



Effective Management of Hilsa Shad (*Tenualosa ilisha*): Prevailing Research Trends in Bangladesh

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Author's contribution

This work was carried out author MGM. Author MGM designed the study, performed the review and statistical analysis, wrote the protocol, write the first draft of the manuscript, managed the analysis of the study and managed the literature searches. Author read and approved the final manuscript.

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ABSTRACT

Aim: The purpose of this review is to support widely accepted knowledge based effective management of Hilsa shad populations through smart decisions.

Study Design: Literature review of the population dynamics based studies along with the relevant papers of Hilsa shad fishery management in Bangladesh. Thus, accurate estimations of population size, growth parameters, mortalities and exploitation rates are critical for success.

Place and Duration of Study: The literature review and other relevant documents are based in the coastal and riverine areas of Bangladesh during last three decades.

Methodology: The review mainly included research findings on the catch and population dynamics of Hilsa shad in the riverine and coastal habitats of Bangladesh. This review comprised of published results on asymptotic length (L_{∞}), growth co-efficient (K), Growth performance index (ϕ'), mortality rates (natural-M, fishing-F and total-Z), exploitation rates (E), gear selectivity (L_c), maximum sustainable yield (MSY), standing stock or steady state biomass (SSB), average weight/length and length-weight relationship parameters.

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Results: The asymptotic length, growth co-efficient and growth performance index were varied from 51.5 to 65.6cm, 0.51 to 0.99 and 3.14 to 3.55 respectively. The variation of growth range was appeared from 21.19 – 37.69, 33.66 – 51.69, 41.0 – 56.89, 45.32 – 59.09, 47.86 – 60.79 and 49.36 – 62.52 cm at the end of age 1, 2, 3, 4, 5 and 6 years respectively. Simultaneously, natural, fishing and total mortality were varied from 0.89 to 1.52, 0.45 to 3.45 and 1.68 to 4.9 respectively. The exploitation rates were varied between 0.27 and 0.70, and the length at first capture were differs to be 39.24 to 57.65% of the mean asymptotic length. The overall mean length and weight value equal to 34.0±2.67cm and 540±120gm respectively. While the majority of the research papers (90%) indicated, overfishing, the annual catch of the species shows an increasing trend of 10,038 tons per year ($R^2=0.81$) between financial year 1989-90 and 2018-19. The estimated MSY varied from 162396 to 283597, 283597 to 404798 and 404798 to 526000 tons from 60%, 30% and 10% studies respectively. The mean MSY value equal to 282174 ±100530 tons. Besides, three case studies showed deviations, inclusion of hypothesis based results and analytical gap. Thus, through the continual publication process the absolute unclear results maybe adjust or accepts in the national policy, including SDG-14s.

Conclusions: The study indicated that the importance of science excellence, precise assessment and accurate estimation of the status of the fish stocks is vital for sustainable management of a fishery. Thus, the technical investigations need experience to analyze, predict results and produce fisheries management related suggestions, which is highly correlated to national or regional resource management decision.

Keywords: Research trends; fishery management; population dynamics; growth co-efficient; exploitation rate.

1. INTRODUCTION

1.1 Bangladesh Fisheries

Fisheries play a critical in Bangladesh economy and it constitutes to 3.57% of GDP, and it is the second target export [1]. It provides full-time employment for more than 1.31 million fishers and 16.69 million part-time fishers or about 11% of the total population [2]. Demand for fish will continue to grow as annual population rise by 1.19% annually in Bangladesh (www.worldometers.info 2016). Conservation is the most significant government supported effort to protect the national resource [2].

The Hilsa shad is an important commercial fish species in the Bay of Bengal, Indian Ocean, Persian Gulf and Arabian Sea. Bangladesh, India and Myanmar have major fisheries in the northern region of the Bay of Bengal. The national fish of Bangladesh is Hilsa. Traditionally Hilsa shad had been seen as common property resource, which is mostly exploited by the artisanal fishery and a major source of earning for the poor fisher's community in the coastal region of Bangladesh [3]. The artisanal fisheries are critically important for diversity and food security, since almost 100% of the landings are directed to human consumption [4]. In recent years, people have become aware of the Hilsa fish and its dynamic nature.

1.2 Hilsa Fishery Management

Hilsa is a tropical species distributed wider areas of the Bay of Bengal region as well as in the inland river water of Bangladesh and South Asian/South-East Asian countries. Hilsa fishery provides around 12% of the total production of fisheries in Bangladesh and 28.47% of the production of the capture fisheries [1,5]. To ensure sustainable management a 22-day Hilsa fishing ban have been applied mostly in the month of October each year for successful spawning of Hilsa shad in Bangladesh. Simultaneously, Juvenile Hilsa (*Jatka*) fishing ban also applied for 6 months to save juvenile Hilsa. Every year, Bangladesh also observes juvenile Hilsa (*Jatka*) conservation week across the country aiming to mobilize people to conserve the juvenile Hilsa (*Jatka*). Apart from this, the Government of Bangladesh decided to ban a 65-day fishing from May 20 to July 23 in the EEZ of Bangladesh for successful boost to sea fish production including Hilsa shad. Bangladesh government also provides livelihoods support during ban seasons.

The Hilsa Fisheries Management Action Plan (HFMAP) have been undertaken to protect Juvenile Hilsa (*Jatka*) through the development of an implementation strategy and identification of responsible agencies and target communities within a specific management timeframe [6].

The Department of Fisheries (DoF), Bangladesh Fisheries Research Institute (BFRI) and Bangladesh Fisheries Development Corporation (BFDC) under the Ministry of Fisheries and Livestock along with other administrative agencies, particularly District Administration, Police, Navy, Coast Guard, River Police, Upazila Administration, Community Based Organizations (CBOs) & user communities performing an exclusive coordinated management program to protect Juvenile and brood Hilsa shad. Consequently, the Hilsa shad also sustaining well, and production increased from 0.193 million in 1989-90 to 0.532 million Mt in 2018-19 [5]. In 2003-04 the Hilsa conservation program started in Bangladesh. Catch trajectories of Hilsa showed annual-scale variability [5].

Fish population dynamics describe how a population changes over time as a function of growth, recruitment, mortality, immigration and emigration [7]. It is the basis for understanding fish populations and associated fisheries, and is the central component in stock assessment models to provide quantitative advice for fishery management [8].

Modern fisheries stock assessment models are evolving towards increasing complexity, with capabilities to assimilate a diverse suite of data and incorporate spatial structure and the influence of environmental factors [9,10]. Bangladesh's Hilsa shad fishery management related documents around the inland, coastal and marine waters were reviewed based on available information, including long-term trajectories of commercial catch and principal parameters of population dynamics.

1.2.1 Hilsa sanctuary

The Government of Bangladesh had declared six Hilsa sanctuaries in Bangladesh and these were located in i) the Meghna River at Chandpur, ii) the lower part of the Meghna River in Doulatkhan, Bhola, iii) the Tentulia River in Lalmohon, Bhola, iv) Andhearmanik River, Kalapara, Patuakhali, v) the lower part of the Padma (Padma confluence) in Shariatpur and vi) the Meghna River (from Hizla to Mehendiganj) in Barisal. As a result, of implementation of juvenile Hilsa (*Jatka*) conservation, protection, effective sanctuary management and reproduction activities, the production of Hilsa shad was 0.532 million metric tons in the fiscal year 2018-19 [5].

1.3 Historical Trends in Hilsa shad production

A combination of empirical data and field studies is needed to build robust, theoretical model that can provide science-based advice for sustainable management of Hilsa shad fishery. Besides, analytical tools and advanced knowledge to use the tools effectively is vital to predict management decision of the dynamic aquatic resource.

1.4 Specific Objectives

The specific objectives of this review are to investigate recent research-based information on Hilsa shad fishery management and does this convenient for decision-making organizations and scientific excellence, and where to improve for sustainable and effective management of the Hilsa shad fishery in this region.

The present review emphasizes the challenges to the fishery manager, biologist, and social sustainability of Hilsa shad fishery management systems: adequate scientific information, assessment accuracy, appropriate management tools, prediction strength or weakness and simulate outputs accurately.

Fisheries in Bangladesh are growing very fast and government initiated huge supports to continue this development for both in inland and marine fisheries. Department of Fisheries, Bangladesh also commenced the vital role to continue this development using sustainable management. In this situation, appropriate research is an important part to support the government agencies. Besides, fisheries research is vital, as it deals not only fishes, but also ecology, habitats, water availability, pollution, waterways, ecosystem, etc. Moreover, results need to be effective and simplified for understanding of managerial agencies and common people as a part of the research results dissemination process. Therefore, people involved with Hilsa shad based livelihoods, consumers, managers and policy makers should know how a science-based technical paper delivered the unique results of the fisheries management decision.

The review would add value for both scientists and managers, and how a science output produces the information for a vital national fish. Besides, scientists from recognized organizations produce science outputs that do

adequate for improvement of a sustainable managed fishery.

2. MATERIALS AND METHODS

2.1 Historical Trends in Hilsa Shad Production

Fisheries Resource Survey System (FRSS) of the Department of Fisheries, Bangladesh implemented fisheries data collection programme throughout the country. According to available catch and landing data from the Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh between 1989-90 and 2018-19 an analysis has been performed to estimate the trend during the last 30 years as well as to determine trends for each decade.

2.2 Research Papers Considered for This Study

In Bangladesh, Hilsa shad related population dynamics research initiatives were implemented in collaboration with the government agencies, mostly the Department of Fisheries, Bangladesh Fisheries Research Institute, Bangladesh Fisheries Development Corporation, public/private universities and research organizations through the course of several projects/researches. The present study were included 20 research articles during 1989-90 to 1918-19 (Table 1). These studies are mostly based on specialized software the “FAO-ICLARM Stock Assessment Tools (FiSAT)” developed by FAO and ICLARM – International Center for

Living Aquatic Resources Management (now WorldFish) for fisheries resources management. The FiSAT was converted to MS Windows, and referred to as FiSAT II. The following analysis conducted through different steps of FiSAT was used in this review (Fig.1):

Brief description of the analysis using FiSAT and other allied methods were as follows:

i) The von Bertalanffy growth equation was used by all reviewed papers, which expresses the length, L as a function of age of the fish, t, in the form of equation below [11]:

$$L_t = L_\infty(1 - \exp^{-k(t-t_0)}) \quad (1)$$

Where,

L_∞ is the asymptotic length or the average length of a very old fish,

K is a growth coefficient, or the rate at which L_∞ is approached (“stress factor” [12],

t_0 is the “age” the fish would have had length zero if they had always grown according to the equation (t_0 generally has a negative value).

t = age and L_t is the length at age t

The growth performance index “Munro’s phi prime (ϕ')” was estimated using equation below:

$$\phi' = \log K + 2 \log L_\infty \quad [13,14].$$

Where, K and L are von Bertalanffy growth parameters.

