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 $K=0.7618$, $L_\infty = 425.2$ mm and $t_\infty = 0.00789$ yrs. The total mortality coefficient ($Z$) varied between 2.331 and 3.168 during 1979-'84. Yield per recruit ($Y_w/R$) was estimated at 10.819$g$ 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 ($t_y$) 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 ton and the average yield was 44,064 ton 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 standardized 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
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

<table>
<thead>
<tr>
<th>Month</th>
<th>1979-'80</th>
<th>1980-'81</th>
<th>1981-'82</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep.</td>
<td>10,180</td>
<td>14,95,018</td>
<td>146,858</td>
<td>3,459</td>
</tr>
<tr>
<td>Oct.</td>
<td>41,340</td>
<td>94,18,631</td>
<td>203,649</td>
<td>35,256</td>
</tr>
<tr>
<td>Nov.</td>
<td>40,763</td>
<td>89,15,813</td>
<td>240,802</td>
<td>61,732</td>
</tr>
<tr>
<td>Dec.</td>
<td>44774</td>
<td>91,32,556</td>
<td>140,991</td>
<td>70,561</td>
</tr>
<tr>
<td>Jan.</td>
<td>55,172</td>
<td>58,69,882</td>
<td>99,142</td>
<td>27,752</td>
</tr>
<tr>
<td>Feb.</td>
<td>44,450</td>
<td>39,28,424</td>
<td>66,287</td>
<td>20,498</td>
</tr>
<tr>
<td>Mar.</td>
<td>29,984</td>
<td>7,63,304</td>
<td>30,632</td>
<td>33,214</td>
</tr>
<tr>
<td>Apr.</td>
<td>50,024</td>
<td>11,79,800</td>
<td>23,586</td>
<td>17,649</td>
</tr>
<tr>
<td>May</td>
<td>14,759</td>
<td>27,34,612</td>
<td>188,536</td>
<td>9,427</td>
</tr>
<tr>
<td>Jun.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>3,46,456</td>
<td>4,19,60,320</td>
<td>121,113</td>
<td>2,81,591</td>
</tr>
</tbody>
</table>

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 : $\log W = -5.878 + 3.1446 \log L$

Females : $\log W = -5.7183 + 3.194 \log L$

Indeterminates : $\log W = -5.3465 + 3.098 \log L$

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:

$\log W = -5.9146 + 3.2786 \log L$

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 $L_{t+1}$ against $L_t$ as read
off the different quarterly growth indicated that the observed points were well represented by the straight line (Fig. 3). \( L_0 \) and \( K \) were estimated by regression analysis (Gulland, 1983). The estimated value of \( L_0 \) is 425.2mm, \( K = 0.7618 \) and \( t_p = 0.00789 \) years which was estimated by back tracing the first modes and using the formula given by Gulland (1983).

\[
t_0 = t + \frac{1}{k} \log \left( \frac{L_0 - L_t}{L_0} \right)
\]

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

\[
\log \left( \frac{N}{A} \Delta t \right) = a + bt
\]

where, \( b = -Z \)

<p>| TABLE 3. Results of Analysis of Variance between two sexes of Harpodon nehereus |
|----------------|---------|---------|---------|----------------|---------|---------|---------|</p>
<table>
<thead>
<tr>
<th>df</th>
<th>( \Sigma x^2 )</th>
<th>( \Sigma xy )</th>
<th>( \Sigma y^2 )</th>
<th>Regression coefficient df</th>
<th>Deviation from regression df</th>
<th>ss</th>
<th>ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>731</td>
<td>7.589</td>
<td>23.869</td>
<td>95.305</td>
<td>3.1446</td>
<td>730</td>
<td>20.2327</td>
</tr>
<tr>
<td>Females</td>
<td>646</td>
<td>6.285</td>
<td>20.088</td>
<td>83.218</td>
<td>3.194</td>
<td>645</td>
<td>19.0098</td>
</tr>
<tr>
<td>Pooled</td>
<td>1377</td>
<td>13.874</td>
<td>43.957</td>
<td>178.523</td>
<td></td>
<td>1376</td>
<td>39.2547</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.0122</td>
</tr>
</tbody>
</table>

