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Dynamics of *Nemipterus japonicus* (Bloch) stocks along the north-east coast of India

M. V. Hanumantha Rao, S. Ghosh, K. Sreeramulu*, V. U. Mahesh, M. Satish Kumar & Muktha M.
Visakhapatnam Regional Centre of CMFRI, Pandurangapuram, Visakhapatnam – 530003, Andhra Pradesh, India
*Department of Zoology, Andhra University, Visakhapatnam – 530003, Andhra Pradesh, India
[E.Mail: subhadeep_1977@yahoo.com]

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The dynamics of Nemipterus japonicus stocks along the north-east coast of India was studied using landings data from 2012-2015. Annual average landing of the northern region was 1251 t and that of the southern region was 2980 t. Growth was found to be allometric in the northern region and isometric in the southern region. Von Bertalanffy growth equation was $L_t = 33.02\ [1 - e^{-0.38\ (t + 0.0625)}]$ in the northern region and $L_t = 29.87\ [1 - e^{-0.42\ (t + 0.0585)}]$ in the southern region. Natural mortality, fishing mortality and total mortality ranged from 0.92 to 1.01, 0.51 to 0.57 and 1.43 to 1.58. Exploitation ratio varied between 0.35 - 0.36 and exploitation rate between 0.27 – 0.29. Annual average stock, standing stock biomass and maximum sustainable yield were 4611 t and 10403 t, 2453 t and 5228 t and 1754 t and 4130 t for the northern and southern regions.

[Keywords: Fishery, *Nemipterus japonicus*, North-east coast, Population parameters, Stock status]

Introduction

Threadfin-breams form one of the major demersal fishery resources of north-east coast of India and are exploited mostly by trawlers in depths extending upto 70 m[1]. Five or six species contribute to the fishery, of which *Nemipterus japonicus* is the most dominant followed by *N. mesoprion, N. nematophorus, N. bipunctatus, N. peronii and N zysron*[2,3,4 and5]. However, first two species together contribute the bulk of the nemipterid landings at Digha, Paradeep, Visakhapatnam and Kakinada trawl landing centres[6]. Threadfin breams landings in the north-east coast contribute to about 5% of the country's landings with an economic value worth of rupees 80 crores on first hand sales. Traditionally, before mechanization of fishing vessels, fishing was restricted to inshore waters up to about 50 m depth for a long time. However the introduction of voyage fishing in late nineties, has led to extension of operations to about 150 m depth and this has led to phenomenal increase in catch and catch rates. Landings along the north-east coast for threadfin breams has increased from 1756 t in 1985 to 7832 t in 2013, with the highest recorded landing of 23344 t in 2011 [7]. Threadfin breams forms the chief raw material for preparation of surimi due to its high gel strength, texture and white meat color of the produce[8]. Availability of these resources has led to the establishment of surimi plants primarily on the source of threadfin breams[9].

There are studies on population parameters and stock estimates of *N. japonicus* from Visakhapatnam and Kakinada dating back to few decades [10,11, 12,13 and 14]. No studies have been conducted in the recent past on stock status for its sustainable management. All studies were from samples obtained from the southern region of north-east coast of India (Visakhapatnam and Kakinada), with no studies from the northern region (Paradeep and Digha). Studies on estimates of population characteristics such as growth, recruitment and mortality are used to identify stocks [15]. In the fisheries management perspective, recognition and assessment of stocks is necessary for effective management. Present study is an attempt to study the population characteristics and stock dynamics of *N. japonicus* landed by commercial trawlers along north-east coast of India for their sustainable management.

