Indian J. Fish., 65(2): 42-49, 2018
DOI: 10.21077/ijf.2018.65.2.65436-05

Biological aspects of spotted seerfish *Scomberomorus guttatus* (Bloch & Schneider, 1801) (Scombridae) from north-eastern Arabian Sea

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ABSTRACT

Spotted seerfish *Scomberomorus guttatus* (Bloch & Schneider, 1801) is one of the highly priced table fishes in India, which contributed 4.7% of all India scombrid fishery with 17,684 t landed in 2014. Its fishery is dominant in the Arabian Sea and northern Arabian Sea contributed 62% to India's spotted seerfish fishery. Biological information on *S. guttatus* is scarce and the same was studied during the period 2010-2014 from Maharashtra coast, north-eastern Arabian Sea. A total of 930 specimens (185-550 mm FL) collected from commercial landings were used for the study. Length-weight relation of pooled sexes was estimated as log (W) = -3.1988+2.66074 log (L) ($r^2 = 0.93$). Fishery was dominated by males with the sex ratio of 0.76:1. Relative fecundity ranged from 105-343 eggs g^{-1} of bodyweight. The length at first maturity (L_m) was estimated to be 410 mm TL for females. Mature and gravid females were dominant in May and August-November. Dietary studies (% IRI) showed dominance of *Acetes* spp.

Keywords: Arabian Sea, Diet, India, Indo-Pacific king mackerel, Reproductive biology, Scombridae, Spotted seerfish

Introduction

The Indo-Pacific king mackerel also known as spotted seerfish, *Scomberomorus guttatus* (Bloch & Schneider, 1801) is a coastal, pelagic scombrid fish, having a wide distribution in the Indo-Pacific from Persian Gulf to the Sea of Japan (Collette and Nauen, 1983). In 2014, the reported global catch of *S. guttatus* was 47,802 t, which increased from 6,282 t in 1950 to a peak in 58,394 t in 2009 (FAO, 2014), Indonesia, India, Iran and Myanmar being the major contributors. In 2014, the estimated catch of *S. guttatus.* from India was 17,684 t (CMFRI, 2015). It is one of the highly priced table fishes in India. Even though, this fish is caught all along the Indian coast, fishery is dominant only in the north-west (Gujarat and Maharashtra) and east coasts of India (West Bengal, Andhra Pradesh and Tamil Nadu) (CMFRI, 2015). Inspite of its high value and importance in commercial and artisanal fishery in the northern Arabian Sea, export of the species from India is limited due to its smaller size, non-availability of large size fishes in larger quantities for all seasons (Pers. Comm., Traders, Sassoon Dock, Mumbai).

Studies on biological aspects of *S. guttatus* from the Indian Ocean is sparse and limited to those of Vijayaraghavan (1955), Krishnamoorthi (1958), Jones (1961), Rao (1964), Kumaran (1964), Devaraj (1987, 1998), Naik *et al.* (1998), Devaraj *et al.* (1999), Muthiah *et al.* (2000; 2002), Kasim *et al.* (2002), Ghosh *et al.* (2009) and Rohit and Ghosh (2012). According to the IUCN Red List of Threatened Species, *S. guttatus* has been assessed as "Data Deficient" since species specific data is not available for making an assessment and possible catch mixing with *S. lineolatus* and *S. koreanus* in its wide distribution range (Collette *et al.,* 2011). Along the Maharashtra coast, *S. guttatus* supports year-round fishery, which contributes 17% of all India *S. guttatus* landings mainly from gillnets, trawl and purse seine. Given the commercial importance of the species and the limited reports on biology of *S. guttatus* from Maharashtra, this study was undertaken to explore the reproductive biology and diet of the species from Maharashtra during 2010-2014. Updated recent biological information of exploited species is important in promulgating effective management strategies to sustainably manage the resource.

