermiculatus.*

Material and methods

Sample collection and study area

The study was based on 546 (110 male and 436 female) specimens of *S. vermiculatus,* ranging in size from 21 cm to 43 cm (total length). Samples were collected from Mirkarwada, Sakhartar and Karla (Fig. 1) landing centres of Ratnagiri, Arabian Sea, Central west coast of India during 2017-2019 and brought to the laboratory for further analysis.

Laboratory procedure and data analysis

After bringing the specimens to the laboratory, the total length was measured from the tip of the anterior-most part of the body to the tip of the longest caudal-fin ray in mm using a measuring board. The total body weight was recorded to the nearest 0.01 g using an electronic balance (Sartorius make, model no. TAPT 300G). The fishes were cut open, and the sex was noted. Gut contents were analyzed both qualitatively and quantitatively using numerical methods (Biswas, 1993). The different items of food found in the stomach were examined either in fresh condition or after preservation in 5% formalin. The various constituents of food were identified into main groups. The intensity of feeding was determined for individual fish based on the distention of the stomach and the amount of food contained therein (Pillay, 1952).

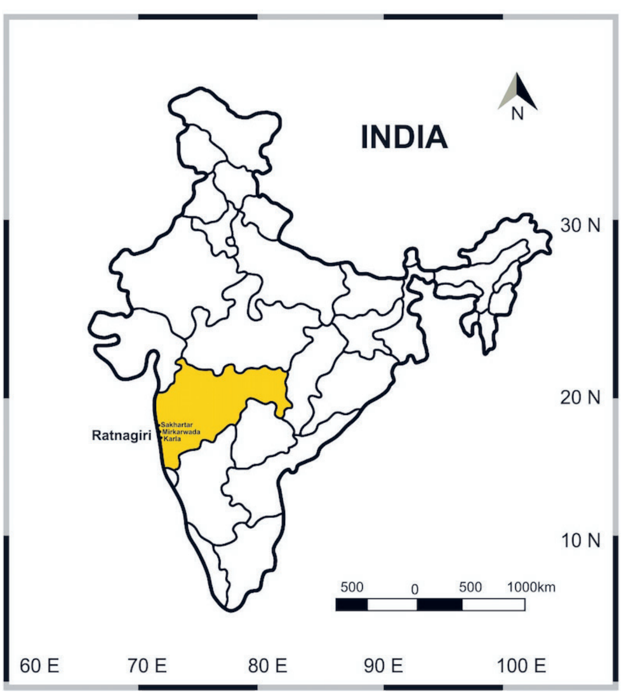

Fig. 1. Location of the study

Gonads were excised and weighed to the nearest 0.01 g using an electronic balance. Gonads were stored in a 4% formalin solution for further analysis. The chi-squared (^{2}) test was applied to determine the homogeneity of the distribution of the sex ratio. The maturation stages were determined by examining the gonads under a microscope (Jayabalan, 1986; Jayasankar, 1990; Al-marzouqi *et al*., 2011). GSI was estimated as per Bal and Rao, 1984.

Size or length at first maturity was assessed using the logistic curve method (King, 1995). For the determination of fecundity, fresh, ripen ovaries were used. The excess moisture was removed by using blotting paper and the ovaries were weighed to the nearest milligram (mg). A sub-sample of 1.0 mg was weighed with an electronic balance of 0.1 mg accuracy. The sample was then taken on a slide and the numbers of mature ova in the sub-sample were counted physically and extrapolated to the whole weight of the ovary to estimate the fecundity.

Results and discussion

Food composition

The food substances of *S. vermiculatus* consisted of algae, seaweed, mangrove remains, and semi-digested food materials. The maximum percentage (77.5%) of algae was in August, while the lowest amount (8.34%) was in May. The maximum percentage (77.1%) of seaweeds was in the month of March, and the minimum percentage (3.33%) was

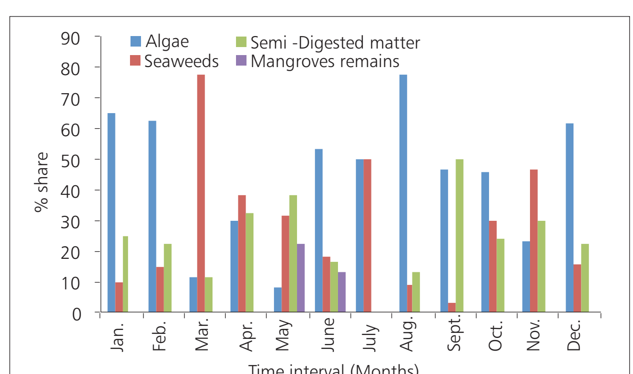

Fig. 2. Month-wise percentage composition of different food items of *S.vermiculatus*

