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POPULATION DYNAMICS OF THE BOMBAY DUCK, *HARPODON NEHEREUS* (HAM.), OFF SAURASHTRA COAST

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ABSTRACT

The growth parameters estimated for *H.nehereus* are K=0.7618, L_∞ =425.2 mm and t_0=0.00789 yrs. The total mortality coefficient (Z) varied between 2.331 and 3.168 during 1979-'84. Yield per recruit (Yw/R) was estimated at 10.819g at F max 1.048. The size at first capture is very low (0.21 year), however, there is no possibility to fish close to optimum age at exploitation (ty) in view of low catch registered in the higher sized mesh *dol* net of 30 and 40mm. The estimated maximum sustainable yield (MSY) was at 44,066 t and the average yield was 44,064 t along the Saurashtra coast. In view of high Z during February to May and low percentage of commercial sized fish, suitable management strategy to be adopted are discussed in the paper.

INTRODUCTION

Bombay duck, *Harpodon nehereus* (Ham.) forms 24.0% of the total catch landed along Saurashtra coast during 1980-'84 (Balan *et al.*, 1987). However, the fishery is concentrated in a narrow belt of 45 km at the depth range of 18-40m. The important landing centres are Nawabunder, Rajapara and Jaffrabad. In addition to these, there are considerable fishery at Diu, Goghla and Simar under Union Territory. The Bombay duck resource along the Saurashtra coast is of an independent stock (Bapat, 1970 and Zafar Khan, 1983). The gear employed is *dol* net (bag net) of 35-60 metres length with a cod end mesh of 20mm. Of late, lot of information have been brought out on the *dol* net fishery along the coast (Zafar Khan, 1985, 1986 and 1988). The present account deals with population dynamics of the species based on detailed data collected from all the three centres along the Saurashtra coast with the objective to assess the status of the fishery and recommend means of rational exploitation of the resource.

MATERIAL AND METHODS

The basic data on effort and catch were collected as per the methods given by Sekharan and Dhulkhed (1963) together with length measurement and sample weight. As three types of crafts varying in tonnage are operated along the coast using 1-3 nets, the efforts were standarized as described by Zafar Khan (1988). The length measurements were grouped in 15mm interval and the number of fish in each size group was estimated. The data was processed according to the methods given by Zafar Khan (1988).

The method employed for age and growth studies and for estimating mortality rates and yield per recruits are given in the respective sections.

RESULTS

Fishery

Bombay duck forms about 80.8% of the *dol* net landings along the Saurashtra coast. The estimated catch at Rajapara, Jaffrabad and

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TABLE 1. *Estimated effort, catch and catch per effort of* Harpodon nehereus *at Jaffrabad, Rajapara and Nawabunder during 1979-'80, 1980-'81 and 1981-'82 fishing seasons*

Month	1979-'80			1980-'81			1981-'82			Average		
	Effort in hauls	Catch in kg	Catch/ haul	Effort in hauls	Catch in kg	Catch/ haul	Effort in hauls	Catch in kg	Catch/ in haul	Effort in hauls	Catch in kg	Catch/ haul
Sep.	10,180	14,95,018	146.858	3,459	8,34,257	241.184	2,398	5,60,310	233.657	5,346	9,63,195	180.182
Oct.	41,340	84,18,831	203.649	35,288	43,05,353	122.006	41,776	72,08,800	172.558	39,468	66,44,328	168.347
Nov.	40,763	98,15,813	240.802	61,732	79,42,788	128.666	60,970	1,56,65,767	256.942	54,488	1,11,41,456	204.474
Dec.	64774	91,32,556	140,991	70,581	95,29,105	135.009	1,11,414	1,39,03,983	124.796	82,256	1,08,55,215	131.968
Jan.	55,172	54,69,882	99.142	27,752	19,39,437	69.885	53,147	36,18,161	68.078	45,357	36,75,827	81.042
Feb.	44,480	29,48,424	66.287	20,489	5,13,264	25.051	20,885	9,27,504	44.410	28,618	14,63,064	51,124
Mar.	29,984	7,65,304	30.632	35,214	17,66,677	50.170	56,669	17,53,134	30.936	38,956	14,28,372	36,667
Apr.	50,024	11,79,880	23.586	17,649	19,81,987	112.300	44,798	17,18,606	38.363	37,490	16,26,824	43.393
May	14,739	27,34,612	185.536	9,427	18,48,075	196.041	15,902	10,43,842	65.642	13,356	18,75,510	140.425
Jun.	0	0	0.000	0	0	0.000	200	16,000	80.000	67	5,333	80.00
Total	3,46,456	4,19,60,320	121.113	2,81,591	3,06,60,943	108.885	4,08,159	4,64,16,107	113.721	3,45,402	3,96,79,123	114.878

