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Stock assessment of Bombay duck *Harpodon nehereus* (Ham.) off Maharashtra coast

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ABSTRACT

The dol nets contribute the major share to the landing of Bombay duck *Harpodon nehereus*. Features of the dol net fishery, fishing area and seasonal distribution of the fishery are presented. Biological studies are chiefly confined to food and feeding habits, analysis of maturity stages, sex ratio and length-weight relationship. The length at 50% maturity was observed as 230 mm. Different spawning cycles were noticed and fecundity evinced a linear increase with fish weight. The growth parameters and mortality estimates were made. Assuming terminal exploitation rate as 0.78, the average catch was observed to be 52 213 tonnes. MSY estimated by Thompson and Bell model was 54 631 tonnes and biomass MSY as 76 893 tonnes and hence it was assumed that the Bombay duck along the Maharashtra coast was optimally exploited.

The Bombay duck holds a place of pride in the long established artisanal fisheries sector of Maharashtra. As a single species fishery, it ranks second only to oil sardine in terms of total landings. Electrophoretic techniques carried out earlier for screening tissue proteins and enzymes for stock identity showed that the fishery for this species off Maharashtra coast is supported by a single homogeneous stock (Kurien 1977 a). Results of the study are briefly discussed, and applicability of different models to assess the stock of Bombay duck critically evaluated.

MATERIALS AND METHODS

Stomach samples (N = 5 780) were examined from the dol net catches at Arnala. Evaluation of food items by volume, number and frequency was done after identifying the items to the lowest possible taxa. A general dietary survey and grading of food items as a preference was made as per Kurian (1977b).

The information on maturity and reproduction is based on the examination of 12 042 fish for 11 years from Arnala.

Maturity stages were classified according to Laevastu (1965). The eight-point classification was reduced to four points for convenience: resting (I-II); maturing (III-IV); gravid (V-VI); and spent-spent recovering (VII-VIII). After estimation of absolute fecundity, simple exponential equations suggested by Bagenal (1967) was followed for expressing the relationship of absolute fecundity (F) with total length and weight of the fish.

The length frequency data collected from 1982 to 1986 from Arnala formed the data base for the stock assessment studies. The data collected were converted into 15 mm class intervals and were treated by computer based analysis for the estimation of growth parameters. Estimation of L_∞ and K were obtained using 'COMPLEAT ELEFAN' package (Gayanilo *et al.* 1988). The length frequency samples were raised to total catch and summed over five-year period. These data

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were used as input to the length converted catch curve analysis (Sickle Van 1977) whereby, total mortality, Z, was estimated. The same data formed input for Jones' length cohort analysis (Jones 1984) to estimate stock size. An estimate of M was obtained from Pauly's emperical formula (Pauly 1983) for a temperature of 28.0° C. Yield and biomass were predicted for various levels of fishing effort using length converted Thompson and Bell analysis (Sparre 1985). The outputs of Jones' length cohort analysis formed the inputs for Thompson and Bell analysis which assessed the effects of increasing or decreasing the effort by the factor X.

RESULTS

Fishery

Maharashtra has a coastline of 720 kilometers spanning over five maritime districts: Thane, Greater Bombay, Raigad, Ratnagiri and Sindhudurg. Total shelf area up to 200 m depth zone is estimated at 89 089 km^2 (Ranade *et al.* 1971). However, dol net is the most important gear contributing nearly 65% of the catch by mechanized sector and 75% of the landings by non-mechanized sector. The dol net fishery also determine the overall level and status of fish production in Maharashtra, since 80–90% of total production by dol is contributed by Bombay duck.