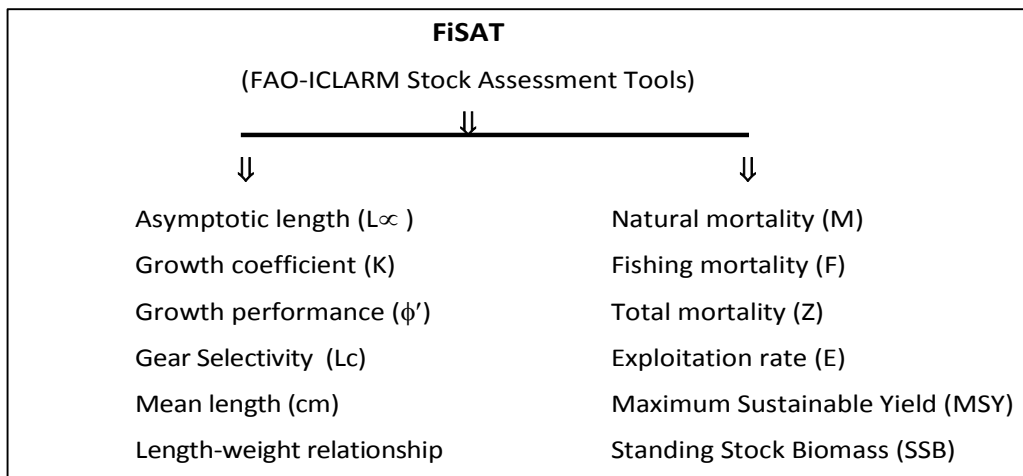


Fig. 1. FAO-ICLARM Assessment tools

ii) The ELEFAN-II estimates the Z from catch curve based on equation as:

$$Z = \frac{K(L_{\infty} - L_{\text{mean}})}{L_{\text{mean}} - L'} \quad (2)$$

Where, L_{mean} is the mean length of fish of length L' and longer, while L' is "some length for which all fish of that length and longer are under full exploitation". L' is the lower limit of the corresponding length interval [15].

iii) The parameter M has been estimated using the empirical relationship [16,17], i.e.:

$$\text{Log}_{10} M = -0.0066 - 0.279 \text{Log}_{10} L_{\infty} + 0.6543 \text{Log}_{10} K + 0.4634 \text{Log} T. \quad (3)$$

Or

$$\begin{aligned} \ln(M) = \\ -0.0152 - 0.279 \ln(L_{\infty}) + 0.6543 \ln(K) + \\ 0.4634 \ln T \end{aligned} \quad (4)$$

Where, L_{∞} is the expressed in centimetres, $K^{\text{year}^{-1}}$ and T ($^{\circ}\text{C}$) is the mean annual environmental temperature ($^{\circ}\text{C}$). These equations provide reasonable estimates of M for fish, and shrimp. The estimate of F was taken by subtraction of M from Z.

iv) The exploitation ratio E was computed from expression:

$$E = F/Z = F / (F+M)$$

The instantaneous total annual mortality rate (Z) was estimated using a length converted catch curve incorporating growth [18]. The natural mortality (M) was estimated using the empirical relationship [16]. The mean annual water temperature was set between 27 and 28 $^{\circ}\text{C}$.

The exploitation ratio, E was estimated as: $E = F/Z = F/(F+M)$. Length at first capture (L_c or L_{50}) was estimated following the method [17].

v) Longevity or life span is the approximate maximum age (t_{max}) that fish of a given population would reach. It was calculated as the age at 95% of L_{∞} using the parameters of the von Bertalanffy growth function, viz: $t_{\text{max}} = t_0 + 3/K$ while t_0 is the "age of the fish at zero length" [19]. Besides, longevity also counted from available growth parameters data and graph directly for some papers.

vi) Mean length is the approximate average size distribution in the catches and it was calculated

from asymptotic length (L_{∞}), growth-co-efficient (K), total mortality (Z) and gear selectivity (L_c) parameters of the 20 reviewed papers, viz:

$$\text{Mean length} = L_{\infty} - [(Z/K)/(Z/K + 1)] [L_{\infty} - L_c] \quad [20].$$

vii) The length-weight relationship between length (L , cm) and weight (W , g) was estimated using the equation $W = aL^b$, where a is a coefficient related to body form, and b is an exponent [21].

Available L_c values used in this study. However, following the recent publications, L_c value was used 27 cm to estimate the mean length where L_c values are not available [22,23]. Calculated mean length was compared with the mean length derived from available original length-frequency data or graph for some studies [22,23,24,25].

The review mainly included growth parameters, natural mortality (M), fishing mortality (F), total mortality (Z), Length at first capture (L_c), Exploitation rate (E), Maximum Sustainable Yield (MSY) & Standing Stock Biomass (SSB) for Hilsa (*Tenualosa ilisha*) species during 1987 to 2019 based on 20 primary research studies in Bangladesh (Table 2).

A set of inclusion criteria was developed before that start of the review to guide in the selection of published literature or available studies. Besides, the review mainly evaluated 20 key papers based on following criteria:

- i. Papers must have population dynamics studies of Hilsa shad,
- ii. Papers must be population dynamics based Hilsa shad fishery management in Bangladesh,
- iii. Papers must have length-frequency based data analysis through ELEFAN/FISAT software,
- iv. Papers should specifically note Hilsa shad population dynamic process,
- v. Papers must have growth parameters, mortality rates (natural, fishing and total mortality) of Hilsa shad,
- vi. Paper must have an estimate of exploitation rate of Hilsa shad,
- vii. Papers must have length-frequency based stock assessment or MSY (Maximum Sustainable Yield) or SSB (Standing Stock Biomass) estimations of Hilsa shad,
- viii. Papers must have review of length-frequency analysis of Hilsa shad.

Table 1. List of reviewed papers

SI no.	Title	References
1	Research-1	Van der Knaap M., Sivasubramaniam, K., Azad, S.A., Islam, M.S., Hossain, M. and Huq, Q.M. (1987). Hilsa fishery in Bangladesh in 1985–1986. In Hilsa investigations in Bangladesh. BoBP/Rep/36. Colombo, Sri Lanka: BoBP 64–80.
2	Research-2	Van der Knaap M., Sivasubramaniam, K., Azad, S.A., Islam, M.S., Hossain, M. and Huq, Q.M. (1987). Hilsa fishery in Bangladesh in 1985–1986. In Hilsa investigations in Bangladesh. BoBP/Rep/36. Colombo, Sri Lanka: BoBP 64–80.
3	Research-3	[BFRI/RS] Bangladesh Fisheries Research Institute, Riverine Station. 1994. Hilsa fisheries development and management. Annual report BFRI/RS 94.
4	Research-4	Miah, M.S., Haldar, G.C. and Rahman, M.A. (1997). Estimation of growth and mortality parameters of Hilsa <i>Tenualosa ilisha</i> (Ham.) population in the Meghna River of Bangladesh, Indian Journal of Fisheries 44(2):133-139. https://www.researchgate.net/publication/266574982_Estimation_of_growth_and_mortality_parameters_of_hilsa_Tenualosa_ilisha_HAM_population_in_the_Meghna_river_of_Bangladesh
5	Research-5	Rahman M.A. and Haldar G.C. (1998). Assessment of current Hilsa resources in Bangladesh. In Mazid MA and Blaber SJM. Hilsa fisheries research in Bangladesh. Proceedings of a BFRI/ACIAR/CSIRO workshop, Dhaka, Bangladesh, 3–4 March 1998. 20–27.
6	Research-6	Rahman M.A., Amin S.M.N. and Haldar G.C. (1999). Some aspects of population dynamics of adult <i>Tenualosa ilisha</i> from Barisal coastal region of Bangladesh. Journal of the Asiatic Society of Bangladesh, Science 25:225–233.
7	Research-7	Rahman, M.A., Amin, S.M.N., Haldar, G.C. and Mazid, M.A. (2000). Population dynamics of <i>Tenualosa ilisha</i> of Bangladesh waters. Pakistan Journal of Biological Science 3:564-567. https://scialert.net/fulltext/?doi=pjbs.2000.564.567
8	Research-8	Rahman, M.A., Haldar, G.C., Milton, D.A., Mazid, M.A. and Miah, M.S. (2001). A study on the population dynamics of hilsa, <i>Tenualosa ilisha</i> (Hamilton-Buchanan) in Bangladesh. <i>Indian Journal of Animal Sciences</i> 71(1):71-73. https://eurekamag.com/research/003/348/003348844.php
9	Research-9	Ahmed, S.M., Mustafa, M.G., Rahman, B.S., Yeasin, A. and Shahadad, A. (2002). Some aspects of population dynamics of hilsa shad <i>Tenualosa ilisha</i> in the River Meghna of Bangladesh. Fisheries Science Vol. 68(sup1):318-321. https://www.jstage.jst.go.jp/article/fishsci1994/68/sup1/68_sup1_318/article
10	Research-10	Amin, S. M. N., Rahman, M.A., Haldar, G.C., Mazid, M.A. and Milton, D.A. (2002). Population dynamics and stock assessment of Hilsa shad, <i>Tenualosa ilisha</i> in Bangladesh. Asian Fisheries Science 15:123–128. https://www.asianfisheriessociety.org/publication/downloadfile.php?id=647&file=Y0dSbUx6QTRNemc0T1Rjd01ERXpOVFU1TVRBNU5UVXVjR1Jt
11	Research-11	Haldar G.C, Islam M.R. and Akanda M.S.I. (2004). Implementation strategies of Hilsa fisheries conservation and management. Fourth Fisheries Project. Dhaka, Bangladesh: DoF. 39.
12	Research-12	Haldar, G. C., and S. M. N. Amin. (2005). Population dynamics of male and female Hilsa, <i>Tenualosa ilisha</i> of Bangladesh. Pakistan Journal of Biological Sciences 8:307–313. https://scialert.net/abstract/?doi=pjbs.2005.307.313
13	Research-13	Haldar, G. C., and S. M. N. Amin. 2005. Population dynamics of male and female Hilsa, <i>Tenualosa ilisha</i> of Bangladesh.