Materials and methods

Catch and effort data from 1985 to 2014 was collected from the Fishery Resource Assessment Division (FRAD) of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), Kochi. Specimens for the biological studies were collected from the gillnetters and dolnetters (stationary stakenets operated in nearshore waters at depths up to 60 m) operated in the north-eastern Arabian Sea at 10-60 m depths and landed at Sassoon Dock, New Ferry Wharf and

Naigaon landing centres along the coast of Maharashtra, India during the period 2010 to 2014. Samples were transported to the laboratory and total length (TL), standard length (SL), fork length (FL) and weight measurements were taken to the nearest mm/g with digital scale/balance. Length-weight relationship was calculated as $W = a L^b$ (Le Cren, 1951), where, W is the weight of the fish in g, L is its fork length (FL) in cm, *a* the regression intercept and *b* is the slope. Sex ratio was estimated and a Chi-square test was performed to test the homogeneity of male and female distribution. Gonado-somatic index (GSI) was calculated using the formula GSI = (GW/BW)*100 (Parmeswaran *et al.,*1974) where, GW is the gonad weight and BW is body weight, both in g. Gonad stages were assessed using macroscopic as well as microscopic characters as per Wallace and Selman (1981). Ova diameter measurements were carried out from formalin preserved representative ovaries of each stage and analysed using image analyser (Motic BA 310). Fecundity was estimated from ripe ovaries characterised by hydrated translucent oocytes. Subsamples weighing from 0.1 to 0.5 g, equally distributed from the anterior, middle and posterior regions from ripe ovary were used to estimate fecundity. Length at maturity (L_m) was estimated using the logistic equation as outlined by King (1995) by fitting the fraction of mature fish (stage III and above) against the total length (TL). Spawning season was determined from the monthly proportion of gravid and ripe females (V and VI). The level of fullness (empty, 1/4, 1/2, 3/4 or full) of each stomach was recorded and prey items were identified to the lowest possible taxonomic unit, preferably to genus or species. Diet analysis was done using compound of indices, Index of Relative Importance (IRI) = (%N+% W)* %O (Pinkas *et al.,* 1971) modified as % IRI (Cortes, 1997), where N is the number of individuals of a given prey, W is the weight of a given prey category and O is the occurrence of the given prey category. Primer 6 software was used for analysis of seasonal changes and similarity in the diet (Clarke and Gorley, 2006).

Results

Fishery

In India, seerfishes have high consumer demand and high market value. Seerfish fishery contributes 1.3% of the all India marine capture fishery supported mainly by two species *S. commerson* (64%) and *S. guttatus* (36%) while catch contribution of *S. lineolatus* (0.02%) is meagre. *Scomberomorus guttatus* contributed 4.7% of all India scombrid fishery with 17,684 t landed in 2014. In Maharashtra, seerfish fishery was mainly supported by *S. commerson* (61%) and *S. guttatus* (39%). The latter species contributed 7,785 t in 2014 with gillnets contributing 49% followed by dolnet (19.5%), trawl (17%), purse seine (12%) and hooks and line (1.3%). Historically the contribution of *S. guttatus* to marine capture fishery of India was low and Maharashtra contributed 17% to Indian *S. guttatus* fishery for the period 1994-2014 (Fig. 1). During 2010-2014, the average landing of *S. guttatus* in Maharashtra coast was 2,046 t. The analysis of past catch data shows that the fishery in Maharashtra peaked to 6,437 t in 2008, however in the subsequent year it declined to 1,485 t possibly due to heavy juvenile bycatch in all gears in previous years (Fig. 1).