Nawabunder during the three fishing seasons of 1979-'80, 1980-'81 and 1981-'82 are given in Table 1. The average catch was 39,679t at the catch rate of 114.878kg per haul. However, for long term studies the data were collected from Rajapara (Table 2) where the estimated catch over a period of five years varied between 12,839.4t (1982) and 20,859.6t (1981).

When the data on CPUE was subjected to time series analysis (Fig. 1) it revealed that in the beginning of fishing season the catch rate was high and as the season progressed it came down due to fishing. The lowest catch was recorded during February-March. April onward the catch tended to rise due to recruitment. Similar observations were made earlier also (Zafar Khan, 1985).

Length-weight relationship

Length and weight data of 732 males in the size-range of 180 to 280mm, 647 females in the size-range of 182 to 350mm and 66 indeterminates in the size range of 84 to 174mm collected during 1979-'80 were used. The relationship was estimated separately for both sexes and indeterminates which are given below :

Males : log W = -5.878 + 3.1446 logL

TABLE 2. *Estimated effort, catch and catch per effort of* Harpodon nehereus *at Rajapara during 1980-'84*

Year	Effort (No. of haul)	Catch (kg)	Catch/haul (kg)
1980	1,96,889	1,87,21,076	95.084
1981	1,32,397	2,08,59,624	157.554
1982	1,61,405	1,28,39,362	79.547
1983	1,69,151	1,51,61,284	89.632
1984	1,63,297	1,85,09,828	113.351

Females : log W = -5.7183 + 3.194 logL

Indeterminates : log W = -5.3465 + 2.998 LogL

As no significant differences were observed (Table 3) in the ` b' values of both sexes at 5% level by analysis of covariance (Snedecor and Cochran, 1967), the data were pooled and a single equation was estimated. The pooled equation is as follows :

log W = -5.9146 + 3.2786 logL

Estimation of growth parameter

The size-group ranged from 15-30 to 360-375mm. The monthly modes present were plotted (Fig. 2). The modes showing quarterly progression were used for the growth estimation. A plot of Lt + 1 against Lt as read

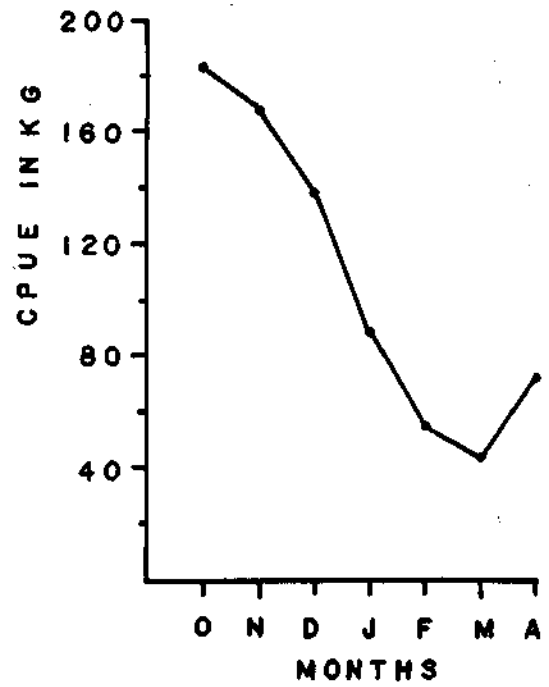

FIG. 1. *Harpodon nehereus* : Monthly CPUE, along the Saurashtra coast based on average of 1979-'80 to 1981-'82 fishing season.

off the different quarterly growth indicated that the observed points were well represented by the straight line (Fig. 3). $L\infty$ and K were estimated by regression analysis (Gulland, 1983). The estimated value of $L\infty$ is 425.2mm, K = 0.7618 and t_0 = 0.00789 years which was estimated by back tracing the first modes and using the formula given by Gulland (1983).

$$t_0 = t + \frac{1}{k} \log \frac{(L\infty - Lt)}{(L\infty)}$$

The estimated size of *H.nehereus* at the completion of I year and II year are 227.9 and 333.0 mm respectively (total length).

