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# The resources of hilsa shad, *Hilsa ilisha* (Hamilton), along the northeast coast of India

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ABSTRACT

The results of a study on the fishery, biology, exploitation and mortality of hilsa shad (*Hilsa ilisha*) are presented. The average annual landing of *Hilsa ilisha* for 1979 - 88 was 5 710 tonnes forming 0.4% of the total landings. The major craft and gears and the contributions of different states are presented. Age at first maturity was estimated as 1.98 years. The details of spawning migrations, maturity stages and fecundity are discussed. The total mortality, natural mortality and fishing mortality coefficients were obtained as 1.71, 0.704 and 0.9444 respectively. The present yield of 4 168 tonnes was the same as the estimated MSY indicating the optimum level of exploitation.

The hilsa shad, *Hilsa ilisha*, is well known for its commercial fishery in the northeast i.e., coastal regions of Bangladesh, West Bengal and Orissa. Hilsa shad spends most of its life in the inshore areas of the sea and undertakes extensive migrations ascending the estuaries and rivers for breeding purpose. The spent fish and their progeny migrate down the river back to the seas. Hilsa shad is widely distributed along the Indian coast. It is delicious and possibly the most highly priced fish in the Indian markets. Antony Raja (1984) estimated a total production of 25 000 tonnes of Hilsa shad from all sources in India.

A great deal of work has been done on the reverine and estuarine phase of life of hilsa shad in India (Pillay 1955, 1958; Jones 1984; Pillay and Rosa Jr 1963; Mathur 1964; Gopalakrishnan 1969, 1973; Bhanot 1973; De and Datta 1990). However, scant attention has been paid to the part of life of this fish spent in the sea, although the works of Hora (1941), Pillay *et al.*, (1963), Jones (1959 a, b), Jhingran and Natarajan (1973) and Roy and Roy (1974) do give some information on this aspect.

The decline in the catch of hilsa shad punctuated by fluctuating catch trends during recent years necessitated this study.

## MATERIALS AND METHODS

The data were collected for 8–20 days in a month from four fish landing centres, namely, Diamond Harbour, Fraser Gunj and Digha in West Bengal and Talsari in Orissa during 1984–88. Gearwise data on catch, fishing effort, species composition and size composition of the catches along with total length and weight of representative samples were collected from sampled boats. Fish samples were collected for further examination of sex, maturity and food and feeding habits. Fish scales and otoliths were collected for examining growth checks. From landing centre data, monthly estimates were made for catch, effort

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and gearwise species composition. Observations were also made on the fish landings from the Hooghly river to understand the movements of mature and spent hilsa shad through the river at Diamond Harbour.

Total length (mm) and weight (g) of fish were taken for calculation of length-weight relationship. The length frequency data of 133 563 fish were collected randomly from gill net and seine net. These data from different centres were grouped into 1 cm intervals. Most of the gill nets used were of variable meshes nullifying the problem of selectivity. The length frequency samples were used to estimate the von Bertalanffy growth parameters (L, the asymptotic length; K, the growth coefficient and $t_0$, the expected age of the fish at zero length) using modal progression method. Estimates of $L_\infty$, $t_0$ and K were also obtained using the ELEFAN I programme of Pauly and David (1981).

The length frequencies were raised to the annual total catches of the states of West Bengal and Orissa separately and the average numbers caught in each class for northeast coast were used as inputs for length cohort analysis of Jones (1984) to estimate stock sizes and fishing mortalities (Sparre 1985). The total mortality Z was estimated by length converted catch curve of Pauly (1983).

The natural mortality coefficient M was estimated by Pauly's (1980) empirical formula using the mean temperature of water (27° C) in which the stock lives. The Rikhter and Efanov (1976) method was also used to calculate the natural mortality by the relationship

$$M = 1.521\, t_m^{0.72} - 0.155$$

where $t_m$ is the average age at which 50% of the population is mature. It was employed by Sekharan (1974) also.

The current state of the stock and the yield and biomass were assessed by length converted Thompson and Bell analysis (Sparre 1985). The estimates were made using a microcomputer with the help of LFSA Package (Sparre 1987). This analysis gives a prediction of the long-term catches assuming recruitment to be constant. The recruitment pattern was computed by ELEFAN II programme assuming the value of $t_0$ as –0.01.

## RESULTS

### *Fishery*

*Fishing gear*: For hilsa, special types of nets and methods of fishing have been evolved and employed. Hornel (1950) and Jones (1959 a,b) have described hilsa fishing gears and their operation in Indo-Bangladesh region.

The drift gill net, locally known as *chandijal*, is made of nylon monofilament or garfil twine. Each net consists of several pieces of netting, each piece having a length of 20 m and a height of 10–11 m with a mesh size of 9–12 cm. A smaller version of *chandijal*, namely, *ilishjal* with a mesh opening of 5–8 cm and height of 5–8 m is also used with the traditional non-mechanized boats.