SI no.	Title	References
		Pakistan Journal of Biological Sciences 8:307–313. https://scialert.net/abstract/?doi=pjbs.2005.307.313
14	Research-14	Ahmed, M.S., Sharif, A.S.M. and Latifa, G.A. 2008. Age Growth and Mortality of Hilsha Shad, <i>Tenualosa ilisha</i> in the River Meghna, Bangladesh. Asian Journal of Biological Sciences 1(2): 69-76. https://scialert.net/abstract/?doi=ajbs.2008.69.76
15	Research-15	Amin, S.M.N., Rahman, M.A., Haldar, G.C., Mazid, M.A. and Milton, D.A. 2008. Catch Per Unit Effort, Exploitation Level and Production of Hilsa Shad in Bangladesh Waters. Asian Fisheries Science 21 (2008): 175-187. https://www.asianfisheriessociety.org/publication/abstract.php?id=262
16	Research-16	Rahman, M.J. and Cowx, I. G. 2008. Population dynamics of Hilsa Shad <i>Tenualosa ilisha</i> , Clupeidae) in Bangladesh Waters. Asian Fisheries Science 21(2008):85-100. https://www.asianfisheriessociety.org/publication/abstract.php?id=251
17	Research-17	Rahman, M.J. and Cowx, I. G. 2008. Population dynamics of Hilsa Shad <i>Tenualosa ilisha</i> , Clupeidae) in Bangladesh Waters. Asian Fisheries Science 21(2008):85-100. https://www.asianfisheriessociety.org/publication/abstract.php?id=251
18	Research-18	Rahman MA, Alam MA, Flura T, Ahmed SJ, Hasan KK, Ahmed U and Zaher M. 2012. Hilsa fisheries research manual Extension manual No. 42, 2nd ed. Mymensingh, Bangladesh: BFRI. 32.
19	Research-19	Rahman, M.J., Wahab, M. A., Amin, S.M.N., Nahiduzzaman, M. and Nicholas, R. 2018. Catch Trend and Stock Assessment of Hilsa <i>Tenualosa ilisha</i> Usng Image Measured Length-Frequency Data. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 10:386-401. https://www.worldfishcenter.org/content/catch-trend-and-stock-assessment-hilsa-tenualosa-ilisha-using-digital-image-measured-length
20	Research-20	Sarker, M.N., Naser, M.N., Sharif, M.U, Das, N.N. and Humayun, M. 2019. On the management of single fish species of Hilsa shad (<i>Tenualosa ilisha</i>) resources of Bangladesh. Bangladesh J. Zool. 47(1): 173-183. https://www.banglajol.info/index.php/BJZ/article/view/42055/31338

Table 2. Growth parameters [Asymptotic length (L_{∞}), growth co-efficient (K), growth performance index (ϕ')], maximum age (longevity), natural mortality (M), fishing mortality (F), total mortality (Z), Length at first capture (Lc), Exploitation rate (E), Maximum Sustainable Yield (MSY) & Standing Stock Biomass (SSB) for Hilsa species during 1987 to 2019 based on 20 research studies in Bangladesh

Sl. no.	L_{∞} (cm)	K	ϕ'	Age	M	F	Z	Lc	E	MSY (tons)	Short Reference
Res-1	58	0.83	3.45	3.61	1.27	0.62	1.89	NA	0.33	NA	Van der Knaap et al 1987
Res-2	57	0.78	3.40	3.85	1.23	0.45	1.68	NA	0.27	NA	Van der Knaap et al 1987
Res-3	61.1	0.71	3.44	4.22	1.16	1.25	2.41	NA	0.52	NA	BFRI/RS 1994
Res-4	57.0	0.66	3.33	4.54	0.89	1.14	2.03	NA	0.56	NA	Miah et al., 1997
Res-5	58.3	0.74	3.40	4.05	1.18	1.43	2.61	NA	0.55	NA	Rahman et al 1998
Res-6	60.9	0.66	3.38	4.55	1.12	2.16	3.28	NA	0.67	NA	Rahman et al 1999
Res-7	61.5	0.83	3.46	3.70	1.28	2.01	3.29	NA	0.61	NA	Rahman et al. 2000
Res-8	59.97	0.99	3.55	3.03	1.41	1.77	3.18	NA	0.56	NA	Rahman et al 2001
Res-9	53.0	0.66	3.27	4.54	1.16	1.24	2.40	29.8	0.52	NA	Ahmed et al. 2002
Res-10	60.0	0.82	3.47	3.65	1.28	2.49	3.77	22.8	0.66	162,396	Amin et al. 2002
Res-11	62.5	0.72	3.45	4.16	1.17	1.62	2.79	NA	0.58	NA	Halder et al 2004
Res-12	51.5	0.53	3.14	5.66	1.01	2.07	3.08	NA	0.67	235,130	*Halder & Amin 2005
Res-13	65.6	0.51	3.34	5.88	0.92	1.95	2.87	NA	0.68	235,130	*Halder & Amin 2005
Res-14	52	0.71	3.28	4.22	1.22	1.39	2.61	NA	0.53	NA	Ahmed et al., 2008
Res-15	54.6	0.67	3.30	4.47	1.15	1.92	3.07		0.62	210,125	Amin et al 2008
Res-16	58.8	0.82	3.45	4.60	1.0	1.38	2.38	32.2	0.58	NA	**Rahman & Cowx, 2008
Res-17	61.0	0.80	3.47	4.00	0.98	1.32	2.30	33.5	0.57	NA	**Rahman & Cowx, 2008
Res-18	53	0.83	3.37	3.61	1.36	1.87	3.23	NA	0.58	NA	Rahman et al 2012
Res-19	58.7	0.90	3.50	6.25	1.36	2.83	4.19	27	0.67	526,000	Rahman M. J et al 2018
Res-20	57.7	0.90	3.47	3.33	1.45	3.45	4.90	27	0.7	NA	M.N. Sarker et al 2019.

NA= Not available, *Single paper: parameters estimated separately for male and female [12,13], and ** river & marine [16,17]

The study also assesses the Hilsa shad fishery management related lessons learned publications, reports and documents.

The study generates understanding of i) Maximum age and annual growth of Hilsa shad from different studies, ii) Variation of mortality and Exploitation rates, iii) Life span or maximum age, iv) Deviation of mean length and v) Length-weight relationship.

The Present study also reviews the relevant published papers on i) maximum sustainable yield (MSY) and ii) standing stock or steady state biomass (SSB).

Besides, four reviewed papers (Res-10, Res-12, Res-15 and Res-19) estimated MSY based on [26] and [27]. The MSY of Hilsa shad also estimated based on data in 2005-06 [28]. BOBLME project also estimated MSY of Hilsa fish in 2013 based on data in 2008-09 [29]. The World Bank reported an estimated MSY of Hilsa shad in Bangladesh in 2009 based on carrying capacity. Besides, MSY of Hilsa shad estimated based on catch and effort data between 2001 and 2017 using CEDA, ASPIC, Fox and Schaefer model [30].

Moreover, four reviewed papers (Res-10, Res-12, Res-15 and Res-19) estimated standing stock (Bt) or steady state biomass (SSB) using Length-structured virtual population analysis (VPA) [31]. VPA are methods which allow the reconstruction of the population from total catch data by age or size (here length). Besides, BOBLME project also estimated Biomass of Hilsa shad in 2013 based on data in 2008-09 and used surplus production model.

The study also undertook a desk-based review, and analysis of the available secondary information, with a particular focus on the recent information published by different studies on Hilsa shad fishery management.

3. RESULTS AND DISCUSSION

3.1 Historical Trends in Hilsa Shad Production

National statistics suggest considerable growth of Hilsa shad production over the past 30 year and according to available catch data from 1989-90 to 2018-19, the Hilsa shad productions have ranged between 193,308 and 532,795 tons with annual rising trend of 10,038 tons ($R^2=0.81$) (Fig.

2). However, from 1989-90 to 1998-99 annual rising trend shows only 1285 tons ($R^2=0.09$) and from 1999-2000 and 2008-09 annual rising trend shows 10,205 tons ($R^2=0.78$). In the recent past years Bangladesh implemented a number of Hilsa shad management interventions, and from 2009-10 and 2018-19 annual rising trend shows 24,822 tons ($R^2=0.89$). Conversely, in the financial year during 2016-17 the Hilsa shad production shows considerably higher (101,466 tons) than previous years that need to be perceived prudently, and which ecological zones as well as seasons and management performance indicators supported to achieve the highest production. Besides, also need to review any variances between actual value and reporting the value of the Hilsa shad production in the financial year during 2016-17.

3.2 Growth Parameters

Asymptotic length (L_∞) is the length that the fish would reach if they were to grow indefinitely. The maximum size of an organism is a strong predictor for many life history parameters [32].

The present review revealed that the asymptotic length (L_∞) widely varies between 51.5 and 65.6 cm. Besides, the range of asymptotic length showed 51.5 to 56.3 cm from 25% studies, 56.3 to 61.1 cm from 60% studies and 61.1 to 65.9 cm from 15% studies respectively (Fig. 3). The mean asymptotic length (L_∞) equal to 58.10 ± 3.75 cm, which represents a sensible parameter and correspond with >70% studies.

Growth coefficient (K) is a parameter of the von Bertalanffy growth function at which asymptotic length is approached. Studies show that the growth co-efficient (K) values vary between 0.51 and 0.99. The range of K values showed 0.51 to 0.63 from 10% studies, 0.63 to 0.75 from 40% studies, 0.75 to 0.87 from 35% studies and 0.87 to 0.99 from 15% studies respectively (Fig. 3). The mean growth coefficient (K) values equal to $0.75 \pm 0.119 \text{ year}^{-1}$, which represents somehow a workable parameters and correspond with 80% studies. However, the K value is highly related to longevity (year) of species and based on the mean K value the longevity of Hilsa shad represents <4.0 years only. Besides, 15% of studies corresponds with K values between 0.87 and 0.99 which represents longevity of species <3.5 years. Therefore, further investigation is needed to confirm the appropriateness of K value of the Hilsa shad for sustainable management.

Growth performance index (ϕ') vary between 3.14 and 3.55. The range of ϕ' values showed 3.14 to 3.24 from 5% studies, 3.24 to 3.34 from 25% studies, 3.34 to 3.44 from 25% studies and 3.44 to 3.55 from 45% studies respectively. The mean growth performance (ϕ') equal to 3.40. The growth performance index should be normally distributed when applied to a large number of populations belonging to closely related taxa [33]. However, ϕ' values proposed by various studies for a single species show

unusual distribution. Therefore, recognize the best index of overall growth performance of Hilsa shad is very challenging to define.