Estimation of mortality parameter

Total mortality coeffiecient (Z) : The total mortality coefficient was estimated by length converted catch curve of Pauly (1982) by using the relation :

$\log (N/\Delta t) = a+bt$

where, b=-Z

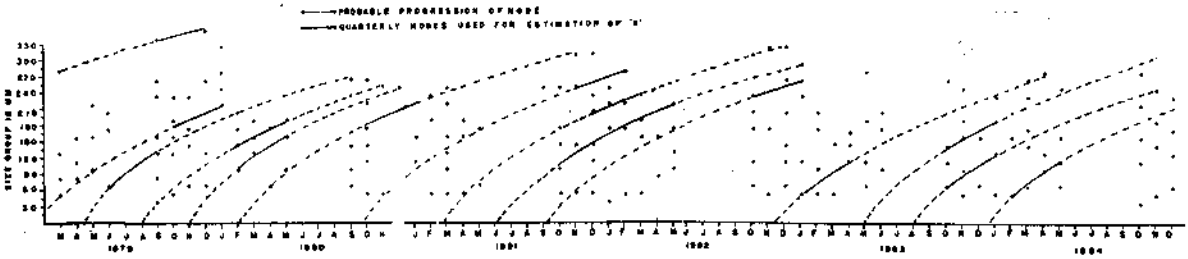

FIG. 2. *Harpodon nehereus* : Monthly distribution of modes.

TABLE 3. *Results of Analysis of Variance between two sexes of* Harpodon nehereus

	df	Σx^2	Σxy	y2	Regression coefficient	Deviation from regression df	ss	ms
Males	731	7.589	23.869	95.305	3.1446	730	20.2327	0.0277
Females	646	6.285	20.088	83.218	3.194	645	19.0098	0.0295
						1375	39.2425	0.02854
Pooled	1377	13.874	43.957	178.523		1376	39.2547	0.02853
						1	0.0122	0.0122

F= 0.428; df=1 and 1376. not significant at 5% level.

The estimated value of Z during 1979-'84 at different centres are given in Figs. 4 and 5. The Z varied between 2.423 and 2.843 at Nawabunder during 1979-'81, and 2.524 and 3.168 at Rajapara during 1979-'84.

Natural mortality coefficient (M) : The natural mortality coefficient was estimated by using Cushing's model (1968), where in the unexploited state, if the number of one year olds is taken as 100 and the number surviving to an age of 3.93 (NT max) year as 1:

$$M = \frac{1}{3.93 - 1} \log \frac{100}{1} = 1.572$$

T max has been estimated as per Pauly's (1980) formula which is as follows :

$$T\ max = 3/K + t_o$$

M was also estimated by Srinath's (M.S.) empirical formula:

$$M = 0.4603 + 1.4753\ K$$

Also by the proposed expression of Srinath (M.S.) for estimating M:

$$NL = R\left(\frac{(L\infty - L)}{L\infty - L_r}\right)^{\frac{M}{K-1}}$$

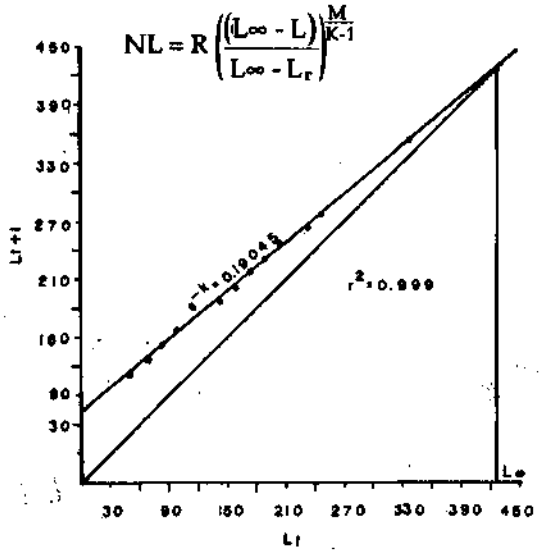

FIG. 3. *Harpodon nehereus* : Estimation of growth parameters by plotting quarterly growth (Lt+1) against the initial size (Lt.).