The *Jangal jal* and *kachal jal* are seine nets used for encircling hilsa shoals during winter months October–February. These are made of cotton twine or a mixture of cotton and nylon. The *jangal* net is 700 m in length and 20 m in height with a mesh size of 3.5–4 cm. The lower 1.5 m height of the net has specially designed pockets of the size 1.5m × 0.9 m along the entire length of the net. The pockets are specially designed to hold the fish once they are encircled.

The *kachal jal* is 300 m in length and 50 m in height with a mesh size of 2.5–3.0 cm. The foot of the rope is thick and has no sinkers. It has no special pockets.

*Fishing craft*: The hilsa fishery in the marine inshore waters is essentially a fishery of the artisanal sector where traditional non-motorized craft and small motorized boats are

operated. The boats are plank built and partly or fully decked ranging in length from 6 to 16 m. The horse power of the marine diesel engines used ranged from 12 to 37. The carrier boats used powerful engines ranging from 60 to 200 hp. About 800 small mechanized boats and 3 500 non-mechanized boats operate in the coastal districts of West Bengal alone. In Orissa, fishermen from northern parts only go for hilsa fishing.

*The area of operation*: The area of operation changes with season depending on the condition of the sea. During winter, as the water recedes, hilsa shad moves into more protected deeper areas. Often fishermen have to travel 8–12 hours covering a distance of 30–40 km to reach the fishing grounds. They fish at a depth of 20–60 m. The non-mechanized boats, which are towed to the fishing grounds by the carrier boats, basically are involved in the operations of the seine nets. During monsoon, hilsa shad move close to inshore areas and lower estuaries when the bulk of the catch is landed.

*All-India landings*: The annual landings of hilsa shad in India (Fig. 1) during 1979–88 showed fluctuations. The annual average catch was 5 710 tonnes which formed 0.4% of the total catch. The landings of hilsa shad in different states showed that east coast accounted for 79.5% with West Bengal (48.4%) and Orissa (18.7%) together contributing over 67% of the all-India catch. Annual marine landings in these states are shown in Fig. 2. Maharashtra (9.5%), Tamil Nadu (7.8%), Gujarat (7.4%) and Andhra Pradesh (4.1%) also contributed to the landings. Hilsa shad landings from other states were poor.

The marine fishery for hilsa shad starts in July and continues till March with peak landings during July–October and January–February. The fishery is generally poor during

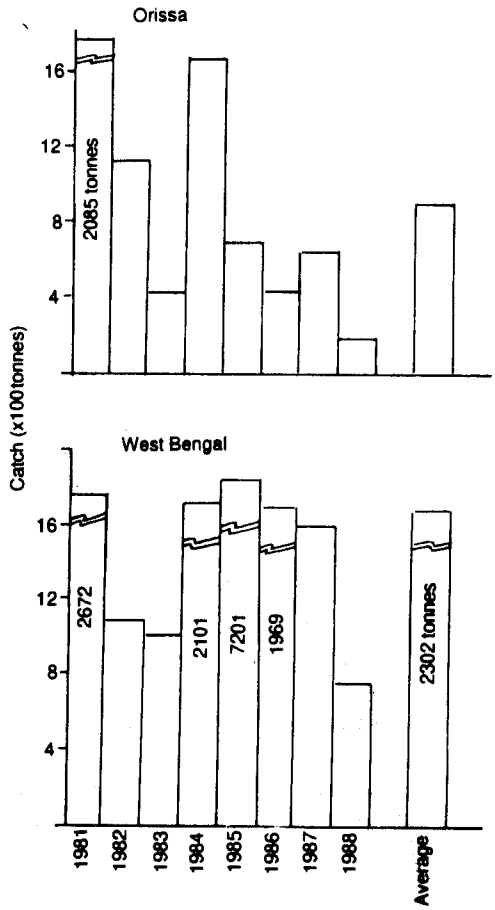


Fig. 2. Annual abundance of *Hilsa ilisha* in Orissa and West Bengal during 1981-88.

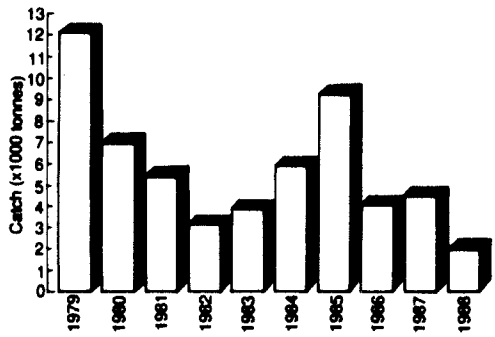


Fig. 1. Annual marine landings of *Hilsa ilisha* in India during 1979-88.

March to June. The principal gears contributing to the fishery were drift gill net (70.4%), *jangal* (18.7%) and *kachal* (10.8%).