3.3 Life Span or Age at 95% of L_{max}

Determination of maximum age or longevity of a commercial species is vital for sustainable management of the fishery. The Maximum age (t_{max}) have been calculated at 95% of asymptotic length (L_{∞}) [19]. The growth range of Hilsa shad

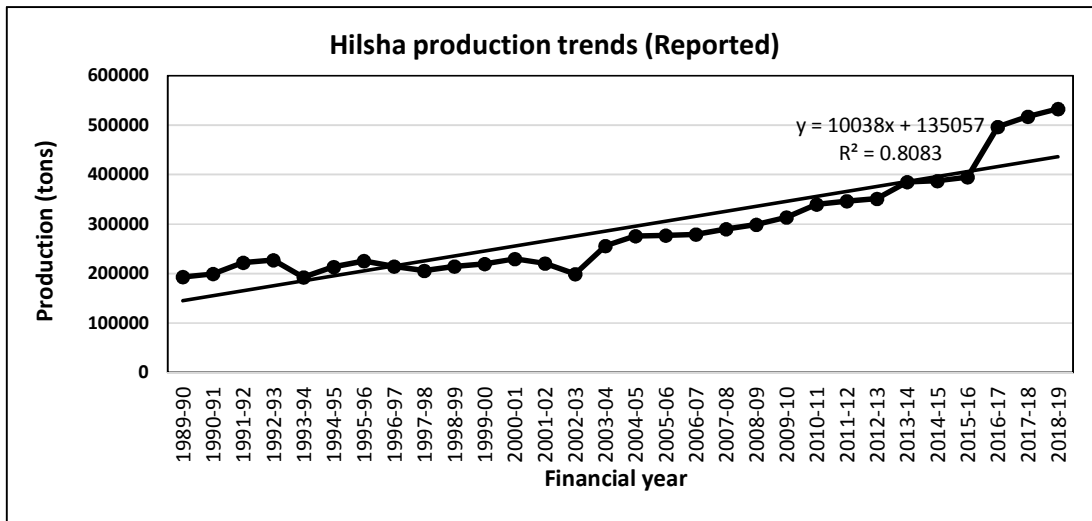


Fig. 2. Historical trends in total Hilsa shad production over a 30-year period, in Bangladesh (Source: Department of Fisheries, Bangladesh)

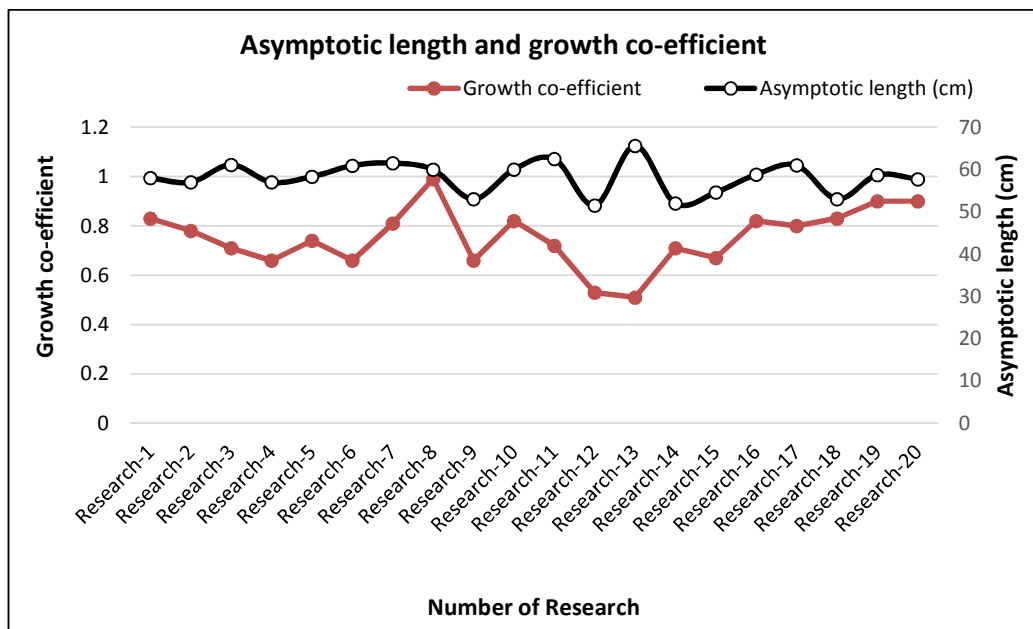


Fig. 3. The asymptotic length and growth co-efficient of Hilsa shad based on 20 key studies

was appeared 21.19 – 37.69cm, 33.66 – 51.69cm, 41.0 – 56.89cm, 45.32 – 59.09cm, 47.86 – 60.79cm and 49.36 – 62.52 cm at the end of age 1, 2, 3, 4, 5 and 6 years respectively (Fig. 4). Which reveals a significant deviation of growth rates proposed by different studies from year-1 to year-6. The mean growth equal to 30.70, 45.02, 51.80, 55.04, 56.62 and 57.40 cm at the end of age 1, 2, 3, 4, 5 and 6 years respectively. However, based on the growth increment formulation in otoliths of Hilsa shad in Bangladesh waters the growth was found 19.2, 27.5, 34.7, 40.8, 45.8, 49.7 and 52.5 cm at the end of 1, 2, 3, 4, 5, 6 and 7 years respectively [34]. Which reveals a significant deviation of growth rates proposed by different studies throughout the life span of Hilsa shad.

Range of annual growth range at the end of 1st year revealed 21.19 to 25.31, 25.31 to 29.44, 29.44 to 33.56 and 33.56 to 37.69 cm from 5%, 30%, 35% and 30% studies respectively, and overall deviation equal to 16.5cm. Simultaneously, at the end of 2nd, 3rd, 4th, 5th and 6th year significant growth deviation were appeared 18.03, 15.89, 13.77, 12.93 and 13.16 cm respectively. Fig. 5 presents details range of annual growth deviation from year-1 to year-5.

Based on Asymptotic length (L_{∞}) and growth coefficient (K) of Hilsa shad from different studies maximum longevity also considerably varies from 3.0 to 8.5 years. Besides, longevity (years) varies from 3.03-4.40, 4.40-5.78, 5.78-7.16 and 7.16 to 8.54 years from 60%, 25%, 10% and 5% studies respectively (Fig. 6).

Based on these wide variations of growth parameters and longevity, a management gap should occur to design the Hilsa Fishery Management Action Plan (HFMAP) for sustainable management. Besides, it is very challenging to use these huge numbers of diversified results due to significant variation of all important management parameters. Besides, the question arises why this huge deviation in growth co-efficient? This might be happening to other fish species also. Hence, scientific audience and decision makers have to be certain about effective and knowledge based publications.

3.3.1 Variation of growth curve (Case study-1)

Growth co-efficient used in analytical stock assessment to model the average changes in fish size with age. In length-based approaches, growth rates are required to partition the length composition into ages to estimate mortality rates [35]. Growth rate depends on growth co-efficient (K) and according to the von Bertalanfy formula the lower K value will act slower growth rate than the higher K value with the adjacent value of asymptotic length (L_{∞}). However, some studies presented slower growth curve with higher K value. Fig. 7a shows Hilsa shad spawning starts in May and up to end of April next year (one year), total length gained 34.6cm (approx.) where K value and asymptotic length were 0.83 and 61.57 cm respectively. Besides, the Fig. 7b shows spawning starts in Oct and up to end of Sept next year (one year), total length gained

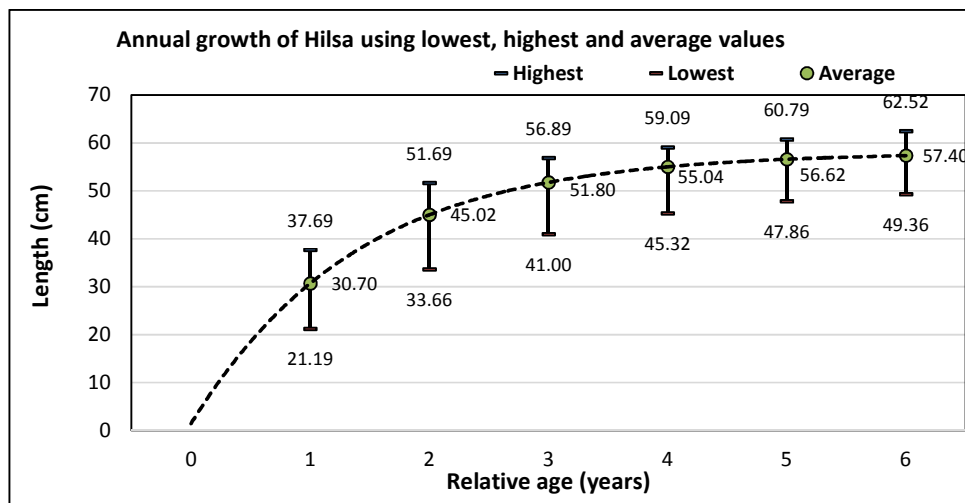


Fig. 4. The growth curve of Hilsa shad using average values along with lowest and highest length values in each year based on 20 key studies

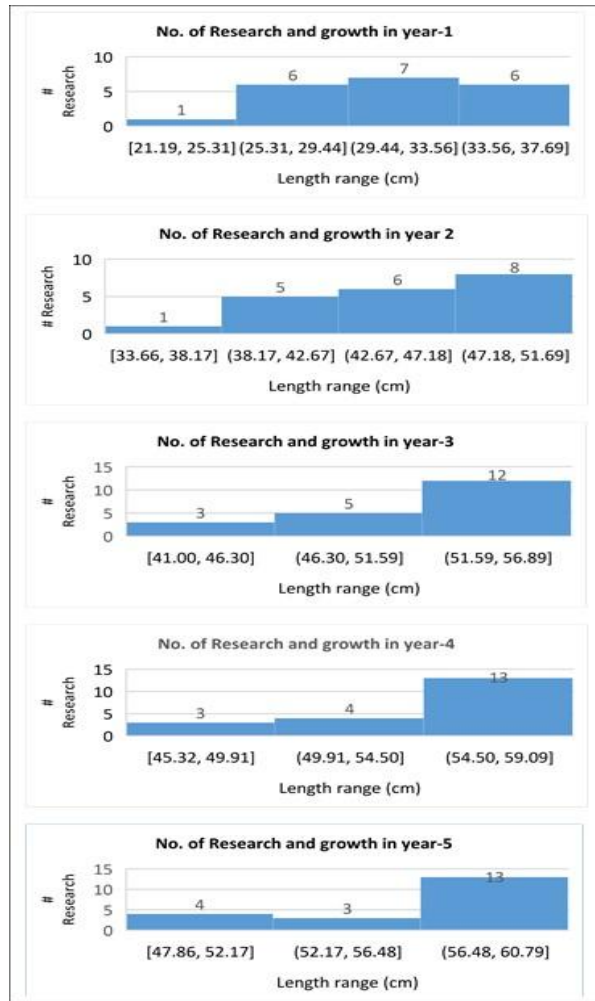


Fig. 5. Range of annual growth of Hilisa from year 1 to 5 using estimated values from 20 key studies

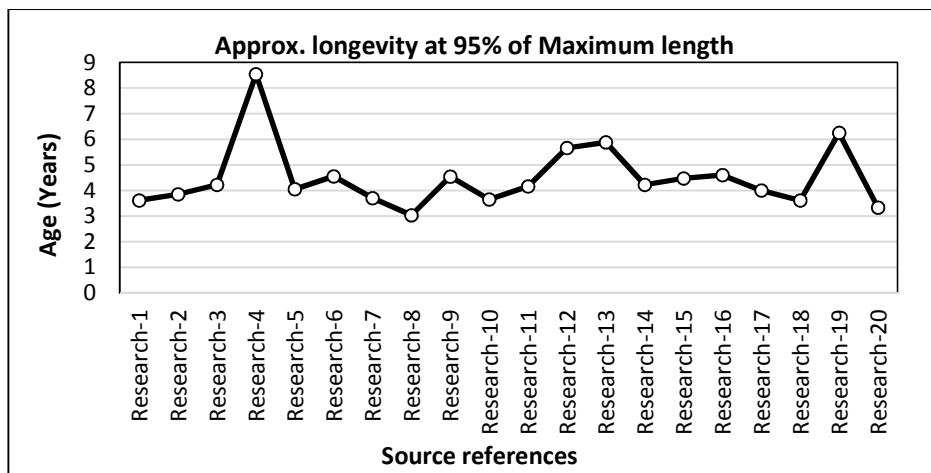


Fig. 6. Approximate maximum longevity - year (t_{max}) of Hilisa shad based on 20 key studies

only 25cm (approx.) where K value and asymptotic length (L_{∞}) were 0.90 and 58.7 cm respectively. However, according to von Bertalanffy formula, Fig. 7a provided approx. particular growth curve and length value. Besides, Fig. 7b provided elusive growth curve and length value (e.g., using data in equation (1) i.e., $L_t = 58.7 (1 - \exp^{-0.9(1-0.003)t})$), hence the length after one year, $L_t = 34.77$ cm).