in September. The mangrove remains were observed only in June (22.2%) and July (13%). The highest percentage (38.3%) of semi-digested food materials was observed in May, while the lowest amount (11.4%) was in March (Fig. 2). Aside from morphological similarities, siganids can be classified into functional categories based on their feeding habits (Moleana *et al.*, 2016). The diet composition of *S. canaliculatus* comprised of algae (65.9 %), echinoderms (5.62 %), molluscan remains (2.72%), crustacean remains (1.49 %) and semi-digested (24.27%) as the main food items in the order of preference (Metar *et al.*, 2019). *S. vermiculatus* differed from *S. canaliculatus* in stomach content composition, which explains the two species' minimal niche overlap. Stomach content implies that *S. vermiculatus* comparably utilizes mangrove resources. Finally, the dominance of *Enteromorpha* species, mangrove-associated algae, in *S. vermiculatus'* diet emphasizes the relevance of mangrove habitats for this species. Siganids are herbivores in nature that eat in small to large groups on varieties of benthic algae (Tsuda and Bryan, 1973; Von Westernhagen, 1973; Bwathondi, 1982). According to Von Westernhagen (1973), they devour algae, and agrophytes of the genera *Laurencia, Hypnea, Graeilaria* in nature. Tsuda and Bryan (1973) found the following algae genera: *Cladophoropsis, Padina, Hypnea, Gelidium, Ectocarpus, Dictyota, Jania,* and *Spacelaria* from the stomach of adult *S. spinus*, and they observed that *S. argenteus* and *S. spinus* consumed 10 of 45 prevalent taxa of reef flat algae. The present study showed that *S. vermiculatus* is a herbivore, that mainly feeds on the alga *Enteromorpha* sp.

Length-wise percentage composition of major food items present in the stomach was analyzed during the study period and presented in Fig. 3. Different food matters present in the stomach were calculated using the class interval of 4 cm to show any variation of food composition according to size. The highest percentages (71%) of algae were observed in the length group of fish 37-40 and the lowest percentage (15%) in the length of fish 21-24 cm. The highest percentage

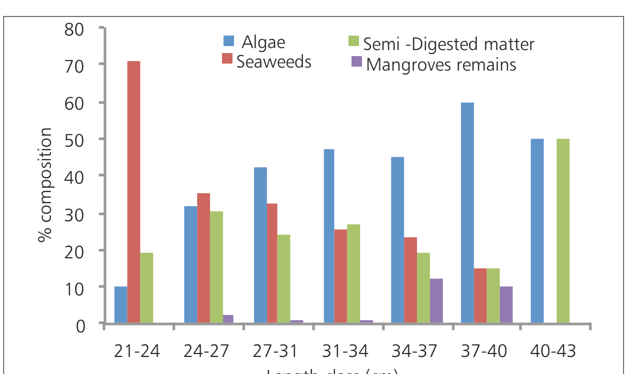

Fig. 3. Length-wise percentage composition of different food items of *S.vermiculatus*

(71%) of seaweeds was observed in the length of fish 21-24 cm and the lowest percentage (15%) in the length of fish 37-40. The fish length 34 to 37 cm was observed highest percentage (12%) of mangroves remaining and the lowest percentage (1.25%) in 21-24 cm. In Fiji waters, Gundermann *et al.* (1983) observed that the *S. vermiculatus* mainly grazed on mangrove roots and other hard substrates, and the stomach was filled with pieces of mangrove bark and numerous algae species such as *Enteromorpha* and seagrasses. Adult fishes (>120 mm in length) were found in several habitats, primarily in mangrove swamps and coral reefs. In the present study, the fish length group 34 to 37 cm was found to have the highest mangrove remains in the stomach indicating that fishes in this size group mainly dwell in the mangrove habitat.

Seasonal feeding intensity

Month-wise percentage of feeding intensity of S. vermiculatus has been presented in Fig. 4. The maximum percentage (53.33%) of empty stomachs was observed in February, coinciding with the breeding season of fish, and the minimum percentage (13.33%) of empty stomachs was observed in the month of May. It is well known that most of the dietary energy is diverted for gonadal maturation during the spawning season, leading to decreased feeding. Reduced feeding intensity in fishes during the spawning season has also been reported by Borah *et al.* (2016); Bhalekar *et al.* (2016) and Sawant *et al.* (2017).

