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Seriolina nigrofasciata (Ruppel, 1829), its fishery and biological aspects off south-west coast of India

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ABSTRACT

A comprehensive study on fishery, length-weight relationship, trophodynamics and reproductive aspects of the blackbanded trevally *Seriolina nigrofasciata* (Ruppel, 1829), collected during January 2013 to December 2017 from fishing vessels operating along eastern Arabian Sea off south-west coast of India was conducted. Among the maritime states of the country, Karnataka was the major contributor (53.9%) followed by Kerala (24.1%), Maharashtra (16%) and Tamil Nadu (4.3%). In Karnataka, 99.5% of the blackbanded trevally catch was exploited by trawl net and rest by outboard gillnets (0.5%). The total length ranged from 16.3 to 57.5 cm with fishes in the size range of 24 to 36 cm forming 80.8% of the catch. The length-weight relationship estimated showed a negative allometric growth for both sexes with b values of 2.595 for females and 2.504 for males. The estimated 'a' values for females and males were 0.00013 and 0.00021 respectively. In all, fifteen prey items under three major groups (teleosts, cephalopods and crustaceans) comprised the diet, with teleosts (73.23%) being the predominant food item followed by cephalopods (26.53%) and crustaceans (0.24%) in terms of index of relative importance (IRI). Overall sex ratio (male: female) of 1:1.15 indicated a slight dominance of females over males. The length at first maturity was estimated at 25.0 cm for male and 27.0 cm for female. The availability of mature and spent specimens all through the year implied that the species has prolonged spawning period with a peak during the summer season (March-May) and a minor secondary peak in post-monsoon season (October to December).

Keywords: Blackbanded trevally, Diet, Reproductive biology, *Seriolina nigrofasciata*, Trophodynamics

Introduction

Blackbanded trevally, *Seriolina nigrofasciata* (Ruppel, 1829) is distributed all along the Indo-West Pacific, from South Africa to Sri Lanka, along the Red Sea and Persian Gulf (Smith-Vaniz, 1986), north to southern Japan and south to Queensland, Australia (Randall, 1995) in a depth range of about 20 to 150 m (Sommer *et al.*, 1996). A fluctuating trend in the global production of *S. nigrofasciata* during 1994 to 2011 has been reported (Smith-Vaniz and Williams, 2016) with the highest catch of 9,384 t in 2002 and the lowest catch of 1,265 t in 2010. Blackbanded trevally is a non-schooling fish belonging to Carangidae family. It occurs largely along offshore continental shelf areas having rocky bottom (Kuiter and Tonozuka, 2001). This species is targeted almost all along its range (Rumpet *et al*., 1998) and exploited by gillnets, traps, trawls, seines and hand lines (Al-Khayat and Al-Ansi, 2007; Anam and Mostarda, 2012), marketed in fresh form and salt dried (Smith-Vaniz, 1984). Regular fishery of blackbanded trevally by trawls in substantial amounts and gillnets in small numbers operating at 30-70 m depth zone around India and Gulf of Mannar has been documented (Abdussamad *et al.,* 2008). The maximum recorded length of this species was 110.8 cm, weighing 9.4 kg, caught by hook and line off Jaffrabad, Veraval (Ghosh *et al*., 2009). A decline in population of this species is not being reported although it is commercially targeted almost throughout its range and no species specific conservation efforts are in place. However, its occurrence range overlaps several marine protected areas (IUCN and UNEP, 2014).

Detailed comprehensive study on fishery, food and feeding as well as reproductive aspects of blackbanded trevally has not so far been reported from any part of the world. This study was conducted for five years from January 2013 to December 2017 to investigate the fishery, feeding behaviour and reproductive aspects of *S. nigrofasciata* along the eastern Arabian Sea off south-west coast of India and this forms the first comprehensive report on the species.