Along Maharashtra, for the period 2000-2014, gillnetters contributed major share of the landings (69%), followed by trawlers (17.9%), dolnetters (4.9%), purse seiners (4.7%) and hook and lines (3.5%) (Fig. 2). Average catch rates in the past 15 years in gillnetters, trawlers and seiners were 4.7, 1.9 and

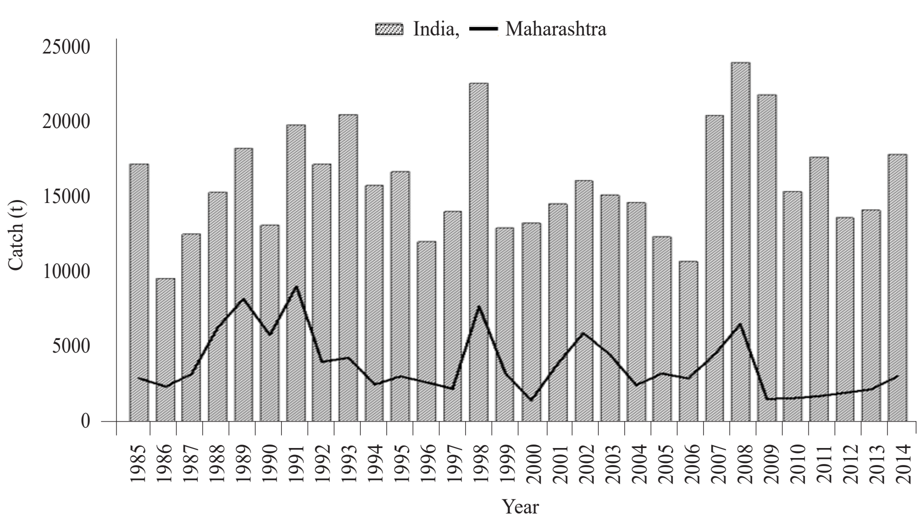

Fig. 1. All India estimated landings of *Scomberomorus guttatus* (1985-2014) and contribution from Maharashtra State

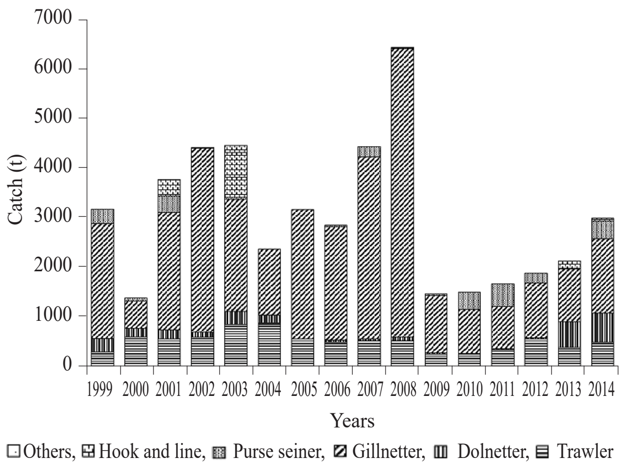

Fig. 2. Gear-wise contribution to *S. guttatus* fishery of Maharashtra

8.8 kg unit^{-1} respectively. Highest average catch rate was reported in 2008 (6.8 kg unit^{-1}) and the lowest was observed in 2001 (1.6 kg unit^{-1}). The average catch rate during the period of study was only 2.6 kg unit^{-1}. The average catch rate in gillnetters during 2000-2014 was high in 2008 (20 kg unit^{-1}) and the lowest in 2013 (2.82 kg unit^{-1}). Monthly fishery trend shows considerable increase in the catch from September to December with a peak in October. Size of *S. guttatus* in the commercial landings ranged between 170-610 mm FL with a mean length of 396 mm FL. (Fig. 3). However, landings from *dolnets* were mostly dominated by juveniles of size range 50-230 mm FL.