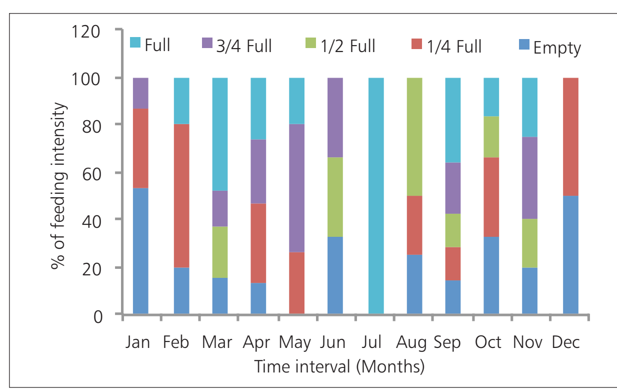

Fig. 4. Month-wise percentage of feeding intensity of *S.vermiculatus*

Sex ratio

The periodic disparity in the population sex ratio of *S. vermiculatus* is shown in Table 1. A significant difference ($P<0.05$) was noted in the sex ratio throughout the year. In all months, females outnumbered males in our study. During the breeding season, the same trend was observed. The highest variation in the sex ratio of male to female was observed in September while the lowest was in December.

Table 1. Month-wise male and female number and sex ratio of *S. vermiculatus*

Month	Male	Female	Sex ratio (M: F)	Significance at 5% level
February 2017	10	24	0.42:1	S
March 2017	8	56	0.14:1	S
April 2017	12	46	0.26:1	S
May 2017	12	50	0.24:1	S
June 2017	10	44	0.23:1	S
July 2017	6	38	0.16:1	S
August 2017	10	48	0.21:1	S
September 2017	4	36	0.11:1	S
October 2017	10	26	0.38:1	S
November 2017	6	26	0.23:1	S
December 2017	10	18	0.56:1	S
January 2018	12	24	0.50:1	S

S= significance at 5% level ($P<0.05$)

In Fiji waters, the ratio for the same species is one female to two males during the spawning season and three females to one male at other times (Gundermann *et al.*, 1983) which confirms the present findings. The mean sex ratio in *S. canaliculatus* was dominated by females except in September and October in the Gulf of Mannar (Anand and Reddy, 2017) In Red Sea, Hashem (1983) reported a slight dominance of female *S. rivulatus* (1:1.3) in populations.

Gonadosomatic Index (GSI)

The gonadosomatic index is an indicator of the state of gonadal development. In the present study, an increase in GSI value indicates increasing development of the gonads from October to April with the peak in the month of February and March which indicates the peak spawning season of this fish (Fig. 5). Alcala (1979) reported that GSI value of *S. vermiculatus* was highest during November to February when the temperature was highest in Philippines waters.

Anand and Reddy (2017) reported that the spawning season of *S. canaliculatus* in the Gulf of Mannar takes place in November and March with a peak in January based on GSI values. The peak values of GSI coincide with the spawning season in *S. canaliculatus* (Grantcourte *et al.*, 2007; Al-Marzoiqi *et al.*, 2011). Sadovy (1998) has mentioned spawning to occur between March-June along the Hong Kong coast. Soh and Lam (1973) observed the spawning period of *S. canaliculatus* in Singapore from January to April. Along the Ratnagiri coast, Metar *et al.* (2019) observed two spawning peaks in *S. canaliculatus* during November-January and April-May. The spawning season of rabbitfish observed in the present study is comparable to those earlier reported from different regions depicted in Table 2.

Size at first maturity

The size at first maturity is estimated as 32.73 cm in females and 28.13 cm in males (Fig. 6). The present study observed that the male reached sexual maturity at a smaller length than the female. Anand and Reddy (2017) estimated the size at first maturity of *S.canaliculatus* along the Gulf of Mannar,