\( F = 0.428; \) 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:

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

$T_{\text{max}}$ has been estimated as per Pauly's (1980) formula which is as follows:

$$T_{\text{max}} = \frac{3}{K + t_{\text{r}}}$$

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

$$M = 0.4603 + 1.4753K$$

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

$$NL = R \left( \frac{L_{oo} - L_t}{L_{oo} - L_r} \right)^M$$

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

If we assume that 95% of the recruit die when they reach 95% of $L_{oo}$ then the equation can be rewritten as:

$$0.05 = \left( \frac{M}{L_{oo} \times 0.05} \right)^M$$

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 ($Y_w/R$) was estimated from the equation of Beverton and Holt (1957):

$$\frac{Y_w}{R} = \frac{F_e M + W}{\left( \frac{1}{Z} - \frac{35}{Z+K} - \frac{35^2}{Z+2K} - \frac{35^3}{Z+3K} \right)}$$

where,

- $S = e^{K(t_{\text{r}} - \text{tc})}$
- $t_{\text{c}}$ = age at first capture,
- $t_{\text{r}}$ = 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 ($t_{\text{c}}$) 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.
The estimated $W_\infty$ is 505 g at $L_\infty$ 425.2 mm.

The estimated $Y_w/R$ 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 44,066 t.

Stock assessment

The exploitation rate ($U$) for different years was estimated from the equation (Ricker, 1975).
Fig. 6. *Harpodon nehereus*: A regression of Z against effort for estimation of M.

\[ U = \frac{F}{Z} (1 - e^{-\lambda}) \]

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 41,355 t; 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).

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Z</th>
<th>M</th>
<th>F</th>
<th>Exploitation rate (U)</th>
<th>Yield in tonnes (Y)</th>
<th>Annual stock (Y/U)</th>
<th>Average stock (Y/F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>2.697</td>
<td>1.572</td>
<td>1.125</td>
<td>0.389</td>
<td>56,950</td>
<td>1,46,401</td>
<td>50,622</td>
</tr>
<tr>
<td>1980</td>
<td>2.819</td>
<td>1.247</td>
<td>1.247</td>
<td>0.416</td>
<td>33,577</td>
<td>80,714</td>
<td>26,926</td>
</tr>
<tr>
<td>1981</td>
<td>2.668</td>
<td>1.096</td>
<td>1.096</td>
<td>0.382</td>
<td>50,215</td>
<td>1,31,453</td>
<td>45,817</td>
</tr>
<tr>
<td>1982</td>
<td>3.168</td>
<td>1.596</td>
<td>1.596</td>
<td>0.482</td>
<td>31,784</td>
<td>65,942</td>
<td>19,915</td>
</tr>
<tr>
<td>1983</td>
<td>2.331</td>
<td>0.799</td>
<td>0.799</td>
<td>0.294</td>
<td>44,988</td>
<td>1,53,020</td>
<td>59,273</td>
</tr>
<tr>
<td>1984</td>
<td>3.022</td>
<td>1.450</td>
<td>1.450</td>
<td>0.450</td>
<td>46,871</td>
<td>1,02,787</td>
<td>32,325</td>
</tr>
<tr>
<td>Average</td>
<td>2.784</td>
<td>1.572</td>
<td>1.212</td>
<td>0.403</td>
<td>44,064</td>
<td>1,08,000</td>
<td>36,346</td>
</tr>
</tbody>
</table>
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 367 mm and as a result the present first and second year growth is 227.9 mm and 333 mm 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 $Y_W/R$ curve is dome-shaped though the $M/K$ ratio is high which may be attributed to low $t$ and $t_x$. According to Gulland (1983) if the $M/K$ is large, many fish will die before attaining their maximum growth and it will
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 *dol* net. (b). Closing of fishing season during February-May.

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