Materials and methods

Details on the landings of *S. nigrofasciata* along Indian coast during 2013-2017 by various commercial fishing vessels were collected from the National Marine Fisheries Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), Kochi. Fish samples for biological investigations were collected on a weekly basis from Mangalore and Malpe fishing harbours of Karnataka during January 2013 to December 2017 from trawlers, since 99.5% of the catch was landed by trawlnets. Samples were collected during all the months except in June and July when a ban on operation of mechanised fishing vessels was in place. Total length and weight of 393 female and 341 male fishes were measured to the nearest cm and 0.1 g respectively. Length-weight relationship was estimated for males and females separately using exponential curve fitting as per the formula $W = aL^b$. The parameters 'a' (intercept) and 'b' (growth coefficient) of length-weight relationship was estimated by least square method (linear regression analysis) on log transformed data and the degree of association between variables (W and L) was calculated by the determination coefficient (r^2).

Feeding and reproductive aspects were studied based on the analysis made on 734 fishes. The stomachs taken out from the individual fishes after careful dissection were preserved for more detailed analyses. The stomach fullness was classified based on the visual observation as: empty, trace, one-fourth full, half full, three-fourth full and full. Total weight of the contents in the stomach was recorded and prey items were broadly categorised into fishes, crustaceans and cephalopods and weight of each prey item was recorded separately. Weightage was given to the various food items encountered in the stomach using points method. The prey items present in the stomach were identified up to the generic/species level following the keys and identifying descriptions given by Fisher and Whitehead (1974) and Smith and Heemstra (1986). The index of relative importance (IRI) was determined for each diet component in the stomach (Pinkas *et al*., 1971). Based on the macroscopic appearance of the testes and ovary and the space occupied by them in the body cavity, maturity stages of males and females were determined. The ICES scale described by Lovern and Wood (1937) was used with suitable modifications to classify the maturity stages. Homogeneity in distribution of male and female was determined by Chi-square test using monthly sex ratio. Length at first maturity (L_m) was estimated by fitting the mature fraction of fish (stage III and above) against length interval using nonlinear least square regression method (King, 1995). Gonadosomatic index (GSI) was calculated considering the gonad weight and total weight of fish using the equation:

GSI= [Gonad weight/ (Body weight-Gonad weight)]* 100

Results and discussion

Trends in fishery

Five yearly trends (2012-2017) in the landings of *S. nigrofasciata* in Karnataka were almost similar to that of the country, with maximum landings of 295 t and 255 t during 2015 in India and Karnataka respectively (Fig. 1). The minimum landing of 119 t was recorded in India during 2016 and 28 t in Karnataka during 2017. The contribution of Karnataka to the total landings of blackbandded trevally of India ranged between 19.45% (2017) and 86.3% (2015) with a five yearly average contribution of 53.9%. A perusal of the five yearly mean landing value along different states revealed Karnataka to be the major contributor (53.9%), followed by Kerala (24.1%), Maharashtra (16%) and Tamil Nadu (4.3%).