Where, R is the number of recruit and Lr is the length at recruitment.

If we assume that 95% of the recruit die when they reach 95% of L∞ then the equation can be rewritten as:

$$0.05 = \frac{(L\infty \times 0.05)^{\frac{M}{K-1}}}{(L\infty - Lr)^{\frac{M}{K-1}}}$$

The M, estimated by both the methods are 1.584 and 1.575 respectively. When the data on effort and Z of Rajapara was regressed to estimate the catchability coefficient, though the r value was poor (0.449) it gives an estimate of M, 1.609 (Fig. 6). Thus all these estimates are close.

Estimation of yield per recruit : The estimation of yield in weight per recruit (Yw/R) was estimated from the equation of Beverton and Holt (1957):

$$\frac{Yw}{R} = Fe^{-M(t_c - t_r)}W\left(\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K}\right)$$

where,
$S = e^{-K(tc-to)}$
tc = age at first capture,
tr = age at recruitment to the fishing ground.

The size at first capture was estimated by experimental fishing by operating 3 gears of 20 to 30 and 40mm cod end mesh with parallel haul. The details of the catch and design of the gear will be described elsewhere. The selection Ogive of 40/20 and 30/2 are given in Fig. 7. The estimated selection factor (SF) are 3.25 and 2.95. By taking SF 3.25 the length of first capture for the traditional gear of 20mm cod end mesh is estimated at 65mm and the estimated age at first capture (tc) is 0.21 year.

The smallest fish observed in the catch is 22mm, therefore the estimated age of it i.e. 0.0635 year was taken as the age at recruitment

