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Stock assessment of Japanese threadfin bream, *Nemipterus japonicus* (Bloch, 1791) from Veraval water

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Fishery, population characteristics and stock estimates of *Nemipterus japonicus* was studied during 2006-2010 from Veraval water. Average annual landing was 5,577 t, which contributed to 4.49 % to the total trawl landings. Length-weight relationship showed growth was allometric for the species. L_{∞}, K and t_0 were estimated as 345.6 mm, 0.60/year and -0.1132 year. Total mortality rate (Z), fishing mortality rate and natural mortality rate (M) were estimated as 4.02/yr, 2.82/yr and 1.2/yr respectively. Exploitation ratio (E) was found to be 0.70 which showed overexploitation of the species. Length at capture and length at maturity were estimated as 165.47 mm and 180 mm respectively. Recruitment of the species was continuous with a peak in June. Thompson and Bell prediction analysis showed at present fishing level, there is depletion in the initial biomass, spawning stock biomass giving less revenue. Hence it is advisable to reduce the effort by 20%.

[**Keywords:** *Nemipterus japonicus*, Spawning stock biomass, Stock assessment, Length at maturity]

Introduction

The threadfin breams are one of the major demersal fishery resources, contributing 15.34% to the total demersal landings in India. In Veraval, threadfin bream fishery was dominated by *Nemipterus mesoprion* (48.4%), *Nemipterus japonicus* (41.9%) and *Nemipterus delagoe* (9.7%) during 2010[1]. *N. japonicus*, the Japanese threadfin bream has widespread distribution throughout the Indian ocean. Species is very abundant in coastal waters, found on mud and sandy bottoms usually in schools and are non migratory in nature. In Veraval, *N. japonicus*, locally called as 'Lal Machala' is mainly exploited by multiday trawls operating at a depth of 35-70 m depth. Catch is mainly used to produce surumi based products by the processing industries. It is also consumed fresh as well as salt-dried form in the domestic market and used as a raw material for the production of fishmeal. Considering the fisheries importance, it is essential to assess the stock of the species for proper management and sustainable exploitation of the resource. Many studies have been done on fishery, biology and population dynamics of the threadfin breams from both east[2,3,4,5,6,7&8] and west coast[9,10,11,12&13] of India. In Veraval, though considerable studies on fishery and biology[14,15,16&17] have already been done still there is a dearth of information on the population dynamics of the species in the north-west coast of India. Hence, the present study will help to suggest some of the management strategies to sustain the heavily exploited fishery off Veraval.

Materials and Methods

Data on catch, effort and length composition were collected weekly from commercial trawlers of Veraval landing centre of Gujarat (Fig. 1) for a period of 5 years from January 2006 to December 2010. A total of 3094 fresh specimens of *N. japonicus* in the size range of 60-300 mm were randomly collected

Fig. 1—map showing Veraval landing centre

and used for analysis. Total length of the fish was measured from tip of snout to up of lower caudal lobe to the nearest mm. Weight was measured from fresh specimens of *N. japonicus* to the nearest mg. Total catch of the species on the day of observation was recorded. Weekly length frequency data collected for the species were raised to the observation day's catch and then to monthly catch following the method of adopted by fisheries resources assessment division (FRAD) of CMFRI. The Von Bertalanffy growth parameters *viz*. asymptotic length (L_∞) and growth co-efficient (K) were estimated using monthly raised values in the ELEFAN 1 module of FiSAT[18]. Third growth parameter i.e. age at length zero (t_0) was calculated from the Pauly's empirical formula**:** $Log_{10} (-t_0) = -0.3922-0.2752 \log_{10} L_\infty - 1.038 \log_{10} K$[19]. Growth performance index (φ) was calculated from formula: $\varphi=\log_{10} K + 2\log_{10} L_\infty$ [20]. Longevity was estimated from the equation $t_{max} = 3/K + t_0$ [21]. The length-weight relationship of *N. japonicus* was calculated following the formula, $W=aL^b$ [22]. The values of W_∞ was estimated from the length-weight relationship ($W_\infty=aL_\infty^b$).