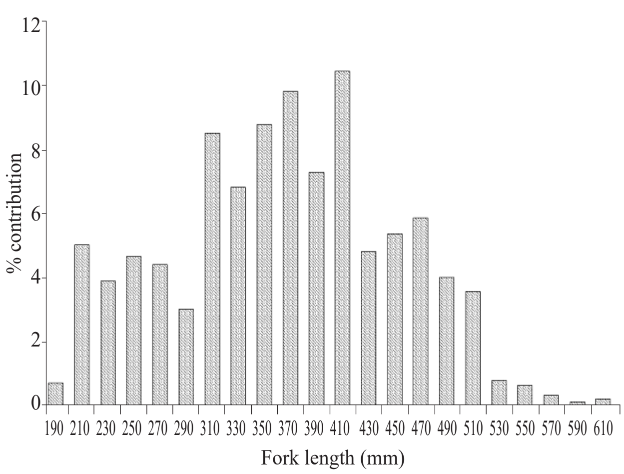

Fig. 3. Length frequency (pooled) of *S. guttatus* landed along Maharashtra coast

Length-weight relationship

A total of 774 individuals, comprising 440 males (205-550 mm FL) and 334 females (254-490 mm FL) were used to generate length-weight relationships for this species. The relationship between fork length and weight for males and females were estimated as follows:

Length-weight relationship (Males) : log (W) = -3.21666+2.632 log (L) (r = 0.93)

Length-weight relationship (Females) : log (W) = -3.36352+2.673 log (L) (r = 0.93)

The regression coefficients of male and female did not show significant difference at 5% level of significance. Hence the male and female data were pooled and a common length-weight relation was calculated as:

Length-weight relation (pooled sexes): log (W) = -3.31988+2.66074 log (L) (r = 0.93)

The *b* value estimated was less than 3 (p= 0.004) and the fish showed negative allometric growth.

Sex ratio and reproductive biology

A total of 930 individuals (185-550 mm FL) of *S. guttatus* were collected for biological studies, comprising of 440 males, 334 females and 156 indeterminant juveniles. The overall sex ratio of female to male was 0.76:1. Month-wise analysis of pooled data shows male predominance in the catch (Fig. 4). The chi square test showed significant dominance ($p<0.05$) of males in the exploited population during February-March and of female during May ($p<0.05$).

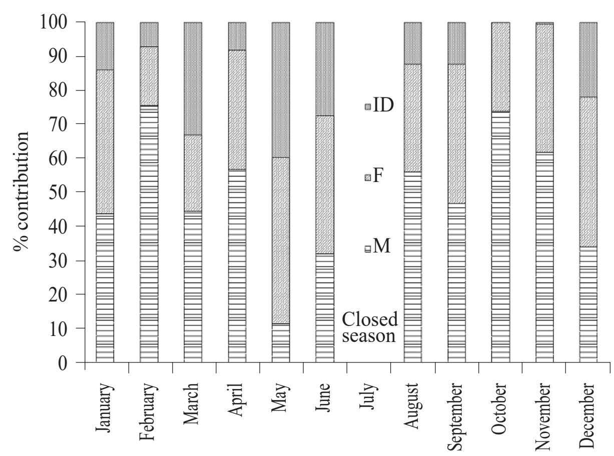

Fig. 4. Monthly % contribution of females and males to *S. guttatus* fishery

Length at maturity (L_m) for females was estimated to be 410 mm TL (Fig. 5). However, mature specimens were recorded in the catch from 310 mm TL onwards. GSI showed two distinctive spawning peaks in a year. The first peak was observed during May (2.1) and the second mode started from August to November with a peak in October (1.7) Ova diameter measurements indicated the presence of both maturing and mature ova in the ripe ovaries. The maturing ova measured from 0.33 to 1.1 mm in dia whereas the mature or ripe ova measured from 0.97 to 1.52 mm. Relative