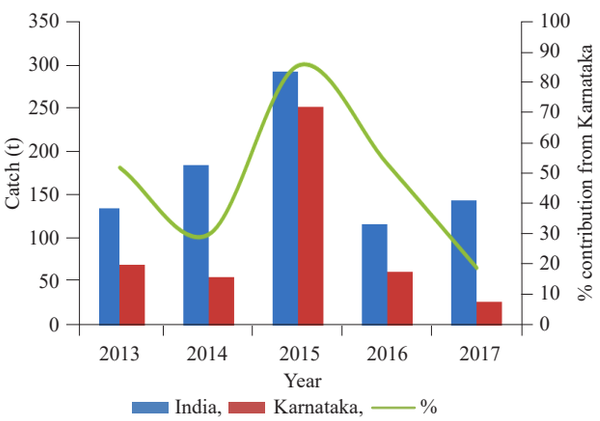

Fig. 1. Landings of *S. nigrofasciata* in India and Karnataka

Puduchery and Odisha contributed less than 1% (Fig. 2) to the total landings of the country. In Karnataka, trawlnet contributed 99.5% of the total landings of blackbanded trevally and rest was by outboard gillnets (0.5%). Among trawlnets, 98.9% of the catch was from multiday trawlers and only 1.1% was from the trawls operating for short duration and mostly for a day. The exploitation of this fish by single day trawls, outboard gillnets and multiday trawl nets confirmed its availability in both inshore and deeper areas. The availability of this fish all along Indo-west Pacific region (Smith-Vaniz, 1984) in a depth range of about 20 to 150 m has been well documented (Sommer *et al.,* 1996). Globally, it is exploited by gillnets, traps, trawls, seines and hand lines in almost all along its distributional range (Al-Khayat and Al-Ansi, 2007; Anam

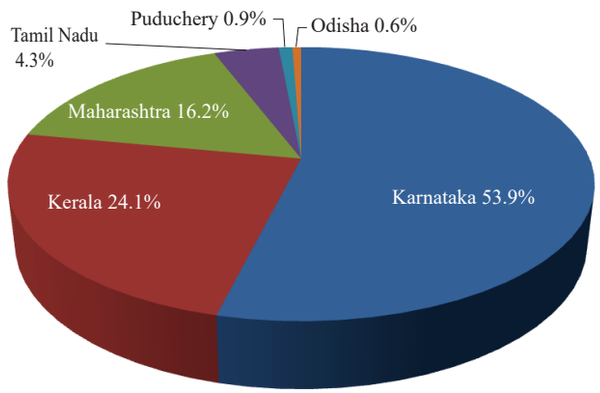

Fig. 2. State-wise (%) mean landings (2013-2017) of *S. nigrofasciata* in India

and Mostarda, 2012). The presence of this fish around Indian waters including Gulf of Mannar and Andaman Islands forming a regular fishery in trawlnets and a minor fishery in gillnets between 30 and 70 m depth has been reported (Abdussamad *et al*., 2008).

Length distribution

The total length of sampled *S. nigrofasciata* ranged from 16.3 to 57.5 cm and fishes in the size range from 24 to 36 cm dominated and formed 80.8% of the catch (Fig. 3). The estimated annual mean length was 28.9 cm. In comparison with the present study, Qamar and Panhwar (2017) reported a lower length range (15.3-35.1 cm) from the northern Arabian Sea coast of Pakistan.

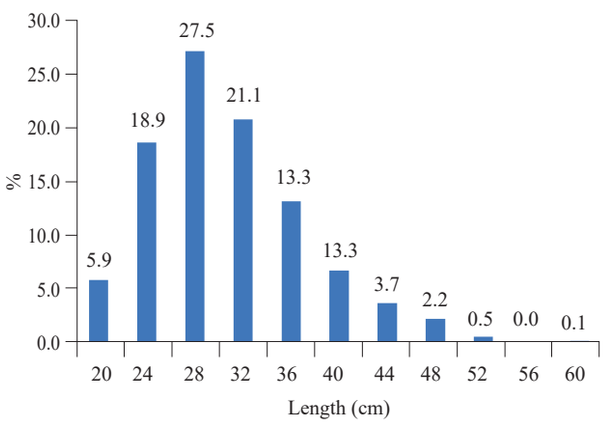

Fig. 3. Length frequency distribution of *S. nigrofasciata* in Karnataka (2013-2017)

The maximum length of 70 cm and weight of 5.2 kg (Smith-Vaniz, 1984) was reported from the Persian Gulf and the Oman Sea. However, in India, maximum length of 110.8 cm and weight of 9.4 kg was reported off Jaffrabad, Veraval (Ghosh *et al*., 2009). In contrast, the present study recorded a maximum length of 57.5 cm and weight of 2.1 kg.