Of the four centres covered for hilsa shad investigations, Diamond Harbour centre contributed the highest (68%) followed by Digha (23.0%), Talsari (6.0%) and Fraser Gunj (3.0%). The seasonal abundance of hilsa shad in drift gill net catches at different landing centres is given in Fig. 3. Highest catch at all the centres was recorded during August. The catch rate was also highest in August at all the centres except Fraser Gunj where the highest catch rate was during October. The catches were generally good during post-monsoon (August–October). There was a second peak in the landings during winter season at all the centres. The *jangal* catch and catch rate were

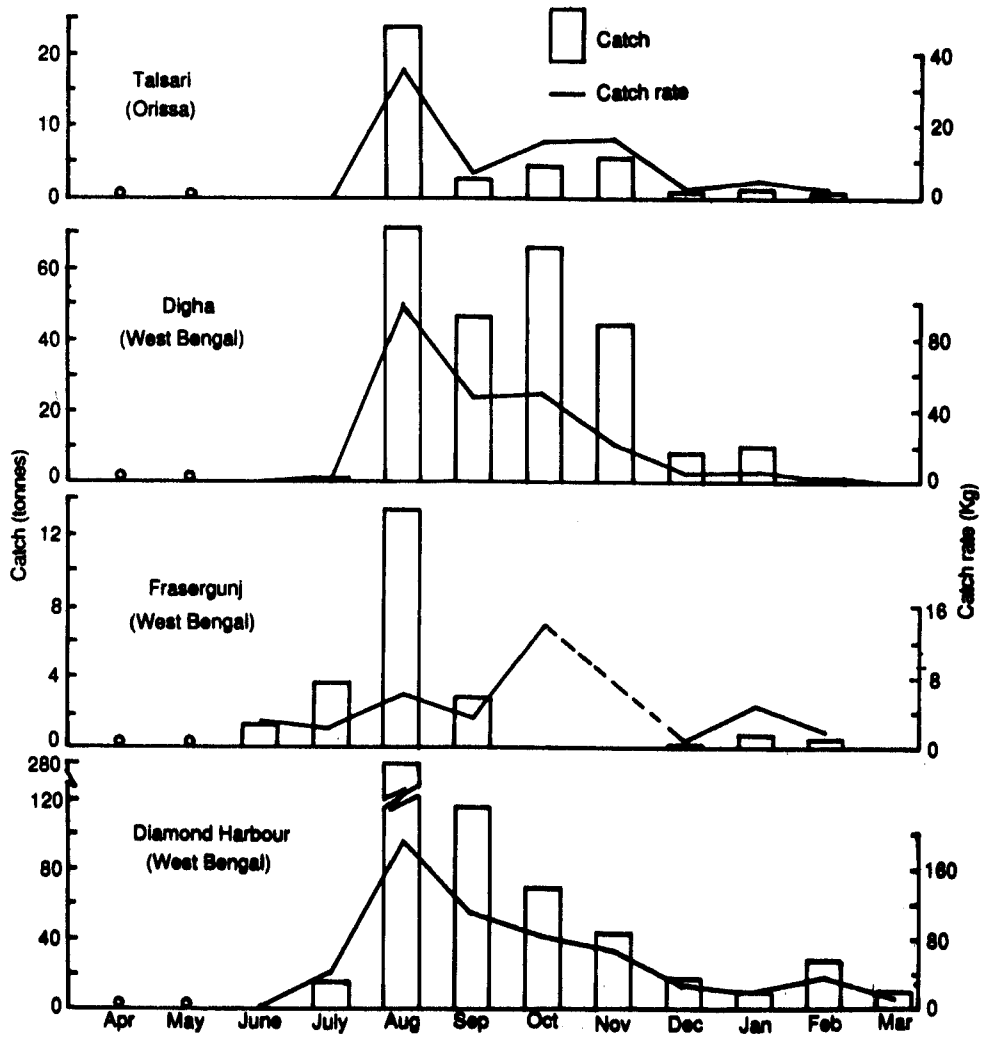


Fig. 3. Seasonal abundance of *Hilsa ilisha* in different centres of West Bengal and Orissa in drift gill net.

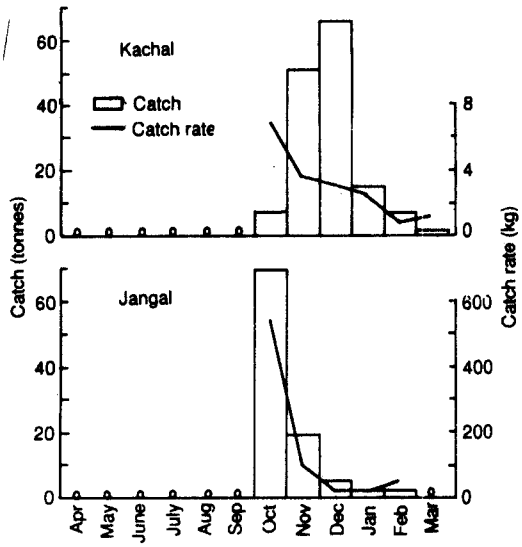


Fig. 4. Seasonal abundance of hilsa in *kachal* and *jangal jal* in West Bengal.

high in October and November whereas the catches of *kachal* were high during November and December (Fig. 4.).

The minimum size at recruitment was 150 mm and the length at capture was 240–270 mm. Hilsa shad were fully recruited into the fishery at a length of 340–370 mm. The size groups that contributed to the bulk of the fishery ranged from 260 to 480 mm. The major portion of the *jangal* catch and almost the entire catch of *kachal* comprised of immature fish.