In the dol net fishery the craft is usually a plank built boat and individually owned. The dol is a stationary bag net worked entirely by the forces of tide. Though synthetic filaments are used, the design and operation of the net is traditional. This gear is highly specialized, requiring much skill in construction and operation. The dol net fishery is labour-intensive. The history of Bombay duck fishery in Maharashtra indicated two phases of exploitation: first between 1958 and 1974 with an average annual yield of 28 493 tonnes and the second between 1975 and 1986 with an average yield of around 57 000 tonnes. With the aid of synthetic models, Kurian (1988, 1989) found that the equilibrium yield is around 55 000 tonnes and the fishery could be explained with a hyperbolic model.

Fishing for Bombay duck extends over a stretch of 480 km from Waroda to Kalai (Bapat 1970). The district of Thane leads in Bombay duck production (85%) followed by Greater Bombay (10–12%).

Seasonal distribution of Bombay duck along Maharashtra coast can be divided into two phases: static and dynamic. During static phase (September, January), the fish becomes temporary resident within the nearshore fishing areas. During the dynamic phase (February–May), the fish actively migrates beyond 25 m depth zone. Large catches are occasionally made from scattered aggregations. Larger and older fish are usually scarce in commercial catches. Bombay duck shares the ecosystem with non-penaeid prawns and grenadier anchovy. Though recruitment is continuous, major recruitment to the stock takes place during April, June–July and September–October.

Biology

Food and feeding habit: The food spectrum appeared to be broad with more than ten prey species occurring in the diet. The final gradings indicated that juveniles of Bombay duck ranked first followed by *Coilia dussumieri* and *Bregmaceros Mc Clellandi.* The mode of selectivity was further confirmed by two indices, index of food selection (Shorygin 1939) and index of electivity (Ivelev 1961).

Food utilization studies showed variation in food preference among different age groups. Juvenile Bombay duck was a preferred item for 1/2 to 2 year-old fish. Analysis of data by

Elliot and Persson method (1978) revealed that daily food intake ranged from 3 g for ½-year old fish to 100.66 g for 2½-year old fish. The maximum growth efficiency was shown by ½-year old fish (K = 0.0135) and the minimum by 2½ -year old fish (K = 0.0019).

Maturity and reproduction: General organization of the ovary of Bombay duck was similar to that described by Hoar (1969) as in other teleosts. The ovary of Bombay duck fall under *Synchronisme par* where two batches of oocytes in different stages are present. Testis was an elongate paired structure covered with delicate peritonium. It consisted of lobules containing germ cells. Testis were usually in a stage of spermatogenesis or spermiation after completion of spermiogenesis and were seldom in spent condition. Average length of attainment of sexual maturity (L_m) was ascertained by plotting percentage of III + to VII + maturity stages against fish length at 5 mm interval. The length associated with 50% maturity was found to be 230 mm in total length.

Ratio of male to female by length groups showed progressive reduction in males with increase in size. Frequency of males and females in different stages of maturity showed that maturation of females synchronized with that of male.

Studies on spawning periodicity showed that recruit spawner took 7.7 months to complete its first spawning cycle. Second spawning cycle involved 8.23 months, third spawning was complete in 9.93 months and for fourth spawning it took 10.68 months. Absolute fecundity ranged from 15 000 for 2-year old fish to 110 000 for 3.5-year old fish. Studies on relation between fecundity and fish length indicated increase in fecundity with length (b = 3.3994) and had almost linear increase with fish weight (b = 0.8431). Intensive fishing in near shore areas permitted a fish to spawn only twice resulting in an average egg production of 115 000 whereas undisturbed deeper areas offered scope for four to five spawnings resulting in egg production of 480 000 ova.

Though bimodality was seen in the distribution of oocytes, development of oocytes progressed in paired manner. Complete absence of any ripe ova in the spent ovary indicated that Bombay duck spawns for prolonged period. The index of reproductive stress (L_m/L_∞) gave a value of 0.54 which suggested very low reproductive stress.

