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23 The Bombay duck : stock status and response to exploitation

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ABSTRACT

The Bombay duck fishery supported by a single species, Harpodon nehereus forms a major pelagic resource in the NW coast and about 91 % of the catch is landed along this region. The NE coast contributed 9%. The exploitation is mainly by 'Dol' net. The paper reviews its biology, fishery and stock assessment in the range of distribution.

Introduction

The original 'Bombay duck' was not a fish. It was a time honoured Anglo-Indian name for the British resident in Bombay Presidency distinguishing him from his Bengal counterpart or his compatriot down south. Originally the term was spelt as 'duckys' and is believed to have been derived from the Latin "duces"-leaders or bosses. With the passing of time, the term lost its, original meaning but the expression surived. 'Bombil' or 'Bummaloe' as the locals called *Harpodon nehereus*, was given the name 'Bombay duck' after being called 'Bombay cow' for some time (Dr. C.V.Kulkarni, Personal Communication).

The Bombay duck fishery along the north-west coast of India is supported by a single species, *Harpodon nehereus* (Ham.). In the long established artisanal fisheries sector where 'dol' nets dominate, a good or poor harvest of Bombay duck exercises direct influence upon the livelihood of fishermen. It is a highly important fish for domestic use and also a valuable export item in dried form. More than 90% of the Bombay duck catch in India is landed along the north-west coast of India.

The biology of and fishery for Bombay duck has been monitored regularly and investigated periodically. Some of the important works are by Setna (1932, 1939), Hora (1934), Bapat *et al.* (1951), Krishnayya (1968), Bapat (1970) Bapat and Alwani (1973), Biradar (1987), Zafar Khan (1985, 1989), Zafar Khan *et al* (1992), Kurian (1987, 1988, 1989) and Kurian and Kurup (1992). The present account is a projection of recent findings on the adaptive response of the species and current status of exploitation of the stock that support the fishery along the north-west coast of India.

Materials and methods

Random samples drawn from major landing centres along the north-west coast during regularly spaced observations formed the data base for the studies. Food habits and feeding relationships have been determined based on Index of Relative Importance (Kurian, 1977) and studies on growth and reproduction by well established methods discussed in detail by Kurian (1987).

For stock assessment, age or length based sequential population models are avoided as estimates for Gujarat are not secure. This may be due to the fact that recruitment strength of a cohort can be determined only if the cohort stays in the fishery for a long period after entry to the fishery. Therefore, experimental relations between fishing effort (f) on one hand and the total catch (Y) and catch per unit of effort (Y/f) from 1986 to 1995 are analysed with the aid of simple models that can provide comparision and flexibility in interpretation. The estimates of fishing mortality (F), exploitable stock biomass (P) and catchability coefficient (q) are determined based on the model of Doi (1962). Its linear form is as follows;

$$f/y = 1/R \,.\, M/q + 1/R \,.\, f \quad \text{———} (1)$$

Where, Y is the total estimated catch,

f is the total estimated effort,

R is the recruitment of the fished stock

M is the natural mortality and

q is the catchability coefficient.

The rate of fishing mortality (F) and exploitable biomass (P) are determined from the relationship

$$F = q \cdot f \text{ and } P = Y/E \text{ where } E = F/Z$$

The value of sustainable catch depending on the fishing effort is determined from the linear relationships.

$$Y/f = a + bf \quad \text{———(2)}$$

$$Y_E = af + bf \quad \text{———(3)}$$

where Y_E is the equilibrium yield.

The maximum value of sustainable yield, (Y_E MSY) is calculated as

$$Y_E \text{ MSY} = a^2/4b$$

and the fishing effort corresponding to MSY (f MSY) as

$$f \text{ MSY} = a/2b. \text{ (Ricker, 1975).}$$

Biology

Food: The food spectrum appeared to be broad, with more than ten prey species occurring in the diet. The major food sources were considered to be those occurring in more than 10% of the sample and formed more than 5% of the total volume of food. Contribution by these food items to the diet by volume, number and frequency of occurence and final grading by Index of Relative Importance are given in *Table 1*. The final grading indicated that juveniles of Bombay duck ranked first followed by golden anchovy confirming that Bombay duck is cannibalistic and piscivorous.