Materials and Methods

Data on catch and effort expended in trawls for *N. japonicus* were obtained for the period from January 2012 to December 2015 from various trawler landing centres along the north-east coast of India (from Frasergunj in the north to Kakinada in the south). The monthly and annual estimates of catch and effort were made following the Multistage Stratified Random Sampling Technique devised by Fishery Resource Assessment Division of Central Marine Fisheries Research Institute, India. Due to proximity in the trawl landing centres of Digha and Paradeep and of Visakhapatnam and Kakinada with great distance in between, the former is considered a separate management unit from the latter. Trawlers from Digha and Paradeep have a common fishing ground, as do the trawlers from Visakhapatnam and Kakinada. There is virtually no mixing of landings in both the regions due to strict measures of state fisheries department to control fishing of their resources in their respective territorial waters. Assorted samples were collected at weekly intervals from Digha and Paradeep (northern region) and Visakhapatnam and Kakinada (southern region). A total of 1,725 specimens of *N. japonicus* in the size range of 4.0 to 31.9 cm were collected randomly the northern region and 1,970 specimens in the size range of 4.0 to 28.9 cm were collected randomly from the southern region. Total length (mm) and wet body weight (grams to 0.01 g precision) were measured. Length - weight relationship was calculated as W = aLb [16] separately for both sexes and indeterminates for each region and significant differences in the slopes of the regression lines for males, females and indeterminates were ascertained by Analysis of Covariance ANACOVA [17].

For estimating Von Bertalanffy growth parameters, L∞ and K of each region, the monthwise length composition data from the landings in northern region and southern region for four years (2012-2015) were pooled and grouped with 1.0 cm class interval and analyzed using the ELEFAN I module of FiSAT software version 1.2.0 [18]. Growth performance index (φ) and probability and size at first capture (Lc) were estimated using standard equations[19 and 20]. Age at zero length (t_0) was calculated [21] and growth and age were determined using the von Bertalanffy growth equation, $L_t = L_\infty (1 - e^{-k (t- t_0)})$. Length at recruitment (Lr) was taken as the midpoint of the smallest length group in the catch. Lifespan (tmax) was estimated at 3/K + t0 [22]. Natural mortality (M) was calculated by Pauly's empirical formula [23] and total mortality (Z) was calculated from length converted catch curve [24] using FiSAT software. Fishing mortality (F) was estimated as Z - M. Length structured virtual population analysis (VPA) of FiSAT was used to obtain fishing mortalities per length class. Exploitation ratio (E) and exploitation rate (U) were estimated as F/Z and F/Z (1-e-z), respectively. Total stock (P) and biomass (B) were estimated from the ratios Y/U and Y/F respectively; where Y is the annual average yield in tonnes. Maximum Sustainable Yield (MSY) was calculated [25] for exploited fish stocks. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated from Beverton and Holt Yield per Recruit model using Excel worksheet [26].

Results

An annual average of 1251 t and 2980 t was landed in the northern and southern regions of north-east coast of India. Landing was highest in 2012 in the northern region (1819 t) and in 2014 in the southern region (3993 t). Fishing effort (hrs) was highest in 2012 in the northern region with an effort of 52.29 lakh hours and in 2015, it declined to 26.45 lakh hours. Similarly in the southern region also, fishing effort (hrs) was highest in 2012 with an effort of 53.65 lakh hours which gradually declined in 2015 to 37.19 lakh hours (Table 1).

Highest fishing effort (hrs) was recorded during October to February along the northern region and during August to December along the southern region. Along the north-east coast of India, 36% of the threadfin bream landings were reported during the fourth quarter followed by the first and third quarters with 30% and 28%, respectively. Landings were very poor in the second quarter with a contribution of 7%. Mean catch rate in trawls along the northern region was 0.34 kg / h, whereas in the southern region it was 0.66 kg / h. Highest landings were recorded during October – December along the northern region and August – December along the southern region (Table 2).