Length-weight relationship

The length-weight relationship estimated for the blackbanded teavally showed a negative allometric growth for both the sexes with b values of 2.595 and 2.504 (Fig. 4 and 5) having high significant correlation (R^2 values of 0.975 and 0.981 at $p<0.05$ for females and males respectively). The estimated 'a' value for female and male was 0.00013 and 0.00021 respectively. The analysis of co-variance showed that there was no significant difference ($p<0.05$) in length-weight relation between the sexes ($F = 2.05$). The estimated coefficients 'a' and 'b' of blackbanded trevally were within the expected range estimated for different fish species (Froese, 2006). Marginally higher values of 'a' (0.040) and 'b' (2.766) were reported for *S. nigrofasciata* from northern Arabian Sea coast of Pakistan (Qamar and Panhwar, 2017). This variation in the degree of growth between the geographical locations could be due to the availability of food, diet selectivity, ecological conditions and physiology of animals (Bhattacharya and Acharya 1984; Jaiswar and Kulkarni, 2002; Froese, 2006).

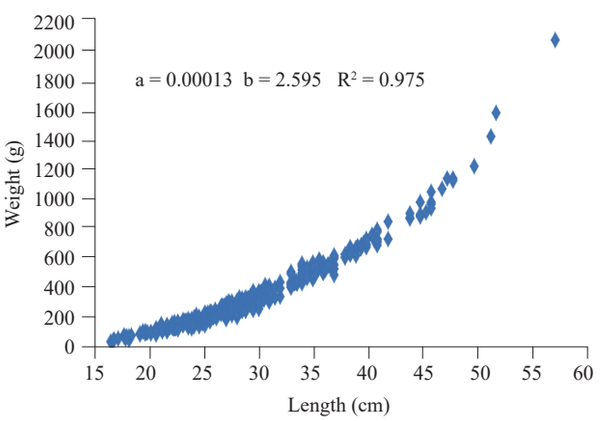

Fig. 4. Length-weight relationship in female *S. nigrofasciata*

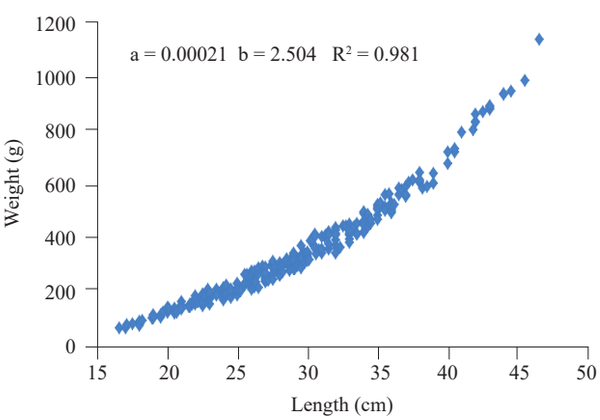

Fig. 5. Length-weight relationship in male *S. nigrofasciata*

Diet composition

Of the 734 guts analysed, 458 (62.4%) were empty, 49 (6.7%) had trace amounts of food, 63 (8.6%) were one-fourth full, 72 (9.8%) were half full, 10 (1.4%) were three-fourth full and 82 (11.2%) were with full stomachs (Fig. 6). Carangids are generally fast swimming carnivores (Honebrink, 2000) and usually prey on fishes by chasing and hunting the predators (Lower-McConnell, 1987). Some carangids follow special feeding behaviour with varied quantity of food intake during different seasons and also, during day and night, they use their sense of vision in capturing the prey (Sivakami, 1996). More numbers of empty stomachs is common in fishes which prey on other fishes (Faltas, 1993; Juanes and Conover, 1994) and probably is because of the spontaneous ejection of food during their struggle to get away from the trawlnets (Rohit *et al*., 2015) with 99.5% of blackbanded trevally being caught using trawlnets along Karnataka. Further, the high percentage of empty stomachs and stomachs with less content of food (trace and one-fourth) could be attributed to the high calorie content of the diet which demands only a lesser intake of food (Longhrust, 1957; Sreenivasan, 1974).