Table 1. Principal prey species in the stomach of Bombay duck and grading by IRI. (N.5780)

Prey items	Volume (V)	%	Number(N)	%	Freuency	%	IRI	Ranking
Acetes spp.	5981.33	3.56	23133	47.26	2454	15.97	0.72	V
N.tenuipes	4825.93	2.94	7479	15.28	2638	17.17	1.93	IV
H.nehereus	102064.69	62.24	1196	24.44	6003	39.04	57.95	I
C.dussumieri	29535.68	18.01	3173	6.48	2337	15.21	24.62	II
Other fish food	21568.36	13.15	3194	6.53	1935	12.59	14.78	III

Stomach contents analysed based on age or size group showed that there is partitioning of the habit and food resources which resulted in reduced intraspecific competition. A form of Volterra-Gause or exclusion principle is achieved by simple size displacement.

The behaviour of cannibalism is quite confounding. In a resource limited environment, this behaviour can be understood. The possible three reasons can be, (1) a very high survival rate during the pre-recruit phase, (2) by being consumed by the maturing size groups, the juveniles might be providing certain essential ingredients for gametogenesis and (3) as a measure of population regulation.

Growth: Studies on growth with the aid of scatter diagram showed that Bombay duck is a multistage population in which large number of broods contributed to the biomass in any one year. On an average, five broods originated each year at an approximate interaval of two months. The average length growth values showed that Bombay duck attained a total length of 165 mm in the first year, 263.75 mm in the second year, 330 mm in the third year, 372 mm in the fourth year and 390 mm in the fifth year.

Reproduction: Absence of any intersex during the period of study confirmed that Bombay duck is a differentiated gonochorist where indifferent gonads differentiated into either testis or ovary. The process of maturation transformed 0-year old fish to express its full reproductive potential. Though bimodality is seen in the distribution of oozytes, microscopic examination showed that the development of oozytes progressed in paired manner. Thus two batches of ova which occurred together in stages 1 and 2 developed through the intermediate stages 3 and 4 into the final stages of 5 and 6. Before the final act of shedding, the development is very fast and the final phase of hydration and spawning had to be very close. The complete absence of any ripe ova in the spent ovary showed that Bombay duck is a total spawner.

The average total length at attainment of sexual maturity is found to be 230 mm. The male-female ratio studied over a period of time showed a progressive reduction in male with increase in size. A new recruit took 7.7 months to complete the first spawning, the second spawning cycle in 8.23 months, the third in 9.93 months and the fourth in 10.6 months. The mean total lengths at first, second, third and fourth spawning were 252.2 mm, 305.5 mm, 347.5 mm and 372.5 mm respectively.

Fecundity increased with increase in total length of the fish while it maintained a rather linear relationship with weight. Increase in fecundity with each spawning is achieved by the reduction in the ova size. The size of ova got reduced from virgin spawners to repeat spawners, associates with an increase in the number of ova.

The presence of immature, maturing, gravid and spent individuals throughout the year showed that Bombay duck is a continuous breeder but the individuals are out of phase with one another. This may be a compromise involving many ecological factors not known clearly.

Length-weight relationship: The relationship studied based on the gutted samples indicated that one and two year old fish did not follow isometric growth. However, the exponent is close to 3 in case of 3 year old fish. The length-weight relationship assume the following form,

$$\log W = -2.9330 + 2.0279 \log L.$$

The intercept and exponent values estimated for different age groups are as follows:

Age group	a	b	r
0-1	-1.4094	1.1785	0.99
1-2	-8.5429	4.3531	0.96
2-3	-5.1214	2.9561	0.41

The above variations in the exponent values must have resulted from balancing of growth at different stages in the life history.

Fishery

The Bombay duck is an abundant species along the north-west coast of India contributing to 91% of its all India landings followed by West Bengal (7%) and other states (2%). The fishery is supported by a single species and formed nearly 5.30% of all India marine fish landings during 1985-93 (Anon, 1995).

From a low catch of 1130 tonnes in 1985, Bombay duck landings has shown steady increase in West Bengal leading to 20,398 tonnes in 1993 with an average annual yield of 8000 tonnes, forming 13.00% of the total marine fish landings of the state. Since detailed information on the resource characteristics and recent trends in production are not available from the north-east coast of India, the present account is based on available information on the resource from the north-west coast of India.

Technically, the gear is common to both the regions with minor variations, but worked entirely by the forces of tide. Details on the construction and operation including seasonal shifts of the gear popularly known as 'dol' along the north-west coast and 'Beenjal, Behundi jal, Thorjal' in West Bengal are discussed by Setna (1949), Gokhale (1957) and Raje and Deshmukh (1989).