Length-weight relationship calculated separately for the two sexes and indeterminates from northern and southern region are presented in Table 3. The regression relation for females in the northern region was significantly different ($P<0.05$) from indeterminates, while in the southern region, the regression relation for both males and females differed significantly ($P<0.05$) from indeterminates (Table 4). Along the

Table 1 — Annual catch and catch rates of *N. japonicus* from northern and southern regions of north-east coast

Years	Northern Region			Southern Region		
	Catch (t)	Catch rate (kg / h)	% in trawlnet	Catch (t)	Catch rate (kg / h)	% in trawlnet
2012	1819	0.35	0.67	2861	0.53	1.82
2013	1748	0.41	1.09	2599	0.50	1.91
2014	796	0.37	0.76	3993	0.96	2.84
2015	640	0.24	0.53	2468	0.67	3.27

northern region, growth was allometric in males, females and indeterminates with slopes significantly differing (P<0.05) from 3; whereas in the southern region, slope for females and males did not vary significantly (P>0.05) from 3 indicating isometric growth but for indeterminates, growth was allometric (Table 3).

Table 2 — Seasonal abundance of *N. japonicus* from northern and southern regions

Months	Northern Region			Southern Region		
	Catch (t)	Catch rate (kg / h)	% in trawl net	Catch (t)	Catch rate (kg / h)	% in Trawl net
Jan	114	0.82	2.47	295	0.73	2.54
Feb	173	1.06	2.90	349	0.82	2.91
Mar	66	0.88	2.74	152	0.46	1.79
Apr	10	0.23	0.56	72	0.41	1.79
May						
Jun	39	0.88	2.27	164	0.48	1.76
Jul	48	0.62	2.18	272	0.65	2.65
Aug	127	1.10	3.05	355	0.65	2.22
Sep	90	0.87	2.27	378	0.74	2.50
Oct	176	1.04	2.75	272	0.73	2.20
Nov	254	1.05	2.31	258	0.56	2.14
Dec	161	1.00	2.36	415	0.77	2.47

Table 3 — Length-weight relation of N. japonicus from northern and southern regions

Sex	Northern Region			Southern Region		
	Male	Female	Indeterminate	Male	Female	Indeterminate
log a	0.026	0.021	0.024	0.015	0.016	0.018
b	2.776	2.855	2.737	2.952	2.937	2.861
r^2	0.96	0.94	0.95	0.94	0.93	0.97
t cal	5.78	5.80	4.97	1.80	2.89	5.79
t critical	1.97	1.96	1.98	1.96	1.96	1.96
P value	0.00	0.00	0.00	0.07	0.06	0.00
Sign.	S	S	S	NS	NS	S

Note: If Prob <0.05 then significant at 5% level
If Prob<0.01 then significant at 1% level
NS: Not significant
S: Significant

Growth and mortality parameters of *N. japonicus* from northern and southern regions are illustrated in Table 5 and Fig. 1. The fishery in both the regions was dominated by fishes of 2-year-old classes as evident from their large numbers in commercial catches. Length converted catch curve utilized in the estimation of Z is shown in Figs. 2 and 3. VPA (Figs. 4 and 5) indicated that main loss in the stock up to 15.4 cm size in the northern region and 13.4 cm size in the southern region was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased. However, never, in any length class, did the fishing mortality exceed the natural mortality.

Recruitment pattern was bimodal in the northern region and unimodal in the southern region. In the

Table 5 — Growth and mortality parameters of *N. japonicus* from northern and southern region

Parameters	Northern Region	Southern Region
Asymptotic length (L_∞) (cm)	33.02	29.87
Growth coefficient (K) (annual)	0.38	0.42
Growth performance index (φ)	2.62	2.57
Age at zero length (t_0) (years)	-0.0625	-0.0585
Lifespan (years)	7.83	7.08
Length at first capture (L_c) (cm)	5.07	5.41
Age at first capture (t_c) (years)	0.38	0.42
Natural Mortality (M)	0.92	1.01
Fishing Mortality (F)	0.51	0.57
Total Mortality (Z)	1.43	1.58
Exploitation Ratio (E)	0.35	0.36
Exploitation Rate (U)	0.27	0.29
Length at recruitment (L_r) (cm)	4.45	4.45
Annual number of recruits (millions)	132.6	394.8