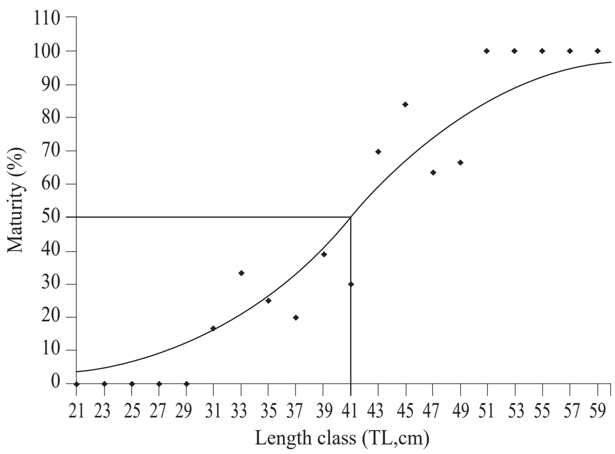

Fig. 5. Length at 50% maturity (L_m) for female *S. guttatus* from Maharashtra coast

fecundity ranged between 105-343 eggs g^{-1} body weight with an average of 255 eggs g^{-1} body weight. Absolute fecundity ranged from 1,09,000-4,27,300 eggs.

Dietary analysis

Stomachs of 930 specimens were examined for understanding the feeding preference and diet content of *S. guttatus* from northern Arabian Sea, of which 22.8% were empty, 55.8% with trace contents, 4.4% half full, 1.3% three quarters full and 3.3% full. Monthly stomach fullness index analysis shows that gut condition was dominated by trace or empty.

The stomach contents analysis revealed that *S. guttatus* fed on a variety of prey items dominated by crustaceans (87.2% IRI) followed by finfishes (12.5% IRI) and cephalopods (0.3 % IRI). Identifiable prey items belonged to seven families of teleosts, two families of crustaceans and one family of cephalopod. Most of the identified teleosts belonged to pelagic or demersal groups. The diet contained pelagic fishes belonging to families Clupeidae, Engraulidae, Trichiuridae and Carangidae while the demersal fishes of Leiognathidae, Lactariidae and Gobiidae were seen in the diet. Crustaceans were found almost in all the months forming 87% IRI of the dietary items (Table 1). The most commonly observed prey was *Acetes* spp. (Sergestidae). The most common teleosts in the diet belonged to the families Clupeidae (5.9% IRI) and Carangidae (4.63% IRI). Most of the fish were in semi-digested condition and the major species was *Sardinella longiceps* (4.19% IRI) and unidentified carangids (2.6 % IRI). Even though the %IRI was high for *Acetes* spp., the weight contribution (%W) was high for *S. longiceps* (20.3% W) and unidentified carangids (18.9% W) followed by *Decapterus russelli* (12.9% W). Family Engraulidae contributed 1.82% IRI in the diet. Cephalopods had very little importance (0.25% IRI) in the diet and the major share was contributed by *Uroteuthis (P.)* sp. (0.15% IRI). Other prey items of very little importance were Leiognathidae (0.05% IRI), Trichiuridae (0.09% IRI), Lactariidae (0.01% IRI) and Gobiidae (0.003% IRI).

Table 1. Percentage contribution by number (%N), weight (%W), occurrence (%O) as well as %IRI of prey items in the stomach contents of *Scomberomorus guttatus* from north-eastern Arabian Sea

Group/family	Prey items	%N	%W	%O	% IRI
Crustaceans					
Sergestidae	*Acetes* sp.	82.33	10.49	9.04	87.15
	Nematopalaemon tenuipes	0.88	0.54	0.54	0.08
Squillidae	*Squilloides leptosquilla*	0.18	0.63	0.11	0.01
Teleosts					
Carangidae	*Decapterus russelli*	2.12	12.94	1.31	2.04
	Unidentified carangid	1.94	18.86	1.20	2.59
	Stolephorus sp.	3.71	8.14	1.42	1.74
Clupeidae	*Sardinella longiceps*	4.42	20.26	1.63	4.19
	Escualosa thoracata	1.77	8.36	1.63	1.72
Leiognathidae	*Leiognathus* spp.	0.18	4.26	0.11	0.05
Engraulidae	*Coilia* sp.	0.35	1.89	0.33	0.08
Trichiuridae	*Eupleurogrammus muticus*	0.35	2.57	0.22	0.07
	Trichiurus lepturus	0.18	2.37	0.11	0.03
Lactariidae	*Lactarius lactarius*	0.18	0.24	0.11	0.004
Gobiidae	*Trypauchen vagina*	0.18	0.08	0.11	0.003
Cephalopods					
	Uroteuthis (P.) sp.	0.35	6.12	0.22	0.15
	Unidentified squids	0.88	2.24	0.33	0.11

