

Reproductive biology, trophodynamics and stock structure of ribbonfish *Trichiurus lepturus* from northern Arabian Sea and northern Bay of Bengal

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Reproductive biology, trophodynamics and stock structure of ribbonfish *Trichiurus lepturus* landed by trawlers along northern Arabian Sea and northern Bay of Bengal was studied during 2007 – 2010. Average annual catch along northern Arabian Sea and northern Bay of Bengal was 42649 t and 31944 t. Mean length was significantly higher in the former region. Growth in adults from northern Bay of Bengal was allometric and from northern Arabian Sea was isometric and growth rate in both the regions was significantly different within sexes and between sexes and indeterminates. Length weight relation for males and indeterminates were significantly different between both the regions. Overall sex ratio was 1.33 in northern Arabian Sea and 1.22 in northern Bay of Bengal. Length at first maturity was 61.2 cm in the former region and 52.9 cm in the latter region. Peak spawning season was December – March with more mature females encountered in Northern Arabian Sea. Total fecundity ranged between 23756 and 208300 along northern Arabian Sea and 21672 and 156695 along northern Bay of Bengal. The mature ovaries from both the regions contained maturing (0.6 mm – 0.7 mm) and mature ova (1.2 mm – 1.3 mm). Fin fishes dominated by clupeids, sciaenids, carangids and scombrids were the most preferred prey, followed by prawns and cephalopods. Feeding intensity was more in northern Arabian Sea than northern Bay of Bengal. Juveniles fed mostly on prawns and cephalopods while adults preferred finfishes. Fishes with empty stomachs were encountered in high numbers in both the regions. Feeding intensity was higher in older fishes in northern Bay of Bengal and in juveniles and very large fishes in northern Arabian Sea. The von Bertalanffy growth equation along northern Arabian Sea was $L_t = 131.6 [1 - e^{-0.15(t + 0.0740)}]$ and along northern Bay of Bengal was $L_t = 114.4 [1 - e^{-0.28(t + 0.0564)}]$. Along northern Bay of Bengal, reduction in fishing mortality from 0.81 to 0.73 – 0.76 will help in rationally exploiting the stock but along northern Arabian Sea, fishing mortality is below optimum and has to be increased from 0.18 to 0.34 for optimally exploiting the resource.

[**Keywords:** Ribbonfish, Population dynamics, Spawning, Food and feeding, India]

Introduction

Bay of Bengal Large Marine Ecosystem (BOBLME) and Arabian Sea Large Marine Ecosystem (LME) are considered Class 1, highly productive ecosystems ($>300 \text{ g cm}^{-2} \text{ yr}^{-1}$)^{1,2}. Arabian Sea LME is one of the six LME's in which reported landings have remained relatively constant or shown increase over the past few decades³. Fisheries of the BOBLME and Arabian Sea LME are multi-gear and

multi-species. The number of collapsed and overexploited stocks in the BOBLME and Arabian Sea LME are on the rise, with over 80% of the landings from fully exploited stocks. Intensive fishing in recent years is the primary force driving biomass changes in the BOBLME and Arabian Sea LME which in turn are threatening their long term sustainability. These changes are well illustrated on the east and west coast of India, where high density of trawlers is inducing changes in the ecosystem⁴.

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Ribbonfish represents an important group of food fish in the Indian waters along the Bay of Bengal (BOB) and Arabian Sea. They form one of the major components of the exploited marine fishery resources and have good domestic and export demand. Annual average catches of ribbonfish during 2007–2010 from West Bengal, Odisha and Andhra Pradesh located along the northern BOB was 44336 t and from Gujarat located along the northern Arabian Sea was 49190 t. *Trichiurus lepturus* Linnaeus 1758 forms the major component of the ribbonfish catches in the Indian waters along the BOB and Arabian Sea while *Lepturacanthus savala* Cuvier 1829 and *Eupleurogrammus muticus* Gray 1831 occur occasionally. Fishery is confined to the shallow depth zone below 70 m. Resource is exploited by a variety of gears but more than three fourth of their contribution comes from multi-day trawl nets. Females of *T. lepturus* spawn more than once in a reproductive season with sex ratio favouring females, particularly in larger size length classes⁵. They are apex predators feeding actively on fishes, crustaceans and cephalopods thus playing a pivotal role in the energy transfer of tropical marine fish ecosystems.

There is no information available till date on the reproductive biology and food and feeding of *T. lepturus* from the Saurashtra coast of Arabian Sea. Available information on the biology of *T. lepturus* from Kakinada⁶ and Visakhapatnam⁷ in the BOB also dates back to a decade. Increasing mechanization from 1995 onwards coupled with modernized fish finding equipments has resulted in trawlers venturing into much more deeper waters in recent decades. This extension in the vertical and horizontal fishing grounds of trawlers targeting ribbon fish can have an impact on the reproduction and diet of ribbon fish. Though there is information available on the population parameters, mortality and exploitation rates of *T. lepturus* from Kakinada waters⁸⁻⁹ and Visakhapatnam waters⁷ in the BOB and from the Veraval waters¹⁰ in the Arabian Sea, there is no published information available on the comparison of the stock structure of *T. lepturus* from BOB and Arabian Sea.

The present study was therefore aimed to compare the stock structure, reproductive biology and trophodynamics of *T. lepturus* caught by trawlers along northern BOB and northern Arabian Sea.

Materials and Methods

Data on catch of *T. lepturus* along northern BOB viz., West Bengal, Odisha and Andhra Pradesh and northern Arabian Sea viz., Gujarat were collected weekly from commercial trawlers for four years from January 2007 to December 2010 except during the months of April and May along BOB and June and July along Arabian Sea for all the years due to suspension of the trawl net fishery during these months. The monthly and annual estimates of catches were made following the procedure adopted by the Fishery Resource Assessment Division of Central Marine Fisheries Research Institute, India¹¹.

A total of 3089 specimens (size range of 20 to 109.9 cm) from Visakhapatnam and Paradeep in northern BOB and 3146 specimens (size range of 26 to 125.9 cm) from Veraval, Mangrol, Porbunder and Okha in northern Arabian Sea of *T. lepturus* were collected and total length (cm) and body weight (grams to 0.01 g precision) were measured. Length-weight relationship of *T. lepturus* from BOB and Arabian Sea was calculated as $W = aL^b$ ¹² separately for both sexes and indeterminates and significant differences in the slopes of the regression lines for males, females and indeterminates were ascertained by ANACOVA¹³. Monthwise sex ratio was determined from 2944 specimens of BOB and 3068 specimens of Arabian Sea and Chi-square test was performed to test the homogeneity of male and female distribution. The size at first maturity (L_{50}) was determined from 1616 female specimens of BOB and 1752 female specimens of Arabian Sea logistically by fitting the fraction of mature fish (stage III and above) against length interval using the nonlinear least square regression method¹⁴. Proportions of gravid and ripe females (V and VI) over time were taken to determine the spawning season along BOB and Arabian Sea. Gonadosomatic index (IG) for females was calculated by the formulae: $IG = (Weight\ of\ gonad \times 100) / Weight\ of\ fish$. Fecundity was worked out by

raising the number of ova in all subsamples of the mature and ripe ovary (V and VI) to the total ovary weight. Ovary subsamples were obtained from the anterior, middle and the posterior regions of the ovary. Ova diameter distribution in each subsample of the ovary was studied under a microscope using calibrated ocular micrometer. Feeding intensity from 3089 specimens of BOB and 3146 specimens of Arabian Sea was assessed based on the distension of their stomach and the volume of food contained in it and was classified as gorged, full, $\frac{3}{4}$ full, $\frac{1}{2}$ full, $\frac{1}{4}$ full, trace and empty. Relative importance of various food items in the stomach was calculated by the index of relative importance¹⁵. Index of relative importance (IRI) was used as it takes into account the frequency of occurrence as well as the number and volume of each food item thus providing a definite and measurable basis for grading different food items. The IRI was computed as given below:

$IRI = (\%N + \%V) \times \%F$; where N = number, V = volume and F = frequency of occurrence.

Multivariate analyses on diet contents were carried out using PRIMER v. 6¹⁶. Prior to the statistical analyses, datasets were square-root transformed, and similarity matrices were constructed using the Bray-Curtis similarity coefficient. Monthly IRI from northern Arabian Sea and northern BOB were used to identify the variation in their dietary composition. For this purpose, one-way Analysis of Similarity Percentages (SIMPER) was performed to test similarity/dissimilarity in the diet contents from both the regions. When seeking similarities between regions/months, hierarchical cluster analysis was applied to the food composition/frequency data in order to distinguish groups of samples of similar dietary composition. SIMPROF permutation procedure was used to test the significance of the clusters.