The raised annual length frequencies of catch of the species were pooled for all the years (2006-2010) and annual average values were obtained; these values were used as input for the study. Instantaneous total mortality rate (Z) was estimated by a combination of length converted catch curve method[23], Jones and Van-Zalinge[24] and Breverton and Holt[25] using the pooled data of all the five years and the FiSAT package. Instantaneous natural mortality rate (M) was estimated by Pauly's empirical equation[26], taking mean sea surface temperature at 27° C and the fishing mortality rate (F) was obtained as F= Z-M. The exploitation ratio (E) was calculated as E= F/Z and the exploitation rate was calculated as $U=F/Z (1-e^{-Z})$. Length structured virtual population analysis (VPA) of FiSAT was used to obtain fishing mortalities per length class.

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length frequency data as described in FiSAT. Temporal spread was reduced by using the restructured data and normal distribution of the recruitment pattern was determined by maximum likelihood method using NORMSEP[27].

The midpoint of the smallest length group in the catch during the five-year period was taken as length at recruitment (Lr). Length at first capture (Lc_{50}) was estimated from length converted catch curve method of Pauly[28]. Probability of capture was approximated by backward extrapolation of the regression line of descending limb of length converted catch curve. Probability of capture of sequential length classes were regressed using a logit curve for the estimation of Lc_{50}.

Length at first maturity (LM_{50}) is the length at which 50% of the female in the stock attain sexual maturity. For determining LM_{50}, 965 nos. of females of *N. japonicus* ranging from 95 to 290 mm in total length collected during January 2006 to December 2010 were used for the analysis. Ovarian development of females was classified into 7 stages *viz*. Immature-I, early maturing-II, maturing-III, mature-IV, ripe-V, spawning-VI and spent-VII as given by Thomas[29]. Females of stage III and above were considered as matured and the proportions of mature female in sequential length classes (5 mm) were used for the logistic regression analysis as described by Ashton[30]:

$$P = e^{a+bL} / 1+ e^{a+bL}$$

and the logit transformation: $\ln [P/(1-P)] = a+bL$. Where P is the predicted mature proportion, a and b the estimated coefficients of the logistic equation and L the length. Maximum-likelihood method was considered to be the most satisfactory methodology for estimating length and age at maturity[31&32]. Goodness of fit of logistic curve was assessed by using chi-square test using by maximum likelihood method. Size at maturity were estimated as the negative ratio of the coefficients (-a/b).

The relative yield per recruit (Y'/R) and relative Biomass per recruit (B'/R) at different fishing levels were estimated by Beverton and Holt's relative yield per recruit analysis method[33] by FiSAT II package. Yield (Y), Biomass (B) and spawning stock biomass (SSB) at different fishing levels were predicted by length based Thompson and Bell bio-economic model[34].

Results

The annual catch of *N. japonicus* during 2006-2010 varied from 4374 t in 2007 to 6711 t in 2008 with an annual average of 5577 t which contributed 4.49% to the total trawl catches and 41% to the threadfin landing at Veraval during the period (Table 1). Similarly, the effort level fluctuated from 45,383 units in 2007 to 54,307 units in 2008. Catch rate (CPUE) was minimum (96 kg/unit) in 2007 and maximum (124 kg/unit) in 2008. Average catch rate during the

Table 1—Trawl effort and catch of *Nemipterus japonicus* landed at Veraval during 2006 to 2010

Year	Total trawl landing (t)	Efforts (units)	Catch of thread fin breams (t)	Catch of *N.japonicus* (t)	CPUE of *N.japonicus* (Kg/unit)	*N.japonicus* in thread fin breams landing (%)	*N.japonicus* to the the total fish landing (%)
2006	118525	51510	10450	5267	102	50	4.44
2007	98517	45383	9784	4374	96	45	4.44
2008	140881	54307	22111	6711	124	30	4.76
2009	130288	52880	11014	6454	122	59	4.95
2010	131337	49535	23842	5079	103	21	3.87
Average	123909	50723	15440	5577	109	41	4.49