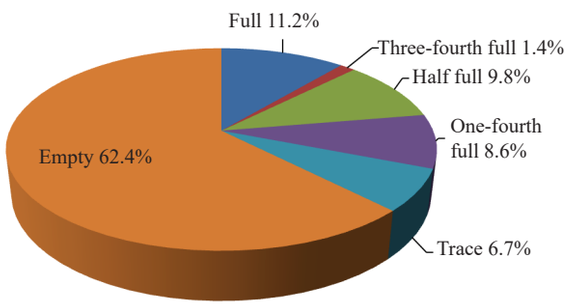

Fig. 6. Feeding intensity (%) observed in *S. nigrofasciata*

A total of 15 different prey items belonging to three major groups *viz*., teleosts (fish), cephalopods and crustaceans were observed. Frequency of occurrence (%F), abundance in terms of numbers (%N) and weight (%W), index of relative importance (IRI and %IRI) of various prey items observed in the gut are given in Table 1. The most predominant food item by frequency of occurrence (72.27%), number (77.01%), weight (80.22%), IRI (1940.75) and % IRI (73.23) was teleosts (Table 1). Eleven genera of fishes and remains of partially digested fishes comprised the teleost group. The most important teleost prey item encountered in the present study were mesopelagic and demersal species such as *Decapterus russelli*, *Nemipterus* sp., *Trachinocephalus myops*, *Saurida* sp., *Lactarius lactarius, Upeneus* sp., *Rastrelliger kanagurta, Platycephalus* sp., *Trichiurus* sp. and *Alectis* sp., in their order of abundance. Among the 11 teleosts observed, demersal fishes formed 66.6% (7 species/genera) of diet components in the gut of *S. nigrofasciata* and rest 33.4% was pelagic fishes (4 species/genera). Demersal fishes such as Leiognathids, Nemipterids and Synodontids as a major diet in the stomachs of *S. nigrofasciata* has been pointed out in an earlier study by Gunn (1990). Partially digested and

Table 1. Index of relative importance (IRI and % IRI) of prey items recorded in the stomachs of *S. nigrofasciata*

Diet components	% Frequency	% Number	% Weight	Index of relative importance	%IRI
Fish (Pooled)	72.27	77.01	80.22	1940.75	73.23
Decapterus russelli	15.45	12.74	29.44	651.97	24.60
Unidentified partially digested fishes	20.45	20.22	9.76	613.32	23.14
Nemipterus sp.	12.73	23.55	15.22	493.44	18.62
Trachinocephalus myops	6.82	5.54	6.88	84.71	3.20
Saurida sp.	3.64	3.32	9.34	46.04	1.74
Lactarius lactarius	3.64	3.60	2.37	21.72	0.82
Upeneus sp.	2.73	2.49	2.17	12.73	0.48
Rostrelliger kanagurta	2.27	2.22	1.78	9.09	0.34
Platycephalus sp.	1.36	1.11	1.11	3.03	0.11
Leiognathus sp.	1.36	0.83	0.85	2.29	0.09
Trichiurus sp.	0.91	0.83	0.90	1.57	0.06
Alectes sp.	0.91	0.55	0.38	0.85	0.03
Cephalopods (pooled)	25.00	21.33	19.13	703.25	26.53
Loligo sp.	20.45	17.45	15.19	667.71	25.19
Cuttlefish	4.55	3.88	3.94	35.54	1.34
Crustaceans	2.73	1.66	0.65	6.30	0.24
Shrimps	2.73	1.66	0.65	6.30	0.24

unidentifiable fish remains formed the second largest prey item after *D. russelli*.

Cephalopods were the second most dominant food item by frequency of occurrence (25.0%), number (21.33%), weight (19.13%), IRI (703.25) and % IRI (26.53). Among cephalopods, squids (*Loligo* sp.) and cuttlefishes were the major food components. Squids represented by *Loligo* sp., formed the major component of cephalopods (IRI of 94.9%) in the diet, while cuttlefishes were observed in less quantity (IRI of 5.1%).