Feeding analysis using MDS plot showed 20% similarity in feeding throughout the year except in April and June. Sixty percent feeding similarity was observed during October-November and 80% similarity was observed in December and February (Fig. 6). Two distinctive clusters of 40% similarity in feeding habit of spotted seerfish were observed. The first cluster was during May, September, October and November and the second cluster comprised of December, January, February and March. Month-wise analysis revealed that, in the first cluster, the major food items were *Acetes* spp. and *Sardinella longiceps* which formed 68% and 15% of the diet respectively. The second cluster was dominated by Carangids (50%) and *Acetes* spp. (31%) followed by *Stolephorus* sp. (16%). Bray Curtis analysis showed that month-wise feeding pattern in the fourth quarter of the year (September-December) had 60% similarity in feeding habits (Fig.7).

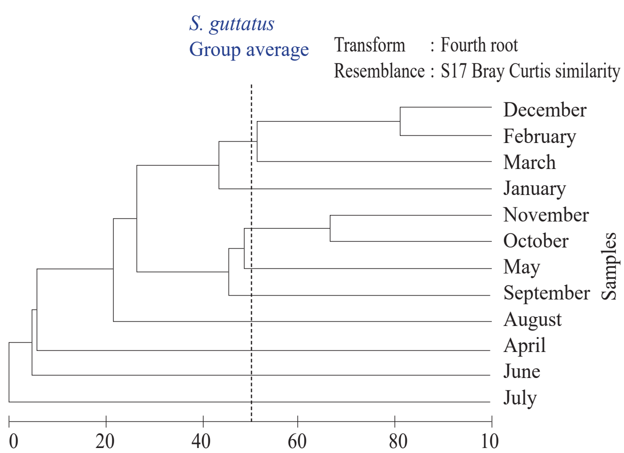

Fig. 6. Monthly feeding similarity analysis of *S. guttatus* using MDS plot

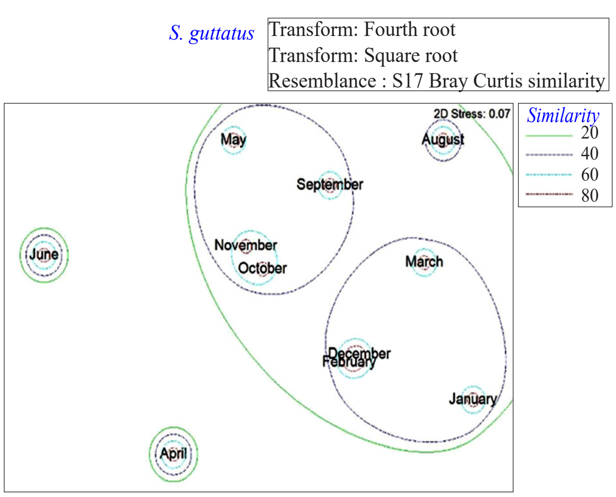

Fig. 7. Monthly feeding Bay Curtis analysis of *S. guttatus* in PRIMER6

Discussion

India is one of the major contributors to spotted seerfish fishery (Devaraj and Kasim, 1998) which formed 38.5% of catch reported from the Indian Ocean region during 2014 (IOTC, 2015). In Maharashtra, the spotted seerfish catch decreased to 1,485 t in 2009 after the peak landings of 6,437 t in 2008 and since then showed a slight increasing trend. It was observed that there was drastic reduction in fishing effort since 2008 (40%) which might have resulted in the poor landings in the subsequent years. Injudicious exploitation of juveniles by non-selective gears like *dolnets* and trawls might have affected the biomass of the stock which reflected in the declining seerfish landings of Maharashtra. A similar decreasing trend was observed in northern Arabian Sea, off Veraval during 2000's by Ghosh *et al.* (2009). The fluctuation in the catch of this pelagic fishery resource could also be due to the cumulative effect of variations in environmental factors, fishing effort and recruitment/growth overfishing (Vivekanandan *et al.,* 2005; Kripa *et al.,* 2015). Muthiah *et al*. (2002) recorded lengths of spotted seerfish landed in the fishery ranging from 160 to 620 mm at Veraval, 160 to 580 mm at Mangalore with the major fishery forming group at 280-540 mm in gillnets at Veraval and 360-480 mm at Mangalore. Ghosh *et al.* (2009) recorded a size range of 200-580 mm in gillnet fishery of Veraval with mean size of 426.5 mm. The size range of 250-720 mm was reported by Naik *et al.* (1998) from the west coast of India (between Calicut and Raigad, 11-18ºN) during trawl surveys. The present results show that the mean length is smaller (396 mm), than that reported from the gillnet fishery of Mangalore (420 mm), Veraval (440 mm and 427 mm reported by Muthiah *et al.,* 2002 and Ghosh *et al.,* 2009) respectively and trawl surveys along the west coast (450 mm) (Naik *et al.,* 1998). Even though fishes having sizes below 100 mm are common in *dolnet* landings as seen during the present study, the commercial fishery was mainly constituted by 310-470 mm sizes, which was similar to the *S. guttatus* fishery forming size class of 360-480 mm at Mangalore (Muthiah *et al.,* 2002). The fishery forming groups and mean length of the fishes landed are different in different gears due to different mesh sizes and selectivity of gears used. However, it is also important to note that mean size of fishes can also reduce due to increasing fishing effort on population (Law, 2000; Ernande *et al.,* 2004), which is evident from the number of fishing vessels operated along the coast of Maharashtra (CMFRI, 2010).

