*Asian Fisheries Science* **21**(2008):175-187
https://doi.org/10.33997/j.afs.2008.21.2.004


Asian Fisheries Society, Manila, Philippines

# Catch Per Unit Effort, Exploitation Level and Production of Hilsa Shad in Bangladesh Waters

**S.M.N. AMIN[1*], M.A. RAHMAN[2], G.C. HALDAR[3], M.A. MAZID[3] and D.A. MILTON[4]**

[1]Institute of Marine Sciences and Fisheries
University of Chittagong, Chittagong 4331 Bangladesh
[2]Bangladesh Fisheries Research Institute
Riverine station, Chandpur-3602, Bangladesh
[3]Bangladesh Fisheries Research Institute
Mymensingh-2201, Bangladesh
[4]CSIRO Marine and Atmospheric Research
PO Box 120, Cleveland 4163 Qld Australia

## Abstract

Catch per unit effort (CPUE) and exploitation rates of hilsa shad (*Tenulosa ilisha* Hamilton 1822) were estimated from the Bangladesh waters to evaluate the productivity of the population. Adult *T. ilisha* was caught mainly by gill net (mesh size 10.6-19.1 cm) with a mean catch rate of 45.7 kg•boat$^{-1}$•day$^{-1}$ during the peak period (September-October) in the Ramgoti area of Meghna River, Bangladesh. Tempo hilsa (immatures) was caught by chandi current jal (monofilament net, mesh size 6-8 cm) with a mean CPUE of 33.5 kg•boat$^{-1}$•day$^{-1}$ and a mean fish weight of 152-235 g. The total catch of hilsa in Bangladesh was estimated to vary between 146,082 and 229,714 mt from 1984 to 2002, with jatka (juvenile hilsa) contributing 19,258 mt in 2000. The average weight of each jatka was 10 g and if 10 - 15% of these jatka were protected, an additional 150,000-250,000 mt of adult hilsa could be harvested each year from the present fishery. Exploitation levels (E) of hilsa were very high during the years 1996-2003 and need to be reduced by decreasing the level of fishing effort or increasing the mesh size that can be used.

* Corresponding author. Tel.: +880 31 710 347, Fax: +880 31 726 310
E-mail address: smnabd02@yahoo.com

## Introduction

Hilsa shad (*Tenualosa ilisha*), locally known as 'hilsa' is widely distributed in almost all the major rivers, estuaries and marine waters of Bangladesh. It is capable of withstanding a wide range of salinities and migrating long distances upstream (up to 1287 km). The majority of the population feed and grow mainly in the sea before migrating to fresh water for spawning (Haroon 1998). Juveniles develop and grow in fresh water, but soon migrate to the ocean, where they spend most of their lives. The fishery for hilsa contributes about 20% of the total annual fish production of the country. The fishery provides direct or indirect employment to about 2% (2.5 million) of the entire population (Mazid 1998).

Hilsa are harvested by different types of crafts and gears in different seasons and environments. In the recent past, the fishery in inland waters had been declining, but the total catch has remained stable (about 200,000 mt annually) due to an increase in catch from the marine sector. The inland sector contributed 32.7% to the total hilsa catch of 229,714 mt during 2000-2001. In the inland sector, most hilsa are caught in the Meghna River (66.2% during 1998-99), from both fresh water and estuarine reaches. The decline in the inland sector of the fishery, particularly in the Padma River, has been a cause of concern (Haldar et. al. 1992; Hussain et. al. 1998; Islam 1998; Mazid 1998; Rahman et. al. 1998; 1999; Amin et. al. 2000a,b; Rahman et. al. 2000; Amin et. al. 2001; Haldar et. al. 2001; Mazid 2001; Rahman et. al. 2001; Amin et. al. 2002; 2003).

There are a large number of vessels fishing for hilsa in all sectors and most are unregistered. This makes it difficult to estimate fishing effort. During the peak hilsa-fishing season (September – October) the number of vessels and types of fishing gear used to catch hilsa increases and many non-traditional fishermen, day laborers and unemployed people participate. These, plus the migratory habits of the fish, add to the difficulty in obtaining reliable estimates of annual fishing effort in each sector. In spite of all these difficulties, it is essential to monitor the catch and production trends and to develop a catch monitoring system.