*Scales and otoliths*: Examination of 187 samples of scales of the fish revealed the presence of radii and growth checks on them. The fish of length 330–440 mm had 9–15 rings with 1–2 fully formed growth checks and those ranging from 440–560 mm had 14–19 rings with 1–3 fully formed growth checks.

## *Biology*

*Length-weight relationship*: The length-weight relationship calculated based on measurements of over 1 300 fish (male and fe-

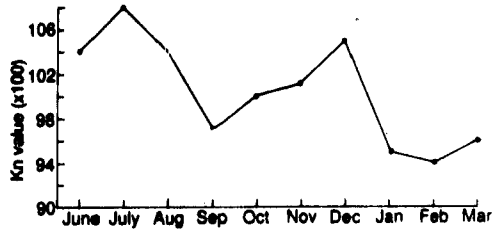


Fig. 5. Relative condition Kn of *Hilsa ilisha* in different months.

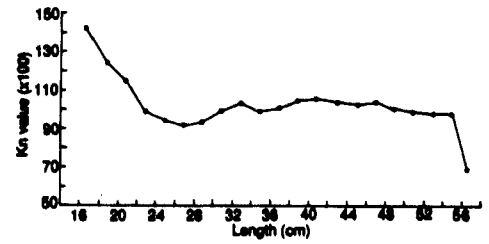


Fig. 6. Relative condition Kn of *Hilsa ilisha* in different length groups.

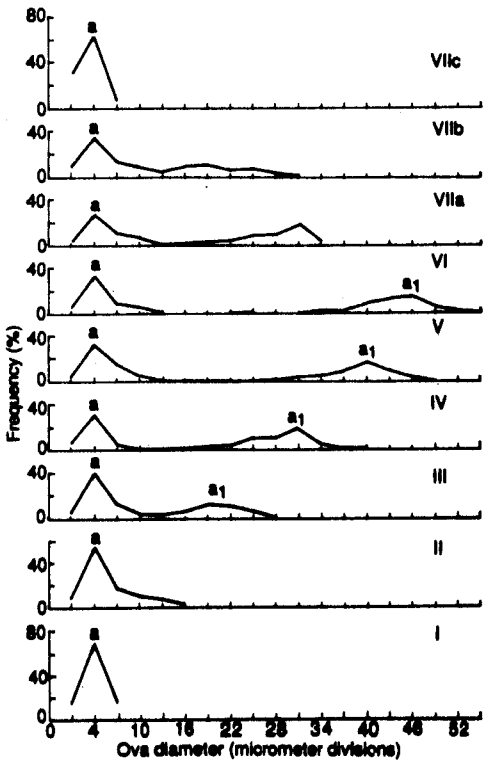


Fig. 7. Ova diameter progression in *Hilsa ilisha*.

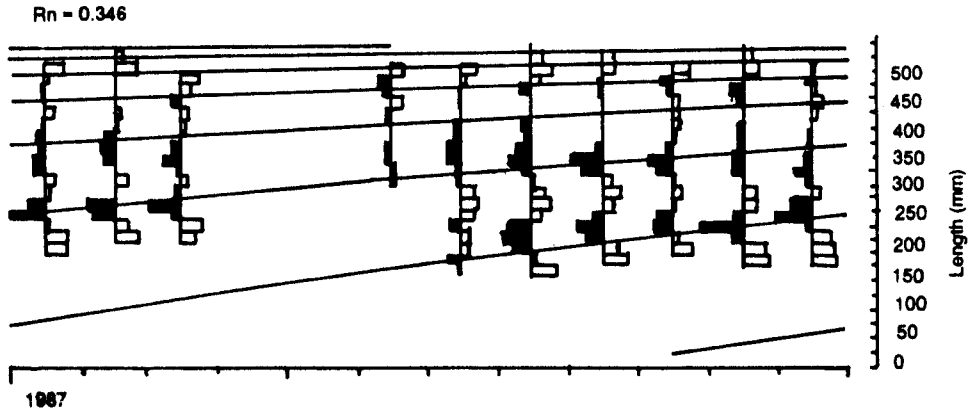


Fig. 8. Growth parameters of *Hilsa ilisha*.

male) was found to be:

$$W = 0.00003693321\ L^{2.8053}$$

The same was used for raising the length frequencies to the total catches.

The relationship between standard length and weight and total length and standard length was calculated as follows:

Log W = −9.3555 + 2.7530 log standard length
Depth = 1.964 + 0.2546 total length
Standard length = −8.0302 + 0.8438 total length

The relative condition (Kn) values of hilsa shad were low in September and February and high in July and December (Fig. 5). The relative condition of hilsa shad in different length groups (Fig. 6) showed that low values were noted at 270 mm, 450 mm, and 560 mm, which are the size groups that take part in spawning migrations. There is a good peak at 170 mm followed by minor peaks at 330 mm, 410 mm and 470 mm. The size of first maturity was observed at 350–370 mm (Fig. 13).