Concurrently, longevity or age calculation also showed extensive variation between two analysis, and the Fig. 7a reflect maximum age 3.7 years (four lines represent age) and Fig. 7b reflect maximum age 6.25 years (six lines represent age). This might be an analysis inaccuracy to fit with the expected longevity or age or K value in the growth curve. In fact, according to von Bertalanffy formula the Fig. 7b represented K value ± 0.55 instead of 0.9.

Besides, this variation of K value will affect other management indicators (Z, SSB, MSY, maximum age, recruitment period, etc.) and produce higher Z, SSB and MSY values (e.g., refer to Fig. 7b and, calculation with the indicated K value (0.55) the Z value equal to 2.56 and MSY stands for 321419 Mt only and, with the present K value (0.9) the Z value equal to 4.19 and MSY stands for 526000 Mt.). Moreover, variation of key spawning months also created concern for the selection of effective ban periods of the Hilsa shad fishery. The variances also exists in other studies where male and female showed same spawning month, but the combined-sex analysis showed different spawning month in the same paper. Similarly, river and marine based analysis showed different spawning month. Besides, spawning month almost exists round the year (e.g., Apr, May, June, Sept, Oct, Nov and Dec).

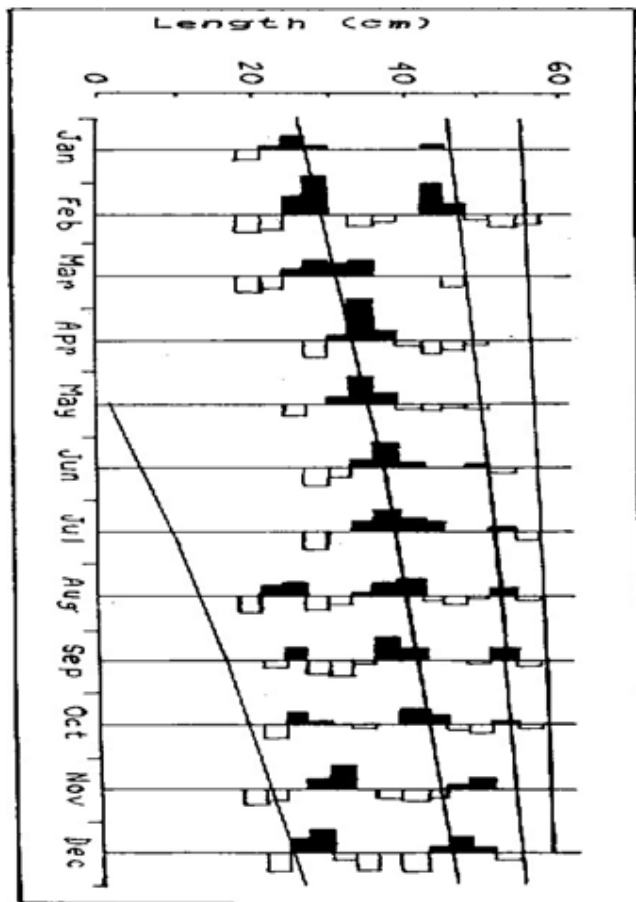


Fig. 7a. The von Bertalanffy growth curves superimposed on the length-frequency distribution of Hilsa shad ($L_{\infty} = 61.57$ cm TL, $K = 0.83 \text{ year}^{-1}$; the four lines represents 3.7 years & after one year total length shows 34.6 cm when $K=0.83$) (Source: Research-7)

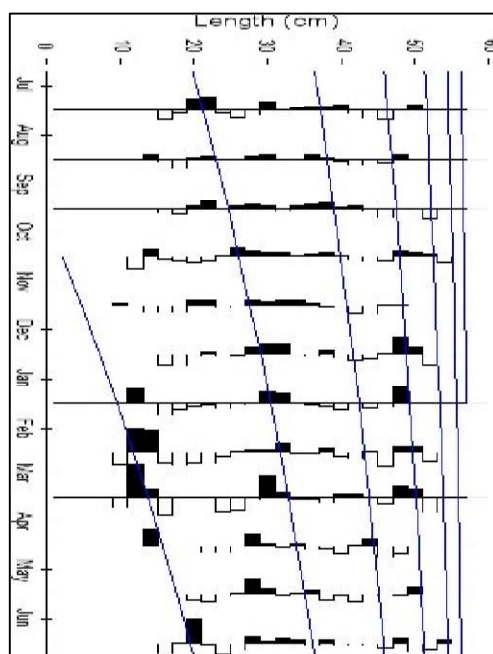


Fig. 7b. The von Bertalanffy growth curves superimposed on the length-frequency distribution of Hilsa shad ($L_{\infty} = 58.7$ cm TL, $K = 0.90$ year⁻¹, the seven lines represent 6.25 years & after one year total length shows 25.0 cm (approx.) when $K=0.90$) (Source: Research- 19)

Generally, Hilsa shad fishers' have raised concern regarding fishing ban period during spawning or breeding season. Thus, analytical limitations and understanding of fish population dynamics, the fishery resources will be critical to safeguarding the sustainable development of the sector and assessing the variability of vital management parameters.

3.4 Mortality Parameters

3.4.1 Natural mortality

The natural mortality rate M is the instantaneous exponential rate at which fish in the population die from natural causes. The natural mortality has varied from 0.89 to 1.52 of the Hilsa shad, which appeared a sensible range of variation. The mean natural mortality equal to 1.17 ± 0.159 (Fig. 8). Natural mortality varies between 0.89–1.07, 1.07–1.26 and 1.26–1.45 from 25%, 40%, and 35% studies respectively. Natural mortality with minor rising trend of 0.0035 ($R^2=0.017$) were found from this review.

A total of 15 predatory fishes preyed on Hilsa, of which tuna, mackerel, shark, Indian threadfin, red snapper and four finger threadfin are dominant predators of adult Hilsa in the Bay of Bengal,

while freshwater shark, giant catfish, river catfish, humped feather back, stripped snakehead and giant snakehead are the main predators of juvenile Hilsa in the Padma-Meghna river systems of Bangladesh [36]. This predation is the part of natural mortalities. However, most of the predators belong to freshwater species are under Endangered and Vulnerable categories and few species are in Least Concern categories [37]. Besides, foremost predators belong to marine species are very low abundance in the commercial catches, and small tuna (skipjack) and mackerel are the abundant species for predation in marine system [38]. Hence, natural mortality due to predation in both freshwater and marine systems are lesser, and this may reflects in the analysis of natural mortality.

3.4.2 Fishing mortality

Fishing mortality is a technical term, which refers to the proportion of the fish available being removed by fishing in a small unit of time. Fishing mortality can be translated into a yearly exploitation rate expressed as a percentage, using a mathematical formula. Fishing mortality has varied from 0.45 to 3.45, which appeared a wide range of variation. The mean fishing mortality equal to 1.72 ± 0.707 . Fishing mortality

varies between 0.45 – 1.2, 1.2 – 1.95, 1.95 – 2.7 and 2.7 – 3.45 from 15%, 55%, 20% and 10% studies respectively (Fig. 8). Fishing mortality with the rising trend of 0.075 ($R^2=0.402$) were found from this review.

controls are less important and overfishing is unlikely to occur [39]. However, where the reverse is true, careful control of the level of effort is required. The present review showed that fishing mortality (F) exceeds twice the natural mortality (M) from 20% studies. Besides, 70% study reveals careful controls of the effort are required.

Besides, fishing mortality (F) should not exceed twice the natural mortality (M) where effort