There have been no published estimates of hilsa CPUE in Bangladesh. However, detailed studies on population biology and genetics of this species have been reported by different authors (Haldar et. al. 1992; Dahle et. al. 1997; Hussain et al. 1998; Islam 1998; Mazid 1998; Rahman et al. 1998; 1999; Amin et al. 2000a,b; Rahman et al. 2000; Rahman & Naevdal

2000; Amin et al. 2001; Haldar et. al. 2001; Mazid 2001; Rahman et al. 2001; Amin et al. 2002; 2003; 2004; Salini et al. 2004). A few studies have recently been made on jatka (Rahman et al. 1995; Amin et al. 2000a; Miah et al. 2000) suggesting that the catch is unsustainable. Thus, the continuous unregulated catch of hilsa will adversely affect the productivity of the population. Therefore, the present study was undertaken to provide an estimate of the catch per unit effort, total annual production and exploitation level (E) of hilsa. These aspects will help in formulating management and conservation policies for hilsa in Bangladesh.

## Materials and Methods

Several surveys were conducted to assess the number of fishing vessels and their gear with the F.B. Hilsa Research boat during 1998-2000. Surveys covered the freshwater and estuarine reaches of the Meghna River from Chandpur (23°10.75′ N and 90 °36.2′ E) to Hatia (22°26.95′ N and 90°53.86′ E) (Fig.1). The number of boats fishing for hilsa was counted during each survey and their positions were taken with GPS. The total length of each fishing boat and net; mesh size and CPUE data were collected from 49 hilsa-fishing boats during September-October 1998 and from 28 fishing boats during September-November 2000. To monitor the catch (landing) of hilsa, the landing data from 1984 to 2002 were collected from the Department of Fishery (DOF) of Bangladesh.


Fig. 1. Geographical location of survey areas (Chandpur to Hatia) and different hilsa landing sites (S) of Bangladesh

Monthly length frequency data for hilsa were collected from the commercial catches at different landing sites (Gualanda, Chandpur, Barisal, Khulna, Chittagong and Cox's Bazar) (Fig. 1). These data were collected from January to December in 2003. The hilsa fishery in Bangladesh uses a wide range of mesh sizes (6.0-13.0 cm) depending on the season. At each landing site, the catch of hilsa from different mesh sizes was subsampled. Total length (cm) and weight (g) of up to 50 fish from each daily catch were measured. The data were then pooled into monthly groups from different landing sites and subsequently grouped into 2.0-cm length intervals (Table 1).

Table 1. Length frequency distribution of *Tenualosa ilisha* in Bangladesh from January to December 2003

| Mid Length | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 67 | | | | | | | | | | | |
| 4 | 180 | | | | | | | | | | | |
| 6 | 237 | 144 | 1 | | | | | | | | | |
| 8 | 40 | 145 | 16 | | | | | | | | | |
| 10 | | 106 | 48 | | | | | | | | | |
| 12 | | 69 | 34 | | | | | | | | | |
| 14 | | | 17 | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 20 | | | | 3 | | 1 | | 16 | | 1 | | 1 |
| 22 | 7 | | 21 | 21 | 2 | 2 | 4 | 12 | 13 | 3 | 7 | 20 |
| 24 | 26 | 4 | 32 | 83 | 16 | 30 | 78 | 46 | 121 | 193 | 25 | 46 |
| 26 | 136 | 43 | 159 | 199 | 128 | 71 | 112 | 86 | 352 | 226 | 177 | 115 |
| 28 | 185 | 304 | 222 | 497 | 170 | 124 | 68 | 91 | 428 | 518 | 410 | 313 |
| 30 | 114 | 314 | 261 | 387 | 170 | 235 | 174 | 146 | 261 | 496 | 560 | 498 |
| 32 | 76 | 220 | 330 | 234 | 144 | 301 | 275 | 173 | 186 | 311 | 352 | 265 |
| 34 | 21 | 135 | 221 | 142 | 101 | 299 | 362 | 156 | 186 | 141 | 138 | 127 |
| 36 | 5 | 78 | 126 | 111 | 150 | 350 | 277 | 208 | 247 | 174 | 94 | 95 |
| 38 | | 1 | 95 | 66 | 145 | 374 | 335 | 236 | 245 | 137 | 88 | 139 |
| 40 | 10 | 10 | 49 | 38 | 105 | 279 | 252 | 177 | 232 | 145 | 62 | 90 |
| 42 | 25 | 25 | 23 | 13 | 32 | 224 | 189 | 136 | 188 | 68 | 29 | 43 |
| 44 | 4 | 4 | 5 | 4 | 8 | 53 | 72 | 61 | 144 | 31 | 4 | 2 |
| 46 | 4 | 4 | 1 | 2 | 4 | 15 | 15 | 29 | 66 | 17 | 1 | 2 |
| 48 | | | | 1 | | 1 | 6 | | 1 | 2 | | |
| 50 | | | | | | 2 | 1 | | 1 | 1 | | |
| 52 | | | | 1 | | | | | 1 | 1 | | |
| Total | 1137 | 1606 | 1661 | 1802 | 1175 | 2361 | 2220 | 1573 | 2672 | 2465 | 1947 | 1756 |