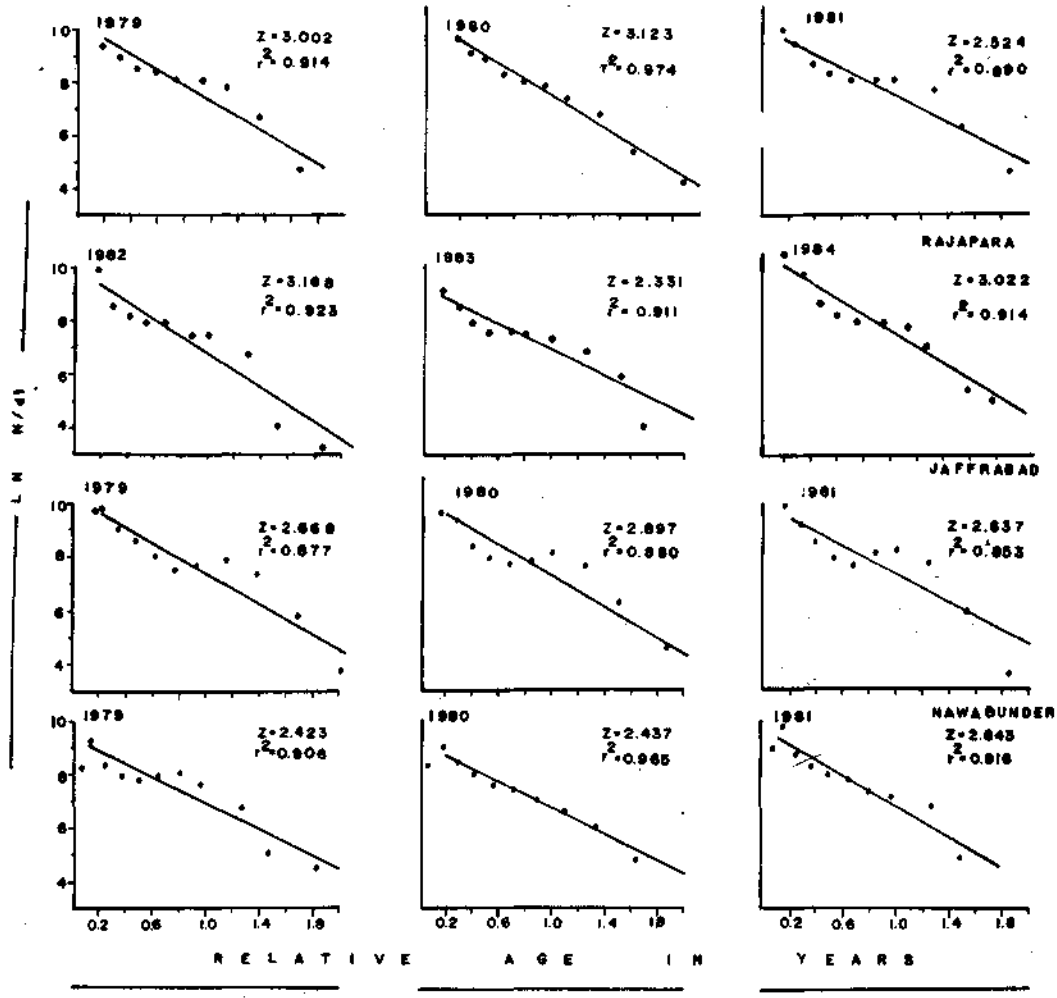

FIG. 4. *Harpodon nehereus* : Estimation of Z by length converted catch curve.

(tr). The estimated W∞ is 505 g at L∞ 425.2mm.

The estimated Yw/R at M 1.572 and to 0.21 year is 10.819 g at F max 1.048 (Fig.8). The present average F is 1.212. The Maximum sustainable yield (MSY) was estimated at 44,066t.

Stock assessment

The exploitation rate (U) for different years was estimated from the equation (Ricker, 1975).

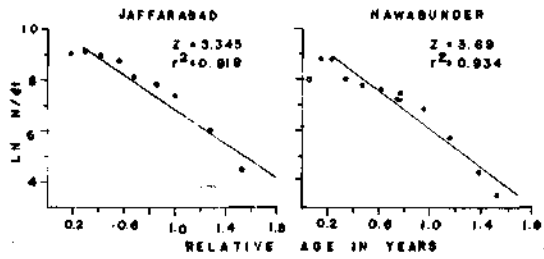

FIG. 5. *Harpodon nehereus* : Estimation of Z by length converted catch curve during February-May.

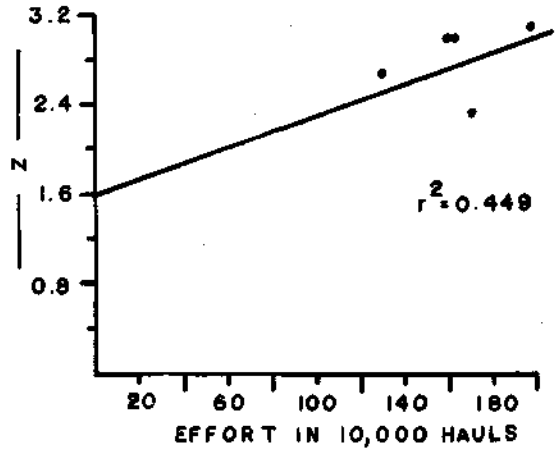

FIG. 6. *Harpodon nehereus* : A regression of Z against effort for estimation of M.

$$U = \frac{F}{Z}(1-e^{-Z})$$

The average standing stock is 36,356 t and annual production 108,000 t (Table 4).

The MSY was also estimated by the Relative Response Model (Alagaraja, 1984) at 41,355t the r value for the regression is 0.753.

DISCUSSION

The growth studies indicate that *H.nehereus* grows at a faster rate than observed by earlier workers (Krishnayya, 1968 and Bapat, 1970).

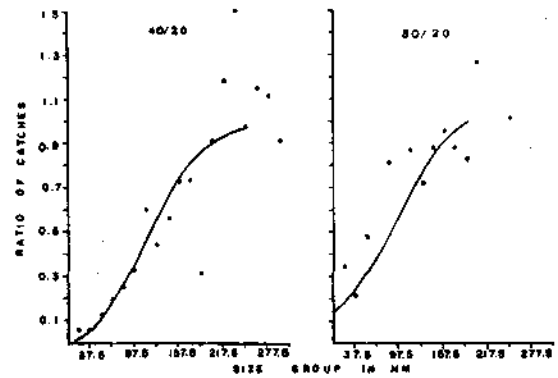

FIG. 7. *Harpodon nehereus* : Selection Ogive.