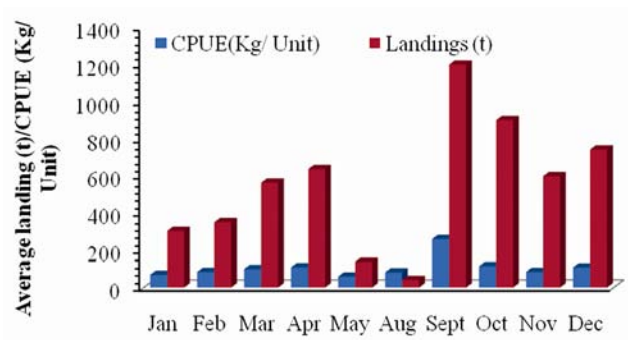

Fig. 2—Seasonal abundance of *Nemipterus japonicus* atVeraval during 2006-2010.

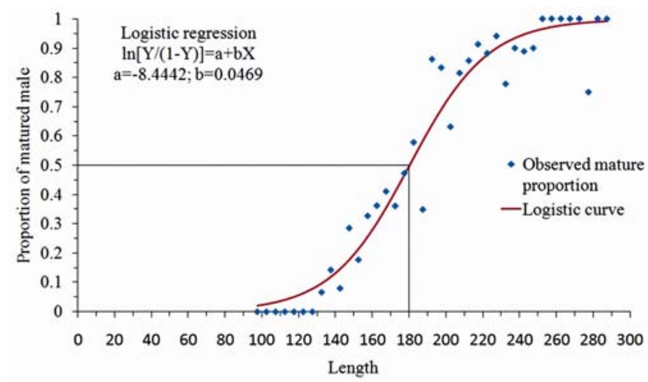

Fig. 3—Size at maturity (LM_{50}) of *N. japonicus*

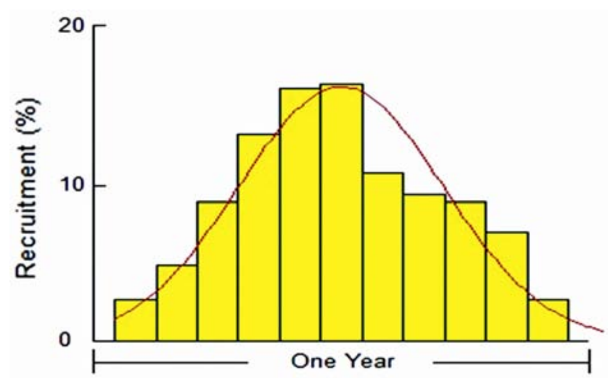

Fig. 4—Recruitment pattern of *N. japonicus*

period was 109 kg/unit. Average monthly catch and CPUE were highest in September (1201 t and 260 kg/unit) (Fig. 2). The catch was lowest in August (40 t) and the CPUE was lowest in May (59 kg/unit).

For length weight relationship, both sexes (sample of 1787 ranging from 101-290 mm total length) were pooled and a common equation was calculated as follows: Log W = -4.69897+ 2.9807 Log L or $W=0.00002\ L^{2.9807}$ (R^2=0.98). Logistic regression of the probability of capture for sequential length classes obtained from length converted catch curve analysis revealed that 50% of the fishes in stock become vulnerable to gear at the length of 165.47 mm (L_{50}%). The L_{25}% and L_{75}% were also calculated as 146.18 mm and 184.76 mm respectively.

Maturity study using 965 nos. of female samples of *N.japonicus* revealed that, first gonadal maturity commences at the length of 135 mm onwards. Proportions of mature female in sequential length classes were analyzed by logistic regression following maximum-likelihood method. The logistic equation obtained from the analysis was as follows:

$$\ln [Y/(1-Y)]=-8.4442+0.0469X$$

Size at maturity was estimated as the negative ratio of the coefficients (-a/b) and found to be 180 mm (Fig. 3).