Table 4 — Analysis of Covariance of length-weight relation between sexes and indeterminates of *N. japonicus* from northern and southern regions

Analysis of Covariance

Northern Region: Sex	Difference between slopes: F cal	Probability	Significance	Southern Region: Sex	Difference between slopes: F cal	Probability	Significance
Female Male	1.916	0.167	NS	Female Male	0.169	0.681	NS
Female Indeterminate	6.649	0.010	S	Female Indeterminate	5.692	0.017	S
Male Indeterminate	0.284	0.594	NS	Male Indeterminate	5.035	0.025	S

Note: If Prob <0.05 then significant at 5% level
If Prob<0.01 then significant at 1% level
NS: Not significant
S: Significant

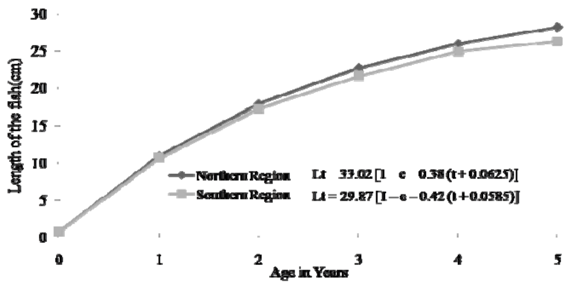

Fig. 1 — Length-at-age of *N. japonicus* from northern and southern regions of north-east coast

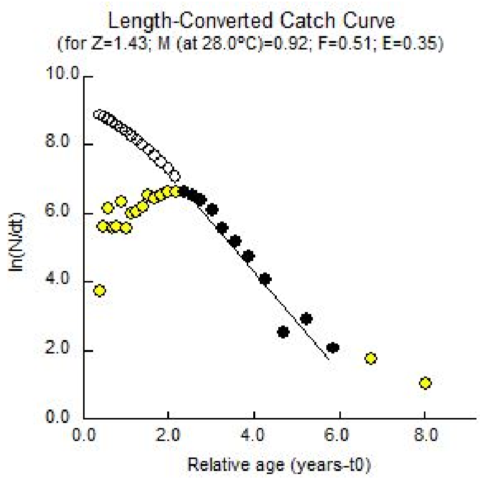

Fig. 2 — Length converted catch curve of *N. japonicus* landed in northern region

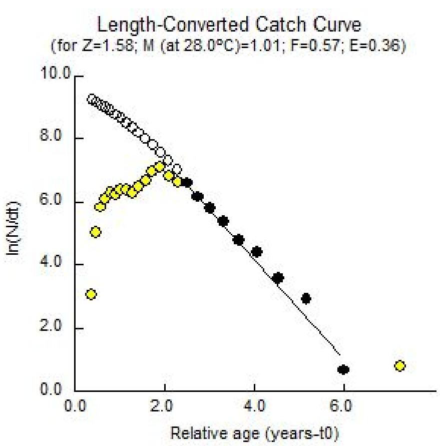

Fig. 3 — Length converted catch curve of *N. japonicus* landed in southern region

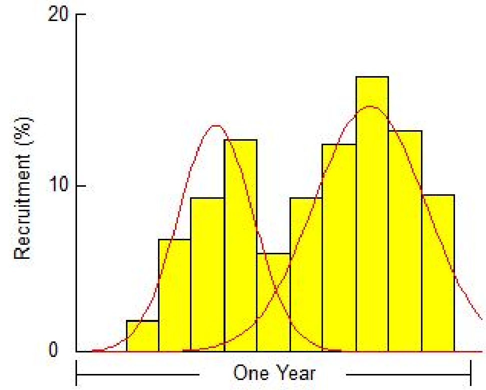

Fig. 4 — Length structured Virtual Population Analysis of *N. japonicus* from northern region