Stock assessment methods essentially work with age composition¹⁷. Temperate waters, age of individual fishes is easily determined by counting the year rings on hard parts viz., otoliths and scales. The year rings are formed due to extreme fluctuations in

environmental conditions from summer to winter and vice versa. In tropical waters such extreme changes do not occur and it is difficult to use seasonal rings for age determination. Hence for age determination in tropical systems, the Von Bertalanffy Growth Model is used which converts length frequency data into age composition¹⁷. For estimating Von Bertalanffy growth parameters, asymptotic length (L_{∞}) and growth coefficient (K) separately from BOB and Arabian Sea, the monthwise length composition data of four years in each BOB and Arabian Sea were pooled and grouped with 2 cm class interval and analyzed using the ELEFAN I module of FiSAT software version 1.2.0¹⁸. Growth performance index (ϕ) was calculated separately for BOB and Arabian Sea from the final estimates of L_{∞} and K ¹⁹. Probability of capture and size at first capture (L_c) were estimated as in Pauly²⁰ and the age at zero length (t_0) from Pauly's²¹ empirical equation, $\text{Log}(-t_0) = -0.392 - 0.275 \text{Log } L_{\infty} - 1.038K$. Growth and age were determined using the von Bertalanffy growth equation, $L_t = L_{\infty} (1 - \exp^{-k(t-t_0)})$. Midpoint of the smallest length group in the catch was taken as length at recruitment (L_r). Natural mortality (M) was calculated by Pauly's empirical formula²², taking the mean sea surface temperature as 28°C and total mortality (Z) calculated from length converted catch curve²³ using FiSAT software. Fishing mortality (F) was estimated by $F = Z - M$. Length structured virtual population analysis (VPA) of FiSAT was used to obtain fishing mortalities per length class. Exploitation ratio was estimated from the equation, $E = F/Z$ and exploitation rate from $U = F/Z(1 - \exp^{-z})$ where, F is the fishing mortality rate. Yield per recruit (Y/R), spawning stock biomass per recruit (SSB/R), fishable biomass per recruit (Fish B/R), total biomass per recruit (Total B/R), total biomass (Total B), spawning stock biomass (SSB) and fishable biomass (Fish B) at different levels of F was estimated from Beverton and Holt Yield per Recruit Model using Yield software ver 1.0, MRAG Ltd, London, UK. Maximum sustainable yield (MSY) was calculated by the equation²⁴ for exploited fish stocks, $MSY = Z \times 0.5 \times \text{Total } B$.

Results

Fishery

The average annual catch of *T. lepturus* by trawlers along northern BOB and northern Arabian Sea for the period 2007–2010 was 31944 t and 42649 t. In northern Arabian Sea viz., Gujarat, the annual catch of 45878 t in 2007 decreased drastically to 35952 t in 2008, after which it increased gradually to 41255 t in 2009 and 47512 t in 2010. Along northern BOB, the annual catch exhibited a steady increase over the years from 18898 t in 2007 to 40251 t in 2010. Average catch by trawlers in Odisha was 18676 t, Andhra Pradesh was 9631 t and West Bengal was 3637 t. In Odisha and West Bengal, the catch of *T. lepturus* has shown a continuous increase while in Andhra Pradesh, the catch displayed fluctuating trend with highest landings in 2008 (Table 1).

Length composition

The length frequency distribution of *T. lepturus* for the four year period indicated exploitation of juveniles in large numbers along northern Arabian Sea (size range 260 – 359 mm) during May of 2008 and northern BOB (size range 200 – 299 mm) during August–October of 2009 and 2010 and in small numbers during February–March in both the years. Change in mean length over the years recorded similar trend along northern Arabian Sea (ANOVA, $F = 0.24$, $P > 0.05$) and northern BOB (ANOVA, $F = 0.42$, $P > 0.05$). A mean length of 626.9 ± 121.9 mm and 510.7 ± 15.1 mm observed in 2007 in Northern Arabian Sea and northern BOB decreased to 619.5 ± 118.8 mm and 504.3 ± 20.6 mm in 2009 after which it increased to 673.6 ± 164.0 mm and 515.6 ± 32.6 mm in 2010.

Monthly mean lengths recorded were significantly (ANOVA, $F = 9.72$, $P < 0.05$) higher in northern Arabian Sea when compared to that of northern BOB. Highest mean length of 561.7 ± 14.6 mm in northern BOB was recorded during December and the lowest mean length of 484.5 ± 5.6 mm was recorded in March (Fig. 1). In northern Arabian Sea, the highest mean length of 817.3 ± 56.8 mm was observed in March and the lowest mean length of 480.9 ± 40.1 mm was observed in April (Fig. 1).

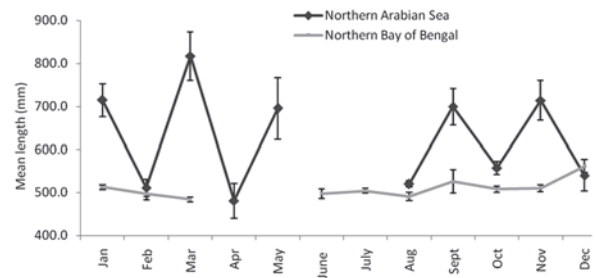


Fig. 1—Mean lengths (Mean ± SD) of *T. lepturus* landed by trawlers in different months along northern Arabian Sea and northern BOB during 2007–2010.

A total of 3089 (1328 males, 1616 females and 145 indeterminates) specimens in the length range of 200 – 1099 mm from northern BOB were used for determining the length-weight relationship separately for the two sexes and indeterminates. Relationships estimated were:

Male: $\log W = -2.9193 + 2.8702 \log L$ ($r = 0.88$) (Confidence Level 95%).

Female: $\log W = -3.5198 + 3.2209 \log L$ ($r = 0.93$) (Confidence Level 95%).

Indeterminate: $\log W = -2.8826 + 2.7741 \log L$ ($r = 0.9$) (Confidence Level 95%).

Table 1—Annual landings (tonnes) of *T. lepturus* by trawlers along northern Arabian Sea and northern BOB

Years	Northern BOB			Northern Arabian Sea
	Andhra Pradesh	Odisha	West Bengal	Gujarat
2007	8136	8369	2393	45878
2008	13979	16078	2547	35952
2009	8240	23459	4322	41255
2010	8167	26799	5285	47512

The slope (b) of the regression relation for males (Student's t test, $t_{\text{cal}} = 2.835$, $t_{\text{crit } 0.05} = 1.962$) and females (Student's t test, $t_{\text{cal}} = 6.833$; $t_{\text{crit } 0.05} = 1.961$) were significantly different from 3 indicating allometric growth. For indeterminates however, the slope (Student's t test, $t_{\text{cal}} = 1.973$; $t_{\text{crit } 0.05} = 1.977$) did not differ significantly from the isometric value of 3. Slope of the regression line for females was significantly different from males (ANACOVA, $F_{\text{cal}} = 40.85$, $\rho < 0.05$) and from indeterminates (ANACOVA, $F_{\text{cal}} = 17.88$, $\rho < 0.05$). However between males and indeterminates, there was no significant difference in the slope of the regression line (ANACOVA, $F_{\text{cal}} = 0.58$, $\rho > 0.05$).

A total of 3146 (1316 males, 1752 females and 78 indeterminates) specimens in the length range of 260 – 1259 mm from northern Arabian Sea were used for determining the length-weight relationship separately for the two sexes and indeterminates. The relationships estimated were:

Male: $\log W = -3.2658 + 3.0547 \log L$ ($r = 0.9$) (Confidence Level 95%).

Female: $\log W = -3.6470 + 3.2632 \log L$ ($r = 0.93$) (Confidence Level 95%).

Indeterminate: $\log W = -0.1970 + 1.3172 \log L$ ($r = 0.8$) (Confidence Level 95%).

Slope (b) of the regression relation for males (Student's t test, $t_{\text{cal}} = 0.71$, $t_{\text{crit } 0.05} = 1.967$) and females (Student's t test, $t_{\text{cal}} = 1.52$, $t_{\text{crit } 0.05} = 1.965$) did not vary significantly from 3 indicating isometric growth. For indeterminates however, the slope (Student's t test, $t_{\text{cal}} = 9.76$, $t_{\text{crit } 0.05} = 1.99$) varied significantly from the isometric value of 3. Regression line slope for females differed significantly from males (ANACOVA, $F_{\text{cal}} = 4.54$, $\rho < 0.05$) and the regression line slope for males (ANACOVA, $F_{\text{cal}} = 55.32$, $\rho < 0.05$) and females (ANACOVA, $F_{\text{cal}} = 68.53$, $\rho < 0.05$) differed significantly from indeterminates.

Length weight relation of *T. lepturus* from northern Arabian Sea and northern BOB varied significantly within males (ANACOVA, $F_{\text{cal}} = 4.3$, $\rho < 0.05$) and within indeterminates (ANACOVA, $F_{\text{cal}} = 40.13$, $\rho < 0.05$). However within females (ANACOVA, $F_{\text{cal}} = 0.47$, $\rho > 0.05$), the variation was not significant.