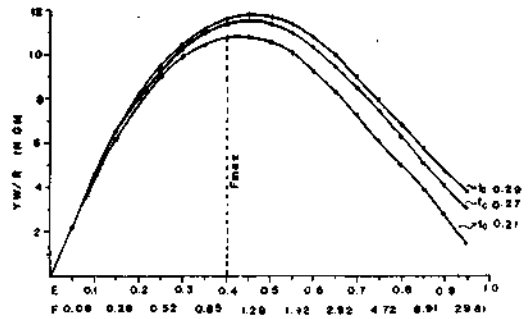

FIG. 8. *Harpodon nehereus* : Yield (Yw/R) curve at different t_c.

TABLE 4. *Estimates of mortality coefficient, exploitation ratio, annual stock and average standing stock of* Harpodon nehereus *off Saurashtra coast*

Year	Z	M	F	Exploitation rate (U)	Yield in tonnes (Y)	Annual stock (Y/U)	Average stock (Y/F)
1979	2.697	1.572	1.125	0.389	56,950	1,46,401	50,622
1980	2.819		1.247	0.416	33,577	80,714	26,926
1981	2.668		1.096	0.382	50,215	1,31,453	45,817
1982	3.168		1.596	0.482	31,784	65,942	19,915
1983	2.331		0.759	0.294	44,988	1,53,020	59,273
1984	3.022		1.450	0.450	46,871	1,02,787	32,325
Average	2.784	1.572	1.212	0.403	44,064	1,08,000	36,346

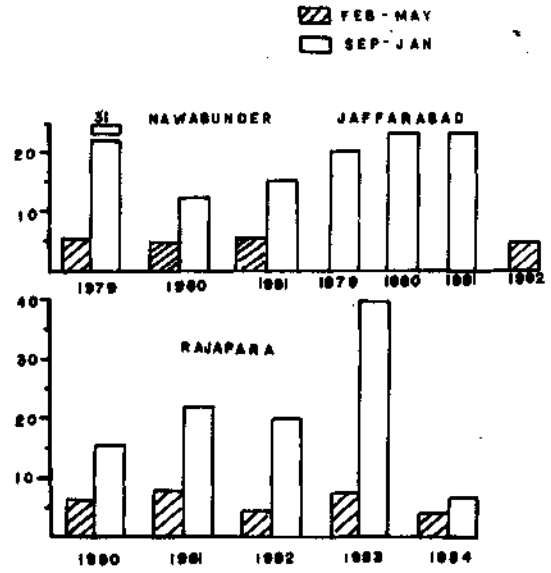

FIG. 9. *Harpodon nehereus*: Percentage of commercial sized fish in the catch.

The present K is the same observed earlier (Zafar Khan, 1985). The estimated $L\infty$ in the present case is higher than the earlier estimates of 367mm and as a result the present first and second year growth is 227.9mm and 333mm compared to earlier estimate of 199 mm and 288 mm. Keeping in view of the maximum size 367 mm recorded during the observation period, the $L\infty$ 425.2 mm appears to be more appropriate estimate.

The M estimated here (1.572) is the same as in earlier works (Zafar Khan, 1985). Keeping in view of short life span and high cannibalism, M 1.572 is quite reasonable estimate.

The Yw/R curve is dome-shaped though the M/K ratio is high which may be attributed to low t_c and t_r. According to Gulland (1983) if the M/K is large, many fish will die before attaining their maximum growth and it will