The average annual yield from Maharashtra (1986-95) is estimated at 29,000 tonnes representing 11.00% of the total marine fish production from the State. The other cohabiting species landed along with Bombay duck are golden anchovy, non-penaeid prawns and silver pomfrets. The Bombay duck landings constitute 19.00% of the total marine fish production of Gujarat. The fishery is well developed along the south Gujarat coast and southern region of Saurashtra, the major centres being Umbergaon, Jaffrabad, Rajpara, Nawabunder and Diu. Influence of high tidal range in the Gulf of Cambay is felt up to north west of Diu thus enabling the fishermen to operate 'dol' in these areas. The average annual yield from Gujarat during 1986-95 is estimated at 60.000 tonnes. This estimate is exclusive of landings from Gulf of Kutch.

The annual Bombay duck landings indicated a downward swing in Maharashtra which is compensated by an upward swing in landings of Gujarat indicating very much that the resource exploited is common to both the states. Though balance between two states has changed, even with high inter annual variability, the fishery has never failed.

It is seen that 1958, 1975 and 1986 have been important transitional years for both the states. The average annual yield prior to the transitional years are given in *Table 2*. The variation in apparent abundance is not driven by changing effort as the trend in effort for the period 1986-95 follow a similar pattern.

Table 2. Average annual yield (t) during the period prior to transitional years.

Period	Maharashtra	Gujarat
1949-1957	30674	19836
1958-1974	28490	46324
1975-1985	63823	46415
1986-1995	29238	59882

It is well established that the Bombay duck fishery operates on the coastal portion of widespread stock which reproduces off shore (Kurian, 1987). Thus the area of production and area of harvest differ. This renders projection of total availability complicated not only by invisibility and mobility of the species but also by the reaction of the species to environmental factors and intensity of fishing effort. Therefore, the periodical fluctuations in yield may reflect changes in the 'catchability' of the species. Evidently, a stock recruitment relationship is very difficult to be established.

Stock assessment

From a practical point of view, the analysis provided results which are considered best under the present exploitation climate. The calculations showed that there is dependence between f and Y. The initial data and the results are presented in Table 3a-c (3a presents the data for Maharashtra, 3b for Gujarat and 3c for north west coast) : the important aspect being the change in the catchability coefficient.

Table 3. a. Dynamics and assessment of Bombay duck stock in Maharashtra.

Years	Y (tonnes)	Y/f (kg)	f (Hauls)	F	Z	E	P
1986	42385	58.75	721446	0.82	1.38	0.59	71839
1987	29306	97.25	301347	0.34	0.90	0.38	77121
1988	30661	41.92	731416	0.83	1.39	0.60	51102

1989	25222	1.75	597112	0.68	1.24	0.55	45858
1990	38566	48.23	799626	0.91	1.47	0.62	62203
1991	48022	53.11	904198	1.03	1.59	0.65	73880
1992	18569	66.73	278270	0.32	0.88	0.36	51581
1993	14884	86.11	172849	0.20	0.76	0.26	57246
1994	15714	94.84	165689	0.19	0.75	0.25	62856
1995	29052	171.20	169696	0.19	0.75	0.25	116208

a = 7.4815b = 1.70*10V-5r = 0.82
R = 58824q = 1.14*10V 6M = 0.56

3.b. Dynamics and assessment of Bombay duck stock in Gujarat.

Years	Y (tonnes)	Y/f (Kg)	f (Hauls)	F	Z	E	P
1986	47889	50.77	943254	0.30	0.86	0.35	137282
1987	42151	105.81	398365	0.13	0.69	0.19	221847
1988	35192	55.00	639855	0.21	0.77	0.27	130340
1989	89546	105.52	848616	0.27	0.83	0.33	271352
1990	78355	102.01	768111	0.25	0.81	0.31	252758
1991	77027	88.35	871894	0.28	0.84	0.33	210412
1992	82335	74.30	1108143	0.36	0.92	0.39	210412
1993	61154	73.16	835894	0.27	0.83	0.33	185315
1994	40790	97.43	418660	0.13	0.69	0.19	216501
1995	44181	63.45	696312	0.20	0.76	0.26	167888

a = 9.1573b = 5.2473*10v-6r = 0.31
R = 190574q = 3.21*10v-7M= 0.56

3c. Dynamics and assessment of Bombay duck stock along north-west coast.