Finally, the length frequency data were analysed with FiSAT (Gayanilo et al. 2002) to estimate the population parameters such as asymptotic length ($L_\alpha$), growth coefficient (K), natural mortality (M), fishing mortality (F) and exploitation level (E).

The growth performance of hilsa population was computed using the index of Pauly and Munro (1984):

$$\phi' = \text{Log}_{10}K + 2\ \text{Log}_{10}\ L_\infty$$

Total mortality (Z) was estimated using the length converted catch curve method. Natural mortality rate (M) was estimated using Pauly's empirical relationship (Pauly 1980):

$Log_{10}M = - 0.0066 - 0.279 \text{ Log10 } L_{\alpha} + 0.6543 \text{ Log10 K} + 0.4634 \text{Log10T}$

where, $L_{\infty}$ is expressed in cm and T, is the mean annual environmental temperature in °C (27.5°C).

Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained from F/Z (Gulland 1971). Where, F is the fishing mortality and Z is the total mortality.

The estimated annual yield (Y) and standing stock (Y/F) was 256,902 and 148,498.27 mt, respectively, during the year 2002. The approximate Maximum Sustainable Yield (MSY) was then calculated using the equation proposed by Troadec (1980) for exploited fish:

$$MSY = Z_t * 0.5 * B_t$$

where $Z_t$ is the rate of total mortality in year t and $B_t$ is the standing stock in year t.

## Results

### *Catch per unit effort (CPUE)*

Adult hilsa

Adult hilsa (>30 cm TL) was caught by gillnets operated by mechanised Chandi boat and a variety of artisanal gears (local names: chandi current, kona, gulti and shangla) along the coast and all the main rivers of the country. A total number of 3,646 boats were estimated to be fishing for hilsa between Chandpur and the Hatia estuarine region of Bangladesh during September-October 1998. Total length of the boats varied between 6.9 and 16.0 m with an average of 13 m. The length of the largest gillnet was 2743.2 m, the smallest was 914.4 m, and the mean length was 1636.1 m. The mesh sizes of gillnets varied from 10.7 to 19.1 cm with the mean of 13.1 cm (SD ±1.9). In 1998, mean catch was estimated to be 45.7 $kg \cdot boat^{-1} \cdot day^{-1}$ corresponding to a total catch of 166.6 $mt \cdot day^{-1}$ for the fishery. The total catch of hilsa was estimated to be 9,997.8 mt during the peak period (September-October) in the investigated area. In the same

region during 2000, mean catch was 33.0 kg•boat$^{-1}$•day$^{-1}$, a reduction of 12.70 kg•boat$^{-1}$•day$^{-1}$ (about 28.2%).

Tempo hilsa

Tempo hilsa (immature fish) length varied between 24 and 29.5 cm and the body weight varied between 152 and 235 g during the study period. Tempo hilsa was mainly caught by chandi current jal (monofilament net, mesh size 6-8 cm) operated by Chandi boat. To estimate catch and effort of tempo hilsa, 31 Chandi boats were intercepted during September-November 2000. The smallest net used was recorded as 135 m and the longest was 1620 m. About 90% of the boats were mechanized and their lengths ranged between 4.5 and 9.0 m, with an average crew of six per boat. The total number of chandi current jal recorded was 3,334 and they mostly fished from Chandpur to Ramgoti in the middle estuary. The CPUE of tempo hilsa was estimated as 33.5 kg•boat$^{-1}$•day$^{-1}$ in the investigated area.