Crustaceans, represented by only shrimps were encountered less frequently in minor quantities in the diet. *S. nigrofasciata* is a voracious carnivore feeding on fishes and cephalopods. Earlier studies have reported similar dietary constituents in carangids (Lower-McConnell, 1987; Sivakami, 1996; Honebrink, 2000). Observations on blackbanded trevally feeding mainly on demersal fishes, cephalopods and shrimps have been reported by Paxton *et al.* (1989) and Gunn (1990) from Australia and Randal (1995) from Oman waters.

Reproductive biology

Sex ratio

Among the 734 fish samples of *S. nigrofasciata* analysed during 2013-2017, 393 fishes were females (53.5%) and 341 were males (46.5%). Overall sex ratio (male: female) was 1:1.15, indicating a dominance of females over males. However, higher dominance by females during January-April and August-December and by males during May and September-November (Table 2) could be attributed to the difference in fishing due to the changes in the migration pattern of sexes to and from the fishing ground (Rajesh *et al*., 2015). Detailed quantitative investigations on reproductive biology of *S. nigrofasciata* are not available globally. Sex segregation during the pre-spawning period was observed in the carangid, *Caranx ignobilis* during summer spawning season in East Africa, wherein shoals of either males or females were only caught (Williams, 1965). A skewed sex ratio with two-third male was observed in *Atule mate,* a carangid fish in Kaneohe Bay, Hawaii and this was attributed to segregation of sex and differential movement in to the bay (Clarke, 1996).

Table 2. Sex ratio of *S. nigrofasciata*

Months	Sex ratio (Female/Male)	Chi-square value
January	1.57	2.2*
February	1.55	2.6*
March	1.12	0.2
April	1.50	0.6
May	0.80	0.5
August	1.18	0.1
September	0.85	0.2
October	0.97	0.0
November	0.82	0.5
December	2.25	3.8*

*$p \leq 0.05$

Length at first maturity

Information on length at first maturity of *S. nigrofasciata* is not available and the present study forms the first report. The length at first maturity was estimated at 25.0 cm for male and 27.0 cm for female *S. nigrofasciata* (Fig. 7 a, b). Results of this study suggested that male fishes of this species mature early compared to females. Similarly, early maturation of male fish was reported in *Decapterus macrsoma,* a carangid fish, in the Java Sea (Widodo, 1991) with size at first maturity value of 14.8 cm for males and 15.5 cm for females. The longer time taken by the female fishes to mature could be related to the diversion of more energy for reproduction (Miller and Kendall, 2009) which is spared from somatic growth.

Gonadosomatic index

The gonadosomatic index (GSI) values for male and female fishes ranged from 1.03 to 8.45 and 2.08 to 22.06 respectively. Maximum GSI values were recorded during April and December for both the sexes (Fig. 8), indicating high reproductive activity during these months. Presence of higher % of mature fish supports the maximum reproductive activity in April (78.9 and 100% for female and male respectively) and December (78.6 and 93.8% for female and male respectively) for both the sexes (Fig. 8). The mature and spent specimens were encountered all through the year during the study, implying that the species spawns throughout the year. However, peak spawning period observed based on the GSI value was during the summer season (March-May) with a minor secondary peak during post-monsoon season (October-December). Since the present study forms the first detailed reproductive biological study on *S. nigrofasciata*, the results are compared with the details available for other carangids. Repeated and periodic spawning (Thresher, 1984) with fairly long peaks during summer months has been reported for most carangid species (Honebrink, 2000). Poojary *et al*. (2015) documented peak spawning period in January and September for *Decapterus russelli* along Maharashtra coast. Studies have recognised prolonged breeding season with peak spawning during May to August off Cochin (Sivakami, 1995) and May to October along Ratnagiri coast off Maharashtra (Jadhav and Mohite, 2014) for horse mackerel, *Megalaspis cordyla*.