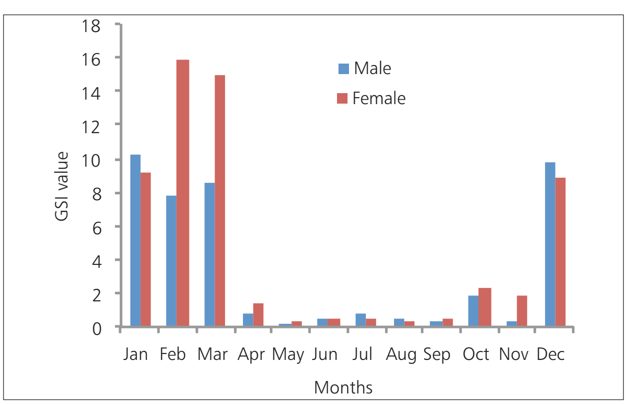

Fig. 5. Month-wise estimated gonadosomatic index of *S.vermiculatus*

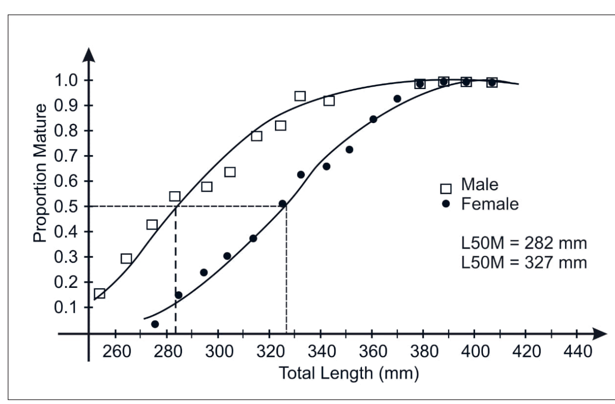

Fig. 6. Size at first maturity of *S.vermiculatus*

Table 2. The spawning season of rabbitfish in different regions

Species	Region	Spawning season	References
S. canaliculatus	Singapore	Jan-Apr	Soh and Lam (1976)
	Philippines	Jan-Apr	Laviña and Alcala, 1974
	Palau	Feb-Jun	McVey, 1972
	Hongkong	Mar-Jun	Tseng and Chan, 1982
	Southern Arabian.Gulf	Mar-May	Al-Ghais, 1993
	West coast India	Nov.-Jan, April-May	Metar *et al.* (2019)
S. argenteus	Philippines	Feb-Sept	Luchavez and Carumbana, 1982
S. fuscescens	Japan	July-Aug	Okada, 1966
S. luridus	Mediterranean	Apr-Sept	Popper and Gundermann, 1975
S. rivulatus	Mediterranean	May-Aug	Popper and Gundermann, 1975
S. guttatus	Philippines	whole year	Soletchnik 1984, Hara *et al.* 1986
S. lineatus	Palau	Feb-Mar	Lam 1974
S. vermiculatus	Fiji	Sept-Feb peak in Nov-Feb	Gundermann, *et al.* 1983
	Ratnagiri, Northwest coast of India	Oct to April peak in Feb-Mar	Present study

as 132 mm and 139 mm in males and females respectively. In the Mediterranean region, George (1972) found that gravid individuals of *S. rivulatus* occurred between 120 and 160 mm in size. Various species of Siganids attained sexual maturity in less than a year, but their size could vary from species to species. Tacon *et al.* (1989) stated that *S. canaliculatus* matures earlier than the other species of rabbitfish. Alcala and Alcazar (1979) found that females and males of *S. canaliculatus* attained maturity at 11.6 cm and 10.6 cm standard length, respectively. Earlier workers have also reported the size of maturity of various siganids species varied from 12 to 31 cm (Manacop, 1937; Westernhagen, 1975; Tseng and Chan, 1982; Bwathondi, 1982; Hashem, 1983; Tacon *et al.*, 1989). Juario *et al.* (1985) found that males and females of *S. guttatus* (hatchery-bred) sexually mature in l0 months at 19 cm fork length and 12 months at 21.5 cm fork length, respectively. Soletchnik (1984) observed captive females of *S. guttatus* attained sexual maturation at a size of 200 g (34 cm fork length) and hatchery-bred ones at 260 g (20-22 cm length).

Fecundity

The fecundity of *S. vermiculatus* was estimated by observing the fishes with 36.5-41.3 cm body length and 1120- 1765 g body weight varied from 780136 to 1256674 eggs per female (Table 3). The ovary weight was observed from 185 g to 320 g. Absolute fecundity of *S. canaliculatus* ranges from 166000 to 1,000,000 eggs reported by many authors (Lam, 1974; Hasse *et al.*, 1977; Alcala and Alcazar, 1979; Woodland, 1979; Tseng and Chan, 1982; Madeali, 1985; Al Ghais, 1993). Soletchnik (1984) reported fecundity of *S. guttatus* between 8,00,000–1,200,000 eggs. Hussein (1986) estimated the fecundity of *S. rivulatus* as 1,03,200 to 3,96,600 eggs. In the present study, we showed that this is highly fecund fish and suitable for the development of hatchery technology for commercial aquaculture practice.

Table 3. Fecundity of *S. vermiculatus*

Sr. No.	Total length (mm)	Body weight (g)	Ovary weight (g)	Observed fecundity
1.	375	1375	180	7,80136
2.	413	1530	200	1170205
3.	405	1500	210	11,70205
4	390	1500	200	10,68863
5	375	1370	185	7,92713
6	373	1425	185	8,03589
7	365	1120	195	8,92302
8	370	1195	200	9,78457
9	383	1510	195	8,26352
10	403	1630	220	11,93,245
11	365	1120	195	8,92,302
12	375	1075	190	8,03,589
13	383	1120	195	10,68,863
14	415	1765	320	12,56,674
15	413	1440	198	11,60,411
16	376	1205	210	9,98,416
17	383	1510	195	8,26352
18	402	1625	225	11,91,248
19	355	1070	190	8,90,460
20	378	1080	195	9,20,581

Conclusion

This study revealed that *S. vermiculatus* is herbivorous in feeding habits and mainly feeds on algae and seaweeds. Reproductive biology study shows that this fish is highly fecund. Information provided on biological aspects such as food and feeding habits, maturity size, sex ratio and reproductive potential will be helpful in a possible culture of this species in this region.

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