Jatka hilsa

To estimate the total catch of jatka (juvenile hilsa, < 18 cm total length), fishers along all the main rivers were interviewed from January-May 2000. The total catch of jatka was estimated to be 19,258.1 mt (Table 2). The average weight of each jatka was 10 g making the total number caught approximately 1925 million. After one year, the average weight of hilsa is usually 700 – 800 g and if 10 – 15% of jatka could be saved, then an additional 150,000 – 210,000 mt hilsa could be added to the present production.

Table 2. Catch (tons) of jatka in different districts of Bangladesh in the year 2000

| Name of District | Name of River | Amount of jatka caught (in tons) |
|---|---|---|
| Rajshahi | Padma | 66.04 |
| Rajbari | Padma | 466.20 |
| Chandpur | Meghna (Satnol, Hazimara, Nilkomal and Hizla) | 18403.00 |
| Barisal | Tetulia, Kirtonkhula, Ilisha and Karkhana | 43.00 |
| Khulna | Rupsha, Shibsha and Pashur | 202.00 |
| Patuakhali | Galachipa, Aundharmanik, Paira and Augunmukha | 30.60 |
| Barguna | Bishkhali, Bhurishar and Kuakata Coast | 47.28 |
| Total | | 19,258.12 |

## *Trend of hilsa production*

Annual production (1984 – 2002) of hilsa in Bangladesh is shown in figure 2. The total production varied between 146,082 and 229,714 mt.

The lowest catch (144, 438 mt) was observed in 1985, with the highest catch (229,714 mt) recorded in 2002. During the years 1984 and 1985, the total catch was 146,082 and 144,438 mt, respectively. In 1986, the total catch suddenly increased to 191,091 mt and remained stable or gradually increasing since that time.

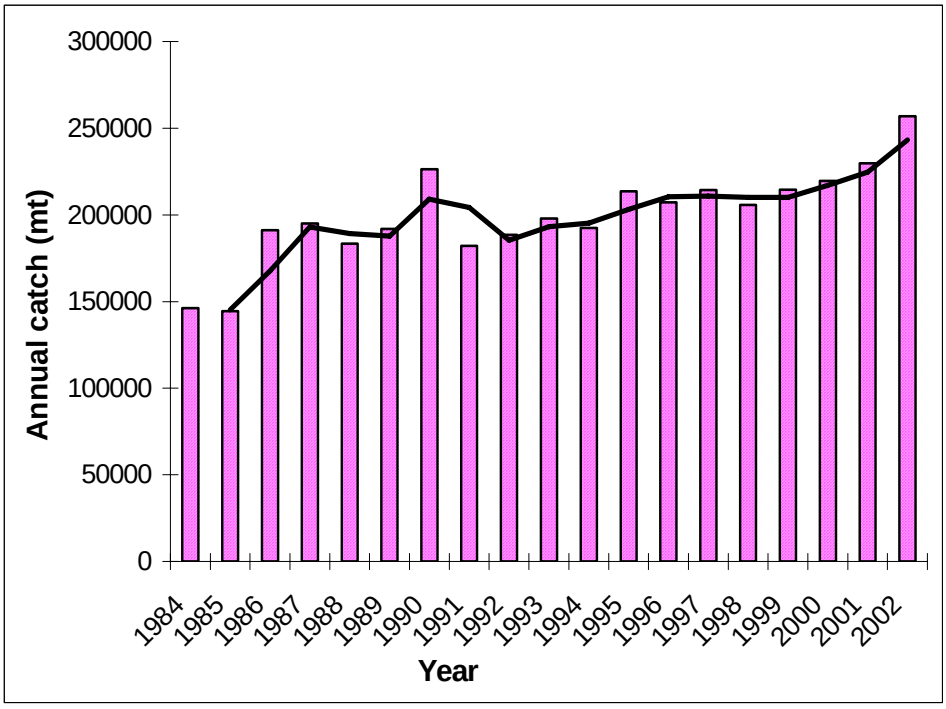


Fig. 2. Trend of production (landing) of *Tenualosa ilisha* in Bangladesh (1984-2002)

## *Population dynamics*

The estimated asymptotic length ($L_\infty$) and growth co-efficient (K) for *T. ilisha* were 54.60 cm and 0.67 $yr^{-1}$, respectively during 2003. The computed growth curve with these parameters is superimposed over the restructured length distribution in figure 3. The asymptotic length ($L_\infty$) and growth coefficient (K) values estimated for hilsa varied between years (Table 3). The $L_\infty$ estimate varied from 53.70 to 66 cm. The lowest value of $L_\infty$ (53.70 cm) was recorded in 2002 while the highest was in 1998. The values of K varied from 0.67 to 1.0 $yr^{-1}$. The lowest value of K was observed in 2003 while the highest was in 1996. The values of growth performance index ($\phi$') varied in the different years from 3.30 to 3.55 (Table 3).