The recruitment pattern demonstrated that *N. japonicus* was recruited in the fishery continuously throughout the year with the peaks from May to July (Fig. 4). The percent recruitment varied from 2.71 to 16.25%. The highest recruitment was observed in the month of June (16.25%) whereas the lowest recruitment was observed during January and November months. The smallest length at recruitment for *N. japonicus* was found to be 60 mm.

The growth parameters L_∞, K were estimated as 345.6 mm and 0.60/yr respectively. Restructured growth curve of *N. japonicus* for 2006 to 2010 has been shown in Fig. 5. The growth performance index

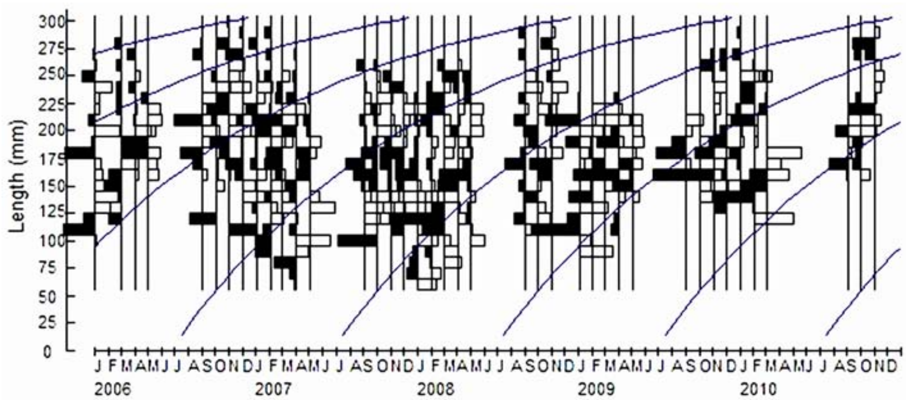

Fig. 5—Restructured growth curve of *N. japonicus* for 2006 to 2010 ($L\infty$ = 345.6 mm, K = 0.60, C = 0, WP = 0 and Rn = 0.141).

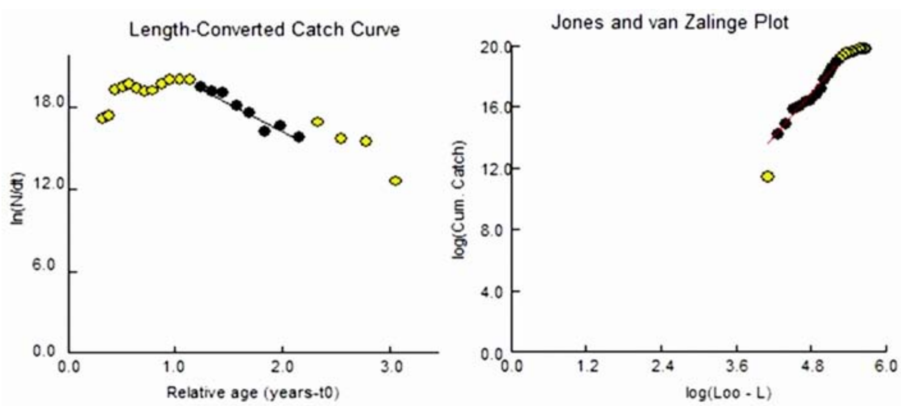

Fig. 6—(a) Estimation of Z from Length converted catch curve method. 6 (b) Estimation of Z from cumulative catch curve method.

(φ) was found to be 2.85 and t_0 was calculated as − 0.1132 years. The growth can be described by Von Bertalanffy growth equation as: Lt = 345.6 [1 – e - 0.60 (t + 0.11)]. In the 1st, 2nd and 3rd year the fish grows up to 135 mm, 248 mm and 292 mm respectively. The longevity of fish was found to be as 4.89 year. The fishery was dominated by 0.6 to 1.3 year age group. The asymptotic weight ($W\infty$) was estimated as 737.49 g from the length-weight relationship.