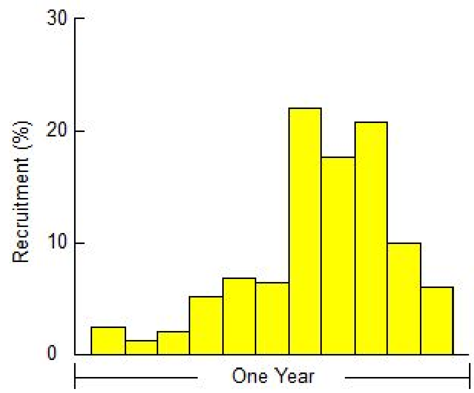

Fig. 5 — Length structured Virtual Population Analysis of *N. japonicus* from southern region

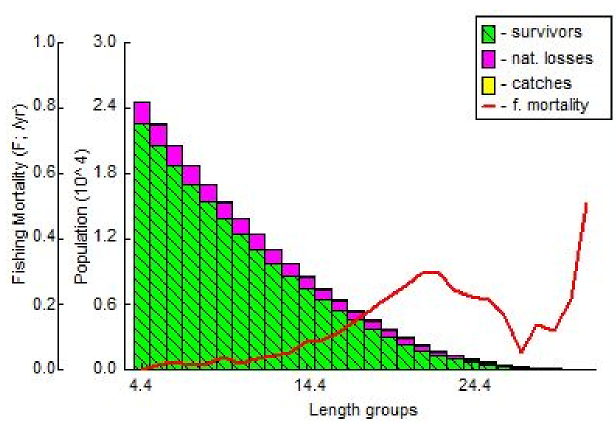

Fig. 6 — Recruitment pattern of *N. japonicus* from northern region

northern region, primary peak in recruitment producing 60.11% of the recruits was observed between July and November with a secondary peak producing 21.53% of the recruits between April and May (Fig. 6). The months from July to October produced peak recruitment in the southern region with 70.29% of the recruits (Fig. 7).

The stock estimates are depicted in Table 6. In both the regions, yield and biomass curves showed that yield and yield/recruit could marginally be increased

Table 6 — Stock estimates of *N. japonicus* from northern and southern region

Parameters	Northern Region	Southern Region
Yield	1251	2980
Annual average stock (t)	4611	10403
Standing stock biomass (t)	2453	5228
Maximum sustainable yield (t)	1754	4130
Yield per recruit (g)	9.43	7.55
Biomass per recruit (g)	18.50	13.24

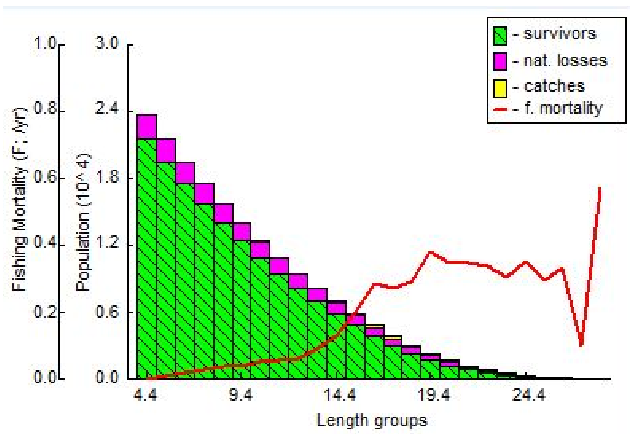

Fig. 7 — Recruitment pattern of *N. japonicus* from southern region

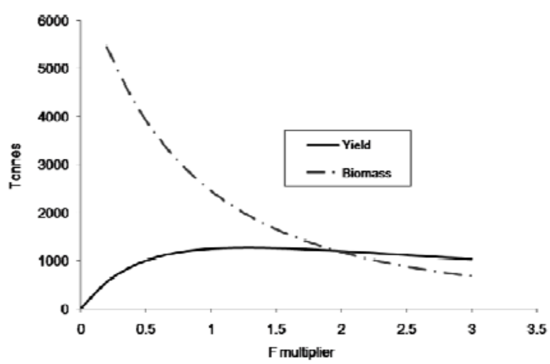

Fig. 8 — Yield and biomass of *N. japonicus* for different multiples of F from northern region