Based on 1 770 pairs of length-weight measurements the relationship between length

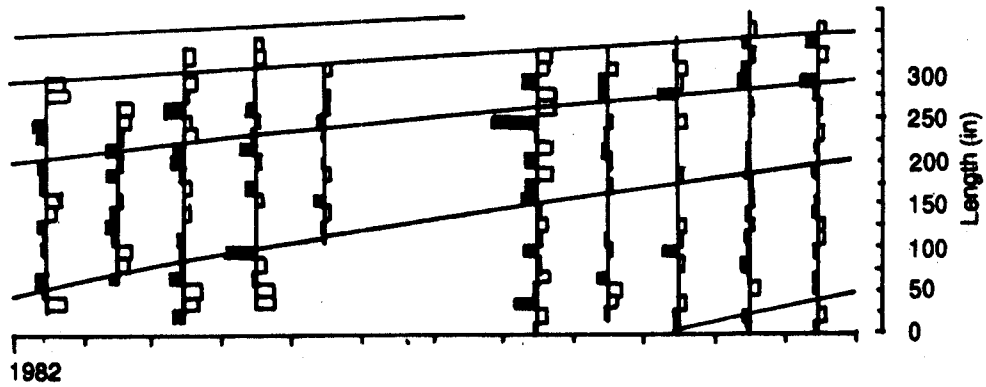

Fig. 1. Growth curve of Bombay duck based on ELEFAN I output (L_∞ = 426 mm, K = 0.52/year).

Table 1. Jones' length cohort analysis for Bombay duck at Maharashtra during 1982 86.

Interval	C	X*	N	F/Z	F	Z
0.00-15.00	16 455.600	1.0194	1 452 218.63	0.2326	0.1682	0.7232
15.00-30.00	17 238.561	1.0201	1 381 461.50	0.2437	0.1788	0.7338
30.00-45.00	13 653.910	1.0209	1 310 716.00	0.2056	0.1437	0.6987
45.00-60.00	16 710.641	1.0217	1 244 319.50	0.2433	0.1785	0.7335
60.00-75.00	28 744.770	1.0226	1 175 649.63	0.3613	0.3140	0.8690
75.00-90.00	25 415.760	1.0236	1 096 090.50	0.3396	0.2854	0.8404
90.00-105.00	44 825.500	1.0247	1 021 246.13	0.4850	0.5227	1.0777
105.00-120.00	35 441.781	1.0259	928 824.88	0.4382	0.4329	0.9879
120.00-135.00	32 316.250	1.0272	847 941.25	0.4262	0.4122	0.9672
135.00-150.00	36 987.301	1.0287	772 109.88	0.4715	0.4952	1.0502
150.00-165.00	35 624.180	1.0303	693 671.69	0.4762	0.5045	1.0595
165.00-180.00	38 939.109	1.0322	618 858.94	0.5145	0.5882	1.1432
180.00-195.00	43 378.512	1.0342	543 176.50	0.5613	0.7100	1.2650
195.00-210.00	48 055.820	1.0366	465 891.41	0.6111	0.8721	1.4271
210.00-225.00	47 523.910	1.0392	387 253.38	0.6386	0.9808	1.5358
225.00-240.00	41 961.320	1.0423	312 836.44	0.6440	1.0040	1.5590
240.00-255.00	35 190.602	1.0460	247 680.41	0.6405	0.9888	1.5438
255.00-270.00	35 348.781	1.0503	192 738.44	0.6840	1.2014	1.7564
270.00-285.00	43 801.680	1.0555	141 059.91	0.7829	2.0009	2.5559
285.00-300.00	27 834.650	1.0620	85 108.67	0.7763	1.9261	2.4811
300.00-315.00	14 334.180	1.0701	49 253.48	0.7299	1.4999	2.0549
315.00-330.00	13 230.080	1.0807	29 615.25	0.8018	2.2451	2.8001
330.00 plus	10 237.400	1.0951	13 114.61	0.7806	1.9747	2.5297
Total	52 213.800					