*Spawing:* The ova diameter progression observed in this study (Fig. 7) indicated that a single batch of ova only get segregated for spawning. Several partially spent ovaries examined during the present study strengthened this view.

*Fecundity:* The fecundity estimates of fish of 370–540 mm in the present study ranged from 467 100 to 1 369 500.

*Sex ratio:* The sex ratio of male and female was 1: 1.3. There was differential growth in sexes, the female having slightly faster growth.

*Stock assessment*

*Growth Parameters:* The growth of the monsoon brood that hatched during September–October and the spring brood released during February–March was traced using the modal progression method. The pattern of growth was estimated employing von

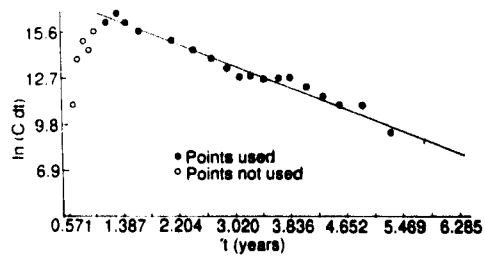


Fig. 9. Length converted catch curve of *Hilsa ilisha*.

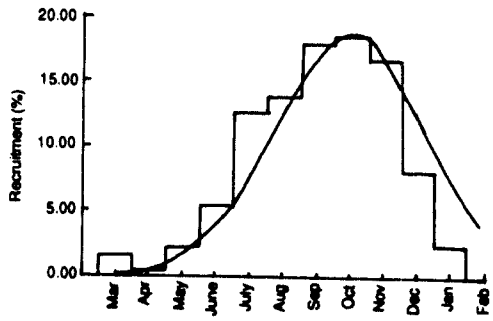


Fig. 10. Recruitment pattern of *Hilsa ilisha* in northeast coast.

Bertalanffy growth equation

$$L_t = L_\infty (1 - \exp(-K(t-t_0))).$$

The fitted equation for monsoon brood released in September–October was

$$L_t = 612 (1-\exp(-0.4486 (t+0.10147))).$$

and for spring brood released in February–March was

$$L_t = 578 (1-\exp(-0.5140 (t+0.07633))).$$

Since the winter and monsoon populations of hilsa in Hooghly belong to the same stock (Pillay 1957), the average value of the above growth parameters were calculated to be used in further computations which were $L_\infty = 595$ mm; $K = 0.4813$ yearly; $t_0 = -0.0889$.

The length frequencies were also used to estimate growth parameters by employing ELEFAN I programme (Fig. 8). These were found as: $L_\infty = 595$ mm, $K = 0.47$ (annual) and Rn = 0.346.

The values obtained through modal progression analysis and ELEFAN I were very close.

The length of hilsa shad at the end of 1, 2, 3, 4, 5 and 6 years was estimated to be 238, 372, 456, 508, 541 and 561 mm respectively.

*Mortality parameters*: The instantaneous rate of natural mortality M estimated as per Pauly (1980) was 0.704. M calculated using Rikhter and Efanov (1976) method was 0.69. M estimated from max T (Sekharan 1974) was M=0.64 which was lower than the former two values. Age at first maturity was estimated as 1.98 yr.

The estimation of the stock size and mean fishing mortality F was done by Jones' cohort analysis and presented in Table 1. The terminal exploitation rate was chosen in such a way that the last five groups would have nearly the same F/Z value to ensure that they are under full exploitation. The mean value of F was calculated as 0.9444. The total mortality coefficient Z was directly estimated by analysis of the length converted catch curve (Fig. 9) as 1.71. The values of mortality parameters and the exploitation ratio are as follows:

| | | |
|---|---|---|
| Natural mortality M | = | 0.704 + 0.69 + 0.64 |
| | = | 0.678 |
| Total mortality Z | = | 1.71 |
| Fishing mortality F (Z-M) | = | −1.006 |
| Mean fishing mortality from cohort analysis F | = | 0.9444 |
| Exploitation ratio E (F/Z) | = | 0.5883 |

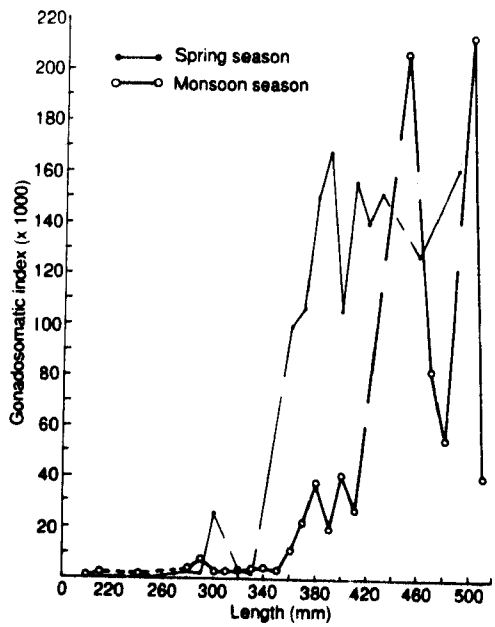


Fig. 11. Gonadosomatic index in *Hilsa ilisha* at various length groups.