Sex Ratio and Size at first maturity

Females dominated the commercial catches in all the years along northern Arabian Sea and northern

Table 2—Monthly occurrence of males and females in the landings along northern Arabian Sea and northern Bengal during 2007–2010

Months	Northern Arabian Sea				Northern BOB			
	Male	Female	F/M	Chi square	Male	Female	F/M	Chi square
Jan	108	218	2.02	37.12	124	192	1.55	14.63
Feb	148	194	1.31	6.19	144	196	1.36	7.95
Mar	172	176	1.02	0.05	136	152	1.12	0.89
Apr	100	210	2.10	39.03				
May	108	146	1.35	5.69				
June					92	172	1.87	24.24
July					108	148	1.37	6.25
Aug	116	100	0.86	1.19	112	96	0.86	1.23
Sept	238	234	0.98	0.03	260	208	0.80	5.78
Oct	86	138	1.60	12.07	92	132	1.43	7.14
Nov	192	200	1.04	0.16	204	188	0.92	0.65
Dec	48	136	2.83	42.09	56	132	2.36	30.72

BOB. This domination by females was significant in 2007 (chi-square = 41.1 & 15.5, $P < 0.05$) and 2010 (chi-square = 44.3 & 12.7, $P < 0.05$) in both these regions. Overall sex ratio during 2007 – 2010 was 1.33 in northern Arabian Sea and 1.22 in northern BOB. Highest sex ratio of 1.68 in northern Arabian Sea was observed in 2010 and 1.35 in northern BOB was observed in 2007. Lowest sex ratio of 1.08 and 1.11 in northern Arabian Sea and northern BOB was observed in 2008. Chi-square values indicated significant ($P < 0.05$) dominance by females in January, February, April, May, October and December in northern Arabian Sea and in January, February, June, July, October and December in northern BOB and by males in September in northern BOB (Table 2).

The length at first maturity was significantly higher (ANOVA, $F = 4.64$, $P < 0.05$) in northern Arabian Sea when compared to northern BOB. *T. lepturus* attained sexual maturity at 52.9 cm total length in northern BOB and 61.2 cm total length in northern Arabian Sea (Figs 2 and 3). However, gonadal development and sexual maturity in the species was observed to commence from 39 cm onwards along northern BOB and 45 cm onwards along northern Arabian Sea.

Spawning season

Gravid and ripe females were recorded in all the months with their peak occurrence observed during December – January and March along northern Arabian Sea and January – March along northern

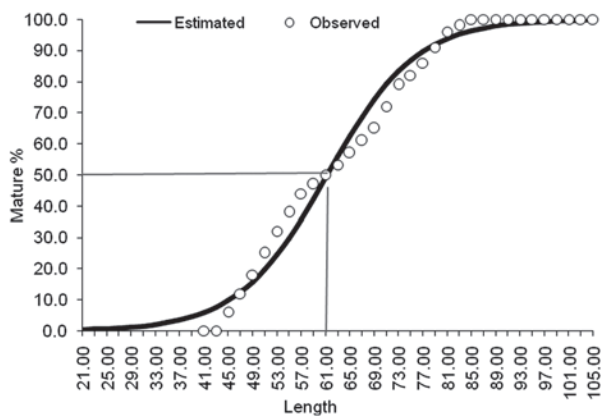


Fig. 2—Size at first maturity of females of *T. lepturus* from northern Arabian Sea.

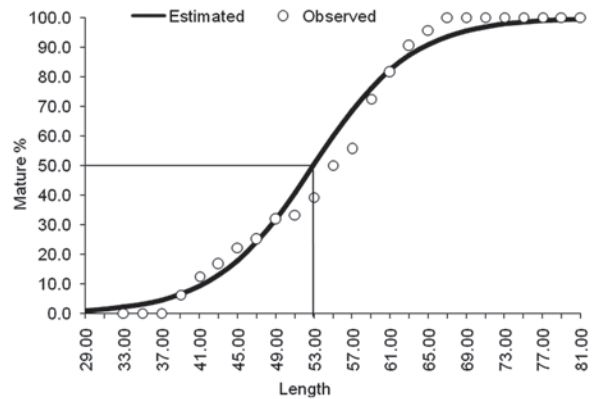


Fig. 3—Size at first maturity of females of *T. lepturus* from northern BOB.

BOB (Fig. 4). Proportion of mature females were found to vary significantly (ANOVA, $F = 5.49$, $P < 0.05$) between years along northern Arabian Sea with their highest occurrence of $77.1 \pm 16.3\%$ recorded in 2007 and their lowest occurrence of $47.1 \pm 28.4\%$ recorded in 2008. Along northern BOB, this variation in the occurrence of mature females between years was insignificant (ANOVA, $F = 0.04$, $P > 0.05$) with their proportion varying between $53.1 \pm 18.8\%$ and

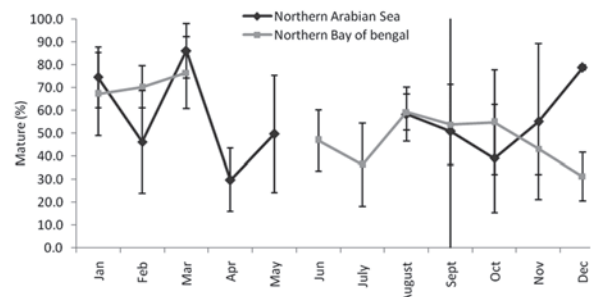


Fig. 4—Month-wise occurrence (Mean \pm SD) of mature females of *T. lepturus* during 2007–2010.

$55.2 \pm 16.2\%$. The proportion of mature females was higher (ANOVA, $F = 0.15$, $P > 0.05$) in northern Arabian Sea than that of northern BOB. In sharp contrary to proportion of mature females, the gonadosomatic index was higher (ANOVA, $F = 0.03$, $P > 0.05$) in northern BOB when compared to northern Arabian Sea. Gonadosomatic index varied within years along northern Arabian Sea (ANOVA, $F = 0.10$, $P > 0.05$) and northern BOB (ANOVA, $F = 0.13$, $P > 0.05$). Highest gonadosomatic indexes in both these regions (2.24 ± 1.28 in northern Arabian Sea and

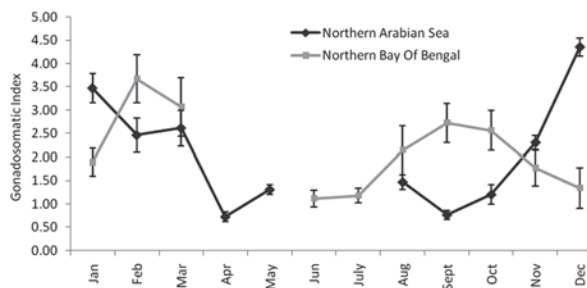


Fig. 5—Gonadosomatic index (Mean±SD) of females of *T. lepturus* during different months along northern Arabian Sea and northern BOB.

2.24±0.86 in northern BOB) were recorded in 2007 and the lowest (1.97±1.18 in northern Arabian Sea and 2.05±0.91 in northern BOB) were recorded in 2008. Gonadosomatic index for females varied in different months in both the regions with peaks of 4.35±0.26 in December and 3.47±0.27 in January along northern Arabian Sea and 3.67±0.25 in January and 3.07±0.51 in February along northern BOB, after which it decreased in subsequent months (Fig. 5). This is in agreement with the peak spawning season observed in the species. The mature ovaries of *T. lepturus* examined from northern Arabian Sea and northern BOB contained both maturing and mature ova. In both the above regions, the modal peak in mature ova diameter was 1.2 to 1.3 mm and of maturing ova diameter was 0.6 to 0.7 mm (Fig. 6). Presence of yolked ova of different sizes in mature ovary for most months of the year indicated prolonged spawning. However the largest sizes of yolked ova were encountered mostly in December and January along northern Arabian Sea and in January and February along northern BOB further confirming this

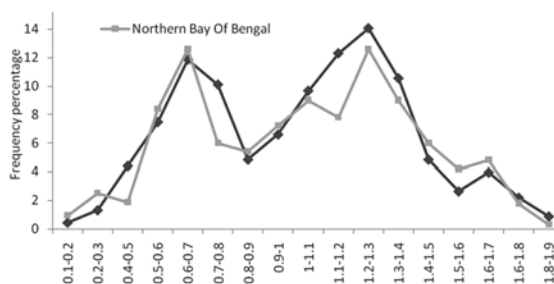


Fig. 6—Ova diameter distribution percentage in mature and ripe ovaries of *T. lepturus* along northern Arabian Sea and northern BOB.

to be the peak breeding season of *T. lepturus* in the respective regions.

Fecundity

The number of eggs released increased with the weight and size of the fish in both northern Arabian Sea and northern BOB. Fecundity was higher in northern Arabian Sea when compared to that of northern BOB. Average number of ova per gram body weight was 158.1 in the former region and 141.6 in the later region. Total fecundity ranged between 23756 and 208300 along northern Arabian Sea and 21672 and 156695 along northern BOB. Relationship calculated between body length and fecundity and body weight and fecundity for northern Arabian Sea was:

$$\log F = -0.5812 + 2.7918 \log L \quad (r = 0.99) \quad (\text{Confidence Level } 95\%)$$

$$\log F = 2.1891 + 1.0039 \log W \quad (r = 0.99) \quad (\text{Confidence Level } 95\%)$$

The relationship calculated between body length and fecundity and body weight and fecundity for northern BOB was:

$$\log F = -1.4091 + 3.2367 \log L \quad (r = 0.99) \quad (\text{Confidence Level } 95\%)$$

$$\log F = 2.0329 + 1.0328 \log W \quad (r = 0.95) \quad (\text{Confidence Level } 95\%)$$

There was significant variation (ANACOVA, $F_{\text{cal}} = 21$, $P < 0.05$) in the slope of the regression relation of body length and fecundity between northern Arabian Sea and northern BOB. However for body weight and fecundity, the slope of the regression relation did not vary significantly (ANACOVA, $F_{\text{cal}} = 0.09$, $P > 0.05$) between northern Arabian Sea and northern BOB.