Mortality, Exploitation and Virtual population analysis:

The total mortality rate (Z) was calculated by a combination of methods using Pauly's length converted catch curve method[21], Jones and van-zalinge cumulative catch curve method[24] and Breverton and Holt[25] and the results were 4.02/yr (Fig. 6(a)), 4.36 (Fig. 6(b)) and 4.19/year (where for Breverton and Holt, L_{mean}=157 mm and L'=130 mm) respectively. Natural mortality (M) was calculated as 1.20/year and for further estimation length converted catch curve was taken into consideration. Fishing mortality obtained as Z-M= (4.02-1.20)=2.82/yr. The exploitation ratio and rate were found out to be 0.70 and 0.68 respectively. Virtual population analysis showed that natural mortality exceeded the fishing mortality upto the length of 160 mm after which the fishing mortality was found to be more than natural mortality. Mean value for fishing mortality was 1.18/ yr and the maximum fishing mortality (5.06/yr) was observed at the length of 290 mm (Fig. 7).

Stock assessment:

The relative Y/R and B/R analysis of *N. japonicus* were estimated using selection ogive procedure of FiSAT II (Fig. 8). L_{C50}/L_∞ as 0.478 and M/K as 2 were used as the input data for knife-edge selection procedure. Analysis indicated that, maximum allowable limit of exploitation level (E_{max}) that gives the maximum relative Y/R was estimated at 0.69 resulting 85.6% decrease in the relative B/R of unexploited stock. Similarly $E_{0.1}$, the level of

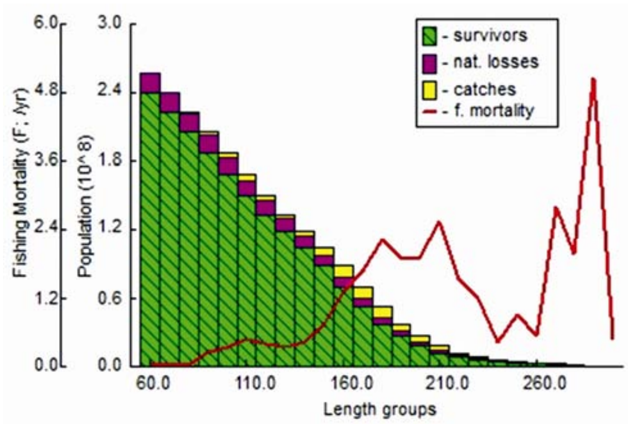

Fig. 7—Length structured VPA for *N. japonicus* for the years 2006 – 2010.

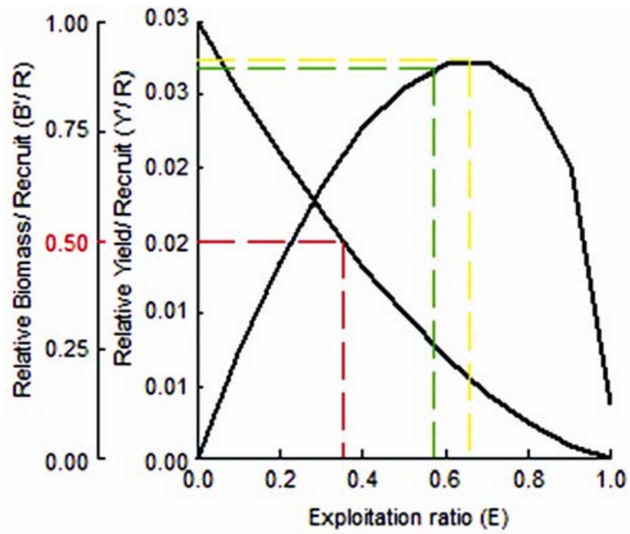

Fig. 8—Selection Ogive for *N. japonicus*

exploitation at which the marginal increase in relative yield per recruit is 10% of its value at E=0 was estimated as 0.56 resulting 77.5% decrease in the relative B/R of unexploited stock. $E_{0.5}$ which corresponds to 50% of the relative B/R of unexploited stock was 0.35. The yield isopleths diagram (Fig. 9) showed that optimum relative yield per recruit could be obtained at L_{C50}/L_∞ of 0.55 and E of 0.5.