Years	Y (tonnes)	Y/f (Kg)	f (Hauls)	F	Z	E	P
1986	90274	54.23	1664700	0.63	1.19	0.53	170328
1987	71457	63.81	699712	0.27	0.83	0.33	216536
1988	65853	48.02	1371271	0.52	1.08	0.48	137194
1989	114768	79.38	1445728	0.55	1.11	0.5	229536
1990	116921	73.64	1567737	0.60	1.16	0.52	224848
1991	125049	70.43	1776037	0.67	1.23	0.54	231572
1992	100904	72.78	1386413	0.53	1.09	0.49	205926
1993	76038	75.41	1008743	0.38	0.94	0.4	190095
1994	56504	96.69	584349	0.22	0.78	0.28	201800
1995	73233	84.57	866008	0.33	0.89	0.37	197927

a = 7.5252b = 5.1054*10v-6r = 0.63
R = 195869q = 3.80*10v-7M = 0.56

Similarly, analytical dependence of Y on f resulted in the following equations for Y/f and Y_E for Maharashtra.

$$Y/f = 123.12 - 0.000097\, f \text{ ———— (4)}$$

$$Y_E = 123.12\, f - 0.000097\, f^2 \text{ ———— (5)}$$

for Gujarat.

$$Y/f = 107.90 - 0.000035\, f \text{ ———— (6)}$$

$$Y_E = 107.90\, f - 0.000035\, f2 \text{ ———— (7)}$$

and for North-West coast,

$$Y/f = 92.86 - 0.000017\ f \text{ ———— (8)}$$

$$Y_E = 92.86\ f - 0.000017\ f \text{ ————— (9)}$$

The values of Y_E MSY and f MSY are given in Table 4 and the equations (4) to (9) in graphic form are are presented in Fig.1.

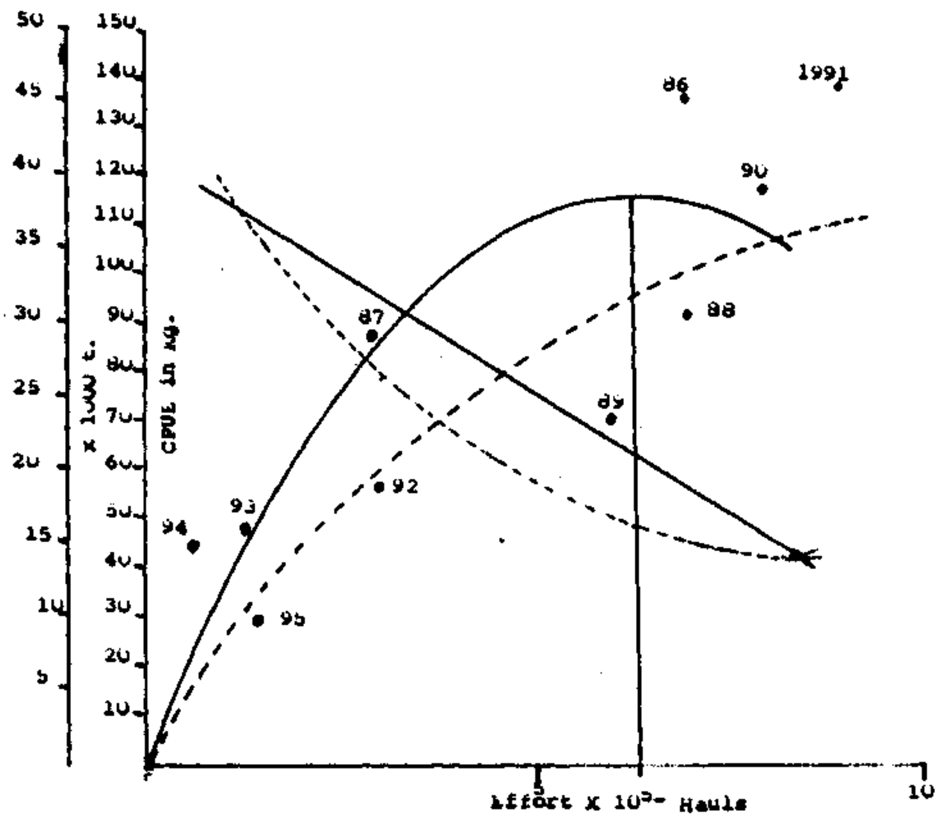

Fig.1. Dependence of catch per unit effort and sustainable yield on fisihing effort-Maharashtra (Broken lines indicate the dependence by power relationship)

Potential yield is measured in two ways - MSY and Equilibrium yield (EY) and has been determined from the time series catch and catch-effort data from the commercial fishery. Both the conditions implicit in the above