Results of the present study on fishery, dietary constituents and feeding intensity, reproductive biology including sex ratio, length at first maturity, gonadosomatic

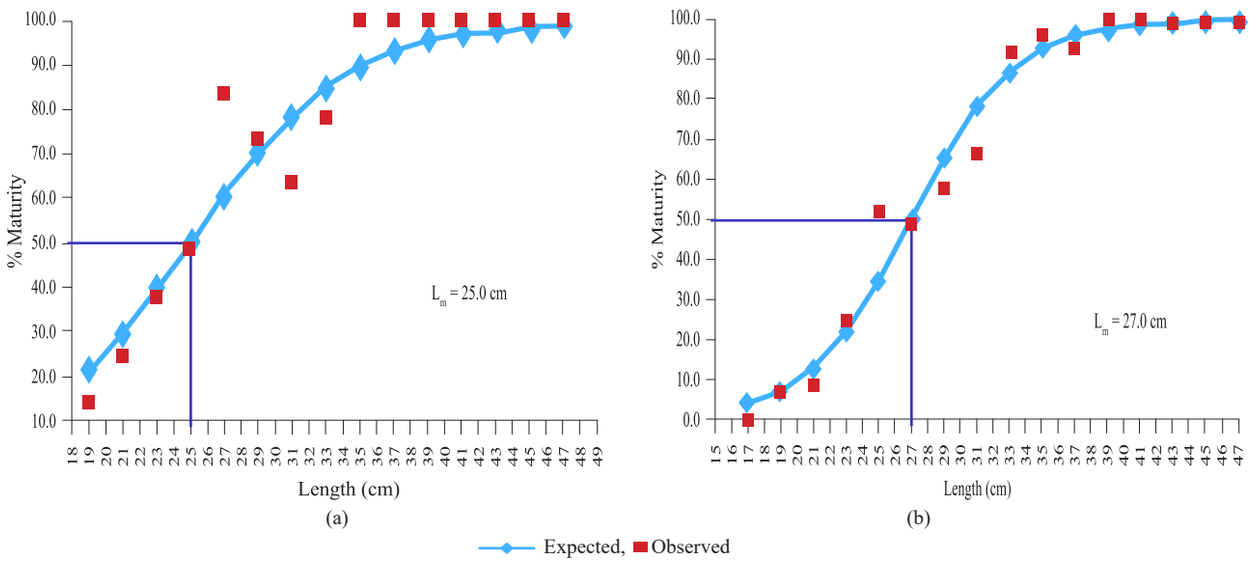

Fig. 7. Estimated length at first maturity of (a) male and (b) female *S. nigrofasciata*

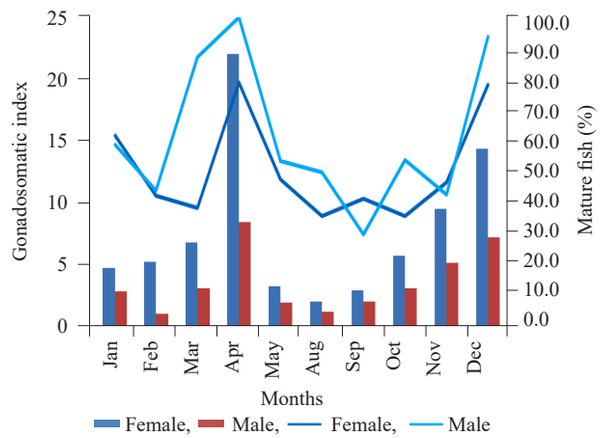

Fig. 8. Mean GSI and % maturity of male and female fish

index and spawning season of *S. nigrofasciata* are first information which would form the basis for future studies and could contribute towards framing management measures and for conservation strategies to exploit the species in a rational and judicious way.

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