Feeding intensity and food composition

The food items in the diet of *T. lepturus* along northern Arabian Sea and northern BOB were broadly classified into fin fishes dominated by clupeids, sciaenids, carangids, scombrids and juveniles of ribbon fishes and shell fishes dominated by non

penaeid prawns, penaeid prawns and cephalopods. Fin fishes and shell fishes in digested and semi digested state were encountered in the gut in varying proportions in different years in all the months with an average IRI % of 42.2 in northern Arabian Sea and 36.1 northern BOB. Non penaeid prawns dominated by *Acetes* with an average IRI % of 15.7 was an important food item in the diet along northern Arabian Sea, followed by cephalopods with an IRI % of 5.4. Non penaeids were most abundant in gut during 2009 – 2010 (average IRI % of 21.5) while cephalopods were mostly encountered in 2007 (IRI % of 11.1). Highest index for non penaeid prawns was observed in February (41%) and April (54.4%) and for cephalopods (38.7%) in January along northern Arabian Sea (Fig. 7). In northern BOB, cephalopods with an average IRI % of 16.9 dominated the gut contents followed by penaeid prawns with an average

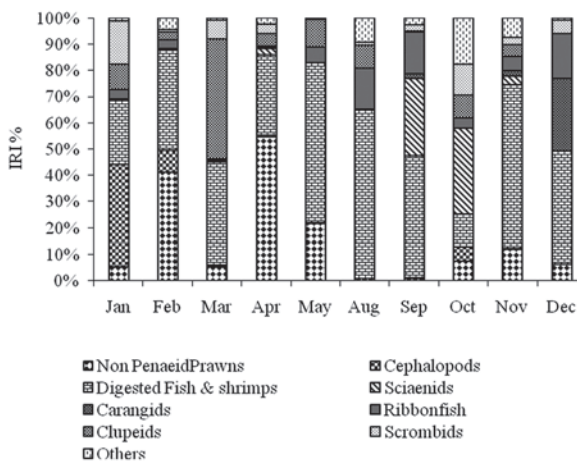


Fig. 7—Index of relative importance (IRI) % of food items encountered in *T. lepturus* in different months along northern Arabian Sea.

IRI % of 10.6. Cephalopods were most abundant in gut during 2010 (IRI % of 21.9) while penaeid prawns were encountered more frequently in 2007 (IRI % of 12.5). Cephalopods and penaeid prawns formed an important food item in all the months along northern BOB (Fig. 8). Among fin fishes, clupeids with an average IRI % of 9.6, juveniles of ribbonfishes with an average IRI % of 7.2, sciaenids with an average IRI % of 7 and scombrids with an average IRI % of 5.1 were the important food items along northern

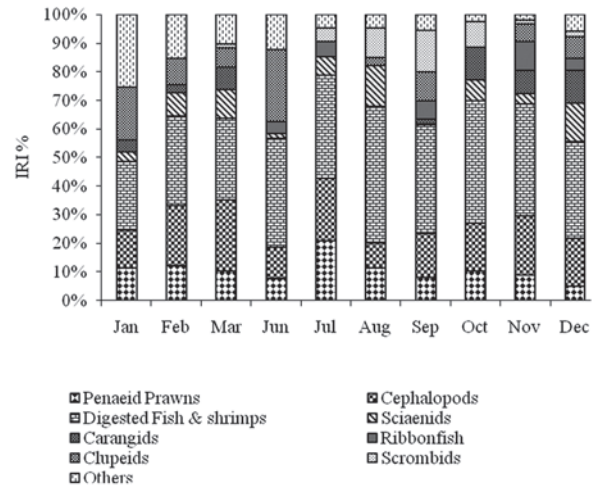


Fig. 8—Index of relative importance (IRI) % of food items encountered in *T. lepturus* in different months along northern Bay of Bengal.

Arabian Sea. Clupeids represented mostly by oil sardine were present in the gut only during 2008 – 2010 while sciaenids dominated the gut contents in 2007 and 2010 (IRI % of 12.3). Juveniles of ribbonfishes were encountered in the gut contents mostly in 2008 (IRI % of 11.4) while scombrids mainly mackerel were found mostly in 2008 and 2009 (average IRI % of 9.2). Sciaenids dominated the gut contents during September – October (average IRI % of 31.1), juveniles of ribbonfishes dominated during August – September (average IRI % of 15.7) and December (IRI % of 17.1), clupeids dominated in March (IRI % of 45.8) and scombrids dominated in January (IRI % of 16.4) along northern Arabian Sea (Fig. 7). Finishes which formed major part of the diet in northern BOB are clupeids with an average IRI % of 8.6, sciaenids with an average IRI % of 6.8, carangids with an average IRI % of 4.7 and scombrids with an average IRI % of 4.3. Clupeids composed chiefly of sardines and anchovies dominated the food items during 2007 – 2009 (average IRI % of 9.7), sciaenids were most abundant in 2007 (IRI % of 12.9), carangids represented mostly by scads was an important food item in 2008 (IRI % of 10.4) and scombrids were encountered more frequently in 2010 (IRI % of 6.3). Clupeids dominated the gut contents in January (IRI % of 18.4) and June (IRI % of 25.3), sciaenids dominated in August (IRI % of 14.2) and

December (IRI % of 13.4), carangids dominated during October – December (average IRI % of 10.4) and scombrids dominated during August – October (average IRI % of 11.3) along northern BOB (Fig. 8).

Feeding intensity was more in northern Arabian Sea than northern BOB. Analysis of food items in relation to body size in both the regions depicted that while juveniles fed mostly on prawns and cephalopods, adults preferred finfishes. Average contribution of fishes in the feeding conditions of gorged stomach, full stomach, $\frac{3}{4}$ full stomach, $\frac{1}{2}$ full stomach, $\frac{1}{4}$ full stomach, trace full stomach and empty stomach were 2%, 8.6%, 4.3%, 26.1%, 13.3%, 10.1% and 35.7% along northern Arabian Sea and 0%, 3%, 7.8%, 11.5%, 17.9%, 17.1% and 42.6% along northern BOB. In northern Arabian Sea, feeding intensity was maximum in 2008 and minimum in 2010. Only little more than a quarter of the fishes exhibited empty stomachs in 2008 with half of them having half or more than half filled stomachs. Proportion of fishes with empty stomachs reached 45% in 2010 with only 32% of them having their stomachs either half or more than half filled. Feeding intensity along northern BOB was highest in 2008 and lowest in 2009. More than half of the fishes in 2009 possessed empty stomachs and in only one fifth of the fishes the stomach was half or more than half filled. In 2008, only a quarter of the fishes had their stomachs empty while 30% of them had their stomachs either half or more than half filled. Intensity of feeding was found to vary throughout the year with fishes possessing empty stomachs encountered frequently in all the months in northern BOB (32.1% - 47.7%) and northern Arabian Sea (24.1% - 44.7%)

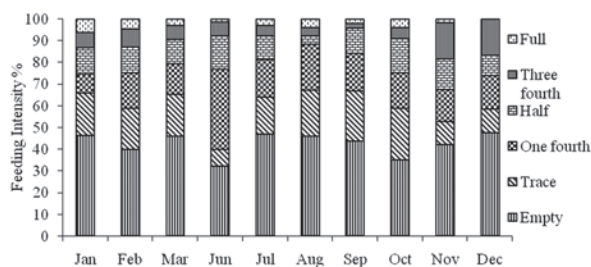


Fig. 9—Month-wise feeding intensity of *T. lepturus* along northern Bay of Bengal.

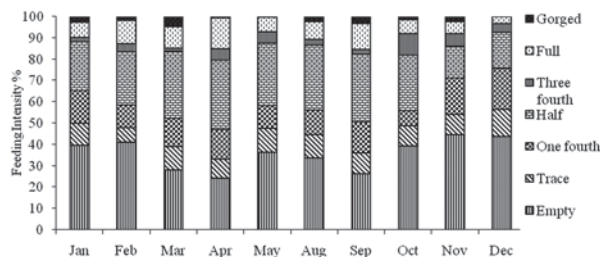


Fig. 10—Month-wise feeding intensity of *T. lepturus* along northern Arabian Sea.

(Figs 9 and 10). Sizewise feeding differences revealed that young ones of *T. lepturus* fed less abundantly than that of adults along northern BOB. Around half of the fishes in the length range of 35 to 64.9 cm were found to possess empty stomachs and in the rest two-third, the stomach was only upto quarter full. Larger fishes of length ranging from 65 cm to 94.9 cm were found to possess empty stomachs to the tune of 40% and 25% of them had stomachs either half or more than half filled. In very large fishes (95 cm and more), only a third of the stomachs were empty and 30% of the stomachs were either half or more than half filled (Fig. 11). Along Arabian Sea, juveniles and very large fishes fed more frequently than medium sized fishes. One third of the fishes in the length range of 35 to 64.9 cm and 95 cm and more had their stomachs empty and more than 40% of the fishes had their stomach half or more than half filled. In fishes ranging from 65 cm to 94.9 cm in length, 43% possessed empty stomachs while in one third the stomach was either half or more than half filled (Fig. 12).