Table 1. Jones' length cohort analysis for *Hilsa ilisha* (Hamilton) in the northeast coast of India

| Interval | C | X*) | N | F/Z | F | Ż |
|---|---|---|---|---|---|---|
| 150-160 | 2 163.927 | 1.0172 | 3256E+07.00 | 0.0025 | 0.0018 | 0.7058 |
| 160-170 | 70 456.617 | 1.0176 | 7248E+07.00 | 0.0768 | 0.0586 | 0.7626 |
| 170-180 | 72 765.398 | 1.0180 | 5514E+07.00 | 0.0802 | 0.0614 | |
| 180-190 | 172 708.406 | 1.0184 | 4785E+07.00 | 0.1740 | 0.1483 | 0.8523 |
| 190-200 | 100 200.797 | 1.0189 | 1955E+07.00 | 0.1107 | 0.0876 | 0.7916 |
| 200-210 | 342 872.313 | 1.0194 | 4968E+07.00 | 0.3036 | 0.3068 | 1.0108 |
| 210-220 | 520 166.094 | 1.0199 | 2016E+07.00 | 0.4064 | 0.4820 | 1.1860 |
| 220-230 | 573 052.000 | 1.0204 | 4018E+07.00 | 0.4404 | 0.5541 | 1.2581 |
| 230-240 | 815 698.875 | 1.0210 | 3903E+07.00 | 0.5418 | 0.8324 | 1.5364 |
| 240-250 | 936 047.875 | 1.0216 | 3345E+07.00 | 0.5926 | 1.0240 | 1.7280 |
| 250-260 | 957 871.375 | 1.0223 | 5385E+07.00 | 0.6174 | 1.1362 | 1.8402 |
| 260-270 | 951 063.688 | 1.0230 | 0249E+07.00 | 0.6368 | 1.2345 | 1.9385 |
| 270-280 | 920 659.625 | 1.0237 | 0905E+07.00 | 0.6520 | 1.3192 | 2.0232 |
| 280-290 | 933 378.125 | 1.0245 | 9 797 056.00 | 0.6797 | 1.4938 | 2.1978 |
| 290-300 | 752 800.000 | 1.0253 | 8 423 798.00 | 0.6577 | 1.3529 | 2.0569 |
| 300-310 | 591 686.000 | 1.0262 | 7 279 259.50 | 0.6274 | 1.1855 | 1.8895 |
| 310-320 | 463 779.313 | 1.0271 | 6 336 191.00 | 0.5934 | 1.0272 | 1.7312 |
| 320-330 | 250 582.000 | 1.0281 | 5 554 569.00 | 0.4610 | 0.6022 | 1.3062 |
| 330-340 | 290 372.094 | 1.0292 | 5 011 053.00 | 0.5160 | 0.7507 | 1.4547 |
| 340-350 | 292 089.188 | 1.0304 | 4 448 363.00 | 0.5387 | 0.8222 | 1.5262 |
| 350-360 | 269 511.906 | 1.0317 | 3 906 167.00 | 0.5416 | 0.8319 | 1.5359 |
| 360-370 | 284 886.813 | 1.0331 | 3 408 566.50 | 0.5806 | 0.9745 | 1.6785 |
| 370-380 | 251 499.594 | 1.0346 | 2 917 867.50 | 0.5807 | 0.9749 | 1.6789 |
| 380-390 | 239 402.094 | 1.0363 | 2 480 094.75 | 0.5959 | 1.0379 | 1.7419 |
| 390-400 | 174 496.703 | 1.0382 | 2 078 314.50 | 0.5486 | 0.8556 | 1.5596 |
| 400-410 | 162 915.406 | 1.0402 | 1 760 236.00 | 0.5616 | 0.9019 | 1.6059 |
| 410-420 | 153 491.797 | 1.0425 | 1 470 149.63 | 0.5800 | 0.9721 | 1.6761 |
| 420-430 | 114 367.297 | 1.0451 | 1 205 499.13 | 0.5417 | 0.8320 | 1.5360 |
| 430-440 | 93 538.922 | 1.0479 | 994 362.63 | 0.5251 | 0.7783 | 1.4823 |
| 440-450 | 67 388.406 | 1.0512 | 816 210.25 | 0.4756 | 0.6384 | 1.3424 |
| 450-460 | 54 490.180 | 1.0550 | 674 509.75 | 0.4536 | 0.5845 | 1.2885 |
| 460-470 | 49 703.121 | 1.0593 | 554 391.75 | 0.4633 | 0.6077 | 1.3117 |
| 470-480 | 49 798.449 | 1.0644 | 447 109.53 | 0.5016 | 0.7085 | 1.4125 |
| 480-490 | 54 122.039 | 1.0705 | 347 830.47 | 0.5705 | 0.9351 | 1.6391 |
| 490-500 | 54 789.172 | 1.0778 | 252 963.75 | 0.6367 | 1.2339 | 1.9379 |
| 500-510 | 39 767.539 | 1.0869 | 166 914.55 | 0.6393 | 1.2478 | 1.9518 |
| 510-520 | 29 031.500 | 1.0983 | 104 710.20 | 0.6548 | 1.3356 | 2.0396 |
| 520-530 | 16 631.270 | 1.1131 | 60 375.92 | 0.6255 | 1.1738 | 1.8798 |
| 530-plus | 22 495.996 | 1.1333 | 33 786.47 | 0.6658 | 1.4027 | 2.1067 |

*) X = ((LB-L(i))/(LB-L(i+i)))^(M/2K)

The MSY was estimated as 4 168.484 tonnes and the biomass as 4 707.222 tonnes at an $F_{msy}$ of 1.025.