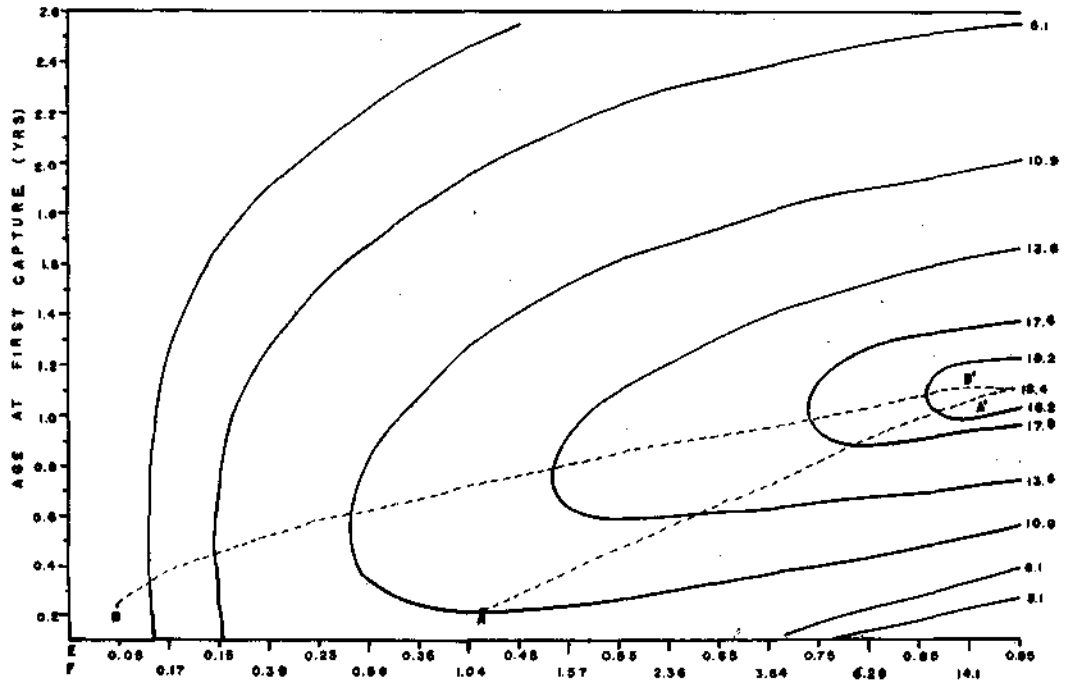

FIG. 10. *Harpodon nehereus* : Isopleth of Yw/R AA and BB line drawn through the maxima of yield fishing mortality and yield-mesh curves respectively.

therefore pay to fish relatively hard with a low size at first capture so as to catch before they die a natural death. However, the present case is the most classical example where the above mentioned statement will not hold good for the following reasons. 1. The young ones form one of the dominant basic food of the species (Zafar Khan, M.S.). 2. The young ones of *H. nehereus* are of no economic value, infact the commercial size of *H. nehereus* (210 mm and above) is far above the present Lc (65 mm).

Bombay duck is highly perishable due to high water content, hence a number of labour hands are required for sorting and hanging them on ropes for sun drying. Generally 4-8 labourers are employed mainly by 2 netter and 3 netter boat owners. As the fishery is labour oriented the effort of *dol* net is regulated in the fishing season. In the beginning of fishing season only single haul is taken as the catch rate is high. Subsequently as the catch rate comes down, 2-3 hauls are taken. However, whenever the catch is very poor the fishing is suspended due to economic reasons.

The *H. nehereus* forms 80.8% of the *dol* net landings. The effort put by the gear is mainly for this species. However, poor relationship was found (r=0.449) between effort and Z as the effort is regularised according to the abundance of the fish. It is evident (Table 3) that whenever the catch has exceeded the estimated MSY there has been a decline in the catch in succeeding year.

It may appear, because of self regulatory nature of *dol* net fishing, that no management policies are needed. But the following observations have to be taken into consideration before coming to any conclusion.

1. Large quantities of juveniles are caught particularly during February-May as a result the Z is high (Fig. 5). The commercial sized fish in the catch is very poor during February-May (Fig.9). The commercial size (210 and above) is much below the size at first maturity (250 mm).
2. The studies on yield per recruits indicate 6-9% higher yield from 25 and 27 mm cod end *dol* net respectively which is already in vogue at Satpati, Maharashtra. In view of poor catches from 30 and 40 mm net in experimental fishing, it is not possible to fish at optimum age of exploitation (ty) (Fig. 10).
3. *Dol* net being non-selective gear, large quantities of young ones of many commercial species are landed. The notable among them is *Pampus argenteus*, the young ones of which are landed mainly during February-May (Zafar Khan, 1988).
4. The non-penaeid prawns which form 4.5 - 7.2% of the catch, form the basic food of *H. nehereus*. Therefore allowing them to escape will increase available food supply and also may reduce the natural mortality due to cannibalism.

Keeping in view of the above, two basic measures are suggested for increasing the yield. (a). Switch over to large mesh size cod end of 25-27 mm. (b). Closing of fishing season during February-May.

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