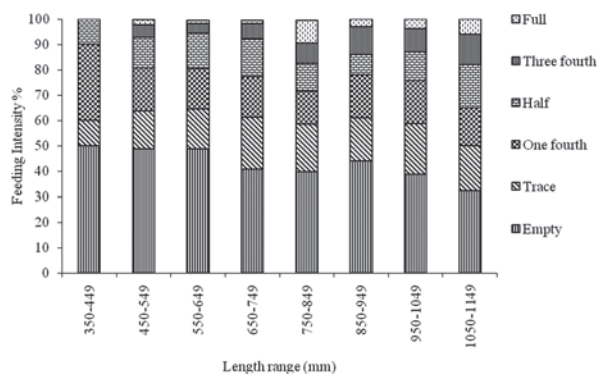


Fig. 11—Size-wise feeding intensity of *T. lepturus* along northern Bay of Bengal.

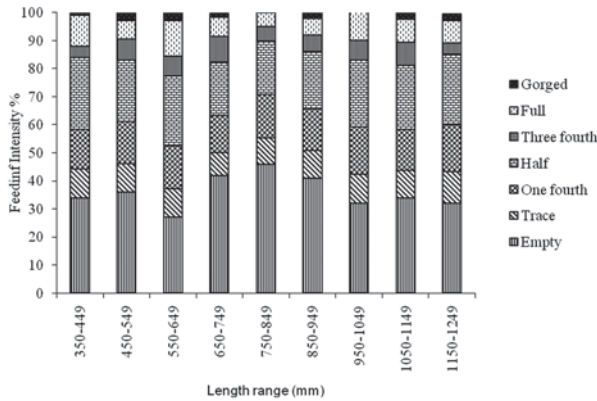


Fig. 12—Size-wise feeding intensity of *T. lepturus* along northern Arabian Sea.

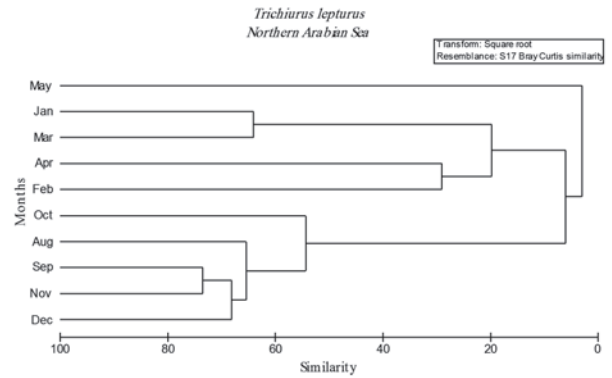


Fig. 14—Dendrogram for clustering food items by IRI for comparing months in northern Arabian Sea using group average linking of Bray-Curtis similarities.

Average SIMPER similarity in the diet contents of *T. lepturus* from northern Arabian Sea and northern BOB were 59.3 and 73.1, respectively. The average SIMPER dissimilarity in the diet contents between both the regions was 47.9. This dissimilarity in the diet was contributed chiefly by Acetes and penaeid prawns with average SIMPER dissimilarities of 5.7 and 4.8. Cluster analysis of food items from northern Arabian Sea and northern BOB (SIMPROF, $\pi = 3.11$, $P = 0.002$) revealed significant regional differences (Fig. 13). However within northern Arabian Sea (SIMPROF, $\pi = 0.83$, $P > 0.05$) and within northern BOB (SIMPROF, $\pi = 0.84$, $P > 0.05$), the cluster analysis on monthly occurrence of different food items did not show any significant difference (Figs 14 and 15).

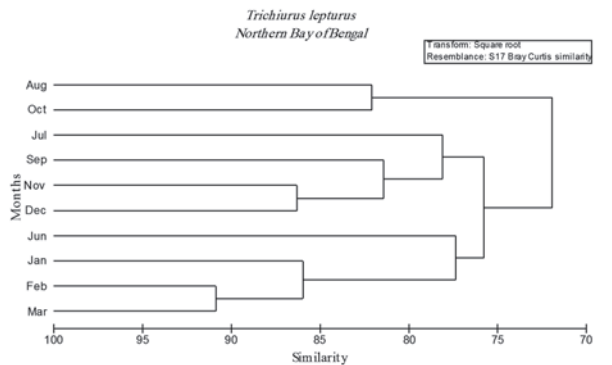


Fig. 15—Dendrogram for clustering food items by IRI for comparing months in northern BOB using group average linking of Bray-Curtis similarities.

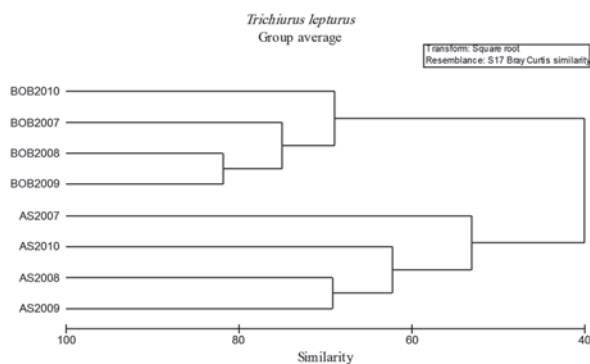


Fig. 13—Dendrogram for clustering food items by IRI for comparison between northern Arabian Sea and northern BOB using group average linking of Bray-Curtis similarities.

Population dynamics

The growth, mortality and exploitation parameters of *T. lepturus* from northern Arabian Sea and northern BOB are presented in Table 3. Length converted catch curve utilized in the estimation of total mortality from northern Arabian Sea and northern BOB are represented in Figs 16 and 17. Von Bertalanffy growth equation along northern Arabian Sea was $L_t = 131.6 [1 - e^{-0.15(t + 0.0740)}]$ and along northern BOB was $L_t = 114.4 [1 - e^{-0.28(t + 0.0564)}]$. Accordingly by the end of 1, 2, 3, 4 and 5 years, the fish attained a size of 19.6 cm, 35.2 cm, 48.6 cm, 60.2 cm and 70.1 cm along northern Arabian Sea and 29.3 cm, 50.1 cm, 65.8 cm, 77.7 cm and 86.6 cm along northern BOB. Fishery was dominated by fishes of 4 year, 5 year and 6 year old classes in

northern Arabian Sea and by 2 year, 3 year and 4 year old classes in northern BOB. A continuous recruitment pattern with recruitment occurring in most months was observed for *T. lepturus*. Highest recruitment in northern BOB was recorded in the month of June with 12.32% of the recruits. Three peaks in recruitment viz., January – March, June and August – November were recorded from northern Arabian Sea producing 27.96%, 12.10% and 47.56% of the recruits. VPA indicated that main loss in the stock up to 34.9 cm size from northern BOB and 54.9 cm size from northern Arabian Sea was due to natural

causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and in northern BOB eventually outnumbered the natural losses from 44.9 cm onwards. Maximum fishing mortality of 1.66 in northern BOB was at 56.9 cm size and 0.33 in northern Arabian Sea was at 110.9 cm size.

Stock

The yield, yield per recruit, biomass and biomass per recruit of *T. lepturus* from northern Arabian Sea and northern BOB is depicted in Table 4. Present Total B, Fish B and SSB along northern BOB are marginally

Table 3—Growth, mortality and exploitation parameters of *T. lepturus* from northern Arabian Sea and northern Bengal during 2007–2010

Parameter	Northern Arabian Sea	Northern BOB
Asymptotic Length (L _∞)	131.6 cm	114.4 cm
Growth Coefficient (K)	0.15	0.28
Growth performance index (φ)	3.41	3.56
Age at zero length (t ₀)	-0.0740 years	-0.0564 years
Length at first capture (L _c)	59.8 cm	39.7 cm
Age at first capture (t _c)	3.96 year	1.47 year
Annual Recruitment Numbers	952812519	651795036
Length at recruitment (L _r)	26.9 cm	20.9 cm
Natural Mortality (M)	0.34	0.54
Fishing Mortality (F)	0.18	0.81
Total Mortality (Z)	0.52	1.34
Exploitation Ratio (E)	0.35	0.60
Exploitation Rate (U)	0.14	0.45

Table 4—Yield, Yield per Recruit, Biomass and Biomass per Recruit of *T. lepturus* from northern Arabian Sea and northern Bengal during 2007–2010

Parameter	Northern Arabian Sea	Northern BOB
Annual Average Yield	42649 t	31944 t
Maximum Sustainable Yield	61604 t	26423 t
Total Biomass	236939 t	39437 t
Fishable Biomass	165346 t	31905 t
Spawning Stock Biomass	184542 t	18908 t
Yield per Recruit	44.8 g	49 g
Total Biomass per Recruit	248.7 g	60.5 g
Fishable Biomass per Recruit	173.5 g	48.9 g
Spawning Stock Biomass per Recruit	193.7 g	29 g

less than their biological reference points of Total $B_{0.5}$ (40049 t – 46758 t), Fish $B_{0.5}$ (32493 t – 39202 t) and $SSB_{0.2}$ (22190 t – 28530 t), which depicts the unhealthy nature of the stock. MSY in northern BOB is also lower than the annual average yield further substantiating the above finding. Slender increase in yield by 131 t – 184 t with no change in Y/R is obtained by decreasing the present F of 0.81 in northern BOB to 0.73 – 0.76. At the decreased F of 0.73 – 0.76, the SSB/R, Fish B/R and Total B/R would be 32 g – 34 g, 51 g – 53 g and 63 g – 65 g, respectively. Annual Total B, Fish B and SSB at F ranging from 0.73 – 0.76 would be 42290 t – 43741 t, 34276 t – 35743 t and 21340 t – 22634 t, respectively which are in concurrence to the values of Total $B_{0.5}$, Fish $B_{0.5}$ and SSB. Therefore the present F is marginally above optimum and can be reduced from 0.81 to 0.73 – 0.76 for rationally exploiting the resource of *T. lepturus* from northern BOB.