*Yield and biomass:* The results of Thompson and Bell analysis are presented in Table 2. An optimum yield of 4 168 tonnes and a biomass MSY of 4 707 tonnes was obtained for an $F_{msy}$ value of 1.0125. Since the present yield of 4 168 tonnes and the MSY 4 168.5 tonnes obtained are more or less at similar levels of effort, it can be said that the present level of exploitation is being done at optimum level. The exploitation ratio of 0.5883 derived also indicates the same.

Table 2. Thompson and Bell long-term forecast for *Hilsa ilisha* in the northeast coast of India

| X | Yield | Mean biomass |
|---|---|---|
| 0.0000 | 0.00 | 20 042.58 |
| 0.2000 | 2 530.08 | 13 376.28 |
| 0.4000 | 3 539.76 | 9 702.80 |
| 0.6000 | 3 963.72 | 7 427.07 |
| 0.8000 | 4 128.18 | 5 914.12 |
| 1.0000 | 4 168.59 | 4 858.54 |
| 1.2000 | 4 147.65 | 4 095.01 |
| 1.4000 | 4 096.58 | 3 526.61 |
| 1.6000 | 4 031.61 | 3 093.18 |
| 1.8000 | 3 961.44 | 2 755.74 |
| 2.0000 | 3 890.77 | 2 488.20 |

MSY = 4 168.484, X = 1.0125, Biomass MSY = 4 707.222

*Recruitment:* The recruitment pattern (Fig. 10) computed assuming the value of $t_c$ as –0.01 showed prolonged recruitment during July–November with a peak in October.

*Migrations*

To study the pattern of migratory movements of hilsa shad into and from the river, the mode of gilling (entangling) of the fish in the net was observed during high and low tides in the gill net operations done in Hooghly river off Diamond Harbour. The direction of gilling of the fish i.e. towards river or sea, and the position of gilling in the net i.e. at the top, centre or the bottom of the net were noted. The sex, maturity and length of the fish caught during the days of observation on board fishing vessel were noted. It was found that hilsa shad were gilled (caught) at the top and central portion of the net during high tide as the fish migrates into the river. However, during low tide migrating spent fishes from the river into the sea were invariably gilled at the bottom position of the net indicating the habitat of the spent fish. However, there were instances of hilsa shad movement against current. The experiments to follow the movements of hilsa shad were conducted during peak periods of migration in monsoon and winter. Further, the examination of gut contents of spent hilsa also testified its habit. As compared to the high catch rates obtained of the aggregating hilsa shad in the coastal areas and the lower estuary, the poor catch rates of this fish caught in the river showed that hilsa shad does not move in the river in dense schools.

Based on the examination of extensive samples of fish for length frequency from the inshore centres, estuarine centres and the riverine centres as also the sex and maturity condition of the migrants the following conclusions could be drawn:

a) There are two well-marked migrations of marine hilsa shad into Hooghly river, once during post-monsoon (September/October) and the other during the winter (January/February).

b) Two size groups of 350–430 mm and 460–490 mm, former being the most dominant, participate in spring mi-

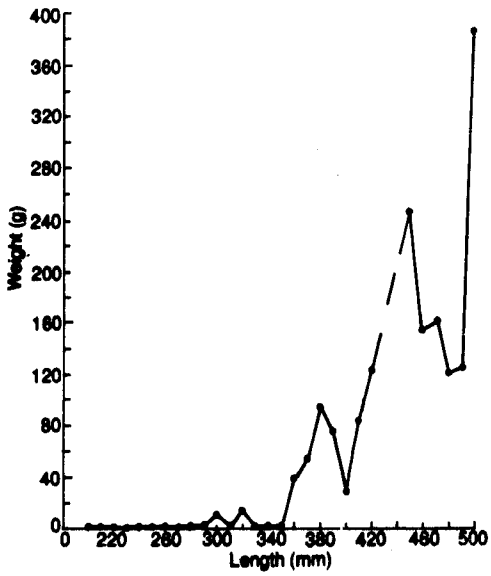


Fig. 12. Fish length-gonad weight relationship of *Hilsa ilisha*.

gration.

c) The monsoon run of hilsa shad comprises two groups of 310–370 mm and 420–500 mm, the later being most dominant and occurring very much in the river catches.

d) Smaller size fish of less than 300 mm also enter the river sporadically in very small numbers along with the bigger size groups of spring as well as monsoon runs of hilsa shad. These fish belong to maturity stages II & III. The gonadosomatic index (Fig. 11) and length and gonad weight relationship (Fig. 12) amply corroborate advanced mature condition of the migrating groups.