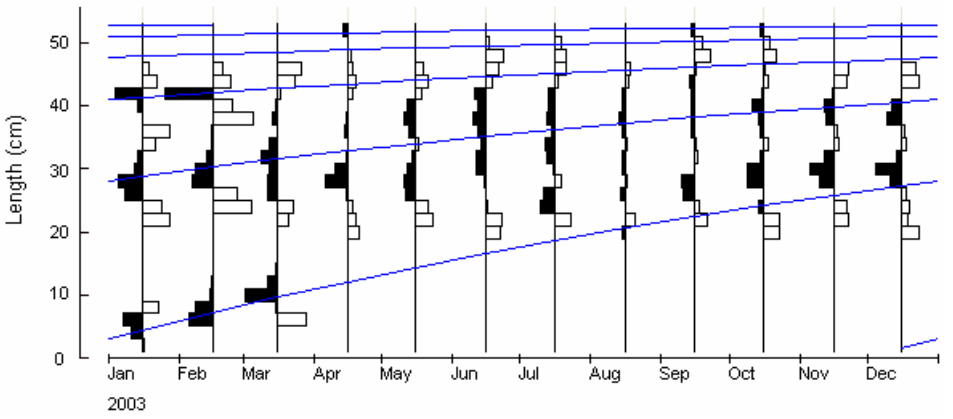


Fig. 3. von Bertalanffy growth curves ($L\infty$ = 54.60 cm and K = 0.67 $yr^{-1}$) for *T. ilisha* superimposed on the restructured length-frequency histograms. The black and white bars are positive and negative deviations from the "weighted" moving average of three length classes and they represent psedo-cohorts.

Table 3. Population parameters of *Tenualosa ilisha* in Bangladesh water (1995-2003)

| Parameters | 1995* | 1996** | 1997+ | 1998+ | 1999+ | 2002++ | 2003+++ |
|---|---|---|---|---|---|---|---|
| Asymptotic length ($L_\infty$) cm | 58.3 | 59.97 | 61.50 | 66.00 | 60.00 | 53.70 | 54.60 |
| Growth constant (K) $\cdot yr^{-1}$ | 0.74 | 0.99 | 0.83 | 0.67 | 0.82 | 0.86 | 0.67 |
| Growth performance ($\phi$') | 3.40 | 3.55 | 3.50 | 3.46 | 3.47 | 3.40 | 3.30 |
| Natural mortality (M) $\cdot yr^{-1}$ | 1.18 | 1.41 | 1.28 | 1.25 | 1.28 | 1.36 | 1.15 |
| Fishing mortality (F) $\cdot yr^{-1}$ | 1.43 | 1.78 | 2.01 | 2.18 | 2.49 | 2.16 | 1.92 |
| Total mortality (Z) $\cdot yr^{-1}$ | 2.61 | 3.19 | 3.29 | 3.43 | 3.77 | 3.51 | 3.07 |
| Exploitation level (E) | 0.55 | 0.56 | 0.61 | 0.63 | 0.66 | 0.61 | 0.62 |
| Sample number (N) | 9,318 | 8,692 | 6,123 | 6,189 | 10,922 | 13,340 | 22,375 |

*Rahman et al. (1998); **Rahman et al. (1999); +Amin et al. (2004); ++ Haldar and Amin (2005); +++Present study

Total mortality coefficient (Z) was estimated as 3.07 $yr^{-1}$ using length converted catch curve (Fig. 4) in the year 2003. The natural mortality varied between 1.15 and 1.41 $yr^{-1}$ in different years and showed a little variation. However, fishing mortality estimates were more variable (1.43 to 2.49 $yr^{-1}$) during 1995 to 2003 (Table 3). The highest fishing mortality (2.49 $yr^{-1}$) was observed in 1999 while the lowest (1.43 $yr^{-1}$) was in 1995.