Yield (Y), Biomass (B) and spawning stock biomass (SSB) at different fishing levels predicted using length based Thompson and Bell bio-economic model [34] has been summarized in Table. 2 and Fig. 10. The analysis shows that, maximum sustainable yield (MSY) can be obtained at a fishing level of 1.4 whereas the maximum economic yield (MEY) can be obtained at a fishing level of 0.8 (Fig. 10).

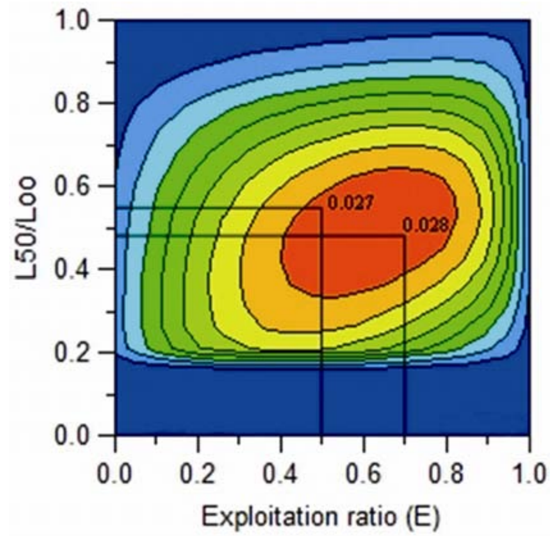

Fig. 9—Yield isopleths diagram for *N.japonicus*

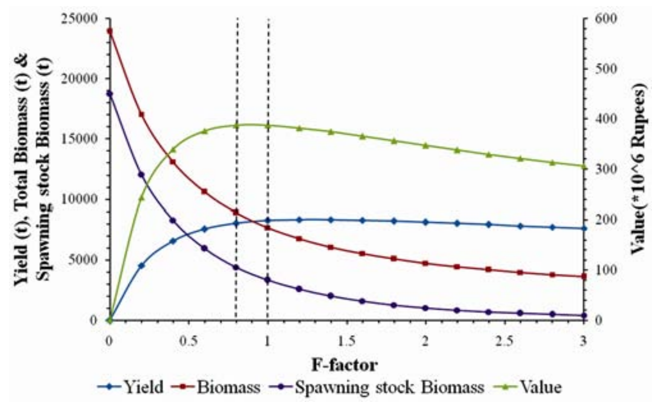

Fig. 10—Thompson and Bell analysis of *N. japonicus*

Discussion

The increase in annual catch of 2008 compared to catch of 2007 is due to corresponding increase in the effort level. Similarly, a considerable increase in the CPUE was also observed during the period (2007 and 2008) despite of an increase in the effort indicating an increase in the abundance. However, this increase in CPUE could be due to the expansion of fishing ground during the period. The highest average monthly catch and CPUE was observed in September following the seasonal closure of mechanized trawl during northwest monsoon. Lowest catch during August is due to the initiation of fishing activity and very less number of fishing units in operation. CPUE were low in May prior to closure which indicates exhaustive exploitation of the resource. This clearly indicates that seasonal closure plays an important role in the revival of *N. japonicus* stock.