The annual average yield of *T. lepturus* is much lower than MSY in northern Arabian Sea indicating further scope for exploitation. Optimum exploitation ensuring harvesting the stock at MSY levels involves increasing the present F of 0.18 to 0.34. At the

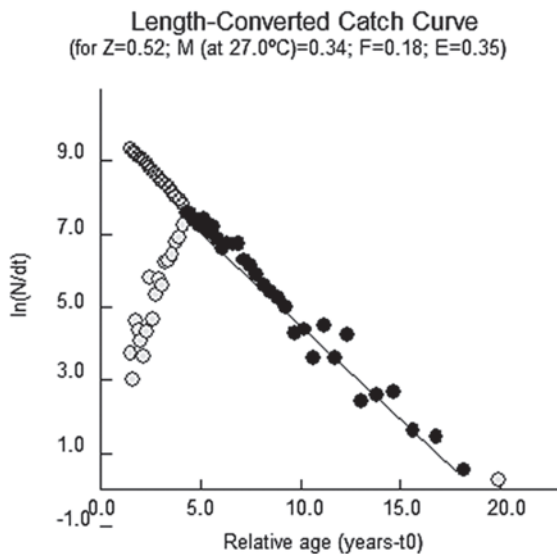


Fig. 16—Length converted catch curve of *T. lepturus* landed by trawlers along northern Arabian Sea; where N is the number of fish in each length class, dt is the time needed for the fish to grow through each length class and t_0 is the age at zero length.

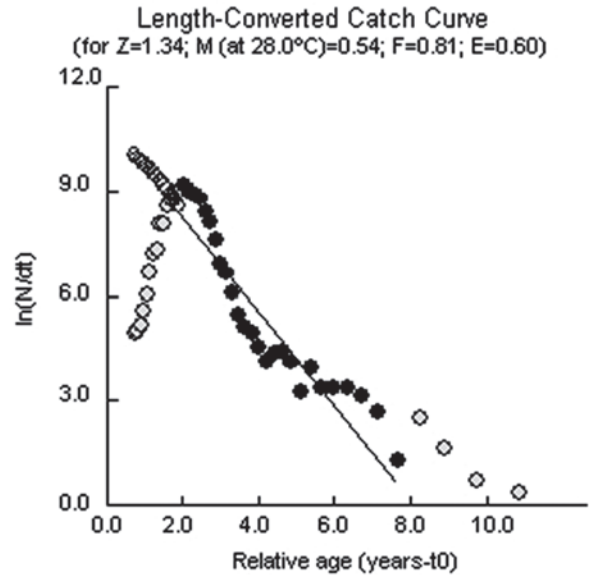


Fig. 17—Length converted catch curve of *T. lepturus* landed by trawlers along northern BOB; where N is the number of fish in each length class, dt is the time needed for the fish to grow through each length class and t_0 is the age at zero length.

increased F in northern Arabian Sea, the increase in yield would be around 19000 t and the increase in Y/R would be 11.2 g. Total B, Fish B and SSB would be 181978 t, 110391 t and 129586 t and Total B/R, Fish B/R and SSB/R would be 165.4 g, 100.3 g and 117.8 g at the increased F of 0.34. Above biomass values are more than the values of their biological reference points (Total $B_{0.5}$, Fish $B_{0.5}$ and $SSB_{0.2}$) indicating the healthy state of the stock. Therefore along northern Arabian Sea, the present F is below optimum and can be increased from 0.18 to 0.34 for optimally exploiting the resource of *T. lepturus*.

Discussion

The annual catch of *T. lepturus* from northern BOB has increased by two folds from 2007 to 2010. Along northern Arabian Sea, the annual catch after registering an initial decline in 2008 increased in subsequent years to an all time high in 2010. Targeted fishing for *T. lepturus* coupled with improvement in the operating efficiency of trawl nets has resulted in their higher catches. Ghosh *et al.*¹⁰ recorded an average annual catch of 18,813 t of *T. lepturus* during 2003 – 2006 from the same area, with a maximum of

39,486 t in 2006. James *et al.*²⁵ have reported the availability of the resource in waters at depths between 25 and 75 m. Multi-day trawlers along both the regions conduct voyage fishing lasting for 4–12 days at the depth of 30–60 m for *T. lepturus*. During the last few years specially designed nets targeted to catch ribbonfishes in column waters have been implemented in northern Arabian Sea and northern BOB by the local fishermen owning multi-day trawlers. These nets possessing cod end mesh sizes of 2 cm – 2.5 cm in northern BOB and 4 cm – 6 cm in northern Arabian Sea and having large mesh openings in the wing sections of the trawl of 25 cm – 40 cm in northern BOB and 45 cm – 60 cm in northern Arabian Sea helps to herd the *T. lepturus* shoals into the trawls and also helps to reduce the drag resistance. Moreover, the injudicious removal of large quantum of fishes in both the regions, which include competitors of *T. lepturus* by intensive fishing over the last few years might have created favourable conditions for *T. lepturus* to proliferate.

Mean length in the present study was significantly higher in northern Arabian Sea than of northern BOB. Abundance of food resulting from large scale seasonal coastal upwelling²⁶ coupled with large meshed cod end of trawlers targeting *T. lepturus* could have attributed to the increased mean length along northern Arabian Sea. Fluctuating mean length recorded in different months in both the regions is possibly because different broods entered the population in different months. Similar mean size⁹ was recorded earlier for the same species from Kakinada along BOB. Length weight relationship showed that adults of *T. lepturus* from northern BOB exhibited allometric growth and from northern Arabian Sea exhibited isometric growth and growth rate in both the regions was significantly different within sexes and between sexes and indeterminates. Length weight relation for males and indeterminates were significantly different between northern Arabian Sea and northern BOB. A congenial feeding environment for juveniles and males in northern Arabian Sea caused by intense upwelling could have resulted in more weight gain of fishes per unit of length. However, higher 'b' values individually for male and female in comparison to

the present study was recorded earlier from Kakinada²⁷, Visakhapatnam⁷ and Veraval¹⁰. This variation is possibly due to factors related to continuous change in ecosystem and in biological phenomena like maturity stages, feeding behaviour and competition for food.

Females dominated the commercial catches of *T. lepturus* in all years along northern Arabian Sea and northern BOB. Dominance by females in most months and by males in few months could be attributed to the differential fishing because of the changes in the pattern of migration of sexes to and from the fishing grounds. Females also outnumbered males in most size and age classes in the South China Sea⁵ and Arabian Sea coast of Oman²⁸. Length at first maturity was significantly higher in northern Arabian Sea when compared to that of northern BOB. The differences in exploitation rates and patterns between northern Arabian Sea and northern BOB is the reason for this variation, as fish tends to mature early when the fishing pressure is very high or when they are overexploited. Peak spawning in winter and premonsoon months with a prolonged spawning season spanning throughout the year was observed for *T. lepturus* from northern Arabian Sea and northern BOB which corroborates the findings of earlier workers from Kakinada along northern BOB^{9,29}. Proportion of mature females during peak spawning period was more in northern Arabian Sea probably because of trophic enrichment caused by monsoon upwelling providing a favourable reproductive regime for *T. lepturus*³⁰. Peak spawning period indicated by IG in the present study from both the regions is in general conformity with the percentage occurrence of maturity stages in different months. Proportion of mature females and IG along northern Arabian Sea was found to be significantly higher in 2007 and lower in 2008. Northern Arabian Sea is strongly influenced by monsoon regime, which causes significant variations in seasonal and annual productivity¹. These variations in annual productivity could explain the possible differences observed in the proportion of mature females and IG over the years. These observations on the spawning season of *T. lepturus* from northern Arabian Sea and northern

BOB are further supported by the size progression of yolked ova during different months. James and Baragi³¹ and Narasimham⁶ stated that two major lots of ova mature and succeed one another in *T. lepturus*. Similarly in the present study from both the regions, the ripe ovaries of *T. lepturus* contained two batches of ova, one maturing and the other mature. Khan³² reported fecundity in the range of 4900–81000 with relative fecundity of 65 ova per g body weight. Similar estimates on 100.6 ova per g body weight for *T. lepturus* were reported by Abdussamad *et al.*⁹. Higher fecundity and higher ova per g body weight recorded in the present study from both northern Arabian Sea and northern BOB as compared to those recorded earlier from subtropical waters is because fish tends to produce large batches of eggs in temperate waters with marked variations in annual temperature. Variation in temperature was higher along northern Arabian Sea when compared to that of northern BOB³³ and this explains the higher fecundity observed along northern Arabian Sea. Higher food availability along northern Arabian Sea³⁰ possibly resulting in an increase in body lipid and its subsequent conversion to gonadal tissue might also contribute to the higher fecundity observed in this region. Relationship between fecundity and body length and between fecundity and body weight from both the regions indicated that the increase in fecundity in relation to the weight of fish is much lower than that of the length of fish.