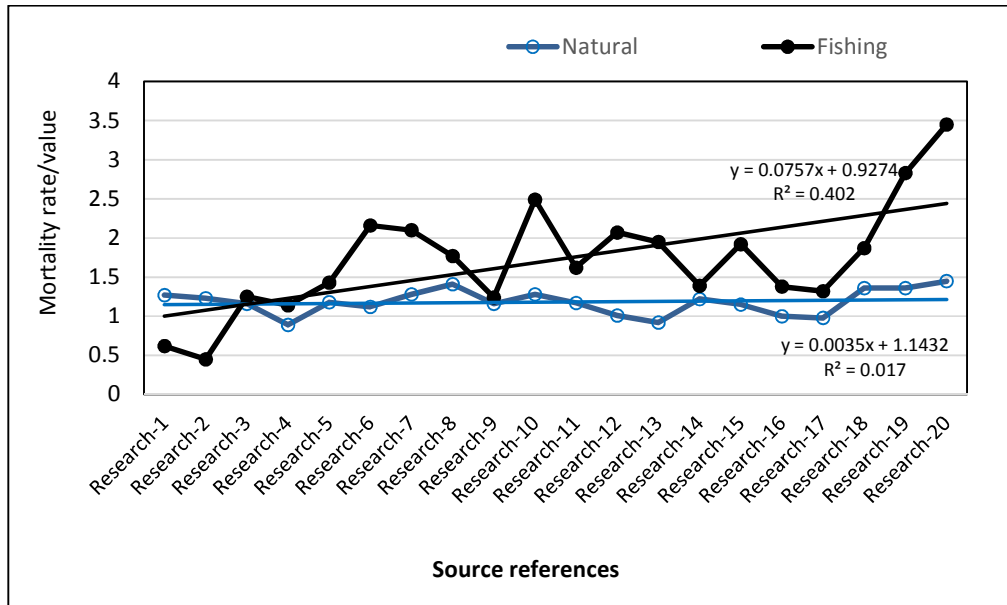


Fig. 8. Natural & Fishing mortality based on 20 key studies

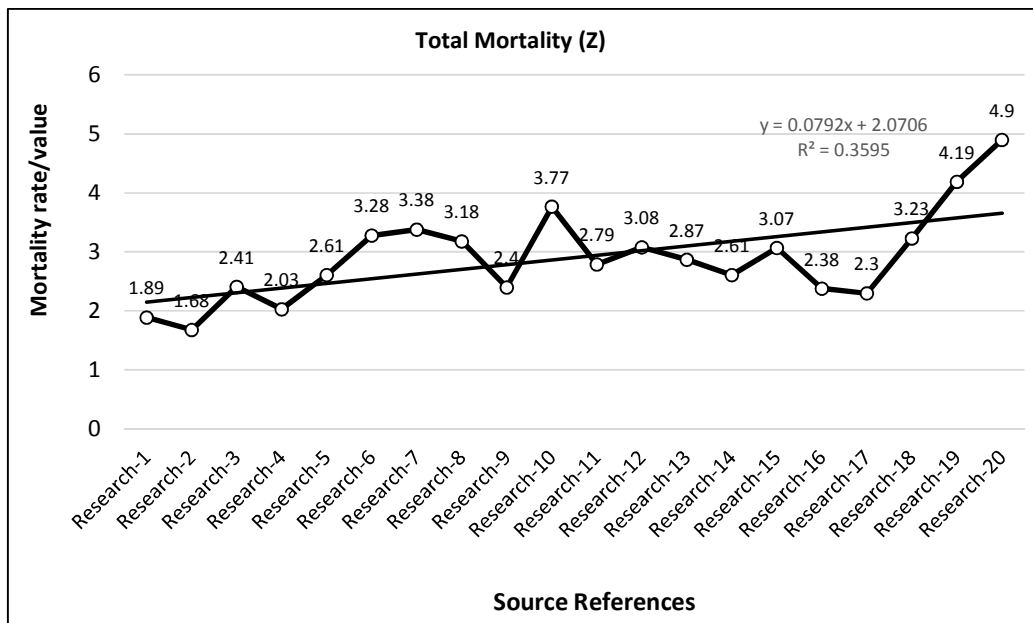


Fig. 9. Total mortality based on 20 key studies

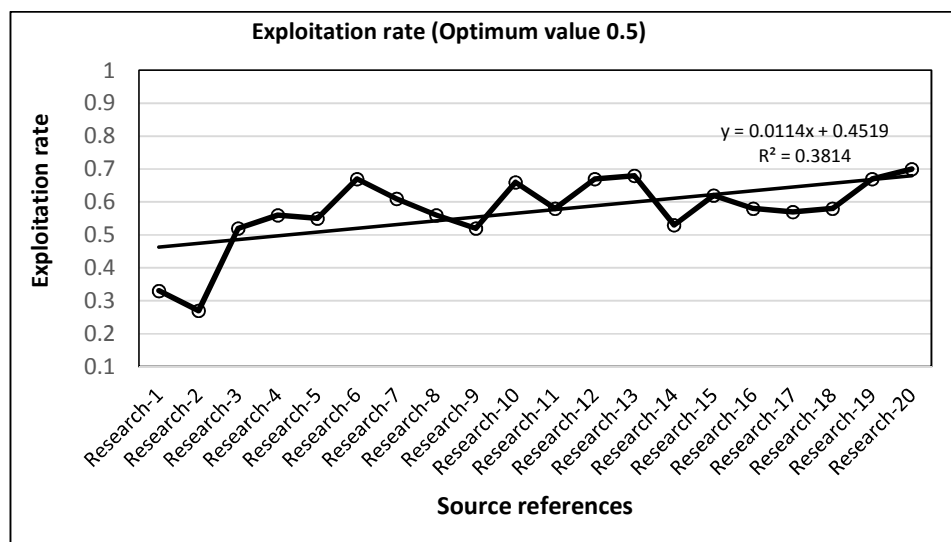


Fig. 10. Exploitation rates of Hilsa shad from different studies in Bangladesh

3.4.3 Total mortality

The total mortality range of the Hilsa shad from different studies were varied from 1.68 to 4.9, which appeared a wide range of variation. The mean total mortality equal to 2.85 ± 0.792 (Fig. 9). Total mortality is an important management parameter to determine the exploitation rate and maximum sustainable yield. Total mortality varies from 1.68 – 2.48, 2.48 – 3.29, 3.29 – 4.09 and 4.09 – 4.9 from 35%, 45%, 10% and 10% studies respectively. Total mortality with the rising trend of 0.079 ($R^2=0.359$) were found from this review.

3.5 Exploitation Rate

Exploitation rate is the function of an age class that is caught during the life span of a population exposed to fishing pressure. Thus the number caught versus the total number of individuals dying due to fishing and other reasons [40]. In an optimal exploited stock, fishing mortality should be about equal to natural mortality, resulting in a fixed $E\text{-optimum}=0.5$ [41]. The variation in exploitation rate was observed among different studies, and the rate varies between 0.27 and 0.7 and, the length at first capture were differs to be 39.24 to 57.65% of mean asymptotic length (Fig. 10). The mean exploitation rate equal to 0.57. The exploitation rates varies from 0.27 – 0.48, 0.48 – 0.59 and 0.59 – 0.7 from 10%, 50%, and 40% studies respectively. Overall rising trend of 0.0114 ($R^2=0.3814$) were found from these studies.

Besides, the 10% studies reveals the stocks are under exploitation and 90% studies reveals the stocks are overexploitation. Thus, there is a need to quantify the exploitation rate of Hilsa shad fishery and define management practices that allow for the conservation and sustainable management of the exploited stocks.

Changed of exploitation patterns to achieve fisheries and conservation objectives simultaneously is a common phenomenon. Balanced harvesting, where species or individuals are exploited in accordance with their productivity has been proposed as a way to minimize the effects of fishing on marine fish communities and ecosystems [42]. Recently, it has been suggested that both objectives can be achieved if species and individuals are exploited in relation to their natural productivity, the so-called balanced harvesting [43,44]. However, significant human exploitation of a single species can affect not only that species but many other species as well. As sustainable exploitation rates are dependent on stock productivity, there is a strong need to explore appropriate exploitation rate in order to sustainable management of Hilsa shad fishery.

3.6 Average Weight/Length (Case Study-2)

The length-frequency data is closely related to weight, age and maturity and can be easily determined. The average length of Hilsa shad was appeared 30cm (approx.) based on the

study during July 2015 to June 2016, and reflect a standard data set (Fig. 11a) [22]. According to the Length-Weight (L-W) relationship results ($W = 0.0368L^{2.717}$) [22], the weight of 30cm Hilsa shad equal to 379.5gm. Besides, Fig. 11b presents the average weight of Hilsa shad were 510, 535, 880 and 915gm in 2014, 2015, 2016 and 2019 respectively [45]. Therefore, average weight/length calculation shows extensive variation in 2015 and 2016 between 2 allied studies. Conversely, according to the mentioned length-weight relationship formula length of 510gm, 535gm, 880gm and 915gm Hilsa shad were equal to 33.5, 34.0, 40.9 and 41.5 cm respectably. Hilsa shad is an open stock, over-exploited and targeted commercial species. An average weight/length (535gm equal to 34.05cm) estimated in 2015 by [45], and sudden increment of 880gm equal to 40.9cm by one year in 2016 with an average weight/length gain 345gm (39.21%) equal to 6.85cm (16.74%) raised questions for the researcher and manager that need to be rethought. Besides, average weight 915gm equal to 41.5cm in 2019 in the fishery created an immense demand regarding data collection design and analysis. Moreover, the paper does not mention why weight ranged divided only four groups in the analysis [45] for a fish highest weight of 3.0 Kg and length 60cm [23]. The weight/length gain is very imperative and need to be estimate sensibly. Furthermore, after a year-class recruits to a fishery the mean length drops, it then steady increases through the year thereafter as the fish grow, until it drops again when the next year-class enters the fishery [46,47]. Besides, Hilsa shad is a multi-breeders species [22,36,48,49,50], which supported the occurrence of juvenile Hilsa throughout the year [22,36,48,49,50]. Thus, significant increment of mean size (6.85 cm) within a year will be extremely difficult as new recruitment is a continuous process in the Hilsa shad fishery in Bangladesh. Moreover, Bangladesh Government adopted a number of management option to save both brood and juvenile Hilsa (*Jatka*) for successful recruitment of Hilsa shad in the fishery. This sudden increment of mean size for any species reflect recruitment gaps in the fishery, and this not reported in the Hilsa shad fishery in Bangladesh as the production shows increasing trends. The mean size of the landing catch (MSL) can be applied as a key indicator within the new ecosystem-based Marine Policy Framework Strategy and MSL can be easily used to assess trends in exploiting commercial communities and fully applicable with any species-size data source [51]. Besides,

evolutionary responses to the long-term exploitation of individuals from a population might include reversal of evolutionary downsizing caused by selective harvesting of large fish [52].

Moreover, the wide range of weight group selection (>500 g, 500-900g and >1000g) also does not reflect effective weight/length increment evidence for the management of the high valued commercial species. Usually, weight/length frequency data could be appropriate to obtain the actual average weight/length of the species rather than cluster group. Besides, the Fig. 11a reflects real value of the length-frequency [22], and average/mean value of the Hilsa shad fishery in Bangladesh and this analysis also supported by [53] with a mean length of 31.36 cm equal to 428g (Fig. 11c) [53].

A similar study was conducted by [25] to identify the variation in catch at different length groups in the three key locations of the Meghna River during spawning season (Aug-Oct) in 2016 [25]. The study reflects the mean length of Hilsa shad were 34.0 cm (553g), 35cm (576g) and 37cm (685g) at Chandpur, Chairman-Ghat (Noakhali) and Monpura (Bhola) respectively. The combined mean length of Hilsa shad was found 35.44cm (597g) (Fig. 11d), this study conducted during spawning season (Aug-Oct), and most brood fishes were available in the river.

An inclusive length-weight relationship study conducted in the Meghna River, Southeastern part of Bangladesh from July 2018 to June 2019 [54]. The study reflects the mean weight of Hilsa shad equal to 453 gm (approx.) equal to length about 32 cm (Fig. 11e) which match with Fig. 11a, 11c and 11d. However, the mean length or weight considerably differ that reported (880g equal to 40.9cm and 915g equal to 41.5cm) in Fig. 11b [45].

Besides, based on the maximum length of Hilsa shad the length-frequency data should group into two centimeters intervals. Measurement should be done with reasonable precision and for most applications the data will be grouped into length-classes, usually 20-40 groups for length-frequency or weight-frequency analysis [55]. Hence, length frequency of Hilsa shad grouped into 2cm intervals in all 20 reviewed papers. The length-weight data were grouped into 5 cm intervals and denoted only 7 groups, which also created preference to determine actual mean length of the species [25].