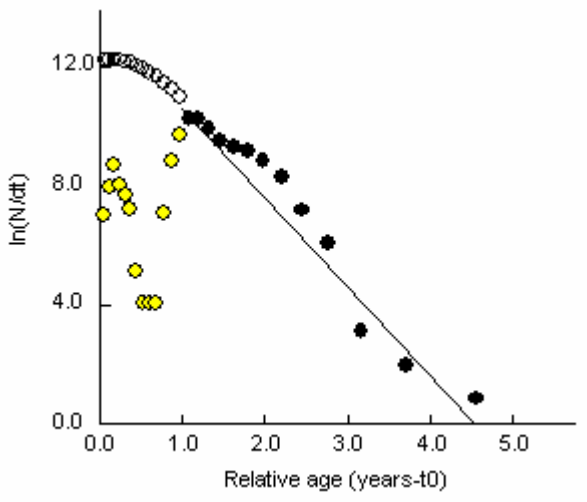


Fig. 4. Length converted catch curve of *T. ilisha*. The darkened full dots represent the points used in calculating through least square linear regression. The open dots represent the point not fully recruited.

## *Exploitation level (E)*

The exploitation rate (E) estimate varied between 0.55 and 0.66 for the years 1995 to 2003 (Fig. 5). The exploitation rate (0.55) recorded in the year 1995 was close to the optimum level (0.50) following which it started to increase gradually until the largest value (0.66) was reached in 1999. This indicated an increase of exploitation rate from the optimum level (0.50) up to a maximum of 0.13 to 0.16 (about 26 to 32%) above optimum during 1998 and 1999.

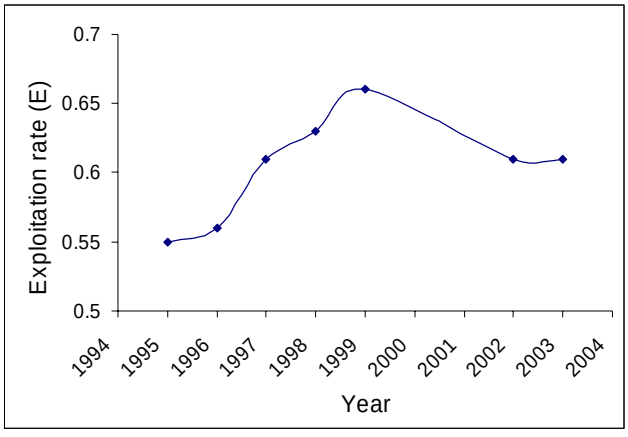


Fig. 5. Trend of exploitation level of *Tenualosa ilisha* in Bangladesh (1995-2003)

### *Stock size and MSY*

The estimated annual yield, standing stock and MSY were 256,902, 148,498.27 and 210,125.04 mt, respectively, during the year 2002. It is observed that the annual total catch of hilsa (256,902 mt) in 2002 was much higher than the estimated MSY (210,125.04 mt).

## Discussion

Haldar et al. (1992) reported that the mean total landing of hilsa from the Feni River was 125.0 mt during July-September 1979 and then peaked during October 1979 at 264.4 mt. Ali (1985) mentioned that hilsa production in the riverine and estuarine sectors is 40.4% (about 90,000 mt) of the estimated annual catch of 207,786 mt. This suggests that the present estimate of catch (9,997.8 mt) from the Meghna River during the peak period (September- October) may not be an over-estimate.

The total catch of jatka which was 19,258.1 mt in 2000 (Table 2) is a dramatic increase from the 1993 estimate of 3,707 mt (Rahman et al. 1995). This six-fold increase in jatka catch has corresponded with a steady decline in adult hilsa production (Fig. 2) and suggests that recruitment overfishing is occurring.

The highest fishing mortality was observed in 1999 while the lowest was in 2003. These findings are consistent with those of previous studies (Rahman et al. 1999; Amin et al. 2000a,b; Rahman et al. 2000; 2001; Amin et al. 2002; 2004). The exploitation rates (Table 3) clearly show that hilsa are overexploited in Bangladesh. Due to such an increase in exploitation rate, the hilsa stock may collapse in the near future. This finding has previously been identified to have occurred even in the 1990s (Rahman et al. 1999; Amin et al. 2000b; Rahman et al. 2000; 2001; Amin et al. 2002; 2004). The quantity of hilsa harvested (in terms of weight) was 17.91% above the estimated MSY during 2002. This indicates that the stock of this species is definitely being overexploited in Bangladesh waters.