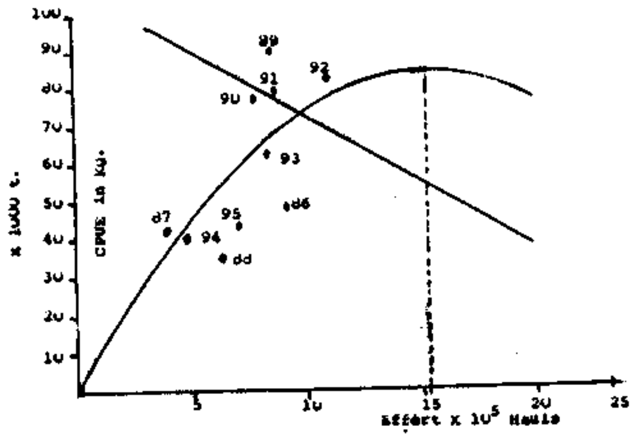

Fig. 1. Conted. Gujarat

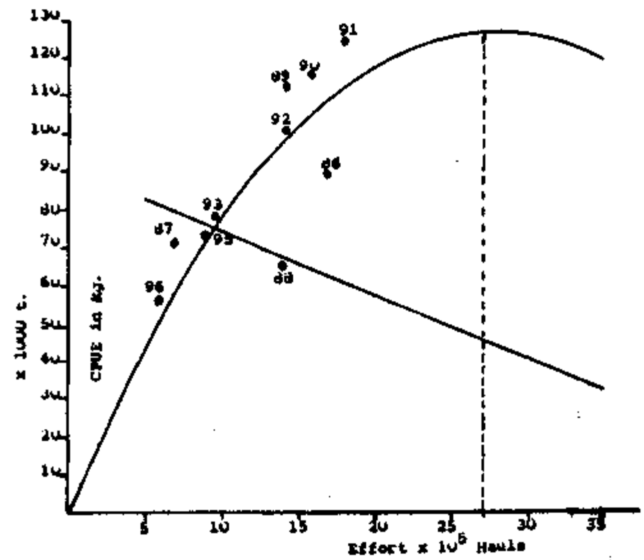

Fig. 1. Conted. North-West Coast

model; (1) absence of a clear stock recruitment relationship and (2) time series exceeding the reproductive life-span of the species, are fulfilled. Further, the fluctuations are assumed to be superimposed on the trend line. The results show that the Bombay duck fishery has been sucessful in keeping the commercial catch well below the annual surplus production. Even if the present estimates are low, they are not restrictive to the fishery.

Table 4. Sustainable and equilibrium yield for the period 1986-1995.

	MSY	fMSY	'q'	F at MSY	Average catch
Maharashtra	39068	634639	1.14x10v-6	0.72	29238
Gujarat	83160	1541428	3.21x10v-7	0.49	59862
N-W Coast	126808	2731176	3.80x10v-7	1.04	89100

Conclusions

The 'dol' is a traditional gear modified to the present perfection by experience through ages. The cod-end mesh size and the depth of operation are seasonally changed to take maximum possible advantage of the bathymetric range of Bombay duck. This practice, along with the closed season prevalent along the north-west coast, serves as a very effective means of conservation. The effort is highly decentralized and further upgrading the efficiency of the gear or controlling the size of the fish caught are not practial objectives. The fishery is operated by fleets from Maharashtra and Gujarat and the cost of operation is rooted in the regional economics (Sehara and Karbhari, 1987). Thus a socially or economically optimum catch is indeterminate. Further, based on regional priorities, stabilization process can also set in. Therefore, rather than taking Bombay duck fishery statewise, assessments are exressed for the entire north-west coast.

The relation between biological characteristics of the species and the fishery are quantified into total catch/catch per unit of effort and effort. The sum of adaptive biological response of the stock to exploitation is measured as 'catchability'. High rate of cannibalism is indicative of high survival during pre-recruit phase thereby ruling out possible drastic recruitment failure. A life style characterised by voracious feeding habits, low reproductive effort, greater reproductive longivity, spawning habitat in deeper areas requiring less maintainance expenditure and a broad spectrum of spawning generations inhabiting areas undistrubed by commercial fishing ensures total protection for Bombay duck against population crashes. The 'dol' is the only gear that can cope with the biological features of Bombay duck. The only suggestion is to avoid any intervention, so as to allow the fishery to find its own equilibrium under the changing exploitation climate. As in the case of any exploited living resource, which are national assets, constant monitoring is to be continued to preserve the resource, in perpetuity.

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