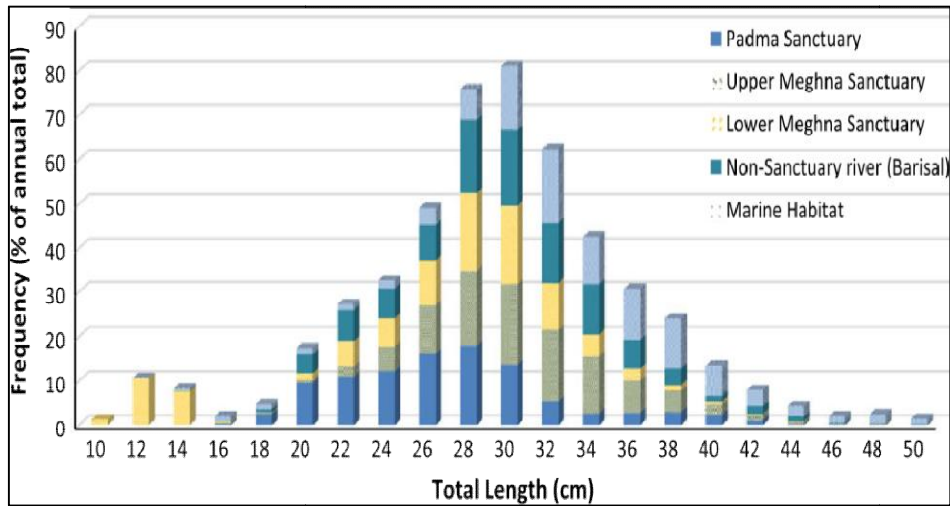


Fig. 11a. Size distribution of Hilsa (mean 30cm) (Rahman et. al, 2018)

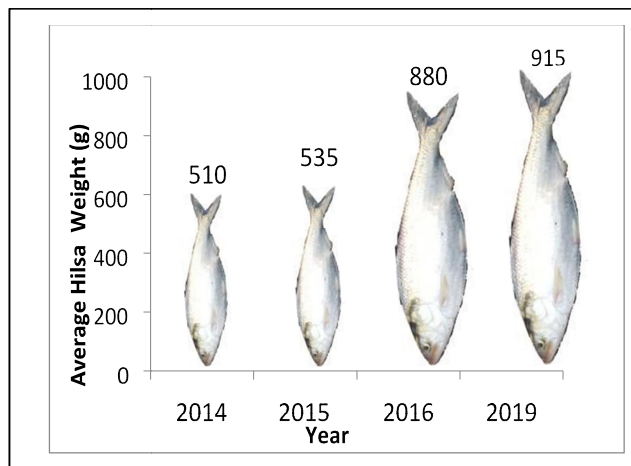


Fig.11b. Average weight of Hilsa (Rahman et.al, 2020)

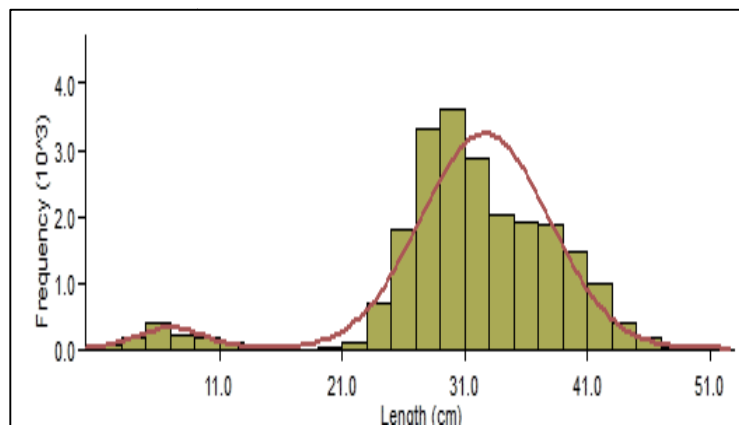


Fig. 11c. Mean length distribution of Hilsa, Amin et al., 2008

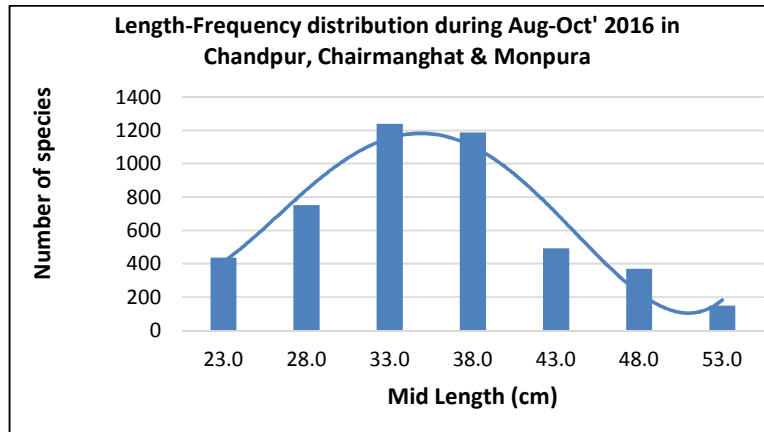


Fig. 11d, Mean length distribution of Hilsa (Aug-Oct, 2016)

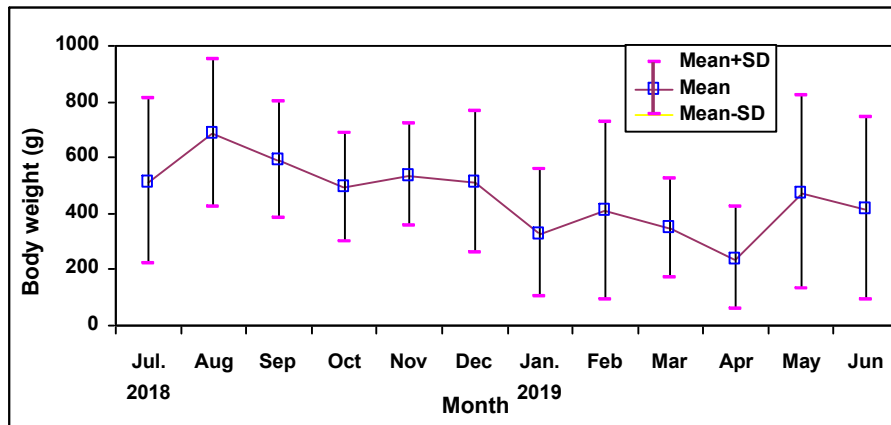


Fig. 11e. Monthly variations of body weight of *Tenuailosa ilisha* in the Meghna River, Southeastern Bangladesh (after [53])

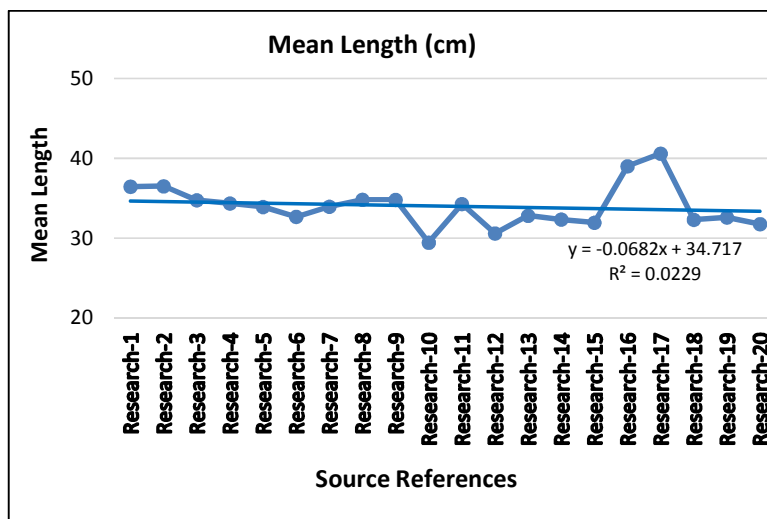


Fig. 11f. Mean length (cm) Hilsa

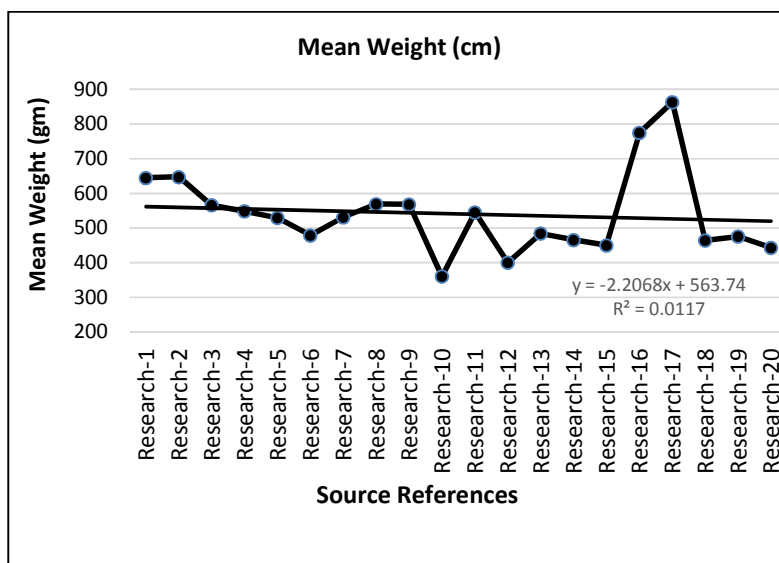


Fig. 11g. Mean weight (gm) of Hilsa

Moreover, the mean length has been estimated from 20 studies and plotted a line graph along with trend line (Fig. 11f) [20]. Simultaneously, using Length-weight relationship ($W = 0.0368L^{2.717}$) [22], the mean lengths (cm) have been converted to weight (gm) and plotted a line graph along with trend line to observe average weight (gm) of the Hilsa shad over the two decades (Fig. 11g). The mean length (cm) varies between 29.4 – 32.2, 32.2 – 35.0, 35.0 – 37.8 and 37.8 – 40.0 cm from 20%, 60%, 10% and 10% studies respectively. Besides, the calculated mean weight varies between 360.7 – 486.3, 486.3 – 611.9, 611.9 – 737.6 and 737.6 – 863.2 gm from 45%, 35%, 10% and 10% studies respectively. However, overall mean length and weight was found 34.0 ± 2.67 cm and 540.5 ± 120.52 gm respectively. The study also reflected very slow declining trends of length (-0.0682 , $R^2=0.0229$) and weight (-2.2068 , $R^2=0.0117$). The Research-16 and 17 presented higher mean values of both length and weight as the two studies specially set for gear selectivity (Lc) and fixed Hilsa's lowest length group 27cm that showed significantly higher mean values compared to other studies.

3.7 Maximum Sustainable Yield (MSY) and Standing Stock or Steady Stand Biomass (SSB)

The maximum sustainable yield (MSY) is a concept used extensively in fisheries science and management. The MSY is the highest theoretical equilibrium yield that can be continuously taken

(on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process [56]. The research-10[48], research-12 [49], research 15[53] and research-19 [22] used almost the same formula ($MSY = Zt * 0.5 Bt$ or $MSY = 0.5 * SSB * Z$) where total mortality (Z) and Standing stock (Bt) or Standing Stock Biomass (SSB) are the main pivotal element for defining MSY [48,49,53,22]. The estimated MSY were 162396, 235130, 210125 and 526000 tons in 1999, 2002, 2003 and 2015-16 respectively. The MSY of 526000 tons estimated by [22] used a non-dependable SSB value (explain in section 3.8.1).