T. lepturus is a voracious carnivore with strong cannibalistic behaviour. Fin fishes were the most preferred prey group in the diet of *T. lepturus*, followed by crustaceans and cephalopods. Similar results were expressed from Vizhinjam³⁴, Visakhapatnam⁷, southwestern Taiwan³⁵, Mediterranean coast³⁶ and South China Sea³⁷. Intensity of feeding was more in northern Arabian Sea than northern BOB probably because of more availability of prey items in the former region. Trophic richness of Arabian Sea LME makes it one of the most productive regions of the world³⁰. Non penaeid prawns and juveniles of ribbonfishes formed an important component of the diet in northern Arabian Sea, while penaeid prawns and carangids were

important food items in northern BOB. Feeding intensity varied within years along northern Arabian Sea and northern BOB. This variation could be attributed to the annual differences in productivity and trophic enrichment caused by the annual fluctuations in upwelling and monsoon. Food item analysis in relation to body size from both the regions depicted that juveniles fed mostly on prawns and cephalopods and adults preferred finfishes. *T. lepturus* exhibited monthly differences in diet composition and feeding intensity. Ontogenetic switches in feeding habits are a general phenomenon among fish and result from increases in body and mouth size that permit fish to capture a broader range of prey sizes and types³⁸. The response of *T. lepturus* to monthly changes in prey availability reflected the opportunistic behaviour and the trophic adaptability of this predator³⁷. Similar results on the sizewise feeding preferences were reported from Mediterranean coast³⁶. Young and immature *T. lepturus* have pointed teeth and are plankton feeders while adults possessing increased number of hooked canine teeth are piscivorous³⁹. Fishes with empty guts dominated throughout the year. Shock and suffocation to which the fish were subjected while being trapped in the trawl net and subsequent hauling probably caused such high incidence of empty stomachs. Feeding intensity varied between younger, middle aged and older fishes. This could be attributed to the fact that as fish grows in size and age several morphological changes occur in the form of increase in mouth size and improvement in locomotion ability which alters their prey catching efficiency.

The growth and mortality of *T. lepturus* was different along northern Arabian Sea and northern BOB. L_{∞} was higher in the former region because the largest fish sampled from this region was much higher than the largest fish sampled from the latter region. Differences in cod end mesh sizes of trawl nets operated along these two regions could have attributed to this difference in sampling. Growth performance index in the present study obtained from both the regions conforms fully to earlier published reports^{7,10,40-43}. Growth performance index is consistent for a particular species and so the values of L_{∞} and

K will compensate each other to arrive at the index value¹⁷. This variation in the growth parameters could also possibly be due to factors related to ecosystem and biological phenomena like maturity stages, feeding behaviour, competition for food, etc. Fishery along the northern BOB was dominated by fishes of two to four year classes, as also observed earlier from Visakhapatnam⁷. However along northern Arabian Sea, fishery was dominated by fishes of four to six year old classes which contradict earlier report¹⁰, where fishery was dominated by fishes of one to four year old classes. Length at first capture along northern BOB was low when compared to the length at first maturity indicating that majority of them were caught before they could mature and spawn at least once in their life. This indicated stress on spawning stock and could be addressed by increasing their size and age at exploitation. Similar length at first capture as compared to the present study was reported earlier from Kakinada⁹. However in northern Arabian Sea, the length at first capture was more or less equal to the length at first maturity suggesting that majority of them could mature and spawn at least once in their life before being caught. Recruitment was much higher along northern Arabian Sea than that of northern BOB. A combination of trophic enrichment and concentration and retention processes in northern Arabian Sea provides a favourable reproductive regime for pelagic fishes. Monsoon and upwelling with consequent replenishment of nutrients affect a plankton bloom giving better chance for the larvae to survive as food is plenty. Moreover, growth becomes faster and the larvae pass quickly through the critical stages. Faster growth of fish larvae in northern Arabian Sea is the reason for the higher length at recruitment observed in this region. Continuous recruitment of *T. lepturus* with three peaks observed in this study from northern Arabian Sea and northern BOB conforms to earlier published reports from the waters off Visakhapatnam⁴², Kakinada⁹ and Veraval¹⁰. Beverton and Holt⁴⁴ pointed out that the natural mortality coefficient of a fish is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_{∞}). The same appeared to be true for *T. lepturus* from northern Arabian Sea and northern BOB. The higher natural mortality in

northern BOB and lower natural mortality in northern Arabian Sea in the present study corresponded to high growth coefficient and low L_{∞} in northern BOB and low growth coefficient and high L_{∞} in northern Arabian Sea. The M/K ratio from both the regions was well within the normal range of 1–2.5⁴⁵. Exploitation ratio observed indicated overexploitation along northern BOB and underexploitation along northern Arabian Sea. However, Abdussamad *et al.*⁹, Reuben *et al.*⁷ and Ghosh *et al.*¹⁰ recorded much higher ratio of exploitation than that of the present study. Yield per recruit because of lower annual recruitment numbers was marginally higher in northern BOB when compared to northern Arabian Sea. The yield per recruit obtained in the present study conforms to that reported earlier from Veraval¹⁰ but differs from those reported earlier from Kakinada^{8,10}. Lower exploitation of *T. lepturus* along northern Arabian Sea has resulted in higher biomass and biomass per recruit. It is evident from the results along northern BOB that since the value of E are marginally higher than the E_{\max} value of 0.58 and the values of MSY, Total B, Fish B and SSB are marginally lower than the values of annual catch, Total $B_{0.5}$, Fish $B_{0.5}$ and $SSB_{0.2}$, the stock is under slightly higher fishing pressure than the sustainable level. A small increase in yield is obtained by decreasing the present F of 0.81 to 0.73 – 0.76. At the decreased F of 0.73 – 0.76, Total B, Fish B and SSB values are in agreement to the values of Total $B_{0.5}$, Fish $B_{0.5}$ and SSB. Therefore the present F is marginally above optimum and can be reduced from 0.81 to 0.73–0.76 for rationally exploiting the resource of *T. lepturus* from northern BOB. The situation is reverse in northern Arabian Sea, where the E is much lower than the E_{\max} value of 0.75 and the MSY is higher than the annual catch allowing for an increase in F from the present 0.18 to 0.34. This increase in F results in an increase in yield and yield per recruit without compromising on the biomass and biomass per recruit values which are still more than the values of their biological reference points (Total $B_{0.5}$, Fish $B_{0.5}$ and $SSB_{0.2}$). Thus, the present F is below optimum and can be increased from 0.18 to 0.34 for optimally exploiting the resource of *T. lepturus* along northern Arabian Sea.

Conclusion

Annual catch of *T. lepturus* has increased along both northern Arabian Sea and northern BOB over the years. Along northern BOB, the stock is marginally overexploited but along northern Arabian Sea the stock is underexploited with ample scope for increasing the exploitation rate. Mean length was higher along northern Arabian Sea with isometric growth while growth was allometric in northern BOB. Females dominated the catches in both northern Arabian Sea and northern BOB with higher length at first maturity and higher fecundity in the former region. Feeding intensity was more in northern Arabian Sea. Juveniles from both the regions fed mostly on prawns and cephalopods while adults preferred finfishes.