Table 2—Thompson and Bell yield and Biomass prediction for *N.japonicus*

Factor-X	Yield (t)	Biomass (t)	SSB (t)	Value (10^6Rupees)	B/B_{init}	SSB/SSB_{init}
0	0	23939.22	18767.07	0	100	100
0.2	4536.18	17057.54	12070.28	243.93	71.25	64.32
0.4	6576.34	13104.59	8291.97	339.50	54.74	44.18
0.6	7557.42	10595.15	5947.63	376.21	44.26	31.69
0.8	8038.63	8886.95	4395.64	387.65	37.12	23.42
1	8262.60	7664.93	3321.53	387.60	32.02	17.70
1.2	8345.30	6757.59	2554.35	382.18	28.23	13.61
1.4	8346.95	6063.61	1993.30	374.28	25.33	10.62
1.6	8301.02	5519.37	1575.20	365.34	23.06	8.39
1.8	8227.11	5083.04	1258.68	356.10	21.23	6.71
2	8137.08	4726.22	1015.73	346.94	19.74	5.41
2.2	8038.32	4429.12	826.93	338.05	18.50	4.41
2.4	7935.48	4177.65	678.53	329.52	17.45	3.62
2.6	7831.48	3961.63	560.67	321.40	16.55	2.99
2.8	7728.16	3773.57	466.17	313.67	15.76	2.48
3	7626.66	3607.91	389.73	306.34	15.07	2.08

According to the study of Gopal and Vivekanandan[14], mature females were observed throughout the year with maximum occurrence during February and March. Similarly, the observations of Vivekanandan and James[4] suggested prolonged spawning season of *N. japonicus* along Veraval coast indicating continuous recruitment. In the present study, we observed continuous recruitment of the species with a peak in June which corroborates with the earlier observations.

The length weight relationship of *Nemipterus japonicus* from Veraval waters was derived to be Log W= -4.7338 + 2.9902 Log L (r =0.9786) by Manojkumar[17] which is found to be in agreement with the present finding (Log W = -4.69897+ 2.9807 Log L). Growth coefficient 'b' of length- weight relationship generally lies between 2.5 and 3.5 and the relation is said to be isometric when it is equal to 3 as reported for most of the aquatic animals[35&22]. Value of b (2.9807) in the present study indicates the isometric nature of growth in the species. Estimated growth parameters L_∞ and K in the present study are 345.6 mm and 0.60 which is found to be in agreement with the findings of Vivekanandan[8] who estimated K = 0.733, t0 = - 0.1167 and L_∞, = 337 mm from Veraval waters. However, the present estimate of L_∞ (345.6 mm) was found to be higher than L_∞, estimated from Visakhapatnam coast[7] (305 mm), Kakinada coast[2] (314 mm) Madras coast (305 mm)[36] and Cochin coast (325 mm)[37]. In the 1st, 2nd and 3rd year the fish grows up to 135 mm, 248 mm and 292 mm respectively in Veraval waters which can be compared with the findings of Gopal and Vivekanandan[14].

The size at first maturity of *N. japonicus* is found out to be 180.04 mm. However, from the previous studies, it has been observed as 165 mm (stage V and above)[37], 125 mm (stage III - IV)[2] and 145 mm (stage III and above)[4], 180 mm (stage II and above)[14], 183mm (stage III and above)[17]. Present finding is more or less same with the earlier reports[14 &17]. Length at first capture of *N. japonicus* was estimated as 165.47 mm which is less than the length at the maturity (180.04 mm). This indicates that fishes enter into peak exploitation phase before attaining the sexual maturity and overexploitation can reduce the yield due to growth overfishing.

The estimated natural mortality (M) was 1.2 which can be compared with the earlier reports[2,4,11,13,36,37,38,39,40,41]where the values ranged from 0.50 to 2.52. Variation in M can be explained as a natural phenomenon which is controlled by density dependent (predation, availability of food etc.) as well as density independent factors (disease, natural calamities etc.) and varies within same species in different location. The estimated M is reasonable as the M/K ratio was found to be 2 which fall within the range (1-2.5) described by Breverton and Holt[42]. Fishing mortality observed in the present study, is quite high (2.82/yr) and the present exploitation ratio was 0.7 which is much higher than the optimum exploitation ratio of 0.5 as reported by Gulland[43] indicating overexploitation of the resource.