## Conclusion

The results clearly indicate that the problem of overexploitation of this species is mainly because of heavy exploitation of juveniles. There-

fore, measures need to be taken to minimize the juvenile Hilsa fishery. The exploitation rate of adults should be reduced either by decreasing the number of fishing boats or by mesh size regulations. Banning the use of nets that catch juveniles and increasing community awareness of the issue of juvenile catch among the fishers will also help. But in order for these measures to be effective, the government needs to provide alternative sources of employment for them during the period of the juvenile fishing (December to April). This would greatly help to minimize juvenile Hilsa fishery in Bangladesh. This would substantially decrease the present over-exploitation and help increase the fishable number of adults in subsequent years. A further increase in the existing fishing level/exploitation will probably result in reduction in the yield-per-recruit and thereby threaten the viability of the population.

## Acknowledgements

This research is part of a project funded by ACIAR. We thank Dr. Stephen Blaber, Project Coordinator, for his guidance and all the staff at Chandpur Riverine Station, Bangladesh Fisheries Research Institute, who assisted in sample collection. We extend our sincere appreciation to the anonymous reviewers of the manuscript for their valuable comments and constructive criticisms.

## References

Ali, M.L. 1985. Inland Fisheries resources: Present status and future potential in Bangladesh. *In*: Souvenir, National Seminar 1985. Fisheries and Livestock Division, Ministry of Agriculture, Dhaka, Bangladesh, pp. 25-33.

Amin, S.M.N., M.A. Rahman, G.C. Haldar, S. Nahar, S. Dewan and M.A. Mazid. 2000a. Population Dynamics of Jatka (Juvenile Hilsa) in the Meghna River, Bangladesh. Asian Fisheries Science 13:383-389.

Amin, S.M.N., M.A. Rahman, G.C. Haldar and M.A. Mazid. 2000b. Some population dynamics aspects of *Tenualosa ilisha* from Khulna offshore region of Bangladesh. Journal of National Oceanography and Maritime Institute 17: 9-17.

Amin, S.M.N., M.A. Rahman, G.C. Hilda and M.A. Mazid. 2001. Studies on age and growth and exploitation level of *Tenualosa ilisha* in the coastal region of Chittagong, Bangladesh. Journal of Inland Fisheries Society of India 33**:** 1-5.

Amin, S.M.N., M.A. Rahman, G.C. Haldar, M.A. Mazid and D. A. Milton. 2002. Population dynamics and stock assessment of Hilsa shad, *Tenualosa ilisha* in Bangladesh. Asian Fisheries Science 15: 123-128.

Amin, S.M.N.**,** M.A. Rahman, G.C. Haldar, M.A. Mazid and M. Sinha. 2003. Exploitation of Hilsa (*Tenualosa ilisha*) juveniles and adults in Bangladesh-a comparative study. Journal of National Oceanographic and Maritime Institute 20: 15-23.

Amin, S.M.N., M.A. Rahman, G.C. Haldar, M.A. Mazid, D.A. Milton and S.J.M. Blaber. 2004. Stock Assessment and management of *Tenualosa ilisha* in Bangladesh. Asian Fisheries Science 17: 50-59.

Dahle, G., M. Rahman and A.G. Eriksen. 1997. RAPD fingerprinting used for discriminating among three populations of Hilsa shad (*Tenualosa ilisha*). Fisheries Research 32: 263-269.

Gayanilo Jr., F.C., P. Sparre and D. Pauly. 2002. The FAO-ICLARM Stock Assessment tools (FiSAT) user's Guide. FAO Computerized Information Series (Fisheries), Rome, FAO

Gulland, J.A. 1971. The fish resources of the ocean. West Byfleet, Surrey Fishing News (Books) Ltd., for FAO, 255p. Revised edition of FAO Fisheries Technical Paper**:** 425p.

Haldar, G.C. and S.M. N. Amin. 2005. Population dynamics of male and female hilsa, *Tenualosa ilisha* of Bangladesh. Pakistan Journal of Biological Science 8(2): 307-313.

Haldar, G.C., M. Rahman and A.K.Y. Haroon. 1992. Hilsa, *Tenualosa ilisha* (Ham.) Fishery of the Feni River with reference to the impacts of the Flood Control Structure. Journal of Zoology 7: 51-56.