Acknowledgements

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References

- Desai, B. N. and Bhargava, R. M. S., Biologic production and fishery potential of the Exclusive Economic Zone of India, in: *Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management*, edited by K. Sherman, E. Okemwa and M. Ntiba, (Blackwell Science, Cambridge, US) 1998, pp. 327–333.
- Dwivedi, S. N., Long-term variability in the food chains, biomass yield and oceanography of the Bay of Bengal Ecosystem, in: *Large Marine Ecosystems: Stress, Mitigation and Sustainability*, edited by K. Sherman, L. M. Alexander and B. D. Gold, (AAAS Press, Washington DC) 1993, pp. 43-52.
- FAO, Trends in Oceanic Captures and Clustering of Large Marine Ecosystems—Two studies based on the FAO Capture Database, FAO Fisheries Technical Paper, 2003, 435 p.
- Vivekanandan, E., Srinath, M. and Kuriakose, S., Fishing the marine food web along the Indian coast, *Fisheries Research*, 72 (2005) 241-252.
- Kwok, K. Y. and Ni, I. H., Reproduction of cutlassfishes *Trichiurus* spp. from the South China Sea, *Marine Ecology Progress Series*, 176 (1999) 39–47.
- Narasimham, K. A., *Maturity, spawning and sex ratio of the ribbonfish Trichiurus lepturus Linnaeus off Kakinada*, *Journal of the Marine Biological Association of India*, 36 (1994) 199-204.
- Reuben, S., Vijayakumaran, K., Achayya, P. and Prabhakar, R. V. D., Biology and exploitation of *Trichiurus lepturus* Linnaeus from Visakhapatnam waters, *Indian Journal of Fisheries*, 44 (1997) 101-110.
- Narasimham, K. A., On fishery, mortality rates and yield per recruit of ribbonfish *Trichiurus lepturus* Linnaeus, *Indian Journal of Fisheries*, 30 (1983) 99-109.
- Abdussamad, E. M., Nair, P. N. R. and Achayya, P., 2006. The ribbonfish fishery and stock assessment of *Trichiurus lepturus* Linnaeus off Kakinada, east coast of India, *Journal of the Marine Biological Association of India*, 48 (2006) 41-45.
- Ghosh, S., Pillai, N. G. K. and Dhokia, H. K., Fishery and population dynamics of *Trichiurus lepturus* (Linnaeus) off Veraval, north-west coast of India, *Indian Journal of Fisheries*, 56 (2009) 241-247.
- Srinath, M., Kuriakose, S. and Mini, K. G., Methodology for estimation fish landings in India, CMFRI Special Publication 86 (2005), 57 pp.
- Le Cren, E. D., The length weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*), *Journal of Animal Ecology* 20 (1951) 201-219.
- Snedecor, G. W. and Cochran, W. C., *Statistical Methods*, (Oxford and IBH Publishing Co., Calcutta, India), 1967, 593 pp.
- King, M., *Fisheries biology, assessment and management*, (Oxford University Press, Oxford, UK) 1995, 342 pp.
- Pinkas, L., Oliphant, M. S. and Iverson, I. L. K., Food habits of albacore, bluefin tuna and bonito in California waters, *California Fish Game*, 152 (1971) 1-105.
- Clarke, K. R. and Gorley, R. N., *Primer v. 6: User manual/tutorial*, PRIMER-E Ltd., Plymouth U.K., 2006, 192 pp.
- Sparre, P. and Venema, S.C., *Introduction to tropical fish stock assessment, Part 1 manual*, FAO Fisheries Technical Paper, 306/1 Rev. 2, (FAO, Rome) 1998, 407 pp.
- Gayanilo, Jr. F. C., Sparre, P. and Pauly, D., *The FAO-ICLARM stock assessment tools (FiSAT) user's guide*, FAO computerised information series: Fisheries, (FAO, Rome, Italy) 1997.
- Pauly, D. and Munro, J. L., Once more, on the composition of growth in fish and invertebrates, *Fishbyte* 2 (1984) 21.
- Pauly, D., Length converted catch curves. A powerful tool for fisheries research in tropics (Part-II), *ICLARM Fishbyte* 2 (1984) 13-14.
- Pauly, D., Theory and management of tropical multi-species stocks. A review with emphasis on the south-east Asian

- demersal fisheries, ICLARM studies and reviews 1, 1979, 35 pp.
- 22 Pauly, D., On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks, *Journal Cons. CIEM* 39 (1980) 175-192.
 - 23 Pauly, D., Length converted catch curves. A powerful tool for fisheries research in tropics (Part-1), *ICLARM Fishbyte* 1 (1983) 9-13.
 - 24 Gulland, J. A., Report of the FAO/UNDP workshop on the fishery resources of the Western Indian Ocean – South Equator, 10FC/DEV/79/45, (FAO, Rome) 1979, pp. 1-37.
 - 25 James, P. S. B. R., Narasimham, K. A., Meenakshi Sundaram, P. T. and Appanna Sastry, Y., Present status of ribbonfishes in India, CMFRI Special Publication 24, 1986, 49 pp.
 - 26 Bakun, A., Roy, C. and Lluch-Cota, S., Coastal upwelling and other processes regulating ecosystem productivity and fish production in the Western Indian Ocean, in: (Eds.), *Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management*, edited by K. Sherman, E. Okemwa and M. Ntiba, (Blackwell Science, Cambridge, US), 1998, pp. 103 – 143.
 - 27 Narasimham, K. A., *On the length-weight relationship and relative condition in Trichiurus lepturus Linnaeus*, *Indian Journal of Fisheries*, 17 (1970) 90-96.
 - 28 Al-Nahdi, A., Al-Marzouqi, A., Al-Rasadi, E. and Groeneveld, J.C., The size composition, reproductive biology, age and growth of largehead cutlassfish *Trichiurus lepturus* Linnaeus from the Arabian Sea coast of Oman, *Indian Journal of Fisheries*, 56 (2009) 73-79.
 - 29 Narasimham, K. A., Occurrence of early juveniles of ribbonfish *Trichiurus lepturus* Linnaeus in the Kakinada area with notes on their food, *Indian Journal of Fisheries*, 19 (1972) 210-214.
 - 30 Codispoti, L. A., Primary productivity and carbon and nitrogen cycling in the Arabian Sea, in: *US-JGOFS: Arabian Sea Process Study. US Joint Global Ocean Flux Study*, edited by S. L. Smith, K. Banse, J. K. Cochran, L. A. Codispoti, H. W. Ducklow, M. E. Luther, D. B. Olson, W. T. Peterson, W. L. Press, N. Surgi, J. C. Swallow and K. Wishner, Planning Report 13, Woods Hole Oceanographic Institution, Woods Hole, US.
 - 31 James, P. S. B. R. and Baragi, V. M., *Ovary as an indicator of frequency of spawning in fishes*, Proceedings of Indian National Science Academy - B, 46 (1980), pp. 479-489.
 - 32 Khan, M. Z., Fishery resource characteristics and stock assessment of ribbonfish, *Trichiurus lepturus* (Linnaeus), *Indian Journal of Fisheries*, 53 (2006) 1-12.
 - 33 Kothawale, D. R., Munot, A. A. and Borgaonkar, H. P., Temperature variability over the Indian Ocean and its relationship with Indian summer monsoon rainfall, *Theoretical & Applied Climatology* (2007), DOI: 10.1007/s00704-006-0291-z.
 - 34 Lazarus, S. and Sarma, P. S. S., The resource characteristics of the ribbonfish *Trichiurus lepturus* Linnaeus at Vizhinjam, south-west coast of India, *Journal of the Marine Biological Association of India*, 33 (1991) 89-98.
 - 35 Chiou, W. D., Chen, C. Y., Wang, C. M. and Chen, C. T., Food and feeding habits of ribbonfish *Trichiurus lepturus* in coastal waters of south-western Taiwan, *Fisheries Science*, 72 (2006) 373-381.
 - 36 Bakhom, S. A., Diet overlap of immigrant narrow-barred Spanish mackerel *Scomberomorus commerson* (Lac., 1802), the largehead hairtail ribbonfish *Trichiurus lepturus* (L., 1758) in the Egyptian Mediterranean coast, *Animal Biodiversity and Conservation*, 30 (2007) 147-160.
 - 37 Yan, Y., Chen, J., Lu, H., Hou, G. and Lai, J., Feeding habits and ontogenetic diet shifts of hairtail, *Trichiurus margarites*, in the Beibu Gulf of the South China Sea, *Acta Ecologica Sinica*, 32 (2012) 18-25.
 - 38 Labropoulou, M., Machias, A., Tsimenides, N. and Eleftheriou, A., Feeding habits and ontogenetic diet shift of the striped red mullet, *Mullus surmuletus* Linnaeus, 1758, *Fisheries Research*, 31 (1997) 257-267.
 - 39 Hanabuchi, S., On the variations of teeth form and number of gill rakers in ribbonfish *Trichiurus lepturus* Linne in the waters adjacent to Tsushima, *Bulletin of the Seikai Regional Fisheries Research Laboratory*, 43 (1973) 37-50.
 - 40 Chakraborty, S. K., Fishery, age, growth and mortality estimates of *Trichiurus lepturus* Linnaeus from Bombay waters, *Indian Journal of Fisheries*, 37 (1990) 1-7.
 - 41 Ingles, J. and Pauly, D., An atlas of growth, mortality and recruitment of Philippine fishes, *ICLARM Technical Report*, 13 (1984) 1-127.
 - 42 Narasimham, K. A., Age and growth of ribbonfish *Trichiurus lepturus* Linnaeus, *Indian Journal of Fisheries*, 23 (1976) 174-182.
 - 43 Somavanshi, V. S. and Joseph, A., Population dynamics and assessment of *Trichiurus lepturus* (Linnaeus) stock in northwest coast of India, *Studies on fish stock assessment in Indian waters*, Special Publication No. 2, Fishery Survey of India (1989), pp. 1-32.
 - 44 Beverton, R. J. H. and Holt, S. J., A review of method for estimating mortality rates in exploited fish population, with special reference to source of bias in catch sampling, *Rapports et Proces-Verbaux des Reunions CIEM*, 140 (1956) 67-83.
 - 45 Beverton, R. J. H. and Holt, S. J., A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics, in: *Ciba Foundation Colloquia on ageing*, edited by G. E. W. Wolsenholmy and M. O'Connor, 5, 1959, pp. 142-180.