The length-weight relationship shows that the species has a negative allometric growth (b=2.67). Froese (2006) stated that this condition occurs when large specimens have changed their body shape to become more elongated or the small specimens were in better nutritional condition at the time of sampling. The present value also supports the suggestions of Carlander (1969) that the exponent b value should fall between 2.5 to 3.5. The magnitude of b may also change with metamorphosis and on onset of maturity (Frost, 1945). Almost similar value of b (2.82 and 2.88) was estimated for spotted seer fish by Naik *et al.* (1998) and Rohit and Ghosh (2012), respectively and reported as isometric growth. As most of the large specimens in the representative sample were thicker than smaller specimens, the term negative allometric can be used since $b<3$ (Froese, 2006). Adult *S. guttatus* also exhibited negative allometry ($b = 2.12$) from Pakistan waters (Ahmad *et al.,* 2014). For *S. guttatus* measuring 320 to 510 mm in length, *b* value of 2.75 was reported by Abdurahiman *et al.* (2004) from Karnataka, India. Bal and Rao (1984) reported female dominance in the seerfish fishery, which is in contrary to current results from Maharashtra coast, where males dominated the catch.

Krishnamoorthi (1958) reported that *S. guttatus* from Rameswaram region had an estimated length at maturity of 360-400 mm TL which is slightly smaller compared to the present result. Length at maturity for females estimated in the present study (410 mm) was nearer to the estimate of 405 mm TL as reported by Devaraj (1987) from Palk Bay. He also stated that the ripe females were occurring from 330-360 mm and in the present study it was from 310 cm which suggests possible early maturation of the fish. Krishnamoorthi (1958) reported the spawning season of spotted seerfish to be from March to October with peak in May-June. Devaraj (1987) reported that the fish had an extended spawning season with three distinctive periods of spawning from January-February, March-July with a peak in April-May and the third one in August. However, both these studies were from the east coast of India and in the present study along the west coast, only two spawning periods were observed. The peak spawning in the present study was similar to the earlier work of Krishnamoorthi (1958) and Devaraj (1987) as the fish mainly spawns during May. Higher values of gonado-somatic index (GSI) also coincided with peak periods of spawning. The size of the ova measured during the present study was similar or even slightly higher than the earlier studies. Devaraj (1987) reported the size of the maturing ova to be 0.12-0.97 mm and the size of ripe ova to be 0.96-1.42 mm. In the present study, size of the maturing ova ranged from 0.33-1.1 mm and ripe ova ranged from 0.97-1.52 mm. The increase in the size may be attributed to the ecology of the north-eastern Arabian Sea. The absolute fecundity of the spotted seerfish in the present study was estimated to range from 1,09,000 to 4,27,300 which is less than that reported by Bal and Rao (1984).