e) The spring spawners that enter the river for spawning in February–March return to the sea and are caught in good numbers during July–August.

f) The monsoon spawners that enter the river during September–October return to the sea after spawning and are caught in good numbers during January–March.

g) Similarly, the offspring of spring spawners journey to the sea from the river during November–January, whereas the offspring of monsoon spawners return to the sea from the river during July–September. The return of the broods of spring and monsoon spawners to the sea is not as precise as the river-ward migrations of hilsa shad. Full recruitment of juveniles into the sea fishery is observed for 5 months in a year i.e. July to January with a peak in October.

h) Although the minimum size at recruitment into the sea is at 160–180 mm the juveniles are fully recruited into the fishery at a length of 260–270 mm approximately at an age of one year. But the maximum exploitation of this stock is effected when they congregate in the near shore areas and lower estuaries at lengths of 350–370 mm at the age of about 2 years approximately. This also coincides with the size at first maturity of hilsa shad (Fig. 13).

i) It is also revealed from the investigations that very few hilsa (especially of the robust monsoon variety of spawners) make more than one spawning migration.

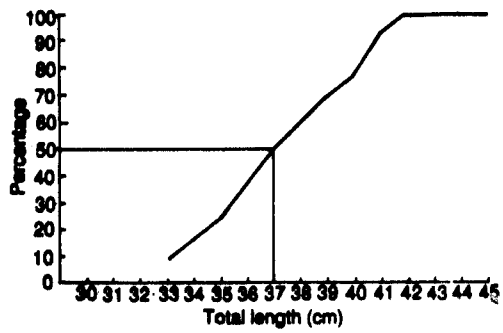


Fig. 13. Size at first maturity of *Hilsa ilisha*.

## DISCUSSION

In recent years there has been a declining trend of the catches of hilsa shad in the northeast coast as well as in all-India catches. Being a migratory species the adtults that swarm at the lower estuaries and the maturing and mature adults that make long journeys into the rivers are subject to great fishing stress. Similarly, the fry that spend their life for a season in the river and the juveniles that make a long trip into the sea through the river and estuary are also subject to great fishing stress. It is also a matter of concern that huge quantities of preadults are caught in the inshore areas by *jangal* and *kachal* even before the fish attains size at first maturity (370 mm)

(Fig. 13). Added to this, the concentrated fishing on the migrating ripe hilsa is also to be viewed with concern. Fishing of any one of these above the optimal levels might contribute to the failure of the fishery. As an interim measure, the mesh size of *jangal* and *kachal* be increased to avoid overfishing of preadults and also the fishermen be advised to refrain from fishing in the river during September and February when large-scale movement of ripe fish is expected in the river.

The present investigations have confirmed that hilsa shad does not breed in the sea as was suspected earlier (Antony Raja 1984). Only developing, spent and resting hilsa shad were recorded from the sea catches but not a single ripe and running fish. On the other hand in the river catches in the vicinity of Diamond Harbour, fish in all stages of maturity except stage I were observed. This study confirmed the earlier findings of Jones (1954), Pillay (1958), Bhanot (1973) and De (1980) that there are two spawning runs of hilsa. The migration of hilsa shad is usually correlated with floods during monsoon rains and to the general rise in temperature of water in the estuaries after the close of winter (Jones 1957). The migration of hilsa in the river Indus and Irravadi during minor floods is caused by the melting of snow in the upper reaches (Antony Raja 1984).

The lowest value of condition factor Kn in February (Fig. 4) depicts the condition of spring spawners which are relatively few in numbers as compared to large number of monsoon spawners represented by a low value of condition in September. The low value of Kn noted at 270, 350, 450 and 560 mm point out at the size groups that take part in spawning migrations as revealed in the length frequency studies of migratory hilsa. Similar results were obtained by De and Dutta (1990b). These size groups do not necessarily represent year classes and annual migration of same fish. Hilsa does not take part in successive yearly spawning migrations as it takes lot more time to recover and rebuild from heavy spawning stress and tiresome long journeys without feeding for months. This can be seen from the large index of empty stomachs of the migrating and spawning stock.

Mathur (1964) with the help of ova diameter studies stated that different modal groups are shed in batches. De (1980) felt that there are groups of ova released at a time. Pillay (1958) opined that the fish bred intermittently during the breeding season. He opined that several spawnings take place with one small portion of ova being shed at each time. These findings were at variance from the present finding of releasing of only one batch of ova.

The value of $L_\infty$ (595 mm) obtained in this study agrees well with that estimated by Gupta (1987) although the value of K (0.825) derived by him is more than 0.47 obtained in this study. The Phi prime value of 3.22 calculated here (as per Pauly and Munro 1984) is close to 3.40–3.49 quoted by Gupta (1987).

According to Thompson and Bell analysis, the estimated maximum sustainable yield is the same as the present yield and it can be said that the present exploitation (0.588) is going on more or less at optimum level, taking $F_{opt}$ as 0.5, and that any increase in fishing effort may affect the fishery.

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