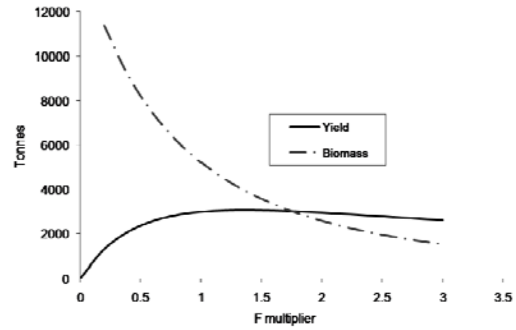

Fig. 9 — Yield and biomass of *N. japonicus* for different multiples of F from southern region

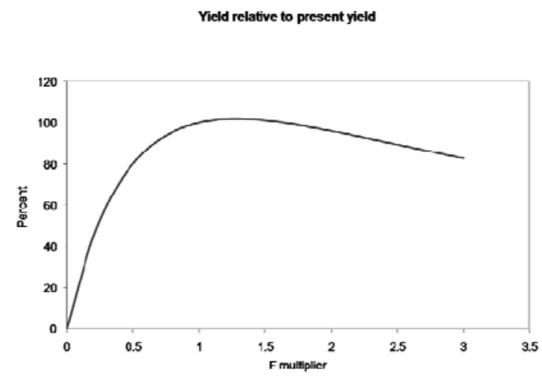

Fig. 10 — Yield relative to present yield of *N. japonicus* for different multiples of F from northern region

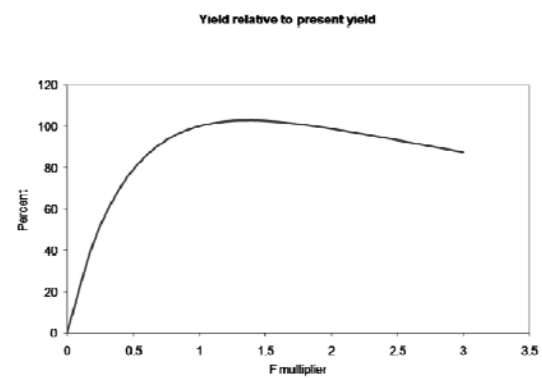

Fig. 11 — Yield relative to present yield of *N. japonicus* for different multiples of F from southern region

by increasing the present level of fishing by 20% to 40% (Figs. 8 and 9). Maximum yield and yield per recruit obtained on increasing the present fishing effort by 20% for northern region is 1272 t and 9.59 g and by 40% for southern region is 3061 t and 7.75 g. Increase in relative yield at the increased effort is a trivial 1.69% in the northern region and 2.72% in the southern region (Figs. 10 and 11).

Discussion

The catch recorded along the north-east coast has increased in recent years due to trawlers extending their range of operations and the duration of voyage. Between the years of study, catches fluctuated. Landings in general were higher during the last quarter of the year coinciding with increased effort. Contrary to earlier observations on peak abundance during January to April because of upwelling [27], no such phenomenon was observed in the present study. Landings and catch rates were higher in the southern region. *N. japonicus* prefers deep water habitat (75 m to 125 m) [28]. Deeper waters, due to very narrow continental shelf, are relatively nearer to the coast in the southern region than in the northern region where the continental shelf is wide. Trawlers, therefore catch the resource more efficiently in the southern region.