In the present study, 55.8% of the guts were observed with trace content of food. Venkataraman (1960) had reported that 65% specimens examined at Calicut (136-496 mm) had empty stomachs. Present study showed that, *S. guttatus* from north-eastern Arabian Sea fed on a variety of prey items; however, prey items were different from earlier report from the east coast by Devaraj (1998) who observed good feeding condition with a dominance of teleost fishes as the major food item at Gulf of Mannar and Palk Bay. Rao (1964) from Visakhapatnam reported that teleosts contributed 91.8% of *S. guttatus* diet mainly supported by whitebaits, *Sardinella* sp. and *Dussumieria* sp., followed by 4.4% crustaceans with *Acetes* sp. as major item. The present study revealed that in north-eastern Arabian Sea region, spotted seerfish mainly fed on non-penaeid shrimps (87% IRI) contributed by *Acetes* sp. This is mainly due to the abundance of *Acetes* sp. in this region which is the single most important group of organism preyed upon by a majority of carnivorous fishes in the coastal waters of north-eastern Arabian Sea (Deshmukh, 2007). There was a clear difference in the food components with two different clusters in a year with the dominance of *Acetes* sp. and carangids in the present study. Vijayaraghavan (1955) reported that *S. guttatus* was a voracious feeder and suggested that the diet component changes with change in the habitat and season. The same phenomenon was observed in the present study along Mumbai coast. However, it is also well understood that the IRI values can be highly variable depending on the numbers of prey observed in the stomach. In the present study, the high % IRI recorded for crustaceans could be attributed to the huge number (%N) of *Acetes* spp. in the diet of *S. guttatus*. The same can be considered as the reason for the feeding similarity in different seasons. Devaraj (1998) stated that the main food item of *S. guttatus* from Gulf of Mannar was *Sardinella* sp. (60% IP) and whitebaits (35.3% IP) and a similar feeding pattern was observed from Palk Bay with *Sardinella* sp. (92.2% IP) and whitebaits (7.2% IP). Kumaran (1964) reported that the juveniles of *S. guttatus* from Vizhinjam (southern coast of India) mainly fed on whitebaits, *Stolephorus commersonnii* (47% O) and other clupeids (23.1% O). This particular feeding pattern could be due to the dominance of clupeids (lesser sardines and anchovies) in southern and south-east coast region which is totally different from north-eastern Arabian Sea where the main prey group dominating the habitat is non-penaeid shrimps. As there is presence of coastal fishes in the diet content, it can also be suggested that *S. guttatus* occurs in nearshore, pelagic waters.

This study provides detailed biological information on *S. guttatus* from northern Arabian Sea which will form important inputs for sustainable management of the stock in the Indian Ocean region. The increasing pressure on coastal waters of India either by developmental activities or by fishing pressure is a matter of concern. Implementation of already existing rules pertaining to fisheries management is an issue in addition to ruling out of very old policies and strict implementation.

Acknowledgements

Authors thank the Director, ICAR-CMFRI, Kochi for the support and facilities provided. The authors also thank Swapnil Tandel, Bala Mhadgut, Dhanasree and all others who assisted in the field and laboratory.

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Date of Receipt : 14.12.2016
Date of Acceptance : 02.05.2018