Haldar, G.C., M.A. Mazid, M.A. Rahman and S.M.Nurul Amin. 2001. The present status of Hilsha (*Tenualusa ilisha*) fishery in Bangladesh. In Stephen Blaber, David Brewer, David Milton and Chirista Baino (eds), Proceedings of the International Terubok Conference, Sarawak Development Institute (SDI), 93000 Kuching, Sarawak, Malaysia: 52-64.

Haroon, A.K.Y. 1998. Hilsa Shad: Fish for the teeming millions, new management alternatives needed for the hilsa young. Shad Journal 3: 7-10.

Hussain, M.G., M.G. Islam and J. P. Salini. 1998. Genetic structure of hilsa shad populations: Preliminary results using starch gel allozymes. In: M. A. Mazid and S. J. M. Blaber (eds), Hilsa Fisheries Research in Bangladesh, BFRI, Mymensingh, Bangladesh: 5-10.

Islam, M.S. 1998 Role of Hilsa in the Socio-economics of the fishing community and consumers. In: M. A. Mazid and S. J. M. Blaber (eds), Hilsa Fisheries Research in Bangladesh, BFRI, Mymensingh, Bangladesh.

Mazid, M.A. 1998. An overview of Hilsa fisheries research in Bangladesh. In: M. A. Mazid and S. J. M. Blaber (eds), Hilsa Fisheries Research in Bangladesh, BFRI, Mymensingh, Bangladesh.

Mazid, M.A. 2001. Present status, Development and Management. In: Stephen Blaber, David Brewer, David Milton and Chirista Baino (eds), Proceedings of the International Terubok Conference, Sarawak Development Institute (SDI), 93000 Kuching, Sarawak, Malaysia: 195-205.

Miah, M.S., M.A. Rahman, G.C. Haldar and M.A. Mazid. 2000. Some aspect of population dynamics of juvenile hilsa shad (*Tenualosa ilisha* Ham.) from the Meghna River, Bangladesh. Bangladesh Journal of Fisheries Research 4: 75-81.

Pauly, D. 1980. On the interrelationships between natural mortality growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. CIEM.39:175-192.

Pauly, D. and J.L. Munro. 1984. Once more, on the composition of growth in fish and invertebrates. Fishbyte 2: 21.

Rahman, M. and G. Naevdal. 2000. Population genetic studies of hilsa shad, Tenualosa ilisha (Hamilton), in Bangladesh waters: evidence for the existence of separate gene pools. Fisheries Management and Ecology, 2000, **7**, 401–411

Rahman, M.A., M.S. Miah, M.J. Rahman and G.C. Haldar. 1995. Jatka Juvenile hilsa, *Tenualosa ilisha* fishery in Bangladesh. Indian Journal Fisheries 42: 13-16.

Rahman, M.J., M.G. Mustafa and M.A. Rahman. 1998. Population dynamics and recruitment of Hilsa, *Tenualosa ilisha.* In: M. A. Mazid, S. J. M. Blaber (eds), Hilsa Fisheries Research in Bangladesh,. BFRI, Mymensingh, Bangladesh.

Rahman, M.A., S.M. N. Amin and G.C. Haldar. 1999. Some aspect of population dynamics of adult *Tenualosa ilisha* from Barisal coastal region of Bangladesh. Journal of Asiatic Society of Bangladesh, Science 25: 225-2333.

Rahman, M. A., S.M.Nurul Amin, G.C. Haldar and M.A. Mazid. 2000. Population dynamics of *Tenualosa ilisha* of Bangladesh water. Pakistan Journal of Biological Science 3 (4): 564-567.

Rahman, M.A. G.C. Haldar, D.A. Milton, M.A. Mazid and M.S. Miah. 2001. A study on the population dynamics of hilsa, *Tenualosa ilisha* (Hamilton-Buchanan) in Bangladesh. Indian Journal of Animal Science 71: 46-48.

Salini, J.P., D.A. Milton, M.J. Rahman and M.G. Hussain. 2004. Allozyme and morphological variation throughout the geographic range of the tropical shad, hilsa *Tenualosa ilisha.* Fisheries Research 66: 53–69.

Troadec, J. P. 1980. Utilization of resource survey results in stock assessment. In selected lectures from the CIDA/FAO/CECAF seminar on fishery resource evaluation. Casablanca, Morocco, 6-24 March 1978. Rome, FAO, Canada Funds-in-Trust, FAO/TF/INT 180 (c) Suppl.: 139-52.

*Received: 18 March 2006; Accepted: 28 June 2007*