Growth was allometric in the northern region and mostly isometric in the southern region. Length–weight relation for indeterminate varied significantly from adults. In contrary to the earlier findings [6 and 29], who observed significant differences in length – weight relation between sexes in fishes caught off Visakhapatnam and Kakinada, no such differences were recorded in the present study. Similar values of exponents for length-weight relation were observed earlier by several authors [31, 31 and 32]. Lower exponent values were also observed [33 and 34]. Spatio temporal alterations in ecosystem and in biological phenomena like maturity stages, feeding behavior, food availability and competition for food influenced the changes in length-weight relationship.

Asymptotic length was higher in the northern region and growth coefficient was higher in the southern region. This is because of the larger length of the sampled fishes in the northern region when compared to the southern region. Differences between the two regions over asymptotic length and growth coefficient are largely due to differences in fishing area and depth of operation. As trawlers venture into much more deeper waters in the northern region because of wide continental shelf, they catch large individuals as abundance of larger sized individuals' increases with increasing depth [9]. Growth performance index is uniform for a species and is therefore similar from both regions. Asymptotic length is similar to 30.5 cm to 35.1 cm recorded earlier from Visakhapatnam and Kakinada [6, 12, 13 and 14]. Growth co-efficient is comparable to 0.31 to 0.52 year^{-1} recorded by the above authors. Earlier authors [6, 14 and 19] from Visakhapatnam and Kakinada found fish to attain an average length of 125 - 180 mm, 210 - 255 mm and 240 – 285 mm at the end of first, second and third year. In the present study, growth was comparatively slower and lifespan was more. Earlier authors [6 and 29] had reported longevity ranging from 3 to 6 years. Spatio temporal differences in environmental parameters, food availability, predation and exploitation pattern caused the observed variation in the growth parameters. Length at first capture was very low in both the regions. Down south, from Chennai, length at first capture was 8.5 cm [35]. This indicates that majority of the fishes were caught before they could mature and spawn at least once in their life signifying stress on the spawning stock. Increasing their size and age at exploitation by increasing the cod end mesh sizes of trawlnets could be used to address this issue.

Natural mortality coefficient of a fish is directly related to the growth coefficient (K) and inversely related to the asymptotic length ($L\infty$) and life span [36]. *N. japonicus* with moderate growth coefficient of 0.38 – 0.42 per year and moderate lifespan between 7 - 8 years was found to have moderate natural mortality coefficient of 0.92 – 1.01 per year. M/K ratio of 2.40 – 2.42 was within the normal range of 1 – 2.5 [37]. Similar natural mortality values of 0.50 [10], 1.14 [11], 1.11 [12], 0.94 – 1.06 [13] and 1.11 [14] were observed earlier from Visakhapatnam and Kakinada. However, exploitation ratio is lower than 0.38 – 0.69 reported earlier by various authors [11, 12, 13 and 14]. Yield per recruit is in conformity to 3.3 g – 22 g reported earlier [10, 11, 12 and 35].

For fisheries management perspective, it is vital to identify stock characteristics of the species and each stock has to be managed individually to exploit it optimally [38]. In multispecies and multigear fishery, managing stocks over a wide geographic area is difficult and often impossible and, therefore, for ease of management, it is appropriate that the management unit for stocks is kept as simple and small as possible. Marginal increase in yield, to the tune of 1.69% in the northern region and 2.72% in the southern region, is possible by increasing the present fishing effort by 20% to 40%. However fisheries along the north-east coast being multispecies in nature, any changes in effort will have to take into consideration other target species as well as it may lead to their growth overfishing. However, the lower length at first capture caused by the use of very small meshed cod end in trawls could have potential deleterious effects (recruitment overfishing) on the stock in future. It is thus recommended to increase the cod end mesh size of trawl nets which will increase the size and age at capture. Increasing size and age at capture will lead to increased yield in future from the existing fishing effort.

Conclusion

Catch and catch rates were higher in the southern region of the north-east coast. Length – weight relation of indeterminates varied significantly from adults. Exploitation rates and yield indicates the species to be near to optimally exploited. Increasing yield by increasing the effort is trivial.

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