The relative Y/R and B/R analysis of *N. japonicus* shows that maximum Y/R is obtained at E_{max}= 0.69 where relative B/R is decreased by 85.6 % compared to unexploited biomass. Similarly at $E_{0.1}$=0.56, relative B/R is decreased by 77.5% compared to unexploited biomass. In the present study, with the current level of fishing mortality, the calculated exploitation ratio is found to be almost equal to the estimated E_{max}= 0.69 which is drastically reducing the biomass. As the fishery has achieved E_{max}, there is no scope for increasing the effort level. Hence it is advisable to reduce the fishing pressure on the stock. Moreover, fishes were caught below maturity size which can affect the yield. The reduction of the cod-end mesh size of trawl nets can result in the reduction of lengths at first capture (Lc_{50}) which in turn cause recruitment overfishing over a period of years[44]. Hence, the present recruitment overfishing can be overcome by increasing the mesh size and length at capture. The yield-isopleth diagram (Fig. 9) shows the eumetric fishing can be done at L_{C50}/L_{∞} of 0.55 and E of 0.5 where the length at capture will be 190 mm with a higher relative Y/R. Hence the mesh size should be increased to increase the length at capture size.

Thompson and Bell bio-economic analysis (Fig. 10) shows that, yield increases as the fishing level increases up to a certain point (F=1.4) after which it decreases suggesting an increase in effort level by 40% to achieve MSY of 8346.95 t. However, the current fishing level (F=1) has already decreased the initial biomass to 32% and spawning stock biomass to 17.70% and increase in effort level by 40% will further decrease initial biomass to 25.33% and spawning stock biomass to 10.62% (Fig. 11) which could be detrimental for the long term sustainability of the resource. However, increase in excess effort could result in overfishing of the stocks and lower economic rent from the fishery[45]. Taking the spawning stock biomass (SSB) as biological reference point, and looking at the maximum economic return, it appears, there is a need to reduce the fishing effort by 20% to maintain the SSB above 20% of the initial biomass for the replacement of the stock[46] and to obtain MEY, a biologically safe reference point than MSY[47]. At fishing level 0.8, the biomass and SSB could be maintained at 37% and 23.42% respectively while generating a yield of 8038 t, with a maximum economic value of 387×10^6 rupees. As the fishery is multispecies in nature, following the principle of uncertainty in the complex ecosystem system, it is advisable to draw conclusion after analyzing the status of other economically important demersal fisheries resources. From the earlier findings for *Pseudosciana diacanthus* *Otolithoides biauritus*[48] and *Pampus argentius*[49], it has been suggested to reduce the fishing pressure along Gujarat coast. Since the above species are economically high valued fishes, care should be taken to reduce the fishing pressure to sustain the demersal fisheries resources including *N. japonicus*.

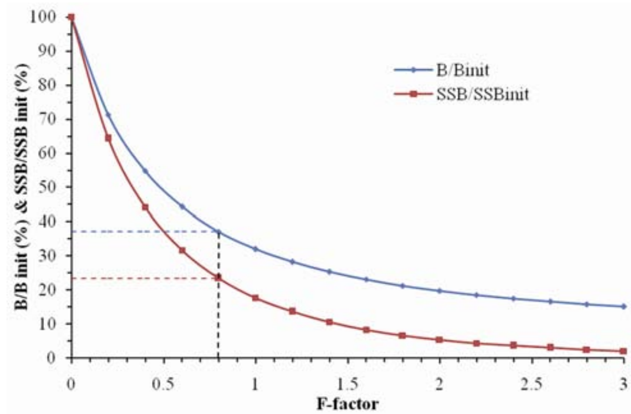

Fig. 11—Percentage of initial biomass and spawning stock biomass at different level of F

Conclusion

The present study reveals that the catch of *N. japonicus* is high during the post monsoon season. The exploitation ratio (E) for the species is 0.70 which indicates overexploitation of the resource. Length at capture (165.47 mm) is found to be lower than length at maturity (180 mm) and for eumetric fishing, the length at capture should be maintained at 190 mm by increasing mesh size of trawl net. As the current fishing pressure is considerably reducing the initial biomass and the spawning stock biomass giving less economic return, it is advisable to reduce the effort by 20% for the sustainable fishery.

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