L_∞	426	Terminal exploitation rate	0.7806101
Plus group	330	M/2K	0.534
K (curvature parameter)	0.519	q in W = q L b (g, cm)	0.00167
M (natural mortality)	0.555	b in W = q L b	2.0279

Table 2. Thompson and Bell analysis for Bombay duck (1982-86)

X	Yield	Mean biomass
0.0000	0.0	262 426.93
0.2000	42 500.48	149 907.62
0.4000	52 696.43	104 510.59
0.6000	54 634.01	80 060.61
0.8000	53 861.64	64 742.52
1.0000	52 135.82	54 203.21
1.2000	50 105.15	46 478.63
1.4000	48 028.69	40 556.38
1.6000	46 012.49	35 862.09
1.8000	44 098.06	32 045.22
2.0000	42 298.58	28 879.21

MSY = 54 631.37, X = 0.6125, Biomass MSY = 76 893.96

and weight, $\log W = a + b \log L$, was estimated where W, weight (g) and L, length (cm). It came to be: $\log W = -2.9330 + 2.0279 \log L$.

Stock assessment

The restructured data with growth superimposed are given in Fig.1. The growth parameters obtained were: L_∞ = 426 mm, K = 0.52/year.

The natural mortality was estimated to be 0.555/year using Pauly's formula. The total mortality was estimated to be 1.444/year by the length converted catch curve (Fig. 2).

Assuming exploitation rate for the larger group to be around 0.781, length cohort analysis was carried out, the results of which are

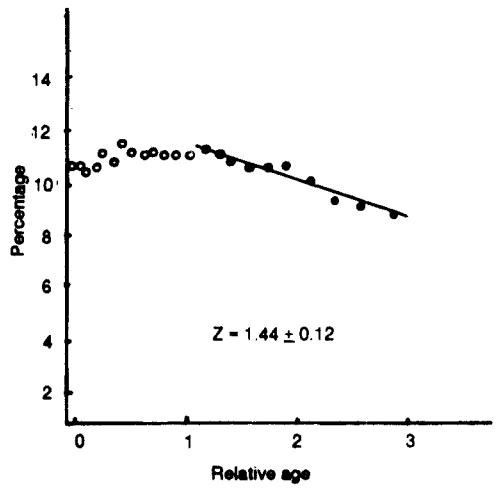

Fig. 2. Catch curve for *Harpodon nehereus* (Hamilton) (L_∞ = 426 mm; K = 0.519/year).
Ten length groups used in analysis were between 195–210 mm and 330–345 mm.

given in Table 1. Thompson and Bell analysis for predicting the catches and stock size are presented in Table 2. The MSY was estimated at 54 631 tonnes and the mean biomass at MSY was estimated at 76 893 tonnes.

DISCUSSION

Earlier estimate on the status of yield of Bombay duck by synthetic model analysis indicated that the catch and effort relation is hyperbolic and the equilibrium yield was estimated around 55 000 tonnes along Maharashtra coast (Kurian 1989). In the present study (1982–86), the MSY estimates obtained by Thompson and Bell Model analysis also showed the MSY value as 54 631 tonnes and current level of exploitation and average catch (length cohort analysis) is around 52 200 tonnes. The X-multiplier showed that the MSY level has been obtained at 0.6125, which indicate a reduction in effort by about 39% to obtain estimated MSY level. However, as opined by Larkin (1977), the MSY may vary according to the temporal and spatial changes of the ecosystem, and the value is a rough measure of the maximum potential. As observed in this study, reproductive longevity, feeding habit, size at maturity and fecundity coupled with the segregation of adults stock from regular fishing grounds and linear increase in fecundity with body weight may influence its recruitment and fishing pressure. The adaptive response shown by the life history characteristics of this species, and the cannibalistic tendency may also play a role in the annual variation in the recruitment to the fishery. It is concluded that a non-parabolic production model analysis would be more appropriate for application to estimate the optimum yield and recruitment for a localized fishery such as for Bombay duck.

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