The estimated MSY of 211000 tons based on age-structured bio-economic model [57] and stated an over-fishing condition of the Hilsa shad stock [28]. The World Bank reported MSY of 286000 tons based on a study conducted by the International Council for the Exploration of the Sea [58]. The BOBLME estimated MSY of 300000 tons based on surplus production model and stated the decline in overall abundance of Hilsa shad to below 50% of virgin biomass, which, indicating an overfishing in the Hilsa shad fishery [29]. Besides, the estimated MSY based on catch and effort data between 2001 and 2017 from downstream of the Bay of Bengal and used the same data through CEDA, ASPIC and TropFishR packages (TropFishR estimated high value MSY "569499 tons" thus, not included in this analysis) [30]. The estimated MSY ranged between 263,500 and 345,486 tons and

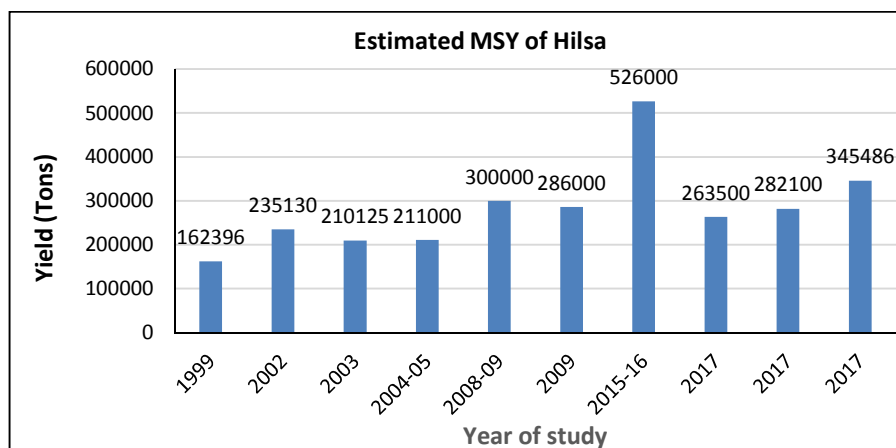


Fig. 12. Estimated MSY of Hilsa shad from different studies in Bangladesh

concluded that the best-fitted MSY was 282,100 tons from the Schaefer and Pella-Thomlinson models of the CEDA [30].

Thus the estimated MSY for Hilsa shad from different studies in Bangladesh were found 162396, 235130, 210125, 211000, 300000, 286000, 526000, 263500, 282100 and 345486 tons in 1999, 2002, 2003, 2004-05, 2008-09, 2009, 2015-16 and 2017 respectively, and shows an increasing trend of MSY between 1999 and 2017 (Fig. 12). The overall review included MSY values from different studies and the range of estimated MSY varies from 162396 to 283597, 283597 to 404798 and 404798 to 526000 tons from 60%, 30% and 10% studies respectively. The mean MSY equal to 282174 ± 100530 tons and, which correspond with 60% studies. Hence, the real reflection of MSY is a query for manager, scientific community and researcher.

3.8 Standing Stock or Steady State Biomass (SSB)

The estimated standing stock or steady state biomass (SSB) of Hilsa shad were found 86152, 217713, 148498 and 251109 tons in 1999, 2002, 2003 and 2015-16 respectively. Besides, through BOBLME project estimated biomass of 1200000 tons based on data from 2008-09 [29]. This deviation may be increasing population size or estimation of standing stock or steady state biomass or biomass of species [29].

3.8.1 Standing stock or steady state biomass (SSB) (Case study-3)

According to the analysis in the Table 3 of the Research-19 (given below) [22], steady state

biomass (SSB) showed 34.85, 197.61 and 568.42 tons for the corresponding length 2, 4 and 6 cm respectively, and biomass continuously increased to 21,986.46 tons (maximum) for the corresponding length 28 cm. Again the biomass constantly decreased to 21,614.52 and 19,512.33 tons for the corresponding length 30 and 32 cm respectively, and continually decreased to 5,578.32 and 3119.53 tons for the corresponding length 40 and 42 cm respectively, and according to the formula the biomass should be further reduced (may be <2500 tons) for corresponding length 44cm. However, the published paper presents estimated biomass of 45586 tons for corresponding lengths 44cm. A simple histogram has drawn for broader understanding using column 1 (mid length in cm) and column 4 (Steady State Biomass-SSB) value of the Table 3 (below) of the mentioned published paper (i.e., Research 19) (Fig. 13). The Fig. 13 created a strange histogram and at 44cm, the length of Hilsa shad where an unusual SSB value was found 45,586 tons? Thus, the article has easily identified as an understanding gap to estimate SSB value. Moreover, the Table 3 on the mentioned paper (Research 19) represents only fishes up to 44 cm and species greater than 44cm not included in the SSB analysis. It appears clear indication of the analytical gap to synthesize VPA (Virtual Population Analysis) for dependable biomass estimation. Besides, through the feeble review process the paper published in an international paid journal. Hilsa shad is a continuous recruiting species and from where huge quantity of Hilsa shad only at 44 cm size appeared in Bangladesh waters does not recognize during the analysis process of the paper. Moreover, this defective biomass used for MSY value calculation (i.e.,

MSY=0.5 * 251109 (SSB) * 4.19 (Z) = 526000 tons), so, this output is an undependable MSY value. However, this uncertain value (0.526 million Mt) again refers in the follow up journal paper as best output (page 5, section 3.1, line 6-7) [45]. Thus, through the continual publication process the absolute unclear MSY may be adjust or accepts in the SDG-14a “increase scientific knowledge, develop research capacity and transfer marine technology” (page-8, section 3.6 [45], by the influence of publications. Thus, the question arises, how undependable information and research results are used through a formal process.

This case study provides a critical overview of the research papers on evidence-based on the context of program improvement in the Hilsa Fisheries Management Action Plan (HFMAP). However, the limitations on analytical processes for consideration of evidence that are vital for the users of research. The relationship between policy processes and research production has become more closely institutionalized in some countries and in some policy domains [59,60,61], thus providing positive opportunities for fruitful influence and interaction.

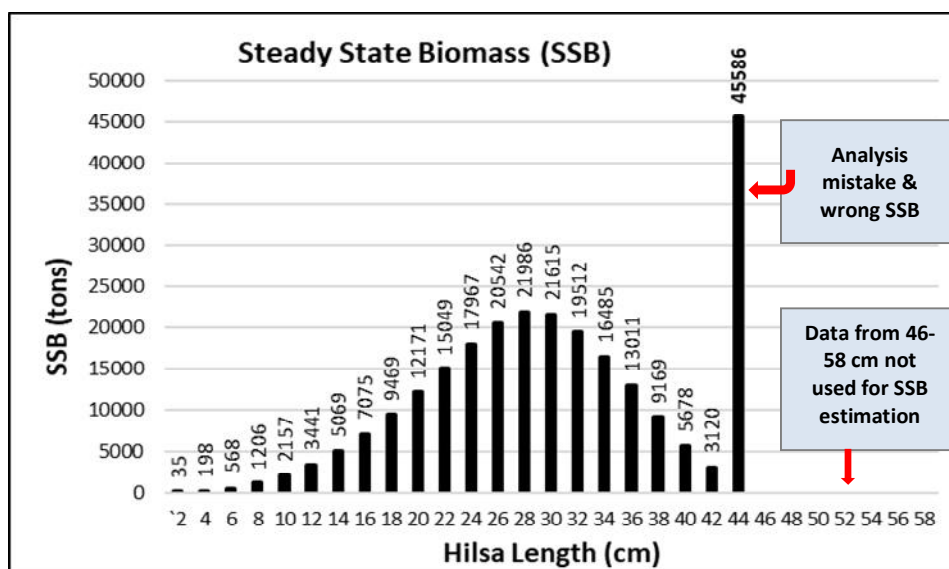


Fig. 13. Drawn from Research-19 (Table 3 below) which shows an erroneous calculation of Steady State Biomass (SSB) and, Hilsa shad data from 45 to 58 cm were not used for SSB estimation

Table 3. From Research paper-19 (title given in Table 3: Population number (N x 10⁶) by size (TL) and steady state biomass (SSB) of Hilsa at different levels of fishing mortality (F) Bangladesh waters)

Length (TL, cm)	Population (N x 10 ⁶)	Fishing mortality (F)	Steady state biomass (SSB) (thousand tons)
2	1,580.48	0	34.85
4	1,498.43	0	197.61
6	1,417.88	0	568.42
8	1,338.85	0	1,206.43
10	1,261.36	0.0186	2,156.80
12	1,184.45	0.1657	3,441.38
14	1,101.49	0.1511	5,069.28
16	1,021.76	0.0497	7,075.22
18	949.47	0.0797	9,468.80
20	877.68	0.24	12,171.03
22	800.62	0.4107	15,049.23

Length (TL, cm)	Population ($N \times 10^6$)	Fishing mortality (F)	Steady state biomass (SSB) (thousand tons)
24	719.2	0.5621	17,966.65
26	635.88	1.042	20,541.73
28	540.08	1.8401	21,986.46
30	428.38	2.7158	21,614.52
32	312.4	3.3027	19,512.33
34	211.88	3.4999	16,484.80
36	136.8	3.9693	13,011.08
38	81.17	4.8855	9,169.07
40	41.49	5.2227	5,678.32
42	18.96	5.5978	3,119.53
44	7.5	2.83	45,585.75
Total SSB			251,109.29

Table 3 source: <https://www.worldfishcenter.org/content/catch-trend-and-stock-assessment-hilsa-tenualosa-ilisha-using-digital-image-measured-length>

4. CONCLUSION

- Bangladesh has implemented a number of Hilsa shad management interventions in the recent past years, and these management performance needs to be capture indicator based rigor, data to investigate the effect of management interventions and achieve the sustainable production.
- The review reveals that the range of asymptotic length between 56 and 61 cm and mean asymptotic length equal to 58 cm, which represents a sensible parameter.
- The majority study corresponds to mean K values that represent a life span of Hilsa shad only <4 years. Therefore, further investigation is needed to confirm the appropriate K value for best management performance.
- The majority study reveals control of fishing effort are required and future studies of this type would benefit from greater consideration to the sampling design and analysis perfectness.
- The greater part of the study reveals that the Hilsa shad stocks are overexploited. Thus, it is important to quantify the dependable exploitation rate and define sustainable management practices that allow for the conservation and sustainable management of the exploited stocks.
- The review included MSY values from different studies, the range varies widely, and the real reflection of MSY is a quarry for fisheries manager and the scientific community.
- Future studies need to explore appropriate management performance

indicators to avoid the problems tinted here arising from less reliance analysis.

- The study indicated that the importance of science excellence, precise assessment and accurate estimation of the status of the fish stocks is vital for sustainable management of a fishery. Thus, the technical investigations need experience to analyze, predict results and produce management related suggestions, which is highly correlated to national or regional resource management decision. Therefore, building a knowledge base analysis is vital to provide precise results for the national resources management and blue economy.

DISCLAIMER

The product used for this research are commonly and predominantly use products in my area of research and country. There is absolutely no conflict of interest between the author and producers